POST-TRAUMA MRI KNEE INTERP RETATION: OUR EXPERIENCE WITH A MECHANISM-BASED APPROACH IN A SOUTH AFRICAN SETTING.

By

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As the candidate's supervisor I have approved this thesis for submission.

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Declaration

I **Dr James Stutterheim** declare that

(i) The research reported in this dissertation, except where otherwise indicated, is my original work.

(ii) This dissertation has not been submitted for any degree or examination at any other university.

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Overview

A mechanism-based approach to the interpretation of complex knee injuries at magnetic resonance imaging (MRI) is cited by several authors to provide increased reporting accuracy and efficiency by allowing accurate prediction of injury to at-risk structures. We took interest in the clinical benefits proposed for such an approach, and set out to assess the approach's validity in our local South African setting.

We identified in the recent literature a consolidated mechanism-based pattern approach to complex post-trauma MRI knee interpretation compiled by Hayes *et al.,* which showed high validity of 85% in a North American setting, and set out to test this approach in our resource-constrained South African setting.

We found a low percentage (average 19%) of knee injuries classifiable by mechanism using the Hayes *et al.* classification. Statistically there was fair agreement between the two observers.

We conclude, based on remediable limiting factors, that the clinical benefit of a mechanism-based interpretation approach could be optimised in our resource constrained setting by focusing its application on cases imaged within a time window when key injury findings such as bone bruising and soft tissue injury will be optimally detectable, as well as in patients injured in sporting and similar athletic activities. We advocate that the development of a digital MRI image reference tool for the implementation of the Hayes *et al.* classification could simplify and enhance its application.

The purpose of this quantitative, observational, investigative, retrospective study is to assess the validity of the Hayes *et al.* mechanism-based classification tool for the interpretation of post trauma MRI knee studies in our South African setting.

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CHAPTER 1: A REVIEW OF THE LITERATURE

Literature Review

The knee is the largest and most complex joint in the human body, and functions predominantly as a hinge joint.[1] Stability at the knee is maintained through the interplay of static and dynamic stabilisers: static stabilisers refer to the ligaments, menisci, joint capsule and tendons, and dynamic stabilisers to the musculotendinous structures around the knee.[1] An understanding of the biomechanics of the knee can heighten awareness of structures at risk for injury and of common and predictable injury patterns that occur with specific injury mechanisms. It is well established that knee injuries occur commonly in the athletically active population, with an estimated incidence of significant knee injury in the region of up to 500 cases per year per 400 000 population.[2] In a ten-year long Swiss-based study of the epidemiology of knee injuries in over 17000 athletically active patients, 50% of knee injuries were found to occur in patients between the ages of 20 and 29 years.[3]

In patients presenting following knee injury sustained by falling, twisting injury or direct impact, clinical examination is highly sensitive for diagnosing soft tissue injury. The accuracy of clinical examination ranges between 75% and 96% for the diagnosis of significant ligament or meniscal injury, according to Rayan *et al*.[4] An MRI is commonly requested by the orthopaedic surgeon as an adjunct to clinical examination and is useful in the setting of equivocal clinical examination or complex knee injury.[4, 5] MRI is highly accurate in the diagnosis of internal derangements of the knee.[6] A systematic review comparing MRI and arthroscopy findings found high sensitivity and specificity for MRI detection of meniscal and cruciate ligament injury with figures between 88% and 99% for all structures excepting a relatively lower sensitivity of 79% for detection of lateral meniscus injury.[6]

Comprehensive imaging texts detailing MRI musculoskeletal imaging in sports injuries -

such as Stoller's[7] 'Magnetic Resonance Imaging in Orthopaedics and Sports Medicine'- tend to favour an anatomical approach to trauma imaging interpretation. A mechanism-based approach adds to this fundamental knowledge of the concept of common injury mechanisms and associated injury patterns.

A biomechanical approach to post-trauma knee MRI interpretation aims to increase reporting accuracy by providing a structured and logical reporting approach in the setting of complex knee injury. [8, 9, 10]

Hayes *et al.*[8] advocate a biomechanical approach because of its proposed increased sensitivity for the detection of subtle but important components of complex injuries, particularly at the posterolateral and posteromedial corners of the knee. This can help to predict important complications such as early or delayed instability. Hayes *et al.*[8] devised a classification system for complex knee injuries based on ten common injury mechanisms around the knee:

- Pure hyperextension
- Hyperextension with varus
- Hyperextension with valgus
- Pure valgus
- Pure varus
- Flexion valgus, external rotation
- Flexion varus, internal rotation
- Flexion with posterior tibial translation
- Patellar dislocation (flexion and internal rotation of femur on fixed tibia)
- Direct trauma

Their study, conducted at the University of Michigan, found that they were able to classify injuries by mechanism in 85% of cases. Fundamental to their classification is the ability to differentiate between impaction and avulsion bone marrow oedema patterns. The reasons Hayes *et al.*[8] advocate for potential classification system failure

include an insufficient injury, a massive injury, or bone marrow oedema due to pre-existing pathologies such as osteoarthritis. A high percentage of MRI cases were classifiable by Hayes et al.[8] (85%) using their classification in a North American setting. This is noteworthy because the validity of this approach relies on the percentage of cases that can be classified by mechanism.

MacMahon et al.[9] and Lim et al.[10] both propose classification of knee injuries according to injury mechanism to allow for more rapid and accurate interpretation of knee injuries by the reviewing of 'at risk' structures, thus helping to improve clinical outcomes. Lim et al. provide a discussion based on the Hayes et al. classification. MacMahon et al. provide a case-based discussion of several common knee injuries. Both authors focus their discussion on the high prevalence of acute knee injuries in the young, athletically active population, emphasising the high incidence of knee injuries sustained in soccer and skiing.

Sanders et al.[11] explore five common knee injury mechanisms and the associated bone bruising 'footprints' left behind. Bone bruising is visible within a few days and has an average healing time of 42 weeks.[12] Pivot-shift, dashboard, hyperextension injury, clip injury and patellar dislocation are the injury mechanisms explored in this article, together with predictable associated soft tissue injuries. These five mechanisms are included in the Hayes et al.[8] classification and the description of injuries occurring with these mechanisms is consistent between the two authors.

Hayes et al. were the only authors encountered in the literature who present a formalised classification, comprising the ten most common injury mechanisms encountered in their setting. Of further interest is that the Hayes et al. classification had been tested in a North American setting.

The South African study population and study setting are likely to differ significantly from that of Hayes et al.[8] There is a low orthopaedic specialist to patient ratio in South Africa - 184 state specialists servicing a population of 52 million[13] - as well as limited

availability of state MRI imaging services in the Kwa-Zulu Natal province where two MRI scanners serve a provincial population of 10.3 million.[14] It is clearly emphasised in a second article published by Hayes *et al.* published six years after the original article presenting their mechanism-based classification, that their classification is tailored towards acute sports-related injuries, and particular mention is made of the high incidence of injuries sustained in contact sports and sports with 'cutting' movements [16] . In addition, the highest percentage of the classifiable injuries in the original Hayes *et al.* article pivot shift injury (46% of the 85% classifiable cases in their study sample), which has strong association with athletic pursuits, particularly basketball, tennis, football and skiing[9,10].

Neither Hayes, MacMahon nor Lin *et al.* describe a specified set of sequences or the magnet strength used in their setting. Some emphasis is placed on the diagnostic value of fast fat saturation sequences in the original Hayes *et al.* article. In the later published article by Hayes *et al.*, the wide variation in imaging protocols between institutions is emphasised, which is influenced by machine variation and physician preference.[15] They also emphasise than no significant difference has been shown between 1.5T and 3T MRI machines in the diagnosis of anterior cruciate ligament (ACL) and meniscal injuries.

Differing epidemiological factors could increase the interval between injury and assessment, imaging and ultimately treatment in a South African compared with a North American setting. Another important variable between the South African and North American settings is the relatively high incidence of motor vehicle and pedestrian vehicle accidents in South Africa (35.8 deaths per 100 000 population [15]) compared to the lower world average of 19 deaths per 100 000[17]. This could increase the incidence of highly complex injuries in our setting.

. The findings of the study could guide adaptations to the implementation of a mechanism-based imaging interpretation approach such as that of Hayes *et al.*[8] in a South African setting.

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CHAPTER 2: A SUBMISSION READY MANUSCRIPT

Cover Letter

Title: Post-trauma MRI knee interpretation: our experience with a mechanism-based approach in a South African setting.

Significance of Work: A mechanism-based approach to MRI interpretation post knee trauma has significant attributed benefits and knowledge of this approach is deemed necessary for radiologists interpreting post-trauma MRI knee studies. Identifying remediable and irremediable factors affecting the use of such a classification in resource constrained settings will better tailor its use to optimise its effect in clinical radiology practice: we conclude with two recommendations for its implementation in our setting.

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Authors' contributions: J.S. (University of KwaZulu-Natal) is currently a radiologist in private practice, and is enrolled for a Masters in Medicine at the University of KwaZulu-Natal. J.S. was the principal investigator. M.G. (University of KwaZulu-Natal) is currently a senior radiology consultant at Grey's Hospital, Pietermaritzburg, a teaching hospital under the University of KwaZulu-Natal. M.G. was the supervisor. Both J.S. and M.G. performed an independent interpretation of the MRI cases in the study sample using the mechanism based approach of Hayes *et al*. The manuscript was written by J.S.

Summary:

Number of words: 2966 (introduction to conclusion).

Abstract: 248 words

Number of pages: 21

Number of tables and figures: 5

Abstract

Background:

A biomechanical approach to imaging interpretation following complex musculoskeletal injury is logical and useful because of the predictable synergisms that occur within a number of joint complexes (consider Young-Burgess classification for pelvic and Lauge-Hansen classification for ankle fractures). The knee lends itself favourably to this concept because of the complex interrelation of its primary and secondary stabilizing structures. We encountered a lack of evidence substantiating the universal validity of a biomechanical approach to post trauma MRI knee interpretation, particularly in resource constrained settings.

Objectives: This quantitative, observational, investigative study aims to validate the biomechanical approach for the MRI interpretation of complex traumatic knee injuries, compiled by Hayes *et al.* (chosen because of high validity shown in a North American setting), in a South African setting.

Methods: 30 post-trauma MRI knee cases performed at Grey's Hospital, Pietermaritzburg (a tertiary South African referral centre), selected chronologically after 1 January 2012, were reviewed independently by two observers with blinding to patient history, using the Hayes *et al.* classification.

Results: We found a low percentage (7% and 30%) of knee injuries classifiable by mechanism in our setting using the Hayes *et al.* classification. Statistically there was fair agreement between the two observers.

Conclusion: We explore several reasons for classification failure in our setting, which

include local injury epidemiology, timing between injury and MRI, and interpreter skill level, and conclude that adaptions need to be made to improve the validity of the classification in our setting, and perhaps similar resource constrained settings.

Introduction

A mechanism-based approach to image interpretation following complex musculoskeletal injury has logical and useful clinical application because of the predictable synergisms that occur within a number of joint complexes, including the knee, ankle and pelvis.

A mechanism-based approach to post-trauma MRI knee interpretation is cited by several authors in the recent literature to provide increased reporting accuracy and efficiency by allowing accurate prediction of injury to at-risk structures.[8, 9, 10, 11] A validity study by Hayes *et al.*[8] of their consolidated mechanism-based classification is noteworthy because of the high percentage of cases which could be classified by their approach, specifically 85%. We took interest in the clinical benefits accredited to such an approach, notably because of its proposed increased accuracy and efficiency, which would be of high value in the radiology workplace. The objectives of the study are:

- To assess the reliability of a mechanism-based approach to complex post-trauma MRI knee interpretation when implemented by general radiologists in a South African setting, and compare our results with findings from a North American setting.

To measure the agreement between the two observers. Such an imaging approach can be incorporated into local practice if found reliable in a South African setting.

Literature Review

The knee is the largest and most complex joint in the human body, and functions predominantly as a hinge joint.[1] Stability at the knee is maintained through the interplay of static and dynamic stabilisers.[1] An understanding of the biomechanics of the knee can heighten awareness of structures at risk for injury and of common and predictable injury patterns that occur with specific injury mechanisms. It is well established that

knee injuries occur commonly in the athletically active population, with an estimated incidence of significant knee injury in the region of up to 500 cases per year per 400 000 population.[2] In a ten-year long Swiss-based study of the epidemiology of knee injuries in over 17000 athletically active patients, 50% of knee injuries were found to occur in patients between the ages of 20 and 29 years.[3]

In patients presenting following knee injury sustained by falling, twisting injury or direct impact, clinical examination is highly sensitive for diagnosing soft tissue injury. The accuracy of clinical examination ranges between 75% and 96% for the diagnosis of significant ligament or meniscal injury, according to Rayan *et al.*[4] An MRI is commonly requested by the orthopaedic surgeon as an adjunct to clinical examination and is useful in the setting of equivocal clinical examination or complex knee injury.[4, 5] MRI is highly accurate in the diagnosis of internal derangements of the knee.[6] A systematic review comparing MRI and arthroscopy findings found high sensitivity and specificity for MRI detection of meniscal and cruciate ligament injury with figures between 88% and 99% for all structures excepting a relatively lower sensitivity of 79% for detection of lateral meniscus injury.[6]

Comprehensive imaging texts detailing MRI musculoskeletal imaging in sports injuries - such as Stoller's[7] 'Magnetic Resonance Imaging in Orthopaedics and Sports Medicine'- tend to favour an anatomical approach to trauma imaging interpretation. A mechanism-based approach adds to this fundamental knowledge of the concept of common injury mechanisms and associated injury patterns.

Hayes *et al.*[8] devised a classification system for complex knee injuries based on ten common injury mechanisms around the knee:

- Pure hyperextension
- Hyperextension with varus
- Hyperextension with valgus

- Pure valgus
- Pure varus
- Flexion valgus, external rotation
- Flexion varus, internal rotation
- Flexion with posterior tibial translation
- Patellar dislocation (flexion and internal rotation of femur on fixed tibia)
- Direct trauma

Their study, conducted at the University of Michigan, found that they were able to classify injuries by mechanism in 85% of cases. Fundamental to their classification is the ability to differentiate between impaction and avulsion bone marrow oedema patterns. The reasons Hayes *et al.*[8] advocate for potential classification system failure include insufficient injury, a massive injury, or bone marrow oedema due to pre-existing pathologies such as osteoarthritis.

MacMahon *et al.*[9] and Lim *et al.*[10] both propose classification of knee injuries according to injury mechanism. Lim *et al.* provide a discussion based on the Hayes *et al.* classification. MacMahon *et al.* provide a case-based discussion of several common knee injuries. Both authors focus their discussion on the high prevalence of acute knee injuries in the young, athletically active population, emphasising the high incidence of knee injuries sustained in soccer and skiing.

Sanders *et al.*[11] explore five common knee injury mechanisms and the associated bone bruising 'footprints' left behind. Pivot-shift, dashboard, hyperextension injury, clip injury and patellar dislocation are the injury mechanisms explored in this article, together with predictable associated soft tissue injuries. These five mechanisms are included in the Hayes *et al.*[8] classification.

Hayes *et al.* were the only authors encountered in the literature who present a formalised classification, comprising the ten most common injury mechanisms encountered in their setting. Of further interest is that the Hayes *et al.* classification had

been tested in a North American setting, and showed high reliability.

Published literature focuses on the value of a mechanism-based imaging approach in the setting of sports injuries, particularly contact sports and sports with 'cutting' movements.[16] In addition, the highest percentage of the classifiable injuries in the original Hayes *et al.* article pivot shift injury (46% of the 85% classifiable cases in their study sample), which has strong association with athletic pursuits, particularly basketball, tennis, football and skiing[9,10]. The South African study population and study setting are however likely to differ significantly from that of Hayes *et al.*[8] There is a low orthopaedic specialist to patient ratio in South Africa - 184 state specialists servicing a population of 52 million[13] - as well as limited availability of state MRI imaging services in the Kwa-Zulu Natal province where two MRI scanners serve a provincial population of 10.3 million.[14] The high incidence of motor vehicle and pedestrian vehicle accidents in South Africa (35.8 deaths per 100 000 population [15]) compared to the lower world average of 19 deaths per 100 000[17 could increase the incidence of highly complex injuries in a South African setting.

Neither Hayes, MacMahon nor Lin *et al.* describe a specified set of sequences or the magnet strength used in their setting. Some emphasis is placed on the diagnostic value of fast fat saturation sequences in the original Hayes *et al.* article. In the later published article by Hayes *et al.*, the wide variation in imaging protocols between institutions is emphasised, which is influenced by machine variation and physician preference.[15] They also emphasise than no significant difference has been shown between 1.5T and 3T MRI machines in the diagnosis of ACL and meniscal injuries.

Methods

Study Sample and Design

The study took place at Grey's Hospital, a state-funded tertiary referral centre and teaching hospital in Pietermaritzburg, KwaZulu-Natal, South Africa.

The study was a retrospective, quantitative, observational, investigative review of digital MRI knee cases stored on a password protected picture archive and communication system (PACS) at this hospital.

Study Description

All post-trauma knee MRI studies performed sequentially at Grey's Hospital from 1 January were included.

Patients with MRI findings clearly not due to trauma, and children aged 12 and under were specifically excluded (see below).

The first thirty MRI knee cases performed after 1 January 2012 were chronologically recorded from the MRI schedule history on the Radiology Information. Information available on the booking schedule included patient name, age, date of examination and type of examination. Two of the 30 selected cases were eliminated: one normal study and one case of septic arthritis. The next two sequential cases with imaging findings fitting with traumatic injury were added to restore a number of thirty cases. Two of the cases belonged to one patient who had imaging of simultaneously injured knees. Thus there were 32 MRI knees performed at the institution between 3 January and 16 July 2012, and 2 were excluded resulting in a final number of 30. . All patients were scanned on a 1.5T Philips MRI scanner. Patients were typically scanned using the following protocol:

- Sagittal T1W
- Sagittal STIR T2W

- Axial & coronal proton density with fat saturation
- Sagittal SPIR

The principal investigator and supervisor independently accessed images of the thirty chronologically selected post-trauma MRI knee cases on the password-protected Picture Archiving and Communications System available to Grey's Hospital radiology and clinical staff. The investigators remained blinded to each other's findings. Both investigators recorded relevant findings on a Microsoft Word template table derived from the Hayes *et al.*[8] mechanism-based classification system. For each case, the investigators recorded the case number, patient age, and imaging findings under the headings *bone bruising* and *ligament injuries*.

The imaging findings for each case were correlated with the ten classified mechanisms in the Hayes *et al.*[8] classification.. Where there was a match between the imaging findings and a particular mechanism in the classification, an injury mechanism was assigned to that case. Identification of bone bruise pattern forms the initial step in the identification of injury mechanism in nine of the ten injury mechanisms, with the exception being Mechanism 8 (flexion with direct posterior tibial translation, resulting in an isolated posterior cruciate ligament (PCL) tear). Where a characteristic bone bruise pattern is present, corresponding soft tissue findings will invariably be present and need to be sought at specific locations. The presence of one or more characteristic soft tissue injuries then confirms the injury mechanism. It is unlikely that a characteristic bone bruise pattern will be present without corresponding soft tissue injury, as these patterns are relatively specific and are not likely to occur co-incidentally. In the case of bone bruise pattern not corresponding with any specific mechanism, classification by mechanism using the Hayes *et al.* classification is virtually precluded (except in the case of a PCL injury). It must also be noted that the Hayes *et al.* classification only includes the ten most common mechanisms encountered in their setting. There are numerous possible knee injury mechanisms that are not included in the classification .e.g. hyperflexion injury.

Following completion of the above described data capture, additional information was obtained from the radiology information system including the history of injury, and timing between injury, clinical assessment and MRI.

Descriptive statistics were used to compare the classification percentage of the investigators with the results of Hayes *et al.*[8]

The Cohen's Kappa coefficient was calculated to measure the inter-observer agreement.

Results

The principal investigator found 30% of cases classifiable according to the classification system of Hayes *et al.*[8] The supervisor found 7% of cases classifiable, as shown in Figure 1.

Insert Figure 1.

The observers agreed that two cases (7%) had assignable mechanisms, and also agreed on the mechanisms in both of these cases. The observers agreed that 21 cases (70%) could not be assigned an injury mechanism. There were seven cases (23%) in which the observers could not agree on whether a mechanism was assignable. These findings are presented in Table 1.

Insert Table 1.

The Cohen's Kappa Coefficient was calculated, and demonstrated fair agreement between the observers, as shown in Table 2.

    The mean patient age was 32 years (range 14-65)
    60% of patients were male; 40% of patients were female
    The left knee was injured in 47% of cases; the right in 47% of cases; and both knees in 6% of patients.

The incidence of bony bruising was 63%, with 93% agreement between the observers.

The mean waiting time (Figure 2):

- Between injury and clinical assessment was 8 months (range 3 days to 5 years)
- Between clinical assessment and MRI was 40 days (range 1 week to 6 months)
- Between injury and MRI was 9.5 months (range 2 weeks to 6 years)

Insert Figure 2.

A retrospective review of the request forms was performed after image analysis was completed to assess injury circumstances (Figure 3):
Insert Figure 3.

Ethical Considerations

Patient confidentiality was protected in the study by: the anonymising of patients by using case numbers instead of names; use of personal passwords by the investigators to access patient images on the password-protected PACS system; the storage of recorded data on a password protected Google Drive account.

Ethics Approval was granted by a subcommittee of the UKZN Biomedical Research Ethics Committee. BREC reference number BE518/14.

Discussion

Outline of results:

Two important observations emerge from our results:

- A significantly lower percentage of cases were classifiable by the Hayes *et al.*[8] mechanism-based classification in our study group compared to the 85% achieved by Hayes *et al.*[8] in their study population.
- There was a fair measure of agreement between the findings of the principal investigator and supervisor.

The low average of 19% percent of cases (30% by the principal investigator and 7% by the supervisor) classifiable in our study group by mechanism could have been influenced negatively by several factors. Bone bruising was identified in an average of 63% of cases, with a high percentage agreement between the observers (93%). The relatively low detection rate of bone bruising is likely to have impacted negatively on the reliability of the biomechanical approach in our setting and could be linked to the significant delay time between imaging and MRI in certain cases. The average time between injury and MRI was 9.5 months this lies within the typical window for the resolution of bone bruising which has an expected resolution time of 6-12 weeks[9], although, depending on the severity of injury, bone bruising may persist for up to ten months.[12] It is noteworthy that the average delay time between injury and MRI was close to two months for the two cases classifiable by both investigators, and bone bruising was agreed present in both cases. In two of the seven cases classified with an injury mechanism by only the principal investigator and not the supervisor, the investigators agreed that there was no bone bruising present.

The epidemiology of injuries in the South African study sample likely differs significantly from the North American study performed by Hayes *et al*,[8]: consider that 34% of patients in the study sustained injury in motor vehicle or pedestrian-vehicle accidents. This epidemiological statistic correlates with South Africa's relatively high statistics in this regard, with an MVA mortality rate double that of world averages.[15,17] This irremediable limiting factor could result in a higher percentage of cases presenting with injuries too complex to classify by mechanism, a pitfall also described by Hayes *et al*.[8] That there was a fair measure of agreement between the two observers in this study suggests that these factors, possibly amongst others, were common limitations that affected both observers.

A further variable we consider is the experience of the investigators in this study. The principal author of the Hayes *et al*.[8] study has a sub-specialist musculoskeletal imaging qualification with significant experience, while both authors in this study are practicing general radiologists. It is possible that a skill gap between musculoskeletal radiologists

and general radiologists with musculoskeletal imaging interest could have led to classification failure; however this would need to be studied further.

Of the MRI studies done within four months of injury, and not agreed classifiable by mechanism by both investigators, eight were not classified due to indeterminate imaging findings, five due to high injury complexity, and two due to insufficient imaging findings. Of six PVA case imaged within four months of injury and not classifiable by mechanism by one or both investigators, high injury complexity was the limiting factor in four cases, and indeterminate imaging findings in two cases

Bone bruising was present in 63% of cases, however only 7% of cases had classifiable injuries. The agreed absent bone bruising by both investigators in 27% of cases accounts for lack of ability to classify these cases. The significant percentage of cases with bone bruising that were not classifiable by mechanism was due to (as detailed in the paragraph above) indeterminate imaging findings, high injury complexity, and insufficient imaging findings.

A limitation of the study is the sample size of 30 cases. The reason why a sample size of 30 was used is that it was apparent following review of the 30 cases that a significant gap existed in the percentage of cases classifiable by mechanism (at this point I was advised by the Head of Clinical Research at UKZN that 30 cases was sufficient to confidently show a significant disparity between the number of cases classifiable in the South African and North American settings).

Recommendations
- Further investigators could look to re-apply the biomechanical approach in the South African setting in a study population which had undergone imaging closer to the time of injury, ideally within one and four weeks post injury.
- A larger study sample could help to better identify limiting factors to the application of this classification in a South African setting.

- A sub-specialist musculoskeletal radiologist could be involved in further studies in resource-constrained settings to test the effects of experience and training on reliability.

Conclusion

Knowledge of the 'footprint' patterns of common knee injuries on MRI it important for all those interpreting post-trauma MRI knee studies, in light of the strong advocated benefits of using such an approach in clinical practice.

Despite the significantly lower reliability we encountered when applying a mechanism-based classification approach in our setting, we advocate several recommendations based on remediable limiting factors in order to improve clinical application. First, we recommend that the classification be applied within a window from the time of injury within which key injury components will be detectable, ideally within one to four weeks post injury. A mechanism based approach may also be most reliable in patients injured in sporting and similar athletic activities. Lastly, the authors advocate that a scrollable digital quick-reference tool summarising imaging findings for each mechanism could enhance its clinical application.

No conflict of interests is noted by the investigators in this study.

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7. Stoller D. Magnetic Resonance Imaging in Orthopaedics and Sports Medicine. Lippincott Williams & Wilkins. 2007;305-731.

8. Hayes CW, Brigido MK, Jamadar DA, Propeck T. Mechanism-based Pattern Approach to Classification of Complex Injuries of the Knee Depicted at MR Imaging. RadioGraphics. 2000;20:S121-S134.

9. MacMahon P, Palmer W. A Biomechanical Approach to MRI of Acute Knee Injuries. AJR. 2011;197:568-577.

10. Lim SY, Peh WCG. Magnetic Resonance Imaging of Sports Injuries of the Knee. Ann Acad Med. 2008 Apr;37(4):354-61.

11. Sanders TG, Medynski MA, Feller JF, Lawhorn KW. Bone contusion patterns of the knee at MR imaging: footprint of the mechanism of injury. Radiographics. 2000 Oct;20:S135-51.

12. Boks SS, Vroegindeweij D, Koes BW, Bernsen RM, Hunink MG, Bierma-Zeinstra SM. MRI follow-up of posttraumatic bone bruises of the knee in general practice. AJR Am J Roentgenol. 2007;189(3):556-62.

13. Dunn R. Are we oversupplying the orthopaedic surgical market? SA Orthop J. 2015;14:n.1.

14. District and Province Profiles: Kwa-Zulu Natal Province. [Online] [access 2016, July 18]; Available: http://www.hst.org.za/uploads/files/dhb0607_kzn.pdf

15. Sukhai A, Jones A, Haynes R. Epidemiology and Risk of Road Traffic Mortality in South Africa. SAGJ. 2009:91(1): 4-15.

16. Hayes CW, Coggins CA. Sports-related injuries of the knee: an approach to MRI interpretation. Clin Sports Med. 2006 Oct;25(4):659-79.

17. Motor Vehicle Deaths: Countries Compared (1999). http://www.nationmaster.com/country-info/stats/Health/Motor-vehicle-deaths

Tables and Figures

Figure 1:

% of Cases Classifiable by Mechanism
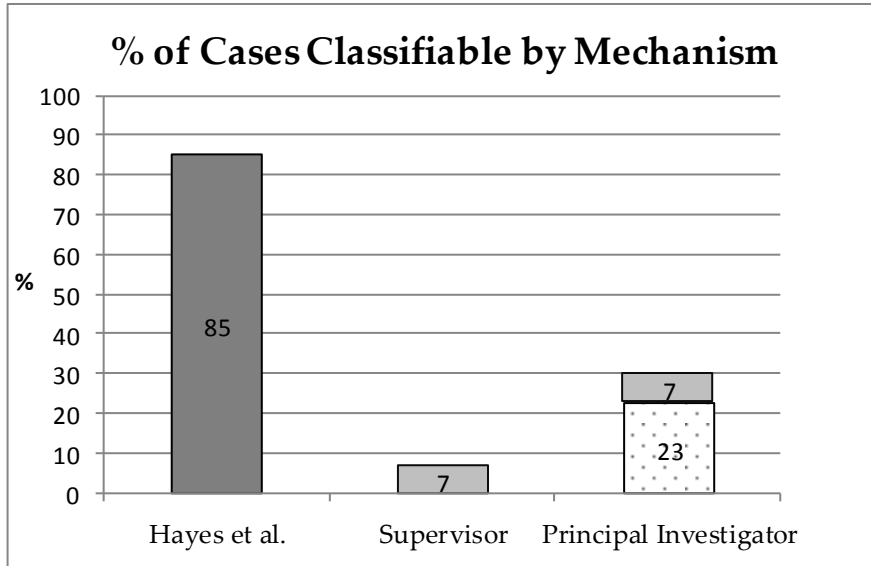
Figure 1. Comparison of the percentage of cases classifiable by the principal investigator and the supervisor compared with the percentage of cases classifiable by Hayes et al.

▨ Cases classified by both PI and S with agreement on mechanism

▫ Cases classified only by PI only

Table 1:

Table 1: Table of Agreement between the Investigators				
Principle investigator		Supervisor		Total
		No	Yes	
	No	21	0	21
	Yes	7	2	9
	Total	28	2	30

- o The number of cases non-classifiable by both investigators is the top left entry i.e. 21 cases
- o The number of cases classifiable by both investigators is the centre entry i.e. 2 cases
- o The sum of these is the total number of cases in which there was agreement between the investigators i.e. 23 cases

Table 2:

Table 2: Cohen's Kappa Coefficient		
	Value	P-value
Measure of agreement (Kappa)	0.286	0.025
Number of valid cases	30	

o   The value of Kappa shows fair agreement between the two observers

Figure 2:
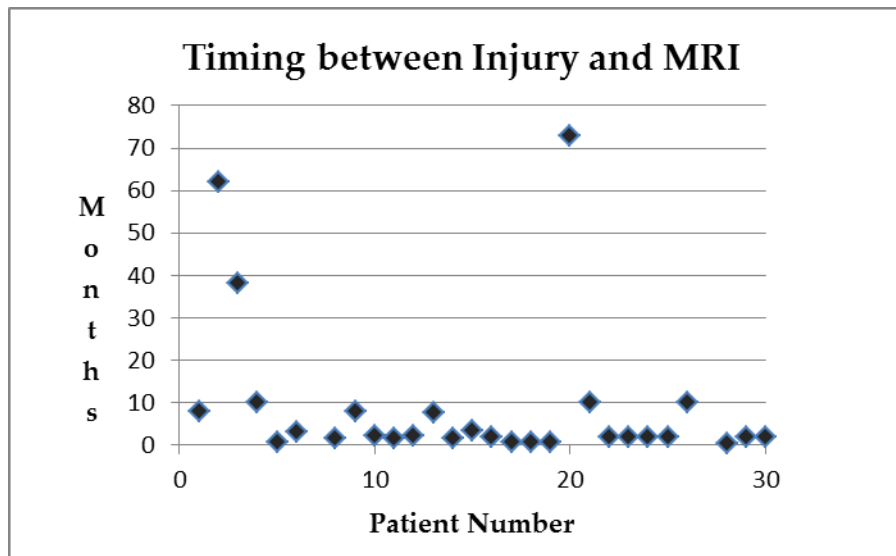
Figure 2. Timing in months between injury and MRI

Figure 3:

Figure 3: Cause of Patient Injury

MVA/PVA   Sports-related   Other e.g. falls   Not specified
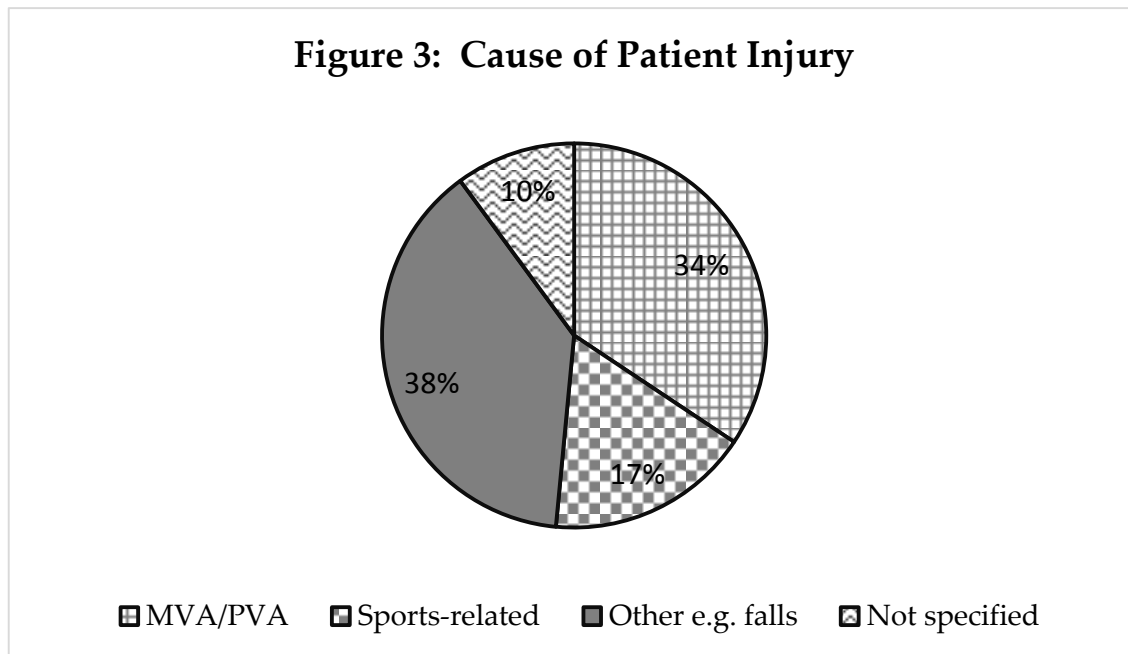
- The chart shows a breakdown of the epidemiology of patient injury in the study sample
- MVA/PVA: motor vehicle and pedestrian-vehicle accidents

CHAPTER 3: APPENDICES

CONTENTS

APPENDIX 1: THE FINAL STUDY PROTOCOL

UNIVERSITY OF
KWAZULU-NATAL

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YAKWAZULU-NATALI

RESEARCH OFFICE CONTACT DETAILS: Biomedical Research Ethics Administration, Westville Campus, Govan Mbeki Building, Private Bag X 54001, Durban, 4000, KwaZulu-Natal, South Africa; Tel: +27 31 2602486; Fax: +27 31 2604609; Email: BREC@ukzn.ac.za ; Website: http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx

SECTION A:								
APPLICANT/PRINCIPAL INVESTIGATOR: *For UKZN statistical reporting purposes*								
Title: Mr		Ms		Mrs		Dr	X	Prof		*(Select option)*

Name : James STUTTERHEIM								

*Gender: Male	
*Race: W	
UKZN College: Medicine	

UKZN School/Discipline:	Radiology	NA	
Hospital/Institution where employed:	Grey's Hospital, Pietermaritzburg	NA	

Professional status:	Registrar
Postal address:	Suite 294, Private Bag X9118, Pietermaritzburg, 3200
Contact phone Numbers: Office:	0338973204
Mobile number:	0721936984
Fax number:	0338973717

Email address:	jamostutt@gmail.com							

Full/Part time Employment: Full time

Current HPCSA Number (or equivalent): MP0685941
*if registration is pending, submit proof of application

Purpose of research: If postgraduate degree *(Please tick)*	Hons	MMedSc	MMed	MSc	MFamMed	MChB	PhD	N/A
			X					

Other degree not listed above:

Student Number and year of study: (*if applicable):* 4th year Registrar. Student number 211560698

If for postgraduate degree, please confirm whether the application has been reviewed and approved by your school's Academic Leader (Research):	Yes X		No

If yes, provide approval date and attach approval letter:

Name and qualifications of Supervisor Dr. Matthew GOODIER, MBChB, FCR (Diag) SA, MMed (Rad)

Name and qualifications of Co-supervisor

If not for degree purposes, state other (example, self-initiated research):

Has this study been, or is it likely to be, submitted to any other Research Ethics Committee?	Yes		No X		N/A	

If yes, please name the Committee/s and or institution and give outcome - i.e. approved/rejected/pending/not applicable? *(If approved, attach approval letter)*

Please state number of Co-investigators in project:[1]				
(if additional space is required for more investigators details please add to the end of application)				
CO-INVESTIGATOR/S ROLE IN PROJECT *For UKZN statistical* *reporting purposes*				
Name: Dr. Matthew GOODIER				
Faculty: Health: Medicine				
Department: Radiology				
*Gender: Male				
*Race: W				
Role: Supervisor				
Signature of Co-Investigator:				
Has the Principal Investigator or any of the co-investigators been previously/or are presently being investigated for alleged research misconduct? *(If yes, please provide details and dates)*	Yes		No	X
FUNDING OF THE RESEARCH:				
Has funding been secured?	Yes		No	X
Is this project funded from a US DHHS funding source?	Yes		No	X
If yes, name the federal fundi agency				

---

[1] Please note that because of conflict of roles and interests that can arise, academic supervisors and co-investigators should be separate individuals.

Can this project proceed without funding? *(give a brief explanation)* An amount of approximately R1000 will be put forward towards basic administration costs by the principal investigator.	Yes		No	
	X			

Has an application for funds been made to other sources to support this project?	Yes		No X	

Note:

For all US Federally funded studies (e.g. NIH, CDC, NIAID, DAIDS, NIMH, etc.), one complete copy of the original funding application and approval must accompany the BREC ethics application.

All University contracts need to be uploaded on the Contracts Management online submission form with either the signed **Approval letter** (non-research) **or Form 1** (research related). The website link to the system is http://legalservices.ukzn.ac.za/ContractsManagement.aspx

If you require assistance with the completion of the online submission form, or with any aspect of the new system, please contact Mr Rendra Phalad on Ext 7455 for all contracts (non-research contracts), and Mr Deon Moodley on Ext 8199 (for research contracts).

FAILURE TO MAKE FULL FINANCIAL DISCLOSURES WILL DELAY ETHICS APPROVAL

Please indicate whether a BREC review fee is applicable for this study? (See Fee Schedule on BREC Website)	Yes		No X	
If Yes, is the study covered by your Centre/Unit's annual levy fee to BREC?	Yes		No X	

Note:

* Expedited review only applies to minimal risk studies – e.g. retrospective chart reviews, studies on stored samples etc., for details see BREC ToR and SoP at

http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx

SECTION B:

NATURE OF STUDY

Quantitative

Type of Study: *(please tick)*	Epidemiological	Observational clinical study	Experimental	**Observational X**

	Retrospective Chart Review	Prospective Chart Review	Laboratory study on stored samples	Audit	Other: X **Quantitative Investigative**
Qualitative					

1. THE PROTOCOL FOR STUDY

1.1 Full title of research project: *(Please DO NOT use abbreviations or acronyms)*

Application of a Biomechanical Approach to the MRI Assessment of Traumatic Knee Injuries in a South African Setting

1.2 Where will the Research be carried out?

Grey's Hospital, Pietermaritzburg.

1.3 Aims (what you hope to achieve) and objectives (how you will achieve your aims) of study:

AIMS: To assess the utility of a biomechanical approach to the MRI interpretation of traumatic knee injuries in a tertiary South African referral centre.

OBJECTIVES: Utility will be assessed by calculating the percentage of post-trauma MRI knee studies that can be classified according to their injury mechanism based on MRI findings in a sample of MRI cases performed at Grey's Hospital (Pietermaritzburg, South Africa) between January 2012 and July 2013. Our results will be compared with those of a North American study that was able to do so in 85% of cases.

1.4 Hypothesis to be tested, or Research Question to be answered:

A biomechanical approach to the interpretation of post-trauma MRI knee studies has been proposed to be a useful model of interpretation in several North American studies because it can be implemented in a high percentage of cases and offers diagnostic benefit. We will investigate the percentage of cases in which such an approach can be implemented in a South African setting and thereby use this as a measure for usefulness in our setting.

1.5 Summary of the proposed research (restrict to 100 words)

We propose to review the MRI studies of patients imaged at Grey's Hospital for traumatic knee injury and app

biomechanical approach to MRI interpretation, where possible categorising each case according to injury mechanism.

The percentage of cases than can be classified by mechanism will be calculated and compared with the resul

a

North American study that was able to do so in 85% of cases. A sample of thirty cases will be selected.

1.6   Keywords (for database):

Traumatic knee injury; MRI interpretation; biomechanical approach

1.7   Background and Literature Review (maximum 1 page):

In their article titled 'A Biomechanical Approach to MRI of Acute Knee injuries' MacMahon et al[8] propose classification and interpretation of knee injuries according to injury mechanism. The theoretical advantage of this approach is that by first identifying the injury mechanism a more focused search for subtle but important injuries will be prompted.

In an earlier article entitled 'Mechanism-based Pattern Approach to Classification of Complex Injuries of the Knee Depicted at MR Imaging', Hayes et al[9] propose classification of knee injuries into one of ten categories according to a pre-defined set of common mechanisms. They claim to have been able to classify knee injuries seen in their setting into one of these ten categories with 85 percent accuracy. This is a promising result: the fact that most knee injuries are complex in nature would suggest that such a high success rate in classification is unlikely.

In contrast, well-known radiology texts - such as Fundamentals of Diagnostic Radiology by Brandt and Helms[10]- present a more traditional approach MRI interpretation of traumatic knee injuries. They propose looking first for primary pathologies - for instance, evidence of an ACL tear - and then looking for secondary supportive evidence for the primary findings, such as bony contusions, joint alignment and associated injuries.

Several recent studies have correlated clinical, radiological and arthoscopic findings. For instance, Rayan et al [11] reported that MRI investigation of the injured knee was less sensitive than clinical examination for the detection of anterior cruciate ligament and meniscal injuries. The authors concluded that MRI is used most effectively to rule out injury in indeterminate cases because it has a better negative predictive compared to

positive predictive value in the evaluation of ACL or meniscal injury. The importance of results such as these is that MRI scans should be used appropriately and in selected cases in order to limit unnecessary expense to both state and patient, and to avoid delays in patient management.

It seems significant that only a few articles were found in the recent radiology literature that focused on the use of a biomechanical approach in the interpretation of the MRI in knee injuries. Such an approach is logical given that only a limited number of knee injury mechanisms are possible, and that certain clusters of injuries occur commonly in combination, such as the 'O'Donoghue unhappy triad.' [8]

Both Hayes [9] and MacMahon [8] provide sound arguments for the advantages of adopting a biomechanical approach to the interpretation of post trauma MRI of the knee.

We expect the epidemiology of our results to differ from Hayes. [9] In comparison to the developed world, as a developing country the South African population is younger, with a bottom heavy distribution curve. South Africa also has an active sporting and outdoor culture, with soccer and rugby being popular sporting pursuits. And finally, the incidence of motor vehicle accidents in South Africa is high (35.8 deaths per 100 000 population). [5] These factors may contribute to a different epidemiological picture of knee injuries.

1.8   Key References: *(Give approximately 5 key references)*

1. Hayes CW, Brigido MK, Jamadar DA, Propeck T. Mechanism-based Pattern Approach to Classification of Complex Injuries of the Knee Depicted at MR Imaging. RadioGraphics 2000;20:S121-S134.
2. MacMahon P, Palmer W. A Biomechanical Approach to MRI of Acute Knee Injuries. American Journal of Radiology 2011;197:568-577.
3. Brandt WE, Helms CA. Fundamentals of Diagnostic Radiology. MRI Imaging of the Knee. Lippincott Williams and Wilkins. 2007

4. Rayan F, Bhonsle S, Shukla DD. Clinical, MRI, and arthroscopic correlation in meniscal and anterior cruciate ligament injuries. International Orthopaedics. 2009;33(1):129-132.

5. Sukhai A, Jones A, Haynes R. Epidemiology and Risk of Road Traffic Mortality in South Africa. South African Geographical Journal 2009;91(1): 4-15.

6. Lim SY, Peh WCG. Magnetic Resonance Imaging of Sports Injuries of the Knee. Annals of the Academy of Medicine 2008;37(4):354-61.

7. Bollen S. Epidemiology of Knee Injuries: Diagnosis and Triage. British Journal of Sports Medicine 2000;34:227-228.

8. Sanders TG, Medynski MA, Feller JF, Lawhorn KW. Bone Contusion Patterns of the Knee at MR Imaging: Footprint of the Mechanism of Injury. Radiographics 2000;20 Spec NoS135-51.

2.   PLAN OF INVESTIGATION FOR STUDY

 * In the case of Higher Degrees, please state name and School of person consulted regarding the design:

2.1 Is this a retrospective chart review with no human contact?	Yes	X	No	
2.2 Is this a study of stored tissue?	Yes		No	X
2.3 Are host genetic factors being studied?	Yes		No	X

2.4   How many hours per week will the PI devote to this project?
  (Timetable the project in terms of the resources and time available)

3.   STATISTICAL PLANNING AND DATA ANALYSIS

3.1 Has this project been approved by a professional statistician? If No, please justify.	Yes		No	X

3.2   If answered "yes" to (3.1), provide the name of the statistician:

3.3   Please provide a brief overview of statistical and data analytic considerations, including:
How was the number of participants determined? Please include assumptions made in any power analysis (e.g. control incidence or mean and standard deviation of primary outcome variable, desired or anticipated effect of treatment or intervention, level of statistical significance and desired power), and list all planned statistical methods to be used. For descriptive studies list statistical operations to be performed.

Simple descriptive statistics will be used to describe the findings. There is no foreseen need for analytical

statistics. Should it become evident that we will require more complex statistical support the UKZN biostatistician will be approached.

3.4   For *qualitative* studies: What is the framework/approach to be used for analysis of the data?

4.	PARTICIPANTS IN THE STUDY

4.1 Is this a multi-national study? (*If yes, state collaborating countries*)	Yes			No	X	

4.2   List all sites in South Africa in which the project will be carried out i.e. Geographic location (e.g. KwaZulu-Natal) and type of place (e.g. hospital, clinic, schools, community etc).

The study will be carried out at a single site: Radiology Department, Grey's Hospital, Pietermaritzburg, KwaZulu-Natal.

4.3 Source: *(Please indicate number per group)*	Inpatients	Outpatients	Volunteers
	X	X	

4.4 Age (human studies) *(Please indicate number per group)*	Neonates (<28 days)	Infants (1-11 month)	Children (1-12 years)	Adolescent (13-17 years) X	Adults X

4.5 Is there a control group(s)?	Yes		No X		

4.6   Demographic profile of participants *(please tick ALL appropriate boxes below.)*

4.6.1   Gender: Female [x]   Male [x]

[x]   [x]   [x]   [x]

4.6.2	Population Group:	Black	Coloured	Indian	White

4.6.3	Language Group/s: Specify:

4.7	Describe the recruitment process in detail for all groups.

A random selection of 50 studies will be made from the data base dating from January 2012 to July 2013

4.8 Will incentives be offered to facilitate recruitment? *(If yes, describe in detail)*	Yes		No		N/A	
					x	

4.9 Will participants be reimbursed in some way for participation? *(If yes, describe in detail)* See SA DoH Guidelines on BREC Website	Yes		No		N/A	
					x	

4.10 Will reimbursement for participants and investigators be in accordance with: *(If no, please explain)* • Guidelines for Good Practice in the Conduct of Clinical Trials in Human Participants in South Africa: Department of Health (2006) and; • Ethics in Health Research: Principles, Structures and Processes: (2004)? • Current SA DoH Guidance on reimbursement (*See BREC website*)	Yes		No		N/A	
					x	

4.11 Will participants be insured against research related injury? *(If yes, please provide details; If no, please provide rationale)* *Mandatory for Clinical Trials*	Yes		No		N/A	
					x	

5.	**POTENTIAL RISKS OR DISCOMFORT**

5.1 Can the project have any potential risks or discomfort on participants, members of the public, researchers, field staff or the physical environment?	Yes		No		
			X		

5.2   If "yes" to (6.1) indicate, for each study group/arm, the potential additional risks as follows:
5.2.1   Biological risks
5.2.2   Psychological risks
5.2.3   Social Risks
5.2.4   Legal risks
5.2.5   Financial risks
5.2.6   Other risks

5.3   Please detail steps that will be taken to minimise the risks indicated above:
5.3.1   Biological risks
5.3.2   Psychological risks
5.3.3   Social Risks
5.3.4   Legal risks
5.3.5   Financial risks
5.3.6   Other risks

6.	INFORMED CONSENT: GIVEN TO PARTICIPANTS

See SAMPLE INFORMATION SHEET AND CONSENT FORM ON UKZN BREC WEBSITE at
http://research.ukzn.ac.za/Libraries/Notices2011/BREC_Informed_consent_form_sflb.sflb.ashx

Other consent forms are acceptable provided that they contain at least the essential elements outlined in the current UKZN BREC Terms of Reference (ToR) and Standard Operating Procedures (SoP) available at
http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx

If necessary, information sheets and consent forms, after ethics approval of the English version, must be translated into appropriate local languages and submitted to BREC for further approval prior to implementation, with a copy of the translator's certificate, and back translations if applicable.

The correct and complete contact details for the UKZN Biomedical Research Ethics Committee should be in the information sheets and consent forms as follows:

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus
Govan Mbeki Building
University of KwaZulu-Natal
Private Bag X 54001, Durban, 4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2602486 - Fax: 27 31 2604609
Email: BREC@ukzn.ac.za

Manuscript Corrections Requested by the BREC Office

<u>RESEARCH OFFICE</u>

Biomechanical Research Ethics Administration, Westville Campus, Govan Mbeki Building,

Private Bag X 54001, Durban 4000, BREC@ukzn.ac.za, 18 August 2015

Dear Professor Madiba

Protocol: Application of a Biomechanical Approach to the MRI Assessment of Traumatic Knee Injuries in a South African Setting: Degree Purposes (MMed) – School of Clinical Medicine (Radiology) Student Number 211560698. BREC REF: BE518/14.

Thank you for the opportunity to meet with you last week on Monday. I hope that the following corrections will bring clarity to my study protocol. I have decided to keep the term 'measurements' when referring to data collection of pre-determined injury combinations in the proposed study but, as we discussed last Monday in our meeting, I wish to emphasise that the term refers to descriptive variables without inherent numerical value.

Response to Request 1: Measurements proposed must be described in more detail:

In summary, our study aim is to validate the biomechanically-based classification approach to the MRI interpretation of post-traumatic knee injuries devised by Hayes et al [8] in a South African setting by retrospectively applying the classification to thirty cases in our setting.

Hayes et al [8] have devised a biomechanically-based classification system based on the identification of ten predictable constellations of injuries or injury patterns that occur with specific injury mechanisms. These are in essence the unit of measure in this study. It must be noted that these categories are descriptive variables and hold no inherent numerical value. The percentage of cases that can be classified using this system in our setting will be calculated and compared with the results of Hayes et al. [8] The table (Appendix 4) outlines the classification system devised by Hayes. [8]

The vertical columns 'Bone Bruise or Fracture' and 'Ligament Injuries' highlight the injuries that commonly occur in combination with specific mechanisms. In cases where a particular pattern is identified, the case will be classifiable into one of the ten injury categories outlined in the table. Where such combinations of injuries are not convincingly present, the case will be recorded as non-classifiable. According to Hayes et al [8] the classification system is necessarily incomplete owing to the complex nature of possible injuries around the knee. Thus certain exclusion criteria have been stipulated. These include the categories of extensor mechanism injury and that of axial loading.

It may be useful at this point to better describe how findings are made in musculoskeletal radiology. Knowledge of normal anatomical morphology and MRI signal characteristics of soft tissue and bony structures is the backbone of musculoskeletal radiology and is a fundamental principle of radiology per se. This knowledge is used to identify abnormal or injured structures. The use of the classification system devised by Hayes et al [8] will be based on differentiating what is normal and abnormal, rather than on physical measurements such as length, volume, density, which are used in many other instances in radiology. All radiological findings need to be considered in the context of clinical and laboratory findings, which will significantly improve the accuracy and relevance of radiological conclusions. A limitation in all radiology is that of subjectivity. Classifications, such as that of Hayes et al [8] address these limitations by aiming to standardize MRI knee interpretation and increase accuracy. Radiological findings are especially important in musculoskeletal MRI because certain injuries cannot be verified by other means, such as strong clinical correlation – for example, the positive anterior draw test in ACL injury; surgical exploration or joint arthroscopy with direct visualization; or biopsy with histological correlation: for example, bony bruising.

Response to Request 2: Will the adaption of Hayes et al [8] be reliable and valid?

The biomechanically-based classification devised by Hayes et al [8] is proposed to increase the accuracy of MRI interpretation of the traumatically injured knee. The classification is postulated to be reliable in the North American setting given that it was demonstrated to be applicable in up to 85% of cases, an unexpectedly high result given the complex nature of knee injuries in general.

We propose to assess the reliability of the classification devised by Hayes et al [8] in a South African setting.

In order to do so we will apply the classification in thirty post-trauma knee MRI cases. Two independent reviewers will retrospectively review the cases blinded to the patient history (as this may increase the accuracy of assignment of an injury mechanism). The classification outlined in the table above will be applied in these thirty cases, and the percentage of cases that can be classified by this mechanism-based classification will be calculated and compared with the 85% achieved by Hayes.[8] The South African setting differs significantly from the North American setting in terms of the differing epidemiology of knee injuries; the relatively limited availability of

health care services; and the resultant delay time to MRI which is often observed in our setting. These factors may influence the reliability of such a classification in the South African setting. An ideal classification will be universally reliable in differing health care systems and population settings. If proved reliable in our setting, consideration may then be given to its integration into local teaching and practice.

Validation of the classification would necessarily involve comparing imaging findings with proven injury mechanisms – for example, directly observed or video-taped injury. This was not part of the original study which retrospectively assumed injury mechanisms based on logical interpretation of MRI findings, and is beyond the scope of this study. As mentioned above, this study will focus on assessing the reliability of the classification in a South African setting.

Many thanks, Dr. James Stutterheim

HPCSA No: MP 0685941. Consultant Radiologist. Ladysmith Hospital. KZN. South Africa. Email: jamostutt@gmail.com 0721936984

Reference

1. Hayes CW, Brigido MK, Jamadar DA, Propeck T. Mechanism-based Pattern Approach to Classification of Complex Injuries of the Knee Depicted at MR Imaging. RadioGraphics 2000;20:S121-S134.

APPENDIX 2: THE GUIDELINES FOR AUTHORSHIP FOR THE JOURNAL SELECTED FOR SUBMISSION OF THE MANUSCRIPT

Structure and style of your original research article

The page provides an overview of the structure and style of your original research article to be submitted to the *SA Journal of Radiology*. The original article provides an overview of innovative research in a particular field within or related to the focus and scope of the journal presented according to a clear and well-structured format (3000 words or less with up to 10 illustrations and a maximum of 15 references). Compulsory as a supplementary file: Ethical clearance letter/certificate.

Please use British English, that is, according to the Oxford English Dictionary. Avoid Americanisms (e.g. use 's' and not 'z'). Consult the Oxford English Dictionary when in doubt and remember to set your version of Microsoft Word to UK English.

- o **Language:** Manuscripts must be written in British English.
- o **Line numbers:** Insert continuous line numbers.
- o **Font:**
    - o **Font type:** Palatino
    - o **Symbols font type:** Times New Roman
    - o **General font size:** 12pt
    - o **Line spacing:** 1.5
- o **Headings:** Ensure that formatting for headings is consistent in the manuscript.
- o First headings: normal case, bold and 14pt
- o Second headings: normal case, underlined and 14pt
- o Third headings: normal case, bold and 12pt
- o Fourth headings: normal case, bold, running-in text and separated by a colon.

Our publication system supports a limited range of formats for text and graphics. Text files can be submitted in the following formats only:

- o Microsoft Word (.doc): We cannot accept Word 2007 DOCX files. If you have created your manuscript using Word 2007, you must save the document as a Word 2003 file before submission.
- o Rich Text Format (RTF) documents uploaded during Step 2 of the submission process. Users of other word processing packages should save or convert their files to RTF before uploading. Many free tools are available that will make this process easier.

.

The structure and style of your original article

Page 1

The format of the **compulsory cover letter** forms part of your submission and is on the first page of your manuscript and should always be presented in English. You should provide all of the following elements:

- **Article title:** Provide a short title of 50 characters or less.
- **Significance of work:** Briefly state the significance of the work being reported on.
- **Full author details:** Provide title(s), full name(s), position(s), affiliation(s) and contact details (postal address, email, telephone and cellular number) of each author.
- **Corresponding author:** Identify to whom all correspondence should be addressed to.
- **Authors' contributions:** Briefly summarise the nature of the contribution made by each of the authors listed.
- **Summary:** Lastly, a list containing the number of words, pages, tables, figures and/or other supplementary material should accompany the submission.

Page 2 and onwards

Title: The article's full title should contain a maximum of 95 characters (including spaces).

Abstract: The abstract, written in English, should be no longer than 250 words and must be written in the past tense. The abstract should give a succinct account of the objectives, methods, results and significance of the matter. The structured abstract for an Original Research article should consist of five paragraphs labelled Background, Objectives, Method, Results and Conclusion.

- **Background:** *Why is the problem important to us?* State the context and purpose of the study (that is, mention what practical, scientific or theoretical gap your research is filling).
- **Objectives:** *What problem are you trying to solve*? What is the scope of your work (is it a generalised approach or for specific situation)? Be careful not to use too much jargon.
- **Method:** *How did you go about solving or making progress on the problem*? How was the study performed and which statistical tests were used (what did you actually do to get the results)? Clearly express the basic design of the study, name or briefly describe the basic methodology used without going into excessive detail. Be sure to indicate the key techniques used.
- **Results:** *What is the answer*? State the main findings. (As a result of completing the above procedure or study, what did you learn, invent or create?) Identify trends, relative change or differences on answers to questions.
- **Conclusion:** *What are the implications of your answer*? Briefly summarise any potential implications (e.g. the larger implications of your findings, especially for the problem or gap identified in your motivation).

Do not cite references in the abstract and do not use abbreviations excessively in the abstract.

The following headings serve as a guide for presenting your research in a well-structure format. As an author you should include all first level headings but subsequent headings (second and third level headings) can be changed.

Introduction (first-level heading): The introduction contains two subsections, namely the background section and the literature review.

- **Problem statement (second-level heading):** The problem statement, also referred to as the setting section, should be written from the viewpoint of readers, that is, without specialist knowledge in that area. This statement must clearly state and illustrate the introduction to the research and its aims in the context of previous work bearing directly on the subject. The setting section to the article normally contains the following five elements:
- **Key focus (third-level heading):** A thought-provoking introductory statement on the broad theme or topic of the research.
- **Background (third-level heading):** Background or the context to the study (explaining the role of other relevant key variables in this study).
- **Trends (third-level heading):** The most important published studies previously conducted on this topic or that has any relevance to this study (provide a high-level synopsis of the research literature on this topic).
- **Objectives (third-level heading):** Indicate the most important controversies, gaps and inconsistencies in the literature that will be addressed by this study. In view of the above trends, state the core research problem and specific research objectives that will be addressed in this study and provide the reader with an outline of what to expect in the rest of the article.
- **Contribution to field (third-level heading):** Explanation of the study's academic (theoretical and methodological) or practical merit and/or importance (provide the value-add and/or rationale for the study).

Literature review (second-level heading): The literature review is the second subsection under the Introduction and provides a brief and concise overview of the literature under a separate second-level heading, e.g. literature review. A synthesis and critical evaluation of the literature (not a compilation of citations and references) should at least include or address the following elements (ensure these are in the literature review):

- definitions of all conceptual (theoretical) key concepts
- a critical review and summary of previous research findings (theories, models, frameworks, etc.) on the topic
- a clear indication of the gap in the literature and for the necessity to address this void
- a clearly established link that exists between formulated research objectives and theoretical support from the relevant literature.

- **Research method and design (first-level heading):** The methods should include:

- **Materials (second-level heading):** Describe the type of organism(s) or material(s) involved in the study.
- **Setting (second-level heading):** Describe the site and setting where your field study was conducted.

- **Design (second-level heading):** Describe your experimental design clearly, including a power calculation, if appropriate. Note: additional details can be placed as an online supplementary addendum.
- **Procedure (second-level heading):** Describe the protocol for your study in sufficient detail (with a clear description of all interventions and comparisons) so that other scientists could repeat your work to verify your findings.
- **Analyses (second-level heading):** Describe how the data were summarised and analysed, with additional details placed in the online supplementary information.

- **Results (first-level heading):** This section provides a synthesis of the obtained literature grouped or categorised according to an organising or analysis principle.

- Tables may be used or models may be drafted to indicate key components of the results of the study.

- Organise the results based on the sequence of tables and figures that you will include in the manuscript.
- The body of the Results section is a text presentation of the key findings, which includes references to each of the tables and figures.
- Statistical test summaries (test name, p-value) are usually reported parenthetically (that is, inserted as a parenthesis in brackets) together with the biological results they support; use SI unit.
- Present the results of your experiment(s)/research data in a sequence that will logically support (or provide evidence against) the hypothesis or answer the question that was stated in the Introduction.

All units should conform to the **SI convention** and be abbreviated accordingly. Metric units and their international symbols are used throughout, as is the decimal point (not the decimal comma).

Ethical considerations (first-level heading): Articles based on the involvement of humans have been conducted in accordance with relevant national and international guidelines. Approval must have been obtained for all protocols from the author's institutional or other relevant ethics committee and the institution's name and permit numbers should be provided at submission.

- **Potential benefits and hazards (second-level heading:** What risks to the subject are entailed in involvement in the research? Are there any potential physical, psychological or disclosure dangers that can be anticipated? What is the possible benefit or harm to the subject or society as a result of their participation or from the project as a whole? What procedures have been established for the care and protection of subjects (e.g. insurance, medical cover) and the control of any information gained from them or about them?
- **Recruitment procedures (second-level heading):** Was there any sense in subjects being obliged to participate – as in the case of students, prisoners, learners or patients – or were volunteers being recruited? If participation was compulsory, the potential consequences of non-compliance must be indicated to subjects; if voluntary, entitlement to withdraw consent must be indicated as well as when that entitlement lapses.

- **Informed consent (second-level heading):** Authors must include how informed consent was handled in the study.
- **Data protection (second-level heading:** Authors must include in detail the way in which data protection was handled.

- **Trustworthiness (first-level heading):** This refers to the findings of the study being based on the discovery of human experience as it was experienced and observed by the participants.

- **Reliability (second-level heading):** Reliability is the extent to which an experiment, test, or any measuring procedure yields the same result on repeated trials. Without the agreement of independent observers able to replicate research procedures, or the ability to use research tools and procedures that yield consistent measurements, researchers would be unable to satisfactorily draw conclusions, formulate theories, or make claims about their research' ability to be generalised.
- **Validity (second-level heading):** Validity refers to the degree to which a study accurately reflects or assesses the specific concept that the researcher is attempting to measure. While reliability is concerned with the accuracy of the actual measuring instrument or procedure, validity is concerned with the study's success at measuring what the researchers set out to measure. Researchers should be concerned with both external and internal validity. External validity refers to the extent to which the results of a study are generalisable or transferable. Internal validity refers to:
  - the rigor with which the study was conducted (e.g. the study's design, the care taken to conduct measurements, and decisions concerning what was and wasn't measured).
  - the extent to which the designers of a study have taken into account alternative explanations for any causal relationships they explore.

- In studies that do not explore causal relationships, only the first of these definitions should be considered when assessing internal validity.

- **Discussion (first-level heading):** This section normally contains the following four elements. It is suggested that subheadings are used in this section:

- **Outline of the results (second-level heading):** Restate the main objective of the study and reaffirm the importance of the study by restating its main contributions; summarise the results in relation to each stated research objective or research hypothesis; link the findings back to the literature and to the results reported by other researchers; provide explanations for unexpected results.
- **Practical implications (second-level heading):** Reaffirm the importance of the study by restating its main contributions and provide the implications for the practical implementation your research.

- **Limitations of the study (first-level heading):** Point out the possible limitations of the study and provide suggestions for future research.

- **Recommendations (second-level heading):** Provide the recommendations emerging out of the current research.

Conclusion (first-level heading): This should state clearly the main conclusions of the research and give a clear explanation of their importance and relevance, with a recommendation for future research (implications for practice). Provide a brief conclusion that restates the objectives, the research design, the results and their meaning or significance.

Acknowledgements (first-level heading): If, through your study, you received any significant help in conceiving, designing, or carrying out the work, or received materials from someone who did you a favour by supplying them, you must acknowledge their assistance and the service or material provided. **Authors should always acknowledge outside reviewers of their drafts and any sources of funding that supported the research.**

- **Competing interests (second-level heading):** A competing interest exists when your interpretation of data or presentation of information may be influenced by your personal or financial relationship with other people or organisations that can potentially prevent you from executing and publishing unbiased research. Authors should disclose any financial competing interests but also any non-financial competing interests that may cause them embarrassment were they to become public after the publication of the manuscript. **Where an author gives no competing interests, the listing will read:**

- 'The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.'

- **Authors' contributions (second-level heading):** This section is necessary to give appropriate credit to each author, and to the authors' applicable institution. The individual contributions of authors should be specified with their affiliation at the time of the study and completion of the work. An 'author' is generally considered to be someone who has made substantive intellectual contributions to a published study. Contributions made by each of the authors listed, can follow the example below (please note the use of author initials):

- J.K. (University of Pretoria) was the project leader, L.M.N. (University of KwaZulu-Natal) and A.B. (Stellenbosch University) were responsible for experimental and project design. L.M.N. performed most of the experiments. P.R. (Cape Peninsula University of Technology) made conceptual contributions and S.T. (University of Cape Town), U.V. (University of Cape Town) and C.D. (University of Cape Town) performed some of the experiments. S.M. (Cape Peninsula University of Technology) and V.C. (Cape Peninsula University of Technology) prepared the samples and calculations were performed by C.S.(Cape Peninsula University of Technology)**.**

References (first-level heading): Begin the reference list on a separate page, and give no more than 15 references in all. The *SA Journal of Radiology* uses the **<u>Vancouver referencing style</u>**, details of which can be downloaded from the journal website. **Note: No other style will be permitted.**

APPENDIX 3: ETHICAL APPROVALS AND SITE PERMISSION

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YAKWAZULU-NATALI

16 September 2015

Dr James Stutterheim
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PROTOCOL: Application of a Biomechanical Approach to the MRI Assessment of Traumatic Knee Injuries in South African Settings: Degree Purposes (MMed) - School of Clinical Medicine (Radiology) Student Number: 211560698. BREC REF No.: BE518/14.

EXPEDITED APPLICATION

A sub-committee of the Biomedical Research Ethics Committee has considered and noted your application received on 09 December 2014.

The study was provisionally approved pending appropriate responses to queries raised. Your responses received on 07 July 2015 to queries raised on 07 February 2015 have been noted by a sub-committee of the Biomedical Research Ethics Committee. The conditions have now been met and the study is given full ethics approval.

This approval is valid for one year from **16 September 2015**. To ensure uninterrupted approval of this study beyond the approval expiry date, an application for recertification must be submitted to BREC on the appropriate BREC form 2-3 months before the expiry date.

Any amendments to this study, unless urgently required to ensure safety of participants, must be approved by BREC prior to implementation.

Your acceptance of this approval denotes your compliance with South African National Research Ethics Guidelines (2015), South African National Good Clinical Practice Guidelines (2006) (if applicable) and with UKZN BREC ethics requirements as contained in the UKZN BREC Terms of Reference and Standard Operating Procedures, all available at http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx.

BREC is registered with the South African National Health Research Ethics Council (REC-290408-009). BREC has US Office for Human Research Protections (OHRP) Federal-wide Assurance (FWA 678).

The sub-committee's decision will be **RATIFIED** by a full Committee at its meeting taking place on **13 October 2015**.

We wish you well with this study. We would appreciate receiving copies of all publications arising out of this study.

Yours sincerely

Professor J Tsoka-Gwegweni
Chair: Biomedical Research Ethics Committee

cc: Supervisor - Dr Matthew Goodier

Biomedical Research Ethics Committee
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4 June 2015

To Whom it May Concern

Site Permission to Conduct Research: Dr James Stutterheim

This is to confirm that Dr James Stutterheim has site permission to gather data in connection with his Mmed research: "Application of a Biomechanical Approach to the MRI interpretation of Traumatic Knee Injuries in a South African Setting".

Yours faithfully,

Dr D Reitz
Head Clinical Department: Radiology
Greys Hospital
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Pietermaritzburg, 3201
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APPENDIX 4: DATA COLLECTION TOOL

Table 1 (Mechanism-based Classification Table compiled by Hayes et al [8].)

	Mechanism	Frequency	Bone Bruise or Fracture	Ligament Injuries	Comments
1	Pure hyperextension	2%	Anterior central tibia, anterior femoral condyles (impactions)	PCL, posterior capsule, ACL	Associated with anterior translation of tibia (ACL tear) or posterior translation of tibia (PCL tear)
2	Hyperextension with varus	8%	Anteromedial tibia, femoral condyle (impactions); posterolateral corner, proximal fibula (avulsions)	Posterolateral corner, ACL, popliteal tendon, posterior capsule	Unstable posterolateral corner injury
3	Hyperextension with valgus	2%	Anterolateral tibia, femoral condyle (impactions); posteromedial tibia (avulsion)	MCL, posteromedial corner, posterior capsule, PCL	Contiguous ("kissing") bone marrow edema pattern aids in distinguishing lateral impaction from typical noncontiguous ACL injury pattern (flexion, valgus, and external rotation)
4	Pure valgus	6%	Lateral tibia, lateral femoral condyle (impactions)	MCL, ACL, PCL (depending on severity of force)	Pure pattern is uncommon
5	Pure varus	1%	Medial tibia, femoral condyle (impactions)	Iliotibial band, LCL	Rarely seen pattern, as varus is usually associated with flexed position and internal rotation
6	Flexion valgus, external rotation	46%	Lateral femoral condyle, posterolateral tibia (impactions); posteromedial tibia, femoral condyle (avulsions vs contrecoup)	MCL, ACL	Medial and lateral menisci at risk
7	Flexion varus, internal rotation	1%	Lateral femoral condyle, posterolateral tibia (ACL tear–related impactions), posterolateral tibia (Segond avulsion), fibular head (avulsion)	ACL, posterolateral corner	Lateral and medial menisci at risk
8	Flexion with posterior tibial translation	8%	None, unless severe force or associated with axial load	Isolated PCL, posterior dislocation with severe force	Most common mechanism for isolated PCL tear
9	Patellar dislocation (flexion and internal rotation of femur on fixed tibia)	6%	Medial patella, lateral condyle (impactions)	Medial patellar retinaculum, MCL, ACL (with sufficient force)	Search for chondral defect, often associated with predisposing conditions (eg, patella alta)
10	Direct trauma	5%	Directly beneath site of trauma	None	May have superficial soft-tissue injury adjacent to bone contusion

APPENDIX 5: RAW DATA AND SUMMARY

Summary of Principal Investigator and Supervisor Data

	GR No.	Patient Age	Sex	Side	Principal Inv: Classifiable?	Supervisor: Classifiable?
1	GR10029247	39	F	R	N	N
2	GR10029317	33	M	L	N	N
3	GR10029327	26	F	R	N	N
4	GR10029744	28	F	R	N	N
5	GR10030644	25	F	L	Y 10	N
6	GR10030313	15	M	R	N	N
7	GR10035055	30	M	L	N	N
8	GR10028821	26	M	L	N	N
9	GR10023202	35	M	L	N	N
10	GR10033820	34	F	R	Y 10	N
11	GR10033987	23	M	L	N	N
12	GR10034248	37	F	R	N	N
13	GR10029756	32	F	R	Y 2	N
14	GR10034647	14	F	R	Y 2	N
15	GR10034853	47	F	L	N	N
16	GR10035309	35	F	L	N	N
17	GR10039671	29	M	R	N	N
18	GR10039771	31	M	R	N	N
19	GR10039771	31	M	L	Y 5	N
20	GR10034271	34	M	R	N	N
21	GR10047495	14	M	L	N	N
22	GR10051211	34	M	L	Y 4	Y 4
23	GR10045452	16	M	L	N	N
24	GR10055191	65	F	R	Y 2	N
25	GR10057968	30	M	L	N	N
26	GR10031187	34	M	L	N	N

27	GR10060501	25	M	R	N	N
28	GR10060711	52	F	R	N	N
29	GR10060863	47	M	R	Y 5	Y 5
30	GR10060863	47	M	L	Y 4	N
				%	30	7

Principal Investigator Data Collection

	GR Number	Side	Bone Bruise or Fracture	Cartilage (patella and trochlear)	Collateral Ligaments	Cruciate Ligaments	Menisci	Comments	Extensor mechanism	Classifiable? Mechanism
1	GR10029247 Age: 39 F	R	No	Intact	MCL + LCL intact	ACL + PCL intact	M + L menisci intact	PL corner intact. Joint effusion Abnormal signal and thickening at PM corner	Intact	No
2	GR10029317 Age: 33 M	L	No obvious oedema. Small subchondral hyperintensity in the MF condyle. 6mm oval structure in anterior joint space: query osteochondral fragment?	Intact	MCL + LCL intact	ACL: subtle increased signal intensity in ACL. PCL intact	M + L menisci intact. Possible rupture of inferior fascicle of post horn lateral meniscus.	Physiological amount of joint fluid. PL corner intact.	Intact	No Non-specific ACL sprain + osteochondral defect and fragment.
3	GR10029327 Age: 26 F	R	Bony bruise posterior aspect of medial tibial condyle.	Intact	MCL + LCL intact	ACL: complete tear. PCL intact	High T2 signal in the extruded lateral meniscus. Gr2 (mucoid degeneration?)	Moderate joint effusion. PL corner intact, but markedly thinned popliteus tendon.	Intact	No ACL + PL corner: flexion varus internal rotation. Late presentati

#	ID / Age	Side	Bony bruise		MCL/LCL	ACL/PCL	Menisci	PL corner / effusion		Notes
							MM intact.			on.
4	GR10029744 Age: 28 F	R	No.	Intact	MCL + LCL intact	ACL: high grade tear. PCL intact	Oblique tear body and post horn LM. MM intact.	PL corner intact.	Intact	No Indeterminate due to late presentation. ACL + LM
5	GR10030644 Age: 25 F	L	Bony bruise lateral aspect lateral femoral condyle	Intact	MCL + LCL intact	Increased signal in ACL. PCL intact.	M + L menisci intact	PL corner intact. Joint effusion.		Yes: 10 Direct impact
6	GR10030313 Age: 15 M	R	No	Intact	MCL + LCL intact Waviness + increased signal in LCL suggests possible injury	ACL: complete tear. PCL intact	M + L menisci intact	Joint effusion. PL corner intact.		No Non-specific ACL injury
7	GR10035055 Age: 30 M	L	No	Intact	MCL + LCL intact	Increased signal in ACL. PCL intact	M + L menisci intact	PL corner intact. Baker's cyst		No Non-specific ACL injury
8	GR10028821 Age: 26 M	L	Bony bruise at medial aspect of the medial femoral condyle.	Hypointensity and irregularity at the anterior medial femoral condyle	LCL intact. MCL disrupted at proximal insertion site	PCL high grade tear. ACL intact.	M + L menisci intact	Joint effusion.		No Complex but including pure valgus. PCL and MCL
9	GR10023202 Age: 35 M	L	Bony bruise articular surface of left formal condyle.	Intact	MCL + LCL intact	Tear of the proximal PCL. ACL intact.	M + L menisci intact	Small joint effusion. Popliteus tendon normal. There is irregularity and high		No Complex but including pure hyperextension

#	ID	Side	Bony		MCL/LCL	ACL/PCL	Menisci	Other		Mechanism
								signal at the posterior capsule.		PCL posterior capsule.
10	GR10033820 Age: 34 F	R	Schatzker 1 fracture with bony bruise at lateral tibial plateau	Intact	MCL + LCL intact	ACL + PCL intact	M + L menisci intact	Small joint effusion. PL corner: high signal in popliteus tendon although no obvious disruption		Yes: 10 Direct impact Schatzker 1 (varus force)
11	GR10033987 Age: 23 M	L	Medial femoral condyle + medial tibia	Intact	MCL + LCL intact	ACL complete tear. PCL intact.	L meniscus completely torn (? radial tear). M meniscus oblique tear.	Small joint effusion. Popliteus tendon intact		No ACL with bilateral meniscal tears
12	GR10034248 Age: 37 F	R	Subtle bony bruise in lateral tibial plateau	Intact	MCL + LCL intact	ACL + PCL intact	L meniscus tear (involves anterior horn, body and posterior horn: grade III). M meniscus intact.	Joint effusion. PL corner intact		No L meniscus tear
13	GR1oo29756 Age: 32 F	R	No	Intact	MCL + LCL intact.	High grade partial tear ACL. PCL intact.	M + L menisci intact.	Small joint effusion. Tear of popliteus at MTJ.		Yes: 2 Hyperextension with varus. ACL + popliteus tear
14	GR10034647 Age: 14 F	R	No	Intact	MCL + LCL intact.	Intra-substance ACL tear. PCL intact.	M + L menisci intact	Small joint effusion. PL corner: popliteus tendon appears thinned		Yes: 2 Hyperextension with varus. ACL + popliteus tear
15	GR10034853	L	Bone bruise at posterior	Intact	MCL: sub-periostea	ACL + PCL	M + L menisci	Small joint effusion.		No Direct

#	ID / Age	Side	Bony injury		MCL / LCL	ACL / PCL	Menisci	Effusion / PL corner	Other	Notes
	Age: 47 F		aspect lateral femoral condyle.		l haematoma proximally; LCL intact but wavy: query stretched or partial tear	intact	intact. Lateral menisco-capsular separation.	PL corner intact.		blow to lateral knee with lateral MCS but MCL and LCL abnormalities make this complex
16	GR10035309 Age: 35 F	L	Central plateau + lateral and medial tibial condyles. Schatzker 5 fracture.	Intact	MCL appears to be stripped from its periosteal attachment inferiorly but remains intact. LCL intact.	ACL + PCL intact	M + L menisci intact	Large joint effusion. PL corner intact	Hyperintensity at tibial insertion of patella tendon: equery enthesopathy versus acute injury	No Direct injury mechanism suspected. E.g. fender injury.
17	GR10039671 Age: 29 M	R	Medial aspect medial femoral condyle Central tibial plateau	Intact	High grade partial tear of LCL. MCL intact.	Complete tear of PCL. High grade partial tear of ACL.	M + L menisci intact.	Moderate joint effusion. PL corner intact.		No PCL complete tear + partial ACL tear + LCL tear: consider varus injury due to direct impact (atypical).
18	GR10039771 Age: 31 M	R	Bony bruise in anterior tibia + lateral aspect LFC Lateral fibular head	Intact	Complete tear MCL and LCL.	Complete tear of PCL High grade partial tear of ACL	Bucket handle tear of medial meniscus. Lateral meniscus intact.	Moderate joint effusion. Postero-medial corner is disrupted. PL corner intact.		No Direct lateral impact with complex injury. Other findings (e.g. MCL and LCL)
19	GR10039771 Age: 31 M	L	Bony bruise antero-medial aspect of MFC.	Intact	LCL completely torn. MCL partial tear	Intra-substance tear ACL PCL	M + L menisci intact.	Moderate joint effusion. PL corner: loss of continuity		Yes: 5 ITB and LCL Direct medial

No	ID / Age	Side			MCL / LCL	ACL / PCL	Menisci			Summary
					proximally.	intact.		of the popliteus tendon		impact with varus injury.
20	GR10034271 Age: 34 M	R	No	Intact	MCL + LCL intact.	ACL torn. PCL intact.	M + L menisci intact.	Joint effusion. PL corner intact.		No Isolated ACL injury.
21	GR10047495 Age: 14 M	L	No	Intact	? Disruption of deep fibres of the MCL or menisco-capsular separation. LCL intact.	ACL intact Proximal PCL is abnormal suggesting an injury here	M + L menisci intact.	Minimal joint effusion? PL corner intact.		No ? Disruption of deep fibres of MCL. Or MCS. PCL abnormal
22	GR10051211 Age: 34 M	L	Bony bruise lateral aspect lateral tibial plateau + central plateau and femur	Intact	MCL wavy + discontinuous inferiorly. LCL intact.	PCL: high signal suggests high grade partial tear. ACL partially torn at tibial insertion.	M + L menisci intact.	Small joint effusion.	Intact.	Yes: 4 MCL + PCL + ACL injury = pure valgus component but complex injury
23	GR10045452 Age: 16 M	L	No	Intact	Horizontal tear of the medial meniscus. LM intact.	ACL + PCL intact.	M + L menisci intact.	No effusion. PL corner: intermediate signal in the popliteus tendon: possible injury?	Intact.	No H tear of the medial meniscus.
24	GR10055191 Age: 65 F	R	Kissing bone bruise anterior lateral femoral condyle and tibial plateau.	Intact	LCL torn. MCL intact.	ACL + PCL torn.	Horizontal tear in the lateral meniscus. L menisci intact.	Joint effusion. Capsular tear at postero-lateral corner. Popliteus tendon discontinuous.	Intact.	Yes: 2 Hyperextension + varus. ACL, PL corner. Also LCL.

25	GR10057968 Age: 30 M	L	No.	Intact	MCL + LCL intact.	High signal in ACL suggests partial tear. PCL bulky at femoral insertion.	M + L menisci intact.	Small joint effusion. PL corner intact.	Intact.	No Non-specific ACL partial tear
26	GR10031187 Age: 34 M	L	Medial and antero-medial aspect of the medial tibial condyle. Med aspect med femoral condyle	Intact.	LCL torn. MCL intact.	ACL high signal : possible sprain. PCL intact.	M + L menisci intact.	Small joint effusion. PL corner intact.	Intact.	No Suspected ACL sprain. Apparent direct impact at antero-medial aspect of the knee. But PL corner intact. Maybe direct injury to proximal MCL.
27	GR10060501 Age: 25 M	R	No.	Intact.	MCL + LCL intact.	ACL completely torn. PCL intact.	Horizontal tear of the medial meniscus. L meniscus intact.	Large joint effusion. PL corner intact.	Intact.	No
28	GR10060711 Age: 52 F	R	Extensive oedema in the anterior tibial plateau and medial plateau. Suspect a comminuted fracture here.	Chondral defect in the medial plateau at fracture site.	Increased signal at the femoral attachment of the LCL. MCL intact.	ACL partial tear. Reduced calibre of the PCL (suggests partial tear).	M + L menisci intact.	Large joint effusion. Although the popliteus tendon is intact there is oedema at the lateral joint margin: suspect disruption of the lateral capsular	Intact.	No Complex injury. Anterior impact with hyperextension (high energy injury).

								ligament.		
29	GR1006086 4$$$37605 Age: 47 M Makhaye, Dennis	R	Medial femoral and tibial condyles	Intact.	LCL disrupted. MCL intact.	ACL: loss of normal parallels (partial tear). PCL: thickening and high signal at femoral attachment.	M + L menisci intact.	Moderate effusion. PL corner partial disruption but popliteus intact.	Intact.	Yes: 5 Medial contact with varus force.
30	GR1006086 3 Age: 47 M Makhaye, Dennis	L	Lateral femoral condyle	Intact.	MCL torn. LCL intact.	PCL torn. ACL intact.	M + L menisci intact.	Small effusion. PL corner intact.	Intact.	Yes: 4 Lateral contact with valgus force.

Supervisor Data Collection

	GR Number	Bone Bruise or Fracture	Cartilage	Ligament Injuries	Menisci	Comments	Mechanism	Frequency	Side
1	GR10029247	No	No	LCL	No	Small effusion	N/A		R
2	GR10029317	Med fem art surface	Med fem central art surface	No	No	-	N/A		L
3	GR10029327	No	No	ACL, LCL	Med, Lat	Small effusion	N/A		R
4	GR10029744	No	No	ACL	Lat	Small effusion	N/A		R
5	GR10030644	Anterolat fem condyle	Lat fem central art surf	ACL	No	Small effusion	N/A		L
6	GR10130313	No	No	ACL, LCL	Lat	Small effusion, semimembranosus sprain	N/A		R
7	GR10035055	Anterolat tibia, medial femur	No	ACL	No	Bakers cyst	N/A		L

8	GR10028821	Anterolateral femur, anteromedial femur, medial tibia, anterolateral tibia	Lateral tibial central art surf	MCL, LCL, PCL	No	Moderate joint effusion, semimembranosus tendon injury	N/A		R
9	GR10023202	Medial femur, medial tibia, lateral fem art surface	Lateral fem art surface	PCL	Lat meniscus	Small effusion, patella subluxation, medial retinaculum injury	N/A		L
10	GR10033820	Lat tibial articular surface plateau fracture	Lat tibial articular surface	No	No	Small effusion	N/A		R
11	GR10033987	Medial femoral condyle	No	ACL, MCL	Lat meniscus	Small effusion	N/A		L
12	GR10034248	Anterolat tibia	No	LCL	Lat meniscus	Moderate effusion	N/A		R
13	GR1oo29756	No	No	No	Medial meniscus torn	Small joint effusion	N/A		R
14	GR10034647 (Normal?)	No	No	No	No	No	N/A		R
15	GR10034853	Posterolat femur	No	MCL	No	No	N/A		L
16	GR10035309	Central and medial prox tibia with plateau fracture	No	MCL	Medial meniscus (contusion)	Moderate joint effusion	N/A		L
17	GR10039671	Anteromedial femur	No	ACL, PCL, LCL	No	Moderate joint effusion	N/A		R
18	GR10039771	Anteromedial tibia, lateral femur	Anteromedial tibial plateau	ACL, PCL, LCL, MCL	Medial meniscus	Moderate joint effusion	N/A		R
19	GR10039771	Anteromedial femur, anterolateral tibia	No	ACL, MCL, LCL	No	Small joint effusion	N/A		L
20	GR10034271	No	No	ACL	No	Small joint effusion	N/A		R
21	GR10047495	No	No	PCL,	No	-	N/A		L

#	ID	Col3	Col4	Ligaments	Meniscus	Findings	Col8	Col9	Side
				MCL					
22	GR10051211	Lateral tibia	No	PCL, ACL, MCL	No	Small joint effusion	4		L
23	GR10045452 (Normal?)	No	No	No	No	No	N/A		L
24	GR10055191	Anteromed femur, posterolat tibia	Posterolat tibia	MCL, PCL, ACL, LCL	Lat meniscus	Posterolat corner inj inc popliteus tendon. Biceps femoris avulsion, posterolat corner fluid collection ?capsular rupture	N/A		R
25	GR10057968	No	No	PCL, MCL	No	-	N/A		L
26	GR10031187	Anteromedial femur, Anterolateral tibia	No	MCL, ACL, LCL	No	-	N/A		L
27	GR10060501	No	No	ACL, LCL	Med meniscus	Moderate joint effusion	N/A		R
28	GR10060711	Anteromedial tibia plateau fracture, anterolateral femur	Anteromedial tibia plateau fracture	PCL, LCL	Med meniscus	Large joint effusion	N/A		R
29	GR10060863 (GR10060864$$$ 37605)	Medial femur and central medial tibia	No	ACL, PCL, LCL	No	Large joint effusion	5		R
30	GR10060863 (GR10060864$$$ 37605)	Lat fem condyle	No	ACL, PCL, LCL, MCL	No	Small joint effusion	N/A		L