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The Cambridge Knee Injury Tool (CamKIT): a clinical prediction tool for acute soft tissue knee injuries

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ABSTRACT

Background/aim This study focuses on the development of the Cambridge Knee Injury Tool (CamKIT), a clinical prediction tool developed as a 12-point scoring tool based on a modified e-Delphi study.

Methods A retrospective cohort evaluation was conducted involving 229 patients presenting to a Major Trauma Centre with acute knee pain over 3 months. The evaluation extracted data on the 12 scoring tool variables as well as diagnostic and management pathway outcomes. CamKIT scores for the injured and non-injured cohorts were then calculated and evaluated.

Results The CamKIT yielded a median score of 7.5 (IQR: 6–9) in the injured cohort, compared with a median score of 2 (IQR: 1–4) in the non-injured cohort, with a statistically significant difference ($p<0.0001$). When constructed as a three-tier risk stratification tool, the CamKIT produces a sensitivity of 100%, a specificity of 94.3%, a positive predictive value of 89% and a negative predictive value of 100% for diagnosing clinically significant soft tissue knee injuries.

Conclusion The CamKIT provides a non-invasive tool that has the potential to streamline the diagnostic process and empower healthcare workers in resource-stretched settings by instilling confidence and promoting accuracy in clinical decision-making. The CamKIT also has the potential to support efficiency in the secondary healthcare setting by enabling more targeted and timely use of specialist resources. This research contributes to the ongoing efforts to enhance patient outcomes and the overall quality of care in managing acute knee injuries.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Acute soft tissue knee injuries (STKIs) are increasingly common, with limited diagnostic options in acute settings that delay optimal patient management.

WHAT THIS STUDY ADDS

⇒ This study shows that the Cambridge Knee Injury Tool (CamKIT) achieves high diagnostic accuracy across a broad spectrum of STKIs. CamKIT's risk stratification model enables targeted triage and management decisions.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ CamKIT could streamline STKI diagnosis in primary and secondary healthcare settings, reducing unnecessary imaging and specialist referrals while aligning care with injury severity. Its success may prompt further research on multi-injury prediction models and guide healthcare policy towards efficient, evidence-based triage tools.

INTRODUCTION

Soft tissue knee injuries (SKTIs) remain a prominent issue in healthcare, where acute knee pain represents 8% of all presentations in accident and emergency departments (A&E).[1] This issue is only becoming more relevant, with an increasing incidence of STKIs observed over the past 20 years.[2] Incidence has also been rising for women, who have been reported to be up to eight times more likely than men to suffer an STKI when participating in the same sports.[3] Furthermore, rates of surgical interventions have increased by 143% overall and 174% among individuals under 25 years of age.[4] While there has been an increased focus on injury prevention and rehabilitation, these escalating rates of injury and preference for surgical intervention underscore the growing need to optimise the diagnostic and management pathway of STKIs.[5]

The diagnosis of STKIs is highly dependent on the proficiencies of the clinician.[6] Currently, multidisciplinary teams lack specialist orthopaedic training to assess and manage STKIs in primary healthcare settings,[7] resulting in an increased reliance on deferred orthopaedic specialist assessment or radiological imaging.[6] However, accessing both diagnostic methods in an acute setting is challenging; without them, clinicians can inappropriately triage patients.[8 9] With the inability to meet an increased demand for specialist assessment, the time to reach a definitive diagnosis for all patients is inevitably delayed.[10] A definitive diagnosis allows the initiation of appropriate management, reducing the injury burdens of disability.[11 12]

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The correlation between a faster diagnosis, commencing optimal management and improved patient outcomes is clear. As such, the current lack of an affordable, accessible and accurate diagnostic method for STKIs in acute settings points towards the potential for more efficiency in the diagnostic pathway. This indicates the need for a quantifiable measure of STKIs among non-specialist departments to guide management and reduce the burdens of prolonged diagnosis, especially within resource-stretched settings.

Current research in STKI clinical prediction tools has used diagnostic clusters combining multiple historical elements alongside physical examination tests to predict the likelihood of an anterior cruciate ligament (ACL) or meniscal injury.[13–15] While these scoring tools were adequate, doubts remain about their clinical utility. This is due to their sensitivity to either ACL or meniscal injuries only and the lack of validation for concomitant injuries, including collateral ligaments. As a range of injuries present in acute settings, the inability to identify the scope of STKIs limits their real-world translatability.

The primary objective of this study was to evaluate the diagnostic accuracy of a clinical prediction tool for STKIs. Secondary objectives include examining deficiencies in the assessment, treatment and management of acute STKIs in A&E and identifying patterns, associations and relationships between risk factors, clinical findings and injury outcomes. Demonstrating accuracy may support the development of a more comprehensive tool for use in acute healthcare settings to facilitate timely clinical management decisions.

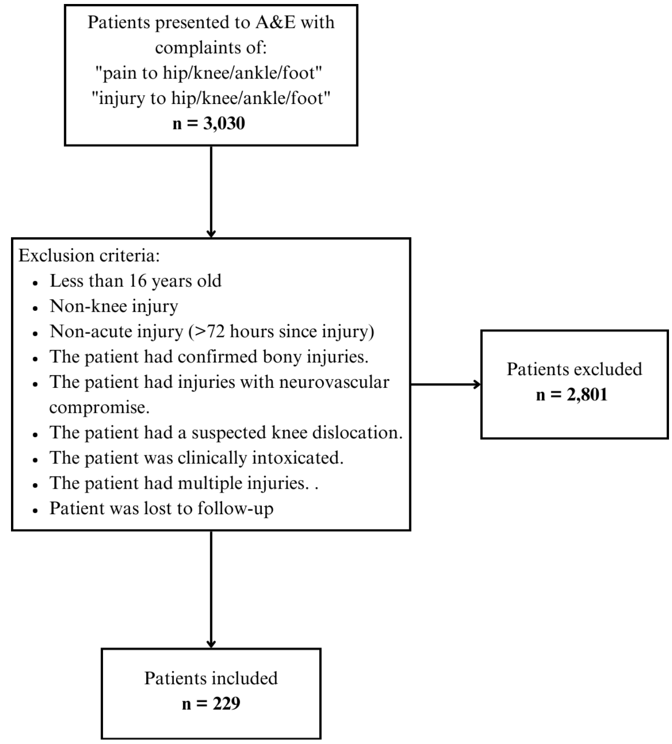

Figure 1 Patient recruitment flowchart. A&E, accident and emergency departments.

METHODS

Retrospective evaluation

The retrospective evaluation was conducted over 3 months, from 1 February to 30 April 2023. Unique patient identifiers were provided for 3030 patients presenting with the triage codes 'injury to hip, knee, ankle and foot' and 'pain in hip, knee, ankle and foot'. For all 3030 presentations, each patient's medical records were accessed to assess eligibility based on admission and clinical notes in the electronic medical records (EMR). Ethical approval was received by National Health Service Cambridge University Hospitals (NHS CUH) for the clinical audit and publication: Clinical Project ID5491. Patients or the public were not involved in the design, or conduct, or reporting or dissemination plans of our research. Figure 1 presents the study selection criteria.

Data Collection

Study data were collected and managed using Research Electronic Data Capture (REDCap) tools hosted at the University of Cambridge.[16 17] REDCap is a secure platform designed to support data capture for research studies. Table 1 presents the variables identified in the Delphi study across patient factors, external factors and signs and symptoms. Data also included injury outcomes and details of the treatment pathway, including documenting specialist consultations and surgical or conservative management. Data were extracted from the EMR of patient healthcare encounters. The primary outcome recorded was a diagnostic report of a clinically significant injury. This was defined as a 'grade 2 or 3 injury', 'partial tear', 'complete rupture', 'meniscal tear', 'meniscal injury' and 'patella dislocation'. This outcome was used to identify individuals with an STKI that requires a specialist consult, diagnostic imaging and surgical management.

Data Analysis

For categorical data, the diagnostic ORs (DORs), 95% CI and the p values were calculated using Fisher's exact test. The DOR is a universal measure of diagnostic accuracy, used to evaluate the effectiveness of diagnostic procedures and compare the accuracies of different tests. The p value was generated with the null hypothesis that the DOR equals one and the alternative hypothesis suggesting that the DOR is not equal to 1. Values of $p<0.05$ were used as the reference point for statistically significant differences. Power analysis is based on literature that suggests having at least 10 events per variable for reliable prediction model development.[18] Fisher's exact tests were performed using GraphPad Prism V.10.1.0 for MacOS, GraphPad Software, Boston, Massachusetts USA, www.graphpad.com. Statistical analysis and presentation are consistent with the CHecklist for statistical Assessment of Medical Papers (CHAMP) statement.[19]

Table 1 The 12 variables and their scorings used for risk calculation in the model

Variables	Answer (score)
Global swelling of the injured knee	Yes (1) / No (0)
Reported feeling of any instability, 'giving-way' or 'shifting' in the injured knee	Yes (1) / No (0)
Inability to weight bear	Yes (1) / No (0)
Reported twisting or pivoting of the knee during injury	Yes (1) / No (0)
Significant reduction in range of movement	Yes (1) / No (0)
Reported sound or feeling of any 'popping', 'cracking' or 'tearing' in the knee during injury	Yes (1) / No (0)
Reported hyperextension of the knee during injury	Yes (1) / No (0)
Reported sound or feeling of any 'locking', 'catching' or 'clicking' in the injured knee	Yes (1) / No (0)
Reported rapid swelling of the knee	Yes (1) / No (0)
Type of sport or activity during injury	High risk (1) / Low risk (0)
Mechanism of injury	Non-contact (1) / Contact (0)
Patient medical history of an ipsilateral STKI	Yes (1) / No (0)

STKI, soft tissue knee injury.

Cambridge Knee Injury Tool

Twelve variables were selected from a modified e-Delphi study that assessed the perceived importance of patient factors, external factors and signs and symptoms among 32 Orthopaedic stakeholders in the UK.[20] These were integrated with the relevant literature.[21] The 12 variables in table 1 employ a binary scoring system based on predefined criteria, facilitating a systematic assessment. The Cambridge Knee Injury Tool (CamKIT) score is the sum of all 12 variables.

CamKIT analysis

Risk scores for total, injured and non-injured cohorts were calculated with the median demonstrating central tendency and the IQR demonstrating the dispersion of data. Individual risk scores were calculated for all 229 patients and subsequently stratified into high-risk, medium-risk or low-risk categories.

RESULTS

Retrospective evaluation

In total, 70 patients were identified with clinically significant injuries, with 44% (31/70) occurring in isolation and 56% (39/70) being concomitant. The total number of injured structures recorded was 128 across the 70 patients. ACL injuries were involved in 54% (38/70) of patient presentations, with 90% (34/38) of all ACL injuries being concomitant. Collateral ligament injuries were prevalent, with 33% (23/70) involving medical collateral ligaments (MCL) injuries and 16% (11/70) involving lateral collateral ligaments (LCL) injuries. 100% of collateral ligament injuries were concomitant. Meniscal injuries were common, with 39% (27/70) involving the medial meniscus and 21% (15/70) involving the lateral meniscus (figure 2).

Of the 229 individuals who presented to A&E with acute knee pain, only 30% (70/229) had a confirmed injury and 17% (39/229) required surgery. Of the 116 individuals referred for specialist consultation, 59% (68/116) had a confirmed injury and 34% (39/116) required surgery. A total of 37% (84/229) of the cohort underwent MRI, with 76% (64/84) having a confirmed injury and 46% (39/84) requiring surgery (figure 3)

Figure 4 presents the diagnostic ORs of the twelve variables utilised in the CamKIT on sustaining a clinically significant STKI. Global swelling (DOR=19.19, 8.53–48.04, p<0.0001) demonstrates the strongest association with sustaining a clinically significant STKI, followed by reported instability (DOR=17.62, 8.38–39.23, p<0.0001). Next are the inability to weight bear (DOR=13.30, 5.86–32.15, p<0.0001), reported twisting (DOR=13.02, 5.86–32.15, p<0.0001), loss of range of movement (DOR=11.38, 5.69–23.64, p<0.0001), and reported 'popping' (DOR=10.63, 5.32–21.96, p<0.0001). Reported hyperextension (DOR=7.69, 3.26–19.42, p<0.0001), locking (DOR=7.68, 3.56–17.30, p<0.0001), and rapid swelling (DOR=7.44, 3.55–16.19, p<0.0001) follow in order. Weaker associations include participation in a high-risk activity (DOR=5.99, 3.26–10.58, p<0.0001), a past medical history of an ipsilateral STKI (DOR=2.48, 1.1–5.22, p=0.0099), and a non-contact injury mechanism (DOR=2.45, 1.29–4.80, p=0.003).

Analysis of the CamKIT

Risk scores were calculated for the injured and non-injured cohorts. For the injured group, the median risk score was 7.5 (IQR: 6–9), whereas for the non-injured group, the median=2 (IQR: 1–4), producing a statistically significant difference (p<0.0001) (figure 5).

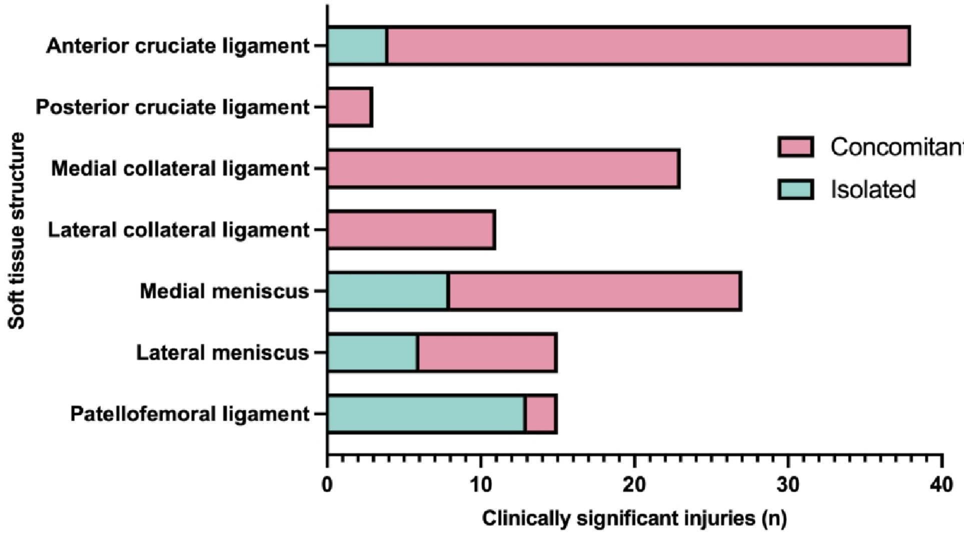

Figure 2 Incidence of total, isolated and concomitant STKIs. The total number of injured patients was 70, with 31 occurring in isolation and 39 being concomitant. STKI, soft tissue knee injury.

Table 2 presents the risk stratification of the cohort into high risk, medium risk and low risk. Table 3 presents the assessment of diagnostic and predictive value involving sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV).

DISCUSSION

STKIs are a complex diagnosis due to influences of risk factors, injury mechanisms, concomitant injuries and clinical findings. In the study cohort, 56% of injuries involved other soft tissue knee structures, indicating the complexity of STKI presentations (figure 2). These injuries, whether isolated or concomitant, presented with a range of signs and symptoms, each with varying degrees of importance (figure 4). Given the multifactorial nature of STKIs, achieving accurate diagnosis requires specialised training and precise clinical decision-making. Furthermore, only 30% of all presentations to A&E had a clinically significant injury, and only 17% required surgical intervention (figure 3). Considering the already challenging nature of diagnosing STKIs, the small proportion of clinically significant injuries among the presenting cohort underscores the need for accurate diagnostic tools in acute settings.

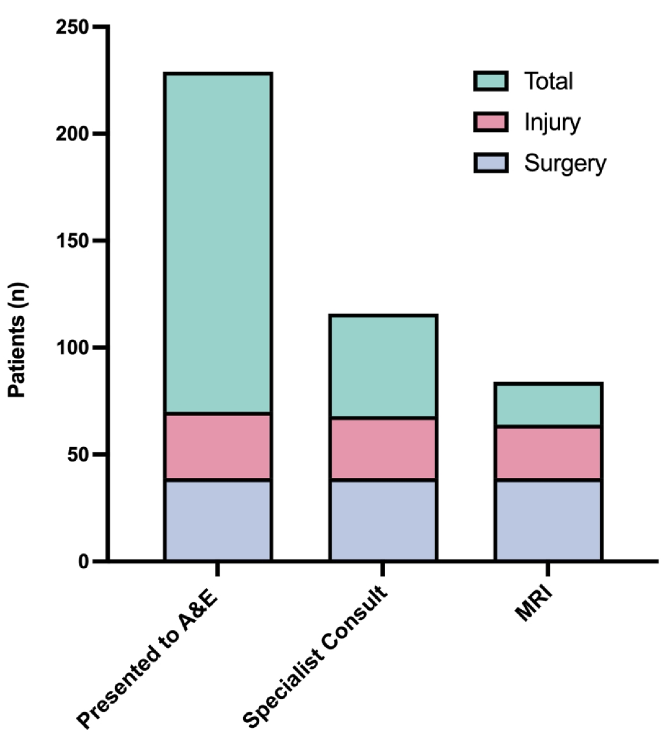

Figure 3 The management pathway of the study cohort overlaid with cohorts diagnosed with a clinically significant injury and those who required surgical intervention. A&E, accident and emergency departments.

The cohort referred for specialist consultation had a low proportion of significant injuries and subsequent surgical interventions. Only 56% of the cohort referred for specialist consultation were found to have a confirmed injury, and only 34% required further surgical intervention (figure 3). This suggests suboptimal diagnostic accuracy in acute settings and overutilisation of the current referral pathway. Currently, orthopaedic specialists conduct many unnecessary evaluations, where physiotherapy or occupational therapy treatment pathways may be more appropriate. Similarly, there was a low injury rate among the cohort who received an MRI referral. Of the cohort who underwent MRI, 76% were found to have a confirmed injury and only 46% required surgery (figure 3). These results suggest that accurate diagnosis earlier in the pathway may enable the referral of patients to the appropriate management streams. By increasing the accuracy of diagnosis on index presentation, an appropriate referral could improve the efficiency of that STKI pathway, reducing the burden of unnecessary imaging requests.

The CamKIT offers a promising development in the diagnosis of acute STKI diagnosis, demonstrating significant accuracy in identifying patients with clinically

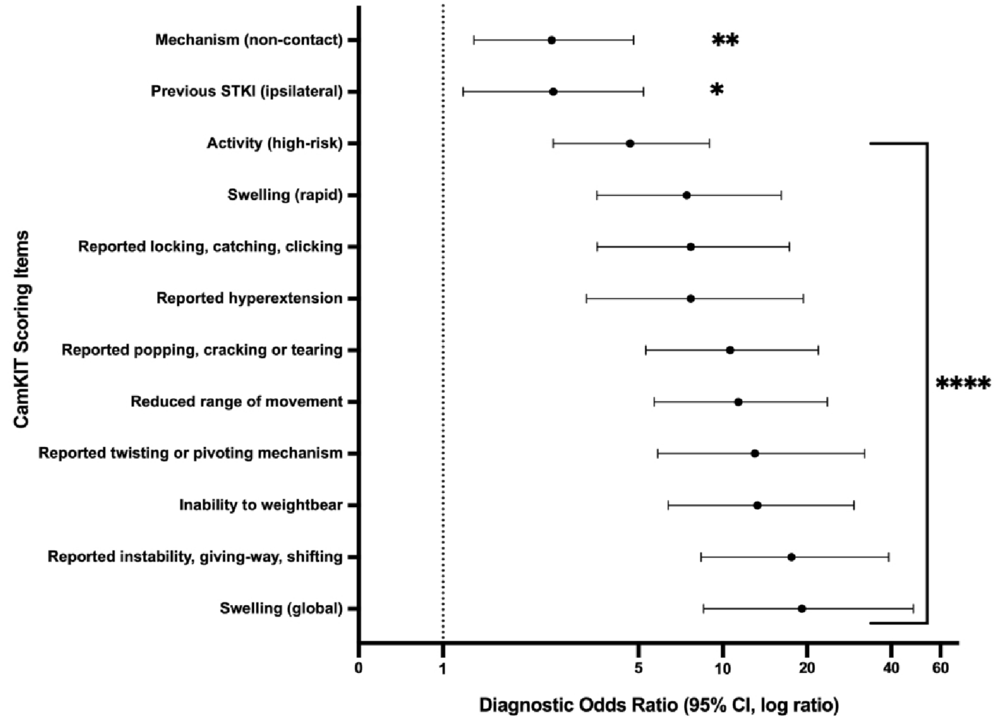

Figure 4 OR with 95% CI for various patient factors, external factors and signs and symptoms associated with sustaining a suspected knee injury. STKI, soft tissue knee injury.

significant injuries. The subsequent utilisation of a three-tier risk stratification model achieves a near-perfect balance by correctly identifying almost all cases with significant injuries while excluding all those without (table 2). The CamKIT was calculated to have a sensitivity of 100% and a specificity of 94%, a PPV of 89% and an NPV of 100% (table 3). These results align with the principles of the Ottawa knee rules, where a sensitivity of 100% is suggested to promote clinical uptake by providing reassurance that no injuries are missed[22 23]

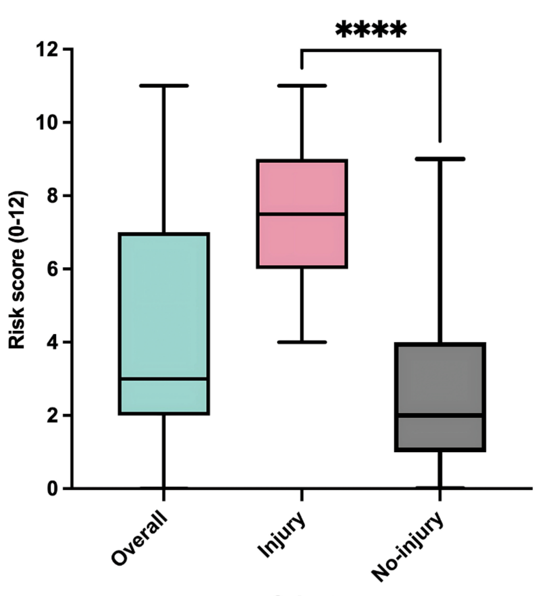

Figure 5 CamKIT risk scores for overall, injured and non-injured cohorts. CamKIT, Cambridge Knee Injury Tool.

Clinical implications

The CamKIT can potentially impact both primary and secondary healthcare settings by aligning patient care with injury risk levels. In primary healthcare, the tool could help identify cases with a high likelihood of severe injury that requires urgent specialist intervention versus minor injuries that can be managed conservatively.

Patients with low-risk injuries can be initially managed with education on acute injury management and safety netting advice. Patients with high-risk injuries can be prioritised for an in-person consult or further diagnostic imaging. Settings that could be utilised include telehealth for rural populations, virtual fracture clinics for orthopaedic referrals and matchday and pitchside sports injury assessment. Patients categorised as medium risk can be advised to present to the nearest emergency department (if assessed pitchside) or referred to an orthopaedic specialist (if assessed in a general practice setting). These patients can provide a clear summary of their CamKIT assessment, including risk factors, injury mechanism and clinical signs and symptoms, to assist in further evaluation.

Table 2 Clinical prediction tool contingency table and calculations of the CamKIT's diagnostic and predictive value

Risk categorisation (CamKIT score)	Injury	No injury	Total
High (7–12)	50	9	59
Medium (4–6)	20	33	53
Low (0–3)	0	117	117
Total	70	159	229

CamKIT, Cambridge Knee Injury Tool.

Table 3 Results of calculations for sensitivity, specificity, negative predictive value, positive predictive value of the Cambridge Knee Injury Tool

Diagnostic measurement	Value
Sensitivity	100%
Specificity	94.3%
Negative predictive value	100%
Positive predictive value	88.6%

Recent advancements in clinical decision-making tools should be integrated into the further development of the CamKIT and subsequent management pathways.[24] By integrating comprehensive clinical decision-making pathways, these tools can improve diagnostic accuracy, streamline care pathways and personalise treatment strategies based on patient-specific and external risk factors. Such integration enables early non-operative management or timely surgical intervention, as appropriate, while aligning diagnostic imaging criteria with evidence-based findings to reduce unnecessary MRI utilisation, healthcare costs and wait times. These advancements support efficient resource allocation and improve patient outcomes by enabling earlier interventions, reducing secondary injury risks and mitigating long-term degenerative complications. This approach underscores the potential of CamKIT-informed pathways to standardise and optimise care for knee injuries, addressing key challenges in contemporary healthcare delivery.

The tool is designed for use by medics or physiotherapists, as they are typically responsible for assessments either in pitchside or in clinical environments. CamKIT is intended to complement standard history-taking and physical examination, particularly for clinicians who may lack confidence or experience in musculoskeletal injury assessments.

Limitations

Limitations involve the use of retrospective data in calculations and patients' lost-to-follow-up. The reliance on retrospective data introduces inherent limitations associated with the completeness and accuracy of the information collected, where data collection relied on thorough assessment, examination and documentation across all healthcare encounters. Regarding loss-to-follow-up, patients who did not represent following discharge were assumed to be uninjured. This was justified as a grade 2 or 3 ligamentous injury or any meniscal damage is considered a severely debilitating injury that would warrant further healthcare encounters.

CONCLUSION

This research contributes to the ongoing efforts to enhance patient outcomes and the overall quality of care in managing acute STKIs. The analysis of the CamKIT advocates for developing a tool that empowers healthcare workers in challenging scenarios by instilling confidence and promoting accuracy in clinical decision-making. The CamKIT's potential for real-world application highlights its potentially transformative impact on healthcare delivery, particularly in orthopaedic treatment pathways and the broader context of primary and secondary care. However, it is crucial to emphasise that while these tools serve as valuable aids, they should complement clinical judgement and assessments to ensure the utmost precision in patient care. Future research initiatives include conducting a prospective study to collect and assess consistent long-term incidence data of STKIs to develop robust clinical prediction models.

Contributors TM contributed to the study design, methodology, investigation, formal analysis and preparation of the original draft and revisions of the manuscript. BG was involved in the investigation and provided critical input through the review and editing process. SC was involved in the investigation, data analysis, review and editing process. SM contributed to the conceptualisation of the study, provided supervision and served as the guarantor.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval NHS Cambridge University Hospitals Trust Clinical Project: ID549. Patients or the public were not involved in the design, conduct, reporting or dissemination plans of our research.

Provenance and peer review Not commissioned; externally peer-reviewed.

Data availability statement Data are available upon reasonable request. The data supporting this study's findings are available from the corresponding author, TM, upon reasonable request.

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