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Physiotherapist experiences and acceptability of a clinical sensor-based kinematic feedback toolkit for movement feedback rehabilitation for people following Anterior Cruciate Ligament reconstruction

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ABSTRACT

Physiotherapist experiences and acceptability of a clinical sensor-based kinematic feedback toolkit for movement feedback rehabilitation for people following Anterior Cruciate Ligament reconstruction.

Background: After knee ligament repair many patients do not recover. Tailored physiotherapy treatments developed from accurate kinematic measurement providing individualised movement feedback may improve outcomes. We have developed a sensor-based kinematic feedback toolkit that generates visual quantifiable data giving precise feedback regarding real time multi-planar kinematic data in the clinical setting and we present physiotherapist opinions about this tool.

Objective: To gather physiotherapist experience and acceptance of a sensor-based kinematic feedback toolkit for anterior cruciate ligament injury rehabilitation to inform tool development for clinical practice

Design and participants: Semi-structured interviews gathered experiences of twelve physiotherapists who used the toolkit for patients undergoing anterior cruciate ligament rehabilitation

Findings: Four themes were identified (1) tool kit usability and future design considerations; (2) clinical integration and decision-making; (3) behaviour change; and (4) future use of biomechanical technology in clinical practice.

Conclusion: The sensor-based biomechanical feedback toolkit report was perceived to be usable and acceptable. Physiotherapists could identify biomechanical movement compensations in patients that could lead to a more individualised targeted treatment approach. Barriers focused on file sharing, IT integration, and compatibility to access and view the digital report. Recommendations were to determine patient acceptance and implementation of real-time data collection in clinical settings for patients and Physiotherapists.

Introduction

Anterior cruciate ligament reconstruction (ACLR) is performed for managing individuals who fail to return to the required function due to signs of knee instability [1]. However, the return to pre-injury level of sport that an individual finds acceptable following ACLR and rehabilitation is variable, ranging from 50 % to 65 % [2,3], with reinjury rates ranging from 12 % at 5 years follow-up to 34 % of patients [4,5], in less than 2 years. One factor associated with lower functional outcomes and re-injury is the presence of kinematic movement adaptations that persist

Abbreviations: ACL, Anterior Cruciate Ligament; ACLR, Anterior Cruciate Ligament Reconstruction; NHS, National Health Service; IMU, Inertial Measurement Unit.

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despite the completion of rehabilitation. For example, reduced hip and knee flexion and ankle dorsiflexion whilst walking, hopping, or drop jumping [6–11].

Therefore, measurement of kinematic movements in the clinical setting to provide individualised movement feedback and assessment of readiness to return to activity, are needed [9,12]. However, in the clinical setting, many physiotherapists rely on subjective visual observation of movement, and observation of multiple joints in multiple planes whilst an individual performs dynamic tasks are required. Laboratory-based motion capture overcomes many challenges but is expensive and not readily available to many clinicians [13].

One solution for the clinic is using Inertial Measurement Units (IMUs) that allow for real-time movement feedback [14,15]. IMUs are small, portable, and lightweight, and can provide objective real-time data in multiple planes of movement that can be presented in a 3D format and data collected are comparable to laboratory-based motion capture systems and are suitable for clinical practice [16]. Studies have reported that physiotherapists accept the use of wearable technology in clinical practice [17,18] and provide feedback to patients in the clinical setting [19–22]. Wearable sensor technology for physiotherapist benefit has been recognised in several studies [21,23–25] and they have also identified kinematic asymmetries in ACLR patients that would benefit from sensor-informed feedback to improve movement performance.

Clinicians need to be able to interpret the outputs from IMUs in a meaningful way that can be translated into appropriate patient feedback that informs rehabilitation. Therefore, we have developed a sensor-based kinematic feedback toolkit (SKFT). This toolkit gives physiotherapists and patients access to multi-planar kinematic data in real-time in the clinical setting and generates reports of quantifiable visual data (Supplementary Figure 1) and avatars (Supplementary Figure 2). The development of the tool kit is reported elsewhere [26].

This study aimed to gather the experiences of physiotherapists and acceptance of a SKFT for rehabilitating patients with ACLR in the clinical setting to inform further system development and strategies for future integration into practice.

Methods

Study design

A qualitative methodology explored the perspectives and experiences of participants when identifying the usability and acceptance of the SKFT for patients with ACLR [27,28]. Trustworthiness and transparency were considered throughout the research process, supported by a reflexive approach that acknowledged the positionality of the lead researcher and potential influence on the interpretation of data [29,30].

Participant sampling and recruitment

Purposive sampling was used, ensuring that participants had experience of using the SKFT in clinical practice. The training to use SKFT was available to all Physiotherapists working in the outpatient department. The lead researcher (KN), male, with 15 years clinical physiotherapy experience with research training, was known to the participants as a work colleague. Each physiotherapist had previously attended a thirty-minute SKFT training session conducted by KN, which included education on biomechanical terminology, waveforms, and temporospatial data, and a clinical reasoning session using a case example.

Feedback from the training session was collected and informed the final design of the SKFT report.

Physiotherapists with experience of using the SKFT with patients following ACLR who met the eligibility criteria (Table 1) were given information about the study by KN. Only physiotherapists that had completed the training and had been referred a patient post ACL reconstruction were asked if they were willing to take part in the study. Informed written consent was obtained from all study participants before data collection.

Data collection

Twelve in-person, semi-structured interviews exploring the experience of Physiotherapists of using the SKFT report were conducted by KN. The interview guide was developed using the seven Technology Acceptance Model 2 (TAM2) categories widely recognised to evaluate the behavioural intentions to use information technology systems [31, 32]. The TAM2 categories include voluntariness, job relevance, output quality, result demonstrability and perceived ease of use. Interview questions also explored accessibility, usability, report design and integration into clinical practice. Following a pilot interview, some of the interview questions were re-worded for clarity and the question order was amended. Interviews were conducted at the convenience of the participant within a hospital rehabilitation setting. The study was completed in a National Health Sevice (NHS) physiotherapy knee clinic in one University Health Board in Wales, UK, where there are 105 physiotherapists in the musculoskeletal service. All procedures were performed in compliance with relevant laws and institutional guidelines and have been approved by appropriate Institutional and Research Ethics Committees. All subjects provided informed consent, and the privacy of the participants was observed.

Data analysis

Interviews were digitally audio recorded and transcribed verbatim. The framework analysis method was used to inductively develop codes, categories, and key themes following familiarisation, open coding, indexing, mapping, and interpretation [33]. NVivo 11 qualitative data analysis software supported the data analysis. Investigator triangulation was performed by two researchers (KN, KB) who independently coded the transcripts and then discussed codes and initial categories [34]. Final categories and themes were discussed, and the iterative process of analysis and discussion supported trustworthiness [30]. Transcripts were not returned to the participants, nor did they provide feedback on the data. KN kept reflexive notes throughout the analysis process to maintain awareness of potential influences due to the positionality of the lead researcher as KN was well known to the group of physiotherapists recruited and KN was aware of the potential bias that could arise from this position in the team in the outpatient department when reviewing the data. In addition. KN kept an audit trail of decisions made during theme development from the codes and categories identified [35].

Table 1
Eligibility criteria for physiotherapist participants.

Participant eligibility criteria
• Qualified physiotherapist working within the outpatient service at the University Health Board in Wales • Physiotherapists that had experience of using the sensor-based kinematic feedback toolkit with patients following Anterior Cruciate ligament reconstruction • Actively treating patients post Anterior Cruciate ligament reconstruction receiving clinic-based movement analysis. • Ability to access National Health Service IT infrastructure • Willingness to participate and provide written consent.

Results

One interview per participant ($n = 12$) was conducted between November 2017 and January 2018 (Table 2). Data collection was discontinued after 12 interviews as data saturation was detected where the last few interviews produced no new insights or information [36]. The 12 participants had completed the SKFT report with 19 ACLR patients at various time points in their rehabilitation, ranging from six to fifty-two weeks post-ACLR surgery.

Four key themes were derived from the data (Table 3): (1) usability of the SKFT report and future design considerations; (2) clinical integration and decision making; (3) behaviour change; and (4) previous, current, and future use towards using biomechanical technology into clinical practice. These themes support the understanding of physiotherapists' acceptance and their experiences utilising the SKFT report as part of routine clinical practice.

Theme 1: Usability of the sensor-based kinematic feedback toolkit report and future design considerations

The participants recognised the importance of a user-friendly SKFT report designed to enhance rehabilitation quality and noted elements that could be adjusted to improve usability. Overall, the consistency plots, axis and waveforms were perceived as positive additional information to support feedback to patients. For example, participants liked that the waveforms provided a visual method of highlighting differences between lower limbs whilst performing dynamic tasks and were the preferred format across all participants for a quick way of evaluating differences between limbs on each task presented in the feedback. This feedback provided greater clarity of movements being observed, and the waveforms were representative of the movement patterns observed in their patients.

"So, the wave forms I quite like because obviously, you have a definite distinction between the operated and non-operated side, […] liked the graphs […] as this made a lot more sense to me […] part of the reason why the graph system works well is because you can see how far or how symmetrical you are" (PT3).

The participants found the format and presentation of the SKFT report to be of good quality and noted that sharing certain information, such as the 'stick figure' diagrams, directly with the patients was beneficial for illustrating the various stages within the movement cycle. The Avatars were seen as a valuable addition alongside waveform and temporospatial data, to confirm patient movement patterns.

"Sagittal plane has got everything you're looking for,[…] you have a direct comparison one on top of the other, you could follow that quite well and was quite easy and you can see each body part as well on the same page, so I thought it was set out nice and easy to interpret" (PT10).

The report enabled an improvement in the structure of a physiotherapy consultation and appeared to satisfy both clinicians and patients.

Table 2
Physiotherapist demographics.

	Physiotherapists:
Number of ParticipantsAge (average in years)Years since graduation (average in years)Gender:	12 29.2
• Male	9.2
• Female	5
Level of experience:	7
• *Band 5*	3
• *Band 6*	5
• *Band 7*	3
• *Band 8*	1
Post graduate Qualification i.e., MSc:Experience treating anterior cruciate ligament reconstruction patients (average in years):Primary employment location:	2 7.6 National Health Service

Table 3
Key themes, categories, and codes with descriptors.

Theme	Category	Code and code description
1 **Usability of the Clinical Movement Analysis Report and Future Design Considerations**	**Usability** The extent to which specified users can use the report to achieve specified goals with effectiveness, efficiency and satisfaction	Positive comments Positive attitude/ expressions/perceptions related to the usability of SKFT report contents. i.e. liked consistency plots, axis, waveforms, stick figure. **Negative comments** Attitudes/expressions/ perceptions related to specific features influencing the SKFT report's usability. i.e. did not like or understand the axis, waveforms, stick figure, consistency plots **Usefulness** Effectiveness, efficiency, and satisfaction of the user's experience, i.e. it is useful to me, meets my needs, helps in my assessment, and is easy to use. **Future report design** Future design and content of the report
2 **Clinical Integration and Decision-Making**	**Interpretation** How physiotherapists comprehend the report using observations and descriptors, mechanistic interpretation	**Strategies used for interpretation**. Strategies, knowledge, and analysis employed to interpret or facilitate and interpret the report. i.e. learning, learning styles, peers, researcher, training **Understanding** Insights, views, and assumptions on interpreting the content of the feedback report. **Hypothetical interpretation** Interpreting the report using hypothetical case examples from physiotherapists' clinical experience, e.g. using this population, we noticed an increase in knee adduction (no reference to report made). **Actual Interpretation** Interpreting the report contents with explicit examples from the report only. e.g. hip adduction at jump landing page 6.
	Application Specific application of report to create and influence change	**Shared decision making** Collaborative approach in analytical decision-making, reasoning, and implications in applying the report findings. **Clinical decision making** Physiotherapists analytical decision-making, reasoning, and implications in applying the report contents from a personal perspective. I.e. single leg squat showed

(*continued on next page*)

Table 3 (*continued*)

Theme	Category	Code and code description
		increased adduction, I added gluts strengthening exercises.
3 **Behaviour Change**	**Behaviour Change** How the report has created, allowed/ influenced or led to a change in usual behaviour	**Individual Behaviour change (COM-B*)** Changing behaviour generated by the report, either physical or psychological. Influencing psychological and physical capability to motivate, lead, influence and create opportunities to change usual behaviour. **Intervention functions** Feedback report creating changes in current clinical practice, i.e. monitoring, engaging, confidence, and providing feedback. **Support** Strategies used to influence to create a change in behaviour
4 **Previous, Current, and Future use with environmental considerations towards using biomechanical technology in clinical practice**	**Previous Experience** Users previous experience with technology in clinical practice	**Technology and Technology use** Physiotherapist's exposure to and experiences of distinct types of technology. (what, why, how) Influence of the immediate environment that has the potential to shape technology integration, i.e., population (athletes, private/NHS, post-op) or patient cohort. **Future Service Provision** Future design, recommendations, and opinions to consider in using biomechanical technology in clinical practice.
	Environment Environmental factors influencing use and accessibility of the report	**Access** The influence of the environment in the access of the report and associated attachments **Facilitators** Environmental factors enabling the integration and engagement of the report. **Barriers** Reported factors, limitations in the work environment **Governance** Governance issues related to the use, integration, acceptance of the report in clinical practice i.e., confidentiality storage of data.

*Key: COM-B: Capability, Opportunity, Motivation for Behaviour change [37].

"So, I definitely think it will speed up the assessment side of things and then this just gives you that more time to focus on actually performing those exercises that are going to hopefully speed things up […] I think it gives you more time to work on the rehab really doesn't it" (PT5).

However, there were concerns that there may be too much data to synthesise, from a patient perspective, risking misunderstanding of findings. The physiotherapists reported that they would carefully select which patients to share it with.

"I would pick and choose who I would give it to, […] I think with some patients, it would be really useful. Either way as long as it's useful to either of us, then it has its place" (PT10).

The physiotherapists felt that the SKFT reports' readability could be improved, and the volume of the feedback be reduced. A summary page of key recommendations, i.e., 'in conclusion' or 'clinical impression' as often seen in clinical reports such as Magnetic Resonance Imaging reporting, was suggested to improve the report's usability and negate the need to review the waveform data. Regarding readability, physiotherapists identified that the y-axis scaling of the waveforms could skew the report's interpretation. Some participants were unaware of the temporospatial data despite a dedicated training page being committed to it.

Physiotherapists wanted more interactive features such as being able to interact with the feedback directly and have the avatar annotated, enabling them to correlate the quantifiable data from the waveform with the movement patterns observed on the avatar. They also suggested giving users control over the playback of the waveforms while viewing them alongside a synchronised avatar, allowing them to select specific time points within the movement cycle, such as peak knee flexion at the initial contact during a jump landing.

Theme 2: Clinical integration and decision-making

Theme two captures how the SKFT report aided the decision-making of the physiotherapist working with patients following ACLR. In addition to uncovering subtle adaptations that might not be obvious to the naked eye, the SKFT report allowed physiotherapists to examine the biomechanical intricacies of patients' movements. These adaptations, whether at the hip, the knee, or the ankle, became the focus of tailor-made treatment plans.

"When he does the double leg squat, it does drop it a little bit, and that would indicate a bit of weakness in his glutes, so that is something that you would want to identify and target with treatment " (PT7)

The feedback boosted the confidence of physiotherapists in treatment decisions as it aligned with their observations and validated their intervention choices.

'It gives you a little bit of reassurance to what you're doing or telling you what you need to work on a little bit' (PT10).

Physiotherapists aimed to engage patients in shared decision-making using feedback, particularly regarding their return to sports post-ACLR surgery. However, while the intention was there, some physiotherapists often spoke about future actions rather than actively implementing the feedback in real-time. This suggests that, despite the goal of increased patient involvement, some physiotherapists still maintained control over clinical decisions. They may not fully embrace a shared decision-making model where patients have an equal say in treatment choices, and it has been reported that Clinicians can be slow to initiate this approach [38]. Instead, they might use the feedback to rationalise their decisions to the patient.

"There is a patient [who] can't quite get why return to sport might not be so sensible at a given point in the rehab and you kind of hope they would understand with you and be able to reason together actually that these are the reasons that lead to that" (PT12)

Effective communication is essential to ensure patients understand their condition and treatment options, as poor communication could compromise the delivery of care (Ratna, 2019). Physiotherapists considered adapting their consultation approach to integrate and explain the feedback effectively. However, some held back from discussing suboptimal aspects, as this was viewed as showing negative feedback or they did not think the patient was ready to understand the findings.

"No, I haven't really broached that element of it yet, she hasn't got her operated leg under any form of progression of strength or control, so that where it is right now" (PT12)

Physiotherapists reported that patients found motivation in tracking progress through the feedback, which optimised rehabilitation. However, there were concerns about whether patients would fully understand the detailed feedback.

"Some patients may have a harder time kind of making sense of it and again you have to sit down and talk them through it, in some patients may find it either beneficial because one, it may show them what is not quite as good and two, it might even help motivate them, look I do this on my right leg I don't do it on my left, so I really need to work on" (PT7)

Overall, the SKFT report was viewed as enhancing treatment planning, increasing confidence, and potentially contributing to shared decision-making. However, there were concerns about the large volume of complex data and effectively conveying that feedback to patients.

Theme 3: Behaviour change

Physiotherapists discussed how they altered their approach to patient rehabilitation based on feedback from the SKFT report and considered it valuable information that supported them. For instance, the feedback made physiotherapists aware of certain factors that were not typically addressed. This allowed them to evaluate their treatment effectiveness and adopt a more proactive approach to address unwanted movement adaptations. Continuous feedback monitoring of patient performance throughout rehabilitation enhanced clinician confidence and provided reassurance about intervention effectiveness.

" By looking at these reports, you can then almost see yourself if you are getting patients that are coming through that are consistently having weaknesses within their abductors, then maybe actually that is something […] that I am perhaps missing in terms of the key part of my rehab because I can consistently see that" (PT9).

The SKFT report gave the clinicians objective evidence that supported their confidence in decision-making about treatment strategies to influence patients (e.g., providing reassurance), types of physical intervention (e.g., targeted exercise) and reconstructing the immediate environment (e.g., reducing follow up appointments). Participants reported that the feedback gave them greater confidence in being more direct with patients and to challenge patients further in their rehabilitation.

"It just backs up what you're doing with the patient, it reassures you what you're doing and gives you a bit of *confidence to push them on a little bit" (PT10).*

The feedback highlighted potential improvements in the consultation process, aiming to offer physiotherapists more flexibility in managing their time during consultations.

"It would almost reassure you [that you] don't have to send them back sometimes for a one-to-one or maybe that they do need a half-hour one-to-one session to maybe run through some of the data and give them a couple of individual things to work on outside of the class" (PT10).

Physiotherapists faced with limited physical space found that the feedback report data alone could be used to recommend therapeutic exercise selection, thereby influencing the standard consultation approach.

Theme 4: Previous, current and future use with environmental considerations in clinical practice

Within the interviews recommendations regarding the future implementation of sensor-based biomechanics feedback and technology used in training and clinical practice were frequently discussed. There was a strong link between the environment and the accessibility of innovative biomechanical equipment. Physiotherapists noted that they were exposed to biomechanical equipment during their undergraduate education, but reported a lack of access to biomechanical equipment, especially in the NHS.

"a lot of private clinics will do this type of thing, and even down to things like podiatry with force platforms, that is quite standard, whereas we don't use any of that, only if it's used in university if you are doing a study" (PT4)

Some physiotherapists have used the video recording features on their patients' smartphones to provide feedback on movement performance.

"So, videoing and photo'ing of patients I have done, […] purely for biomechanical reasons in helping them understand different biomechanics that they may not necessarily see, feel or know about and for them to have that feedback to take away, I have used that, using their phones." (PT12)

Data governance issues emerged as a concern within the NHS. For instance, participants expressed concerns that the NHS policies, and procedures posed challenges for physiotherapists regarding recording and uncertainty about storing electronic patient data. This finding suggests a potential data storage and protection training gap, highlighting an unmet need. Participants also noted the environmental factors that could facilitate the report integration into routine clinical practice as this was thought to be advantageous, however time availability was a concern.

"Yes, it does take a little time to look through it […] you have your half-hour slot to see your patient, you need 10 minutes to look through this, then you have 10 minutes to chat to patient […], you would not have enough time" (PT4)

The successful integration of the SKFT report was perceived to hinge on several key factors, primarily the time required for data collection, feedback report generation, and interpretation, and considerations of cost-effectiveness. A particular concern was the time needed to download and interpret the SKFT report before the patient consultation. One proposal was to use a tablet to access the SKFT report, to provide mobile access, expedite assessments and enhance the overall efficiency of physiotherapists' work.

"If it means I can do assessments quicker, it takes the stress off the rest of the day and, like I say, kind of just get on with what you want to, and it might speed things on a little bit." (PT4)

Physiotherapists face challenges in incorporating biomechanical technology into their clinical practice, primarily due to limited access to technology at work. However, physiotherapists do express a strong interest in expanding the use of technology in rehabilitation of various musculoskeletal conditions.

Discussion

This qualitative study assessed physiotherapists' experiences and acceptance of using the SKFT report when rehabilitating patients following ACLR. The aim was to gather insights to inform the system's development and strategies for future integration into clinical practice. All twelve participating physiotherapists expressed a positive view of the SKFT report in its current form, but with concerns about the volume of data provided. They recommended future design improvements and demonstrated a keen interest in incorporating this feedback into their clinical practice. The physiotherapists recognised that utilising objective data from the feedback report for targeted decision-making could enhance the quality and effectiveness of rehabilitation. However, it became evident that additional training was essential to improve physiotherapists' understanding of biomechanical terminology and kinematic waveform data interpretation. This training requirement should be considered when implementing feedback on a larger scale, as it may change decision-making processes from relying on experiential data from other cases to actual data interpretation, which is more relevant to individual patients.

The training package was designed to provide physiotherapists with a comprehensive understanding of biomechanical feedback data and promote deep learning [39], that enabled physiotherapists to interpret and utilise this data in their practice. Not everyone achieved this, so if implemented into practice, wrap around support will be needed.

The methods used by physiotherapists to understand the biomechanical feedback report were influenced by preference and style of data presentation. The similarities between reading biomechanical waveforms can be drawn from how clinicians visualise and detect abnormalities in electrocardiogram (ECG) waveforms for cardiac monitoring. The presence of visual waveform data for clinicians to identify abnormalities and pattern recognition has been reported in the ECG literature [40]. The clinicians' preference for graphical data over numerical data, i.e. temporospatial data, has implications for how clinicians perceive and interpret the images presented [41]. It is reported that clinicians utilise a visual search strategy of an 'initial rapid' search for apparent abnormalities followed by a 'slow' search for further detail [40]. A hands-on practical approach to training with physiotherapists participating in a workshop environment, using the technology whilst participating in the data collection process and education on biomechanical waveforms to interpret the data would be key components to build upon.

Barriers

Despite the optimistic projections of the increased use of wearable technology [42], many challenges including connectivity, and data processing remain [43]. Physiotherapists had limited access to desk top computers in the clinical areas and limited time for reviewing the reports. Challenges identified were primarily due to inconsistent IT software infrastructure (operating systems and outdated software) across the health board that limited access to avatar files. Future designs should utilise online or cloud-based systems to allow seamless access to stakeholders through a central portal such as TRAK [44].

Limitations and future research

The lead researcher (KN), who is a Chartered Physiotherapist working in the local health board is well-acquainted with the participants as a working colleague, and this familiarity may have introduced a bias in the respondents' answers during the interviews. Extensive background work from KN was required to re-format and upload files onto network drives to enable physiotherapists to access the SKFT report across the health board. In future studies, it is recommended to explore the patient experience with the SKFT and to develop it to cater for the needs and perspectives of all stakeholders involved.

Conclusion

The SKFT report was perceived to be usable and acceptable by physiotherapists in this study. Barriers were the compatibility of file sharing and digital software across used platforms and IT operating systems to allow seamless access. Physiotherapists could identify biomechanical movement adaptations in ACLR patients that would potentially lead to more individualised targeted approach to treatment. However, there was variability in the descriptions of the feedback report and the terminology used, thus training is essential to upskill physiotherapists in understanding biomechanical data and its integration into clinical practice. The acceptability of the SKFT report is currently being explored with patients to inform the development of a personalised sensor-based movement feedback intervention.

Ethical approval

Ethical approval. XXX REC number XXX: 10/MRE09/28.

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Declaration of competing interest

The authors declare that they have no competing interests.

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Supplementary materials

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