A SYSTEMATIC REVIEW OF METHODOLOGIES USED TO ASSESS "UNANTICIPATED" CUTTING MECHANICS

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Biomechanical analysis of cutting mechanics is a popular approach to assessing risk factors for injuries such as anterior cruciate ligament ruptures. The purpose of this study was to systematically review the methodological approaches to assessing unanticipated cutting mechanics and provide a review of such approaches. A total of 93 articles where identified that had assessed unanticipated cutting. The most common methodological design was a 45° cutting task following a run-up where the direction of the cut was determined by a light-based stimulus. External light stimuli create a worst-case scenario by providing information about the task at the last moment meaning opportunity for preparatory mechanics is limited. However, light stimuli do not allow for perception-action to take place and may therefore not truly reflect an athlete's cutting mechanics.

KEY WORDS: ACL, change-of-direction, anticipation, perception-action

INTRODUCTION: Cutting or side-stepping tasks have been identified as high-risk movements that can lead to injuries such as anterior cruciate ligament ruptures. The high-risk nature of cutting has led to researchers using them as a movement screening tool to identify biomechanical risk factors (Nedergaard et al., 2020). However, the complexity of cutting tasks mean it is often difficult to assess the movements in representative settings.

Cutting is influenced by an athlete's mechanical capacity to change direction and often the ability to do so in a manner which leads to evading an opposing player. Traditional assessments of cutting focused on the mechanical capacity by asking participants to perform a pre-determined cutting movement at a pre-determined location (i.e. foot contact with a force plate) (Nagano et al., 2009). While useful in assessing the athlete's capacity to meet the mechanical demands of the task, these approaches failed to capture the complex nature of cutting tasks that occur in sporting environments, particularly the role of perception-action coupling and the spatiotemporal demands of evading an opponent (Connor et al., 2018).

To better represent cutting in sporting environments, researchers began to include external cues to influence the direction of the cut or what task is performed. It was demonstrated that by an athlete reacting to an external cue and therefore adding a component of uncertainty, their biomechanics changed (Lee et al., 2013). Whilst the inclusion of an external cue is more representative of sporting situations, the information provided by the cue may limit its capacity to capture the perceptual challenges faced by athletes.

Gibson's (2014) ecological approach proposed that perceptual systems are continually active resulting in a cyclical process of detecting and creating new information that is used to control movement. In the context of cutting this approach suggests that athletes continually perceive specific information like a defender's position and movement and use it to plan and execute a cutting movement. It has been demonstrated that expert performers are better able to anticipate an opposition's movement during cutting interactions compared to novices and that the rate of errors is reduced the longer the player waits before anticipating (Brault et al., 2012). A player's ability to correctly anticipate an oppositions movement has implications on the time available to prepare for a movement such as cutting, and therefore is a key consideration when designing approaches to biomechanically assess cutting technique.

The aim of this article was to provide a systematic review of the methodological approaches used to create unanticipated cutting tasks for the purpose of biomechanical analyses and to evaluate the identified approaches. Findings from this review will inform future research design for change-of-direction studies.

METHODS: A search strategy (Figure 1) was ran in CINAHL, MEDLINE and SPORTDiscus from inception to 31st December 2021. After the removal of duplicates, the titles and abstracts of identified articles were screened for inclusion and exclusion criteria. Inclusion criteria were a primary experimental study, cutting or side-stepping task was completed, the direction or type of cut or movement was dictated by an external cue and biomechanical data were collected. Exclusion criteria was insufficient methodological information about the external cue to allow replication and change of direction during walking. Full texts of articles that were not excluded based on screening of the titles and abstracts where subsequently screened against the same criteria. Data extraction consisted of the methods of the cutting task including details of the external cue used and the timing of the cue. As this review focused on methodological approaches no results were extracted.

cutting *OR* cut *OR* side-step* *OR* side-cut* *OR* sidecut* *OR* sidestep*
AND
anticipat* *OR* unanticipat* *OR* unplanned *OR* planned
AND
injur* *OR* acl *OR* “anterior cruciate ligament” *OR* biomechanic*

Figure 1: Employed search strategy. * *denotes truncation wild card*.

RESULTS: Excluding duplicates the search strategy identified 363 articles, and 93 were found to meet the inclusion and exclusion criteria (Figure 2). Due to the number of identified articles it is not possible to include all references within this paper however, a full reference list of all identified articles can be found by clicking this link. The cutting protocol used in 46 articles matched that of other articles conducted by the same researcher or research group with the remaining 47 presenting unique protocols based on cutting angle, the task preceding the cut (e.g., run up), the type or timing of the cue, and the choice of possible movements.

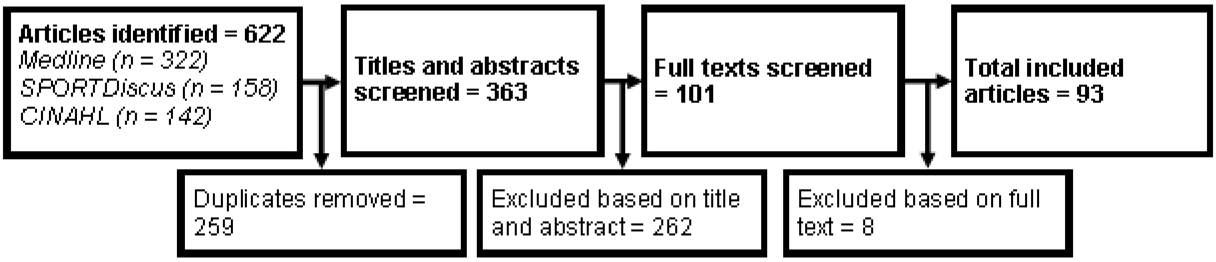

Figure 2: Article screening flowchart.

A target cutting angle of 45° was the most common making up 73% of the reported angles, followed by 90° at 12%. Other angles included 20, 30, 55, 60 and 75° that each accounted for 5% or less of the tasks. Running was the preceding task in over three quarters of the identified methodologies with hopping, horizontal jump, drop jump and dropping from a hang the other identified approaches. Whilst cutting left or right using either foot was the predominate choice of tasks presented to participants (32%), a variety of protocols were identified including cutting in either direction using the same plant foot, and the addition of run straight, stop, pivot, and back pedal options in addition to cutting. In only 65 of the 92 identified articles was the direction of the cutting task dictated by the visual cue, with the rest having the visual cue influence the type of movement (e.g., cut left, run straight, or stop). The type of cue was overwhelmingly related to visual stimulus through lights or colours on a tv screen, with only one article using a live defender (Table 1). Reporting of the timing of the cue was varied, and often did not allow for the time between presentation of the cue and task execution to be established. Where the time available to attend to the cue was presented this varied between 300-650 ms.

Table 1: Types of visual cue used in identified articles to instruct participants on the desired movement.

Description of Visual Cue	N*
Shapes (e.g., arrow) of the same colour to show direction or task presented in front of the approach direction	26
Light gates set at the end of line of the desired cut	22
Offset lights in front of the participant as they approach to show direction	15
Shapes (e.g., arrow) of different colours to show direction or task presented in front of the approach direction	11
Different coloured lights in front of the participant	8
Player position in a virtual football scenario presented on a screen in front of the participant	6
A “visual cue” on a TV in front of the participant	4
Videos of two defensive scenarios (1 or 2 defenders) presented on a screen in front of the participant	3
Video of a simulated rolling football presented on a screen in front of the participant	2
Light gates set at the end of line of the desired cut with auditory beep	1
Live defender in front of the participant	1

**Where an article presented various stimuli they were included more than once*

DISCUSSION: The identified methodological approaches to simulating cutting tasks are varied, with differences in the movement, timing and type of visual stimulus, and cutting angle. Whilst reporting was overall of a good standard, details of the timing of the cue followed different approaches that made comparisons difficult. The time available from the cue to initial contact of the movement was the most common reporting method, and the most valuable by providing the temporal constraints of the unanticipated task. Other reporting methods included distance from the force plate and time after commencement of the preceding task. Whilst this information would allow the replication of the methodological approach, it does not provide a direct measure of the time available for the participant to react to the stimulus and prepare for the movement. The need to understand the available time for movement preparation is also a consideration when exploring the effect of visual cue type.

Light stimuli offer an approach that is both repeatable and relatively easy to implement. This is one explanation for their extensive use. However, it is important to consider the implications of such approaches on the task demands. By adjusting the timing of the light stimulus researchers can increase the temporal demand on the task and provide a worst-case scenario whereby the available time is just enough to complete the task. For example Besier et al. (2001) adjusted the timing of the cue to account for reaction time of the athlete meaning the athlete did not know what movement to perform until the very last moment. This approach is by no means unvaluable but needs to be considered in relation to it limitations surrounding a player’s ability to anticipate.

The information available to the participant using light stimuli is binary, in other words no information to all available information ‘*in a flash*’. This binary approach to the available information does not reflect the cyclical process of perception-action that influences an athlete’s decision making and anticipation (Dicks et al., 2019). Findings from research that included visual stimuli that enable anticipatory mechanisms (Lee et al., 2013; Schroeder et al., 2021) support that the perception-action process does impact on cutting mechanics. One mechanism by which perception-action processes may influence cutting mechanics is the differences in an athletes ability to successfully anticipate an oppositions movements (Brault et al., 2012). It has been shown that higher level athletes have a greater capacity to accurately predict the movements of an opponent compared to more novice athletes (Rowe et al., 2009). The difference in anticipatory skill means that the temporal demands of a cutting task will not only be determined by the time that all the information is available for prior to execution of the task (e.g., on the provision of a light stimulus), but also by the athlete’s ability to anticipate the opponents’ movements prior to this point to allow preparatory action to be undertaken.

Therefore, the use of external stimuli that would allow anticipatory mechanisms to take place during cutting tasks may be more representative of sporting environments and provide insight into the interaction between anticipatory skill and cutting mechanics but may also reduce the difficulty of the task by allowing more preparatory movements to take place.
The ability to replicate sporting interactions within a laboratory setting has always been a challenge for biomechanical researchers. The compromise between generalizability and replicability is particularly prevalent within cutting tasks, due to the sheer complexity of the inputs and scenarios that influence how the movement is performed. This article presented an argument for the inclusion of visual cues that better enable anticipatory skill to be captured in the analysis, and therefore produce more generalisable findings. By implementing data collection methods that are more representative of sporting environments, such as the inclusion of live defenders as in Schroeder et al. (2021), researchers can be more confident that they are truly assessing cutting technique and producing outcomes that generalise to more applied settings. However, the need to be able to replicate these methodologies and accurately describe the stimulus is still important. Therefore, it is recommended that research exploring cutting mechanics should look to include more representative external cues (e.g., live defenders or virtual reality) but look to quantify this stimulus in more detail than simply stating the direction a defender stepped.

CONCLUSIONS: The current methodological approaches to cutting biomechanics create a worst-case scenario by offering an athlete no chance to anticipate the required task. Whilst useful to assess the mechanical capacity of an athlete these approaches do not allow for the assessment of perception-action mechanisms including anticipation. More representative designs including visual cues that allow anticipatory mechanisms to take place may be useful in providing a broader assessment of an athlete's capacity to cut safely and effectively.

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