EXPLORING HOW TO QUANTIFY STAGE 4 OF THE RETURN TO SPORT PROTOCOL IN PREVIOUSLY CONCUSSED COLLEGE ATHLETES

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After concussion, progression through the return to sport process is guided by subjective symptom ratings, rather than objective measures of performance. We are currently investigating ways to quantify functional performance in concussed athletes using turning velocity. Here we present case data from three concussed individuals at different stages of recovery and one healthy control. All participants completed a repeated reactive agility task. Performance was assessed using turning velocity (yaw, deg/s) collected using an inertial measurement unit (IMU), and a series of response times captured using timer gates. Due to the exploratory nature, we present descriptive statistics only to provide a foundation for further work in this area.

KEYWORDS: IMU, turning velocity, agility, mTBI, concussion

INTRODUCTION: Returning to sport prematurely after a concussion can put athletes at risk of further injury (McCrory et al., 2017), such as an increased risk of musculoskeletal injury, even despite medical clearance to play (Brooks et al., 2016; Lynall et al., 2015; Nordström et al., 2014). The question of when an athlete is functionally capable of returning to their sport and ready to perform at a pre-injury standard, has remained a challenge. Team sport requires athletes to perform complex perceptual-motor tasks within time-pressured and rapidly changing environments (Parrington et al., 2015). Yet current protocols for determining readiness to play after a concussion either do not test these complex skills, or progress athletes using subjective ratings of performance.

Clinical evaluations rely heavily on the use of unimodal tests that target one system at a time, such as balance for assessing neuromotor control (Riemann & Guskiewicz, 2000), or computerized neurocognitive testing for cognition (Meehan et al., 2012). Such tests, are not representative of the constraints embedded in team sports and therefore lack task fidelity. On the other hand, the graduated return to sport guidelines (McCrory et al., 2017) recommend the progression of movement, exercise intensity and cognitive challenge be based off subjective reporting of symptoms from the athlete. Thus, this process is limited by the lack of objective quantification of athletic performance during these steps. Objective measures of performance during the later stages of the return to sport protocol (where drills involve more complex coordination and increased cognitive demand), may assist athletic trainers and clinicians in their clinical decision making.

Changes in direction (turns) occur frequently in sports and in everyday life, and requires the integration of multiple sensory systems. Turning deficits are common in neurological disorders, including chronic concussion, and seem to be amplified when performing these movements at a faster pace (Fino et al., 2018). Given turning movements require greater cognitive control for planning and execution, it is plausible, that measuring turning ability in recently concussed athletes' performing an agility task may provide insight into their recovery. Thus, the purpose of this paper is to provide preliminary concept data from a study investigating whether turning during a reactive agility task can discriminate between concussed and healthy athletes. Here we present descriptive data collected on three previously concussed male athletes and one healthy control.

METHODS: Four male collegiate athletes participated in this case study (3 previously concussed and one healthy control). Participant information is provided in Table 1.

Table 1: Participant demographic information

	Sport	Age	Height (m)	Mass (Kg)	# Previous concussions	Days since last injury
H1	Basketball	20	1.96	98.8831	0	N/A
C1	Basketball/Football	18	1.96	88.4505	2	1071
C2	Football	21	1.83	106.594	4	26
C3	Soccer	19	1.75	70.7604	3	183

Participant H1 (healthy control) had never sustained a concussion. Participant C1 was participating in competition but reported symptoms, while participant C2 and C3 had been cleared for non-contact drills. The participants completed eight trials of a reactive agility course (Figure 1), with a one minute rest in between each trial. Participants were encouraged to complete the test as quickly as possible. Prior to starting, participants were given a demonstration, walk through, and a full-speed run through to habituate to the course. The agility course was designed to test 1) turning ability, 2) motor reaction times (RTs), and 3) repeat 15 m sprint performance. The participant completed the course while instrumented with three IMUs (128Hz, Opal V2, APDM Wearable Technologies, Portland, OR) on the head, sternum and waist, which were securely attached using elastic Velcro straps. Reaction times and repeat sprint performance were measured using timer gates with customized programming to randomize the turn direction (Zybek Sports, Broomfield, CO).

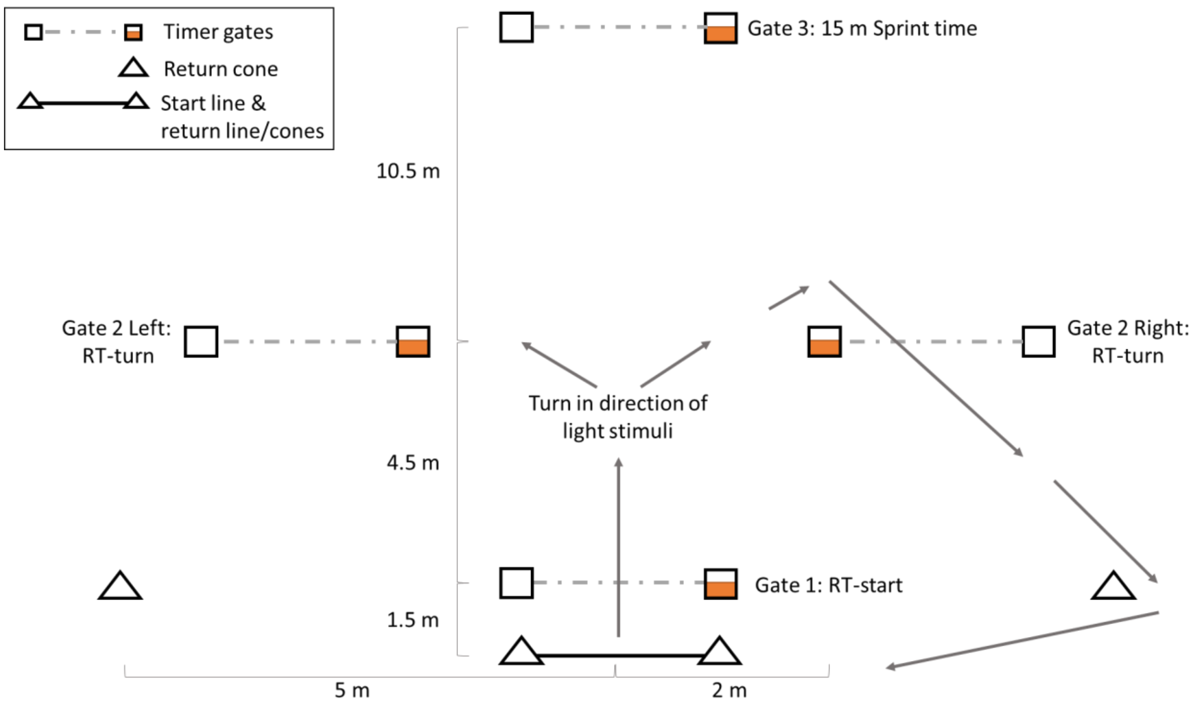

Figure 1: Reactive agility course. Participants line up on the start line and moved into a ready position. At a random interval between 1 and 2 seconds, gate 1 flashes to indicate for the participant to start. Once this gate is cleared, gate 2 (either left or right) will illuminate to indicate for the participant to turn left or right. The participant then runs around the return cones and back through the gate 1, representing lap 1 and initiating lap 2. As gate 1 is cleared, the process is repeated for a second lap. When the participant clears gate 1 the third time, they sprint down to gate 3 to finish the trial and the 15 m sprint time is recorded.

Raw IMU data were extracted from inertial sensors and processed in MATLAB R2017a (The Math-Works, Inc., Natick, MA). Power spectrum analysis and residual analysis were completed on the angular velocity (yaw component) of the sternum and waist sensors to determine the optimal cut-off frequency for filtering. Data were then filtered using a phaseless low-pass Butterworth filter (fourth order, 10Hz cut-off). Continuous angular data were segmented into two laps, with the first turn of each lap being used for analysis. For these turns, the peak angular velocity of the waist sensor was extracted relative to the global reference frame. Times to clear each of the gates were extracted relative to the onset time of the initial start light stimuli. Data were exported as a csv file and reaction times and repeat sprint times were calculated.

RESULTS: Descriptive results for turning velocity (waist, yaw), reaction times and the 15 m sprint are provided in Table 2, and an example trace of yaw velocities for each segment is provided in Figure 2.

Table 2: Descriptive data for each of the eight trials completed by the participants, mean (SD).

	Lap 1 turn (deg/s)	Lap 2 turn (deg/s)	Start RT (s)	Lap 1 turn RT (s)	Lap 2 turn RT (s)	15 m sprint (s)
H1	302 (52)	317 (48)	1.04 (0.06)	1.78 (0.09)	1.78 (0.12)	2.49 (0.07)
C1	242 (36)	276 (49)	1.03 (0.10)	1.59 (0.06)	1.67 (0.07)	2.40 (0.05)
C2	270 (29)	315 (44)	1.08 (0.05)	1.76 (0.09)	1.81 (0.11)	2.78 (0.07)
C3	193 (26)	227 (15)	1.08 (0.19)	1.87 (0.06)	1.88 (0.14)	2.49 (0.06)

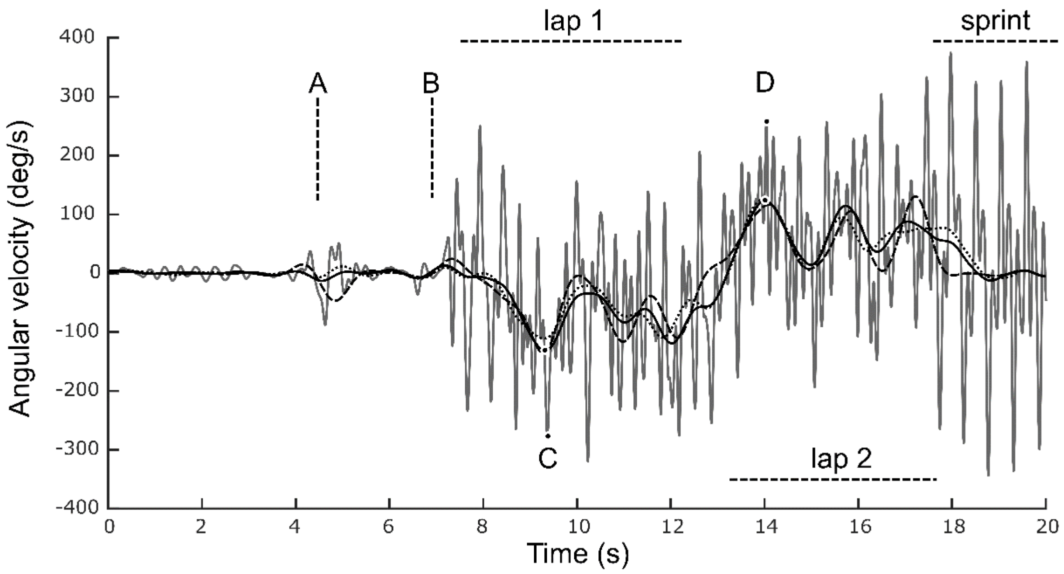

Figure 2: Example yaw velocity trace for trial 2 (left-right sequence). Black lines represent waist (solid), sternum (dotted) and head (dashed) data filtered at 1Hz to aid pattern recognition. Grey line represents waist data filtered at 10Hz used for determining peak rotation velocity. A) Athlete moves into start position; B) Initiation of agility course; C) Peak of main turn 1; D) Peak of mean turn 2.

DISCUSSION: This paper provided preliminary case data from three previously concussed college athletes and one healthy control who participated in a repeated reactive agility task. Data were collected as part of a pilot grant investigating the use of functional performance testing in evaluating return to play readiness. To the authors' knowledge, this is the first study to investigate turning velocity using inertial sensors and reaction times during a reactive agility task.

The average peak turning velocities ranged from 193 deg/s to 315 deg/s in the previously concussed athletes, while the averages for the healthy control were 302 deg/s and 317 deg/s for turns in response to the first and second stimuli. These velocities appear of a reasonable magnitude compared with previous values reported during turning gait and quantified with IMUs. In a population with chronic symptoms following concussion, pelvic yaw velocities ranged between 62 (13) deg/s and 120 (24) deg/s for smaller and larger turns while walking at a self-selected pace (Fino et al., 2018). Not surprisingly, the velocities during turning reported here are much higher, given the participants were attempting to complete the task as fast as possible rather than walking at a comfortable speed. Differences may have otherwise arisen from filtering and protocol.

Although only descriptive data are presented here, average peak turning velocities were generally lower in magnitude for the previously concussed athletes, with the exception of C2's second turns falling within the healthy control's range. Though using a different task (i.e. walking not running), Fino and colleagues found participants with chronic concussion issues to turn slower on average than their matched healthy counterparts. The preliminary findings presented may suggest this difference is present in more functional reactive agility tasks, however, further work is required to extend the present findings to a larger population of concussed athletes and healthy matched controls. On average the turn velocity in response to the stimuli during the second lap of the course was faster. Contrastingly, the response time recorded, representing the time taken to see and react to clear the timer gate was slower for these turns. It may be of interest to investigate any trade-offs between turning performance, reaction time and whole task performance with a greater sample of athletes.

CONCLUSION: Albeit early stages of analysis, these data provide an interesting foundation for further work in this area. Testing of more concussed athletes as well as healthy controls is required, as is validation of turning velocities collected by inertial sensors against criterion motion capture. Anticipatory adjustments prior to turning and jerkiness of movements are also of interest. Up to date findings will be presented at the conference.

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ACKNOWLEDGEMENTS: This study was funded by the Medical Research Foundation of Oregon. We would like to acknowledge the support of George Fox University athletic trainers and athletes.