Cognitive and motor control mechanism for ballgame defenders in 1-on-1 defensive situation

(Abstract)

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Skilled players in invasive ballgames such as basketball execute accurate, quick and strong decision making and motor control. In the ballgame, an attacker with the ball aims for the scoring point, and a defender stops the aim of the attacker. However, many researchers have separated cognitive and motor aspects, and have not focused on the skill actually executed by ballgame players. Therefore, the present thesis simultaneously focused on cognitive and motor skill in defending an attacker, which is in common among various invasive ballgames.

In the thesis, first, anticipatory (cognitive) mechanism in replicated 1-on-1 defensive situation was investigated using video-based approach. In study I, I

examined the timing for the detection of relevant information in the final running direction of attackers' cutting maneuvers. Skilled basketball players and novices performed sidestep and reach tasks in response to a ready-go choice stimuli using light emitting diode (LED task) and video stimuli (video task) wherein skilled ball players executed cutting maneuvers. The time at which the defenders first obtained relevant visual information was estimated by subtracting the visuo-motor processing time, acquired from the reaction time in the LED task, from the reaction time in the video task. Skilled basketball players reacted to and reached the target faster than novices, whereas the estimated video cue timings for the skilled players were not different from those for the novices. The results suggest that the anticipation of attacker's direction in this task would be a general visuo-motor skill, even without previous specialized perceptual training. Combined with the results from the reaction performance in the video task, I conclude that novices are afforded shorter times and more uncertain information before their stepping when they are in a 1-on-1 ballgame defensive scenario because their sidestepping takes a relatively long time.

In Study II, to investigate what specific information is relevant for defenders and how defenders process this information to decide on their opponents' running direction, I hypothesized that defenders extract information regarding the position and velocity of the attackers' CoM and the contact foot. I used a model which simulates the future trajectory of the opponent's CoM based upon an inverted pendulum movement. The hypothesis was tested by comparing observed defender's cue timing, model-estimated cue timing using the IPM (IPM cue timing) and cue timing using only the current CoM position (CoM cue timing). The IPM cue timing was defined as the time when the simulated pendulum falls leftward or rightward given the initial values for position and velocity of the CoM and the contact foot at the time. The model-estimated IPM cue timing and the empirically observed defender's cue timing were comparable in median value and were significantly correlated, whereas the CoM cue timing was significantly more delayed than the IPM and the defender's cue timings. Based on these results, I discuss the possibility that defenders may be able to anticipate the future direction of an attacker by forwardly simulating inverted pendulum movement.

In Study III, to clarify the defending-dribbler mechanism, the interaction between the dribbler and the defender should be investigated. The purposes of Study III were to identify variables that explain the outcome (i.e., “penetrating” and “guarding”) and to understand how defenders stop dribblers by categorizing defensive patterns. Ten basketball players participated as 24 pairs of dribblers and defenders, who played a real-time, 1-on-1 subphase of the basketball. The trials were categorized into penetrating trials, where a dribbler invaded the defended area behind the defender, and guarding trials, where the defender stopped the dribbler’s advance. The results demonstrated that defenders in guarding trials initiated their movements earlier and moved quicker than the defenders in penetrating trials. Moreover, linear discriminant analysis revealed that the difference in initiation time and mediolateral peak velocity between the defenders and dribblers were critical parameters for explaining the difference between penetrating and guarding trials. Lastly, guarding trials were further categorized into three defensive patterns during 1-on-1 basketball (i.e., “early initiation” trials, “quick movement” trials and “dribbler’s stop” trials). The results suggest that there are three defending strategies and that one strategy would be insufficient to explain the defending-dribbler mechanism, because both players’ anticipation and reactive movement must be considered.

In Study IV and V, the defender’s motor control mechanism of the earlier and quicker movement was investigated using force plates. The preparatory motion of a defensive motion in contact sport such as basketball should be small and involve landing on both feet for strict time and motion constraints. In Study IV, I thus proposed the movement creating an unweighted state. Ten basketball players performed a choice reaction sidestepping task with and without the voluntary, continuous vertical fluctuation movement. The results indicated that the preparatory movement shortened the time of their sidestep initiation (301 vs. 314 ms, p = 0.011) and reaching performance (883 vs. 910 ms, p = 0.018) but did not increase their peak ground reaction force or movement velocity. The mechanism of the improvement was estimated to be the following: in the preparation phase, the vertical body fluctuation created the force fluctuation; after the direction signal, the unweighted state can shorten the time required to initiate the sidestepping (Unweighted: 279 ms; Weighted: 322 ms, p = 0.002); around the initiation phase, the dropping down of the body and weighted state can contribute to the reaching performance. I conducted additional experiment investigating muscle-tendon-complex dynamics and muscle activity using ultrasound device and electromyography. The result suggests that the building up of active state of muscle might explain the improvement of sidestepping performance.

In Study V, I investigated how the outcome of 1-on-1 subphase of team sports determines. Previously, I focused on the kinetic preparatory state (i.e., ground reaction forces) and demonstrated improved sidestepping performance. The purpose of Study V was to clarify the effect of the kinetic preparatory state on 1-on-1 basketball outcome and performance. Ten basketball players participated in this study as 10 pairs of dribblers and defenders who played a real-time, 1-on-1 subphase of basketball. The outcomes (penetrating and guarding) and the kinetic preparatory state (non-weighted and weighted states) were assessed by separating the phases in determination level. The results demonstrated that the non-weighted state made guarding in 78.8% probability, whereas the weighted state did so in 29.6%. The defenders would adopt the non-weighted strategy to prevent delaying the step before the time to peak velocity of the player in the determination phase. In the one-previous phase (prior to the determination phase), both the non-weighted and weighted state were likely to transition to the weighted state, at which time the phase-transition of the defender’s kinetic state determined the outcome of a 1-on-1 subphase. Consequently, these results suggest that a defender’s creation of a non-weighted state before the defender’s initiation of the determination phase would enable a quick defensive step and successful guarding of the dribbler in a 1-on-1 basketball subphase.

The significance of this thesis is three-fold: (1) it developed the methods to simultaneously analyze cognitive and motor skill in the invasive ballgame. These findings of the studies would provide the evidence of the unexplained mechanism for the expertise of human cognitive and motor control. (2) It approached anticipatory mechanism for humans. Study II applied the mechanical model used in standing and walking biomechanics to the cognitive model. This approach would develop the paradigm of anticipatory mechanism of human movement to more practical level with enhancing neurophysiological, mathematical background. (3) It contributed to the application to the field of ballgames. The studies in this thesis quantitatively and explicitly demonstrated the cognitive and motor skills which were sensuously or implicitly understood in the field. These evidences would be accumulated as scientific knowledge of the coaches, and would potentially improve the ballgame player's skills.

In conclusion, in both cognitive and motor control strategies, the thesis suggests that because skilled dribblers have a variety of deceptive movement, defenders should take strategies to prevent slow step initiation due to the weighted state and being deceived by the dribbler's deceptive signals other than the information of CoM, rather than strategies to achieve quick step initiation by the unweighted state and excessive anticipation using specific body parts.