ANTICIPATION EFFECT ON KNEE JOINT STABILITY DURING PLANNED AND UN-PLANNED MOVEMENT TESTS IN LABORATORY

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The purpose of this study was to investigate the anticipation effect on knee stability during functional test in laboratory. Ten healthy male subjects were recruited and instructed to perform a series of planned and un-planned stop-jumping tasks. Knee joint kinematics was measured by a motion analysis system. The subjects demonstrated different abduction and rotation angles for reactive tasks. This suggested that if knee abduction or rotational stability is considered as a primary measurement in documenting knee stability, such as in the investigation of rehabilitation progress after anterior cruciate ligament reconstruction, both planned and un-planned tasks should be considered as to take the anticipation effect into account.

KEY WORDS: stop-jumping, knee kinematics, unanticipated

INTRODUCTION: Anterior cruciate ligament (ACL) rupture is a common sport-related trauma which causes knee instability (Hurd and Snyder-Mackler, 2007). It is often treated operatively to reconstruct the ligament in order to restore the joint stability (Zaffagnini et al, 2007). Ten years ago, orthopaedics surgeons managed to reconstruct the ACL in a single-bundle fashion, with either patellar tendon or hamstring tendon as the graft (Eriksson, 2007). However, anatomical studies showed that the intact ACL contains two bundles which provide translational and rotational stability respectively (Petersen and Zantop, 2007). Therefore, in the recent decade, surgeons began to consider reconstructing the ACL in a double-bundle fashion (Zella et al, 2006). The effect has been well demonstrated in cadaveric study to be successful in restoring mechanical stability in both translational and rotational directions (Woo et al, 2002).

However, for athletes, the functional stability is much more important than the mechanical stability. Therefore, functional test has to be included during follow-up consultation to evaluate if a patient is adequately rehabilitated (Risberg and Ekeland, 1994). Such functional test often includes jogging, running, jump-landing, and most importantly, pivoting and cutting tasks. These functional tests allow subjects to preplan movement patterns and it may not reflect the movement patterns performed in competition during which athletes must react to unanticipated events (Besier et al, 2001). Numerous studies showed the anticipation effect on knee joint loading and muscle activation patterns during these tests (Ford et al, 2005). However, such effect on knee rotational stability is not yet demonstrated, and is awaited by orthopaedics surgeons to evaluate the functional outcome after ACL reconstruction with the recent double-bundle technique. The current study aims to investigate the anticipation effect on knee rotational stability during functional test in laboratory. Kinematics at foot strike (Cham and Redfern 2002) was considered in our study as ACL injury was reported to occur 17-50 milliseconds after initial foot strike during landing (Krosshaug et al, 2007). We then hypothesis that there is no difference for the landing maneuver between planned and un-planned stop-jumping tasks. Such information is important for biomechanists to decide whether to conduct both planned and un-planned tasks to document the rehabilitation progress of ACL patients.

METHODS: Data Collection: Ten healthy male subjects without any previous injury history on lower limbs were recruited. Informed consent in written format was obtained from each subject. The study was conducted in a motion analysis laboratory. Fifteen reflective markers were attached to the lower extremity of the subject at the major anatomical positions, including sacrum, left and right greater trochanter, anterior superior iliac spine, lateral femoral condyle, tibial tuberosity, lateral malleolus, calcaneus, and fifth metatarsal heads. The lower extremity motion was captured by an 8-camera high-speed motion analysis system (Vicon, UK) at 120Hz.

A series of functional tasks were performed planned and un-planned randomly for each subject. For each task, the subject was instructed to run straight on a 5-meter walkway approaching a ground-mounted force plate (AMTI, USA), with a running speed of 3.1 to 3.5 m/s (De Cock et al, 2005) as monitored by the forward speed of the sacrum marker by the motion analysis system. Trials with running speed out of the range were discarded.

In the planned tasks, the subjects were instructed to stop with both feet on the force plate and jump immediately either to four directions, including anterior, vertical, left and right as far as they could. The order of the four directions is selected randomly. In un-planned tasks, a light gate was set at a distance of 0.5 meters in front of the force plate. When the subject passed through the gate, a signal was delivered to a computer to trigger an instruction to change the movement direction as shown on a 17-inch monitor in front of the walkway. Upon the availability of the instruction signal, the subject stepped on the force plate and jumped to the instructed direction in the shortest time he could. Four directions were delivered to the subject in a random sequence. Five successful trials for each direction for planned and un-planned tasks were collected.

Data Analysis: The lower extremity biomechanics were calculated with a standard procedure (Soderkvist and Wedin, 1993). The primary measurement was the knee rotational displacement at the time of foot strike, as this suggests if the anticipatory effect is significant to the preparatory stage of the functional task. Knee adduction/abduction angle and flexion/extension angle were calculated as well. Stratified paired t-tests were conducted for each of the four tasks to determine the anticipatory effect on knee rotational stability during planned and un-planned movement tests. A 0.05 significant level was chosen a priori to denote statistical significance for the comparisons.

RESULTS: Ten male subjects with mean age 26.4 (1.78) were recruited. Their mean height and body mass were 1.73m (0.72 m) and 70.9 kg (15.62 kg). The result of the three knee angles at the time of foot strike was summarized in the Table 1. Significant differences were found in adduction/abduction angle and internal/external rotation angle for anterior jump.

Table 1 knee kinematics for planned and un-planned tasks at the time of foot strike

Knee joint angle at landing	Jump direction	Planned	Un-planned	Statistical analysis p-value[a]
Flexion (+ve) or extension (-ve)	Anterior	25.8° (7.4)	23.8° (7.4)	No significant differences (p = 0.367)
	Vertical	27.0° (12.0)	23.5° (6.5)	No significant differences (p = 0.252)
	Right	28.9° (3.6)	23.5° (7.2)	No significant differences (p = 0.068)
	Left	21.4° (4.4)	22.4° (4.5)	No significant differences (p = 0.491)
Abduction (+ve) or adduction (-ve)	Anterior	9.4° (8.9)	6.0° (10.9)	Significant differences (p = 0.049)*
	Vertical	8.9° (10.4)	6.5° (8.1)	No significant differences (p = 0.112)
	Right	9.3° (10.2)	6. 9° (10.1)	No significant differences (p = 0.125)
	Left	5.7° (10.3)	7.9° (8. 9)	No significant differences (p = 0.193)
External rotation (+ve) or internal rotation (-ve)	Anterior	20.2° (8.8)	13.9° (6.4)	Significant differences (p = 0.030)*
	Vertical	17.4° (8.8)	14.1° (5.4)	No significant differences (p = 0.231)
	Right	18.3° (9.7)	14.5° (4.9)	No significant differences (p = 0.173)
	Left	12.1° (10.6)	15.9° (6.8)	No significant differences (p = 0.111)

* Significant difference observed between planned and un-planned tasks ($p < .05$)

DISCUSSION: Currently, research investigating anticipated effect was limited. Pollard et al (2007) and Landry et al (2007) reported that both male and female performed similarly in randomly cued cutting maneuver. However, neither research group focused on stop-jumping maneuver, in which most of the ACL injuries occurs during such landing movement with a change in direction. Sell et al did comparison between planned and un-planned stop-jumping tasks and demonstrated increased knee joint loading characteristics such as greater knee valgus and flexion moments. They suggested that directional and reactive jumps should be included in research methodology.

In the current study, we included anterior jumping addition to vertical and horizontal side jumping. Kinematics of the knee joint was measured at the time of foot strike as investigators believe that ACL injuries typically occur at this moment (Olsen et al, 2004). Subjects in this study performed similarly in flexion angle and differently in abduction angle between planned and un-planned tasks. There was a significant difference on abduction during anterior jumping task, which suggests anterior jumping should be considered as one of the jumping directions when performing stop-jumping tasks.

Most importantly, we measured knee rotational displacement, which is the major laxity the ACL patients suffer. The healthy subjects in our study demonstrated decreased knee internal rotation for unanticipated tasks and significant difference was found in anterior stop-jumping task. Since the current study incorporated a few high risk movements of ACL injury including a sharp deceleration, a change in direction and a landing maneuver, the result of this study may indicate that both planned and un-planned stop-jumping tasks should be considered when evaluating knee rotational stability after ACL reconstruction and before safe return-to-sports.

CONCLUSION: Different kinematics results were demonstrated in healthy male subjects between planned and un-planned stop-jumping tasks. This suggests that both planned and un-planned tasks should be conducted to document the rehabilitation progress of ACL patients, especially for evaluating ACL reconstruction with double-bundle fashion which claimed to better restore rotational stability.

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