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Effect of anticipation on knee kinematics during a stop-jump task

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ABSTRACT

Knee stability during a functional assessment of the stop-jump task is a key factor to determine if an athlete is adequately rehabilitated after knee ligamentous injury. This study aimed to investigate knee stability due to the effect of anticipation on landing maneuvers during planned and unplanned stop-jump tasks. Knee kinematics of ten healthy male participants were collected using an optical motion analysis system during stop-jump tasks. Stop jumps were performed in four different landing positions either in planned movement or in an unplanned movement on a signal triggered as participants passed through a photocell gate. Kinematic data at the time of foot strike at landing in the stop-jump considered for investigating the anticipation effect during the stop-jump tasks. Two-way multivariate analysis of variance (MANOVA) with repeated measures and stratified paired *t*-tests were conducted to compare the knee kinematics data between planned and unplanned tasks. Statistical significance was set at the $p < 0.05$ level. External rotational angle showed a significant decrease in unplanned stop-jump tasks during forward ($p < 0.05$) and right ($p < 0.05$) jumps when compared to that of planned tasks. Flexion angle and abduction angle during forward, vertical and right jumps were significantly decreased in the unplanned tasks. Anticipation significantly influenced the landing maneuvers of stop-jump task. The results indicated that both planned and unplanned stop-jump tasks should be considered when monitoring the rehabilitation progress after a ligamentous injury.

1. Introduction

The knee is one of the most commonly injured body sites in sports, which accounts for 10–25% [1] of all injuries. Among all sport-related knee injuries, around 45% are related to ligamentous injury [2]. Athletes who suffer from ligament disruption generally experience knee instability [3]. Knee ligament reconstruction such as anterior cruciate ligament (ACL) reconstruction aims to restore the functional stability and allows athletes to return to sports activity at the pre-injury level [4]. Several functional tests are used during follow-up consultation to evaluate if an athlete is adequately rehabilitated [5]. The movement tasks employed vary with different purposes; for example, running is used to evaluate gait pattern [6] while hopping is used to test muscle power [7]. During these movement tasks, however, knee stability is seldom considered during high demand functional tasks.

Knee stability is usually evaluated by clinicians and athletes themselves through subjective assessments such as clinical examination and questionnaires [8,9]. Objective assessments have been developed for assessing anterior-posterior translation [10] and axial rotation [11] of the knee. However, these measurement tools are limited to a passive laxity test. Knee rotational stability in terms of tibial rotation has been investigated during dynamic functional tasks [12,13]. These studies evaluated tibial rotation with respect to the femur during a high demand pivoting task before and after ACL reconstruction. Besides pivoting, stop-jump [14,15] and cutting [16–19] tasks have been used in kinematics studies but no study focused on knee rotational stability. The knee joint rotational stability is recently being emphasized because of the latest technique to reconstruct the anterior cruciate ligament to restore its double-bundle anatomy [20], and is usually defined as the maximum rotation, the rotation at a specific moment, or the range of tibial rotation with respect to the femur when the knee is under an external load application, being examined physically by a clinician, or when the participant is performing a specific dynamic functional task [21].

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To simulate a real game situation in the laboratory, anticipation has been considered in the literature. The anticipation effect refers to the phenomenon that individuals change their motion pattern when potential threats or dangers are expected [22]. It is involved in most sport movements and research has revealed that unplanned movement is more dangerous than planned movement [17]. Possible reasons suggest that quick and unplanned movements affect muscle activation patterns and result in abnormal joint kinematics [14,16,17]. For example, Besier and colleagues [17] suggested that unplanned cutting maneuvers would increase the risk of non-contact ACL injury and Sell and colleagues [14] found lateral jump was the most dangerous among 3-direction stop-jump tasks as they found higher ground reaction forces, proximal anterior tibia shear forces, greater valgus and flexion moments, and lower flexion angles. However, there is limited knowledge if unplanned movements affect knee rotational stability during functional tasks. This information would be important to decide if the anticipation effect should be considered during dynamic functional assessment after knee ligamentous injury.

This study aimed to investigate the anticipation effect on knee rotational stability and other knee kinematics during stop-jump tasks in laboratory. Kinematics at foot strike [22] was considered in our study as ACL injury was reported to occur 17–50 ms after initial foot strike during landing [23]. We hypothesized that there would be a significant difference in knee rotational stability in terms of tibial rotation (knee external rotational angle from a standing anatomical position) and other knee kinematics (knee flexion angle and abduction angle from a standing anatomical position) at the time of touch down between planned and unplanned stop-jump tasks. The information is important for designing a functional test protocol for assessing the knee rotational stability for patients receiving knee surgery such as anterior cruciate ligament reconstruction. Regular assessments during the rehabilitation process will allow physicians to determine if the patient is good for returning to sports.

2. Methods

Subjects: Ten healthy right-leg dominant male participants without any lower limb injury history were recruited. They were recreational athletes, currently participating at least twice a week in their sport of choice. The mean age, body mass and height of the participants were 26.4 ± 1.78 years, 70.9 ± 15.62 kg and 1.73 ± 0.72 m, respectively. The university ethics committee approved the study. Informed consent was obtained from each participant before beginning the experiment.

2.1. Experimental tasks and procedures

A series of stop-jump tasks were performed in planned and unplanned manners for each participant. Fig. 1 showed the experimental setup in the laboratory. For each trial, the participant ran straight on a 10 m walkway approaching and landing on a ground-mounted force plate with his right foot (Position A), with a running speed of 3.1 m/s to 3.5 m/s [24] monitored by the forward speed of the sacrum marker by a motion analysis system (VICON 624, UK). The instantaneous speed was extracted from the VICON software immediately after each trial, and trials with a running speed out of the range were discarded.

After landing on the force plate, the participant jumped immediately to one of the four directions (left, right forward, vertical) as far as they could. The direction of the jump was randomized by a computer program, and was delivered to the participant by an instruction signage displayed full-screen on a 17-inch monitor in front of the walkway. The display was either a left arrow, a right arrow, an upward arrow, or a “UP” sign, instructing the participant to perform a left jump, a right jump, a forward jump, and a vertical jump respectively. For the planned tasks, the instruction signage was displayed before the participant started the trial. For the unplanned tasks, a blank screen instead of the instruction signage was displayed until the participant passed a light gate at a distance of 0.7 m from the force plate and at a height of the participant’s waist level. The placement of the light gate allowed approximately 0.2s for the subject to read the instruction signage on the screen, to react and to perform the jump. The direction of the jump was also randomized by the same computer program. The procedure continued until three successful trials for each stop-jump direction for planned and unplanned tasks were collected.

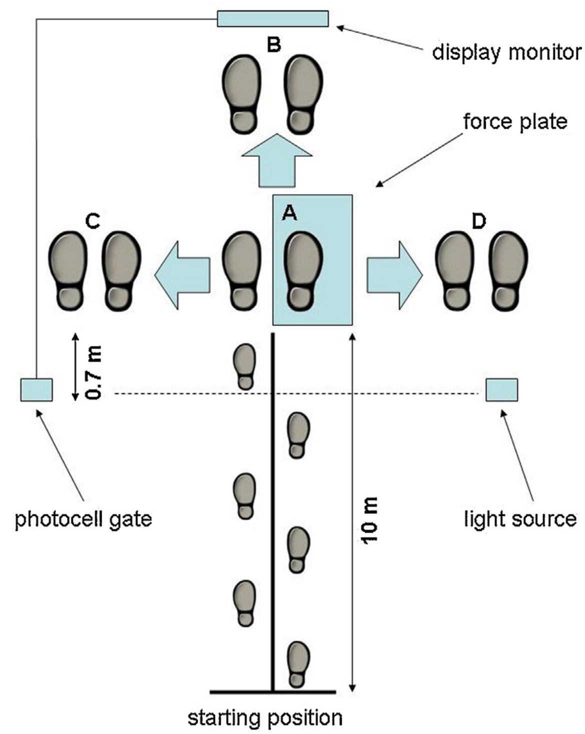

Fig. 1. Laboratory setting of planned and unplanned stop-jump tasks (Vertical jump: A–A; Forward jump: A–B; Left jump: A–C; Right jump: A–D).

2.2. Data collection and reduction

All experiments were conducted in the Gait Laboratory of Alice Ho Miu Ling Nethersole Hospital, Hong Kong. An optical motion analysis system with eight cameras was employed to collect three-dimensional rotation movements of lower extremities at 120 Hz capturing frequency. The system was calibrated on the same day of testing and the mean residual was less than 1 mm, otherwise the system was recalibrated. A synchronized force plate (AMTI OR6-7, Massachusetts, USA) was used to record complete ground reaction force data at 1080 Hz.

After an explanation of the study’s procedures, anthropometric measurements were taken; including body height and mass, anterior superior iliac spines (ASIS) breadth, thigh and calf length, mid-thigh and calf circumference, knee diameter, foot breadth and length, malleolus height and diameter. A fifteen-marker model was adopted to collect lower limb kinematics (knee flexion, knee abduction and knee rotation) during stop-jump movements [13]. The markers were secured with double-sided tape to the participants’ bony landmark, including the