KINETIC ANALYSIS OF LOWER EXTREMITY DURING SIDESTEP CUTTING UNDER DIFFERENT DIRECTIONS

Jung-Chan Shih[1], Tzu-Lin Wong[1], Jin-Cherng Wang[2] and Chia-Hung Lin[1]
[1]National Taipei Teachers College, Chinese Taipei
[2]National Chia-yi University, Chia-yi, Chinese Taipei

The purpose of this study was to investigate the ground reaction forces, joint reaction forces, net muscle joint moments of the ankle, knee and hip during elite handball athletes executed typical cutting maneuver under four different directions. Four male elite handball players were tested during fast running (4.5~5.5 m/s) and then performed cutting to the right off (30°, 40°, 50°, 60°). A JVC camera (60 Hz) and synchronized with force plate (1200 Hz) were used to collect the relative parameters of braking leg during cutting maneuver. Each participant's braking leg (right leg) was modeled as a system of rigid bodies. The inverse dynamics approach was used to integrate the body segment parameter, kinetic and force plate data, and to solve the resultant joint moments. The results showed that sidestep cutting maneuver would produce a load and according to the increase of cutting angles, the lower extremity could receive a strike force and moment during the braking phase. Besides, while the knee angle of flexion was small and repeated loading of this magnitude were enough to produce the fatigue of lower extremity joints that would eventually result in complete disruption and clinical lower extremity joints injury.

KEY WORDS: sidestep cutting, inverse dynamics, handball, joint moment

INTRODUTION: Many sport activities required sudden deceleration or rapidly changes in direction included handball, soccer, basketball, and American football. This motion has a high incidence of ruptures of lower extremity joints. The direct mechanical causes of the ruptures was numerous. Bencke, Nesborg, Simonsen, and Klausen (2000) describe this mechanical may be caused by (1) rotation of the tibia, (2) forward shear of the tibia caused by the knee joint extensor muscles or (3) by rotational and shear forces in combination. Specifically, the landing phase of these movements typically incorporated large quadriceps force at relatively small flexion angles, a combination known to induce anterior force on the tibia (Durselen, Claes, & Kiefer, 1995). Besides, joint moments are often used as a representation of the musculoskeletal stresses to the lower extremity, the effects of turning direction on moments acting on joints of the leg played an important role. However, previous studies on sidestepping or crossover cutting had not definitely restricted the cutting angle, which could result in a large variation in the loads experienced at lower extremity joints (Mclean, Neal, Myers, & Waters, 1999 ; Simonsen, Magnusson, Bencke, Nasborg, Havkrog & Ebstrup , 2000 ; Besier, Lloyd & Ackland, 2003). In order to understand the differences between angles in cutting techniques, a narrow range of direction changes should be studied about lower extremity risks. The purpose of this study was to examine the ground reaction forces, joint reaction forces, net muscle joint moments of the ankle, knee and hip during elite handball athletes executed typical cutting maneuver under four different directions (30°, 40°, 50°, 60°).

METHODS : Four male elite handball players(mean age 21 ±1.3 yrs; height 1.8 ± 0.4 m; body weight 82 ± 2.2 kg) took part in the experiment. Each one signed an informed consent form and own handball shoes were worn during experiment(all subjects were right-handed shooters). The movements were filmed with a JVC camera (GR-DVL9800) placed 12 m from the force plate facing the subject in sagittal plane. The direction of movement was always from right to left and only the right leg was used for the analysis. Seven reflective markers were placed on head, shoulder, hip, knee, ankle and the fifth metatarsal joint. Two-dimensional coordinates were derived by a video analysis system (Kwon3D 3.0 motion analysis system) to gain the kinematics parameters of human lower extremity. The force plate (AMTI) data were converted by DASY Lab6.0 analysis system from volt to Newton and the reaction forces expressed in multiples of bodyweight (BW). Three reaction forces (Fx, Fy and Fz) and two moments of torsion (Mx and My) were measured. Mx, My and the vertical ground reaction force were used to obtain the location of the center of pressure (COP) in both the lateral and the sagittal direction. Anthropometric measurements preceded the experimental trials of each subject included body mass, foot length, shank length, thigh length. Segment mass, segment moments of inertia and joint center were estimated by using Ho (2002) Body Segmental Parameters. The subjects ran along an 10-meter runway at 4.5~5.5 m/s game speed. They were instructed to plant the test limb (right leg) and change direction to the lateral side at four angles (30°, 40°, 50°, 60°), using the other limb as the first step in the new direction. They then performed four different changes of direction tasks in random order. Five trials were recorded at each direction condition for each subject. For each trial, 2D position data were determined from video analysis at 60 Hz and synchronized with force plate at 1200 Hz. An inverse dynamics approach was used to integrate the body segment parameter, kinematics and force plate data, and solve for the resultant forces and moments at the ankle, knee, and hip joints using Enoka (2002) inverse dynamics equations.

RESULTS AND DISCUSSION:

Ground reaction forces: The first force peak of the vertical ground reaction force was greater than the second force peak during the braking phase (Figure 1).The first force peak of horizontal and vertical ground reaction force were getting more according to the increase of cutting angles. Besides, the second force peak of horizontal and vertical ground reaction force were similar according to the increase of cutting angles (Table 1).

Table 1 Ground reaction force during the whole contact phase under four different cutting maneuver directions.

		1st peak (BW±SD)		2st peak (BW±SD)	
		Anterior force	Vertical force	Anterior force	Vertical force
Force	30°	0.6±0.1	2.2±0.1	0.3±0.2	1.9±0.3
	40°	0.7±0.1	2.2±0.2	0.2±0.2	2.1±0.3
	50°	0.8±0.1	2.3±0.2	0.2±0.1	1.9±0.2
	60°	0.8±0.2	2.4±0.2	0.2±0.2	2.0±0.2
Time (msec)	30°	77.2±2.2	49.1±2.0	223.1±2.6	130.3±2.5
	40°	76.4±2.5	54.2±2.2	216.2±2.3	98.3±3.0
	50°	84.3±2.1	50.1±2.2	248.4±2.1	136.3±2.5
	60°	88.5±2.5	56.2±2.5	205.7±2.7	122.2±2.5

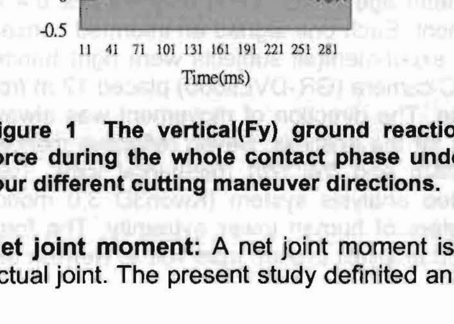

Figure 1 The vertical(Fy) ground reaction force during the whole contact phase under four different cutting maneuver directions.

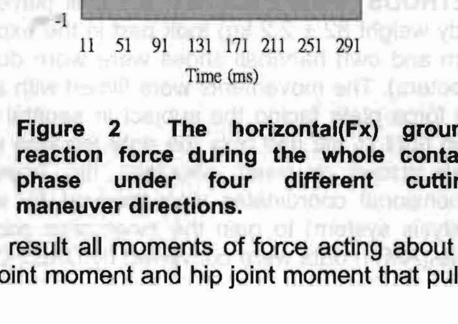

Figure 2 The horizontal(Fx) ground reaction force during the whole contact phase under four different cutting maneuver directions.

Net joint moment: A net joint moment is the result all moments of force acting about the actual joint. The present study definited ankle joint moment and hip joint moment that pulling in an encounterclockwise was considered positive, and knee joint moment pulling in a counterclockwise was negative. The sign of ankle joint moment and hip joint moment indicated the flexor-dominated moments, and knee joint moment indicated the extensor-dominated moment during the braking phase. By the increase of the cutting angles, the moments of lower extremity were getting more (Figure 3 - Figure 5). The flexor of lower extremity joints was dominated during the braking phase to restrain the flexion of lower extremity joints and stable the lower extremity motion. Shoemaker, Adams, and Daniel (1993) reported that anterior tibial displacement resulting from a quadriceps muscle force was greatest at 30° to 45° of knee flexion in knees with intact ACL and 20° to 25° in knees with a sectioned ACL. The results of this study clearly show that at and after foot strike, the knee is positioned at an angle that will allow the quadriceps muscle to strain the ACL. In our study, the average knee-flexion angles at foot strike were 17.9°, 22.0°, 23.9° and 24.7° for four angles (Figure 6), ranged from 17° to 25°, suggesting that the knee was at angle that will allow the quadriceps muscles to strain the ACL.

Shear force: Shear force was easy likely to rupture the lower extremity joints. In our study, the average 30° maximum shear force of lower extremity knee leg was 531 N (0.7 BW) and knee thigh was 1220 N (1.5 BW), the average 40° maximum shear force of lower extremity knee leg was 547N (0.7 BW) and knee thigh was 1261 N (1.6 BW), the average 50° maximum shear force of lower extremity knee leg was 698 N (0.9BW) and knee thigh was 1295 N (1.6BW), the average 60° maximum shear force of lower extremity knee leg was 719 N (0.9BW) and knee thigh was 1225 N (1.5BW) (Figure 7 and Figure 8). Remarkably, the peak knees loading in the present study were greater, according to the increase of cutting angles. Woo, Hollis, Adams, Lyon, and Takai (1991) reported the strength of the ACL at ultimate failure to be about 2000N in specimens taken from young cadavers. The results of the present study suggest that a sidestep cutting maneuver will unlikely produce a load sufficient to create lower extremity joints injury.

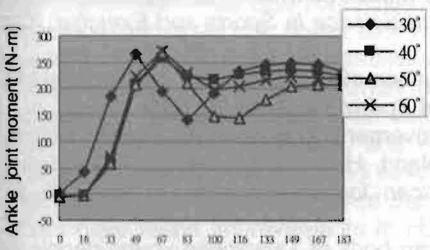

Figure 3 Ankle joint moment during different directions.

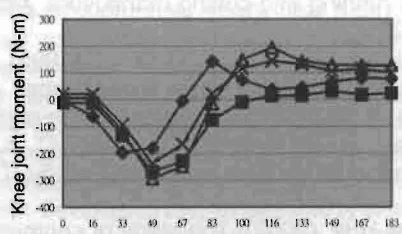

Figure 4 Knee joint moment during different directions.

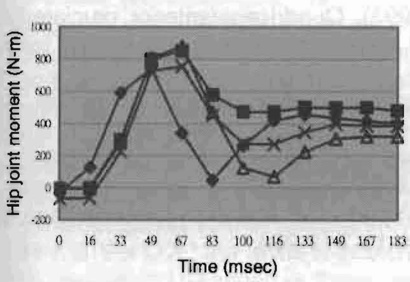

Figure 5 Hip joint moment during different directions.

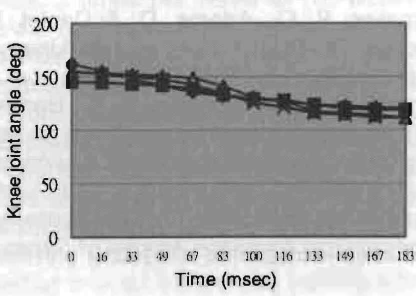

Figure 6 Knee joint angles during different directions.

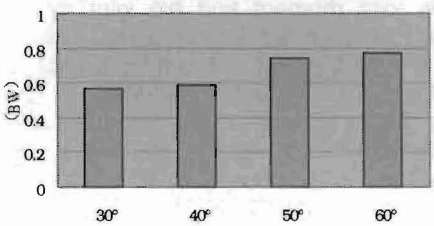

Figure 7 **Maximum shear force of lower extremity knee leg.**

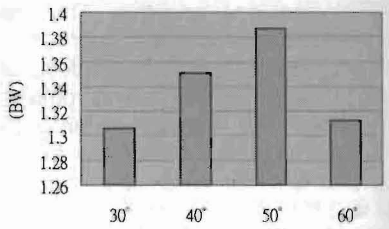

Figure 8 **Maximum shear force of lower extremity knee thigh.**

CONCLUSION: In this study, we observed that sidestep cutting maneuver could produce a load and according to the increase of cutting angles, the lower extremity could receive a strike force and moment during the braking phase. Besides, while the knee angle of flexion was small and repeated loading of this magnitude were enough to produce the fatigue of lower extremity joints that would eventually result in complete disruption and clinical lower extremity joints injury.

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