THE EFFECT OF TURNING DIRECTION ON LOWER EXTREMITY JOINT MOMENTS DURING FAST CUTTING MOVEMENT

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The purpose of this study was to investigate the effect of turning movement on the three-dimensional moments at the ankle, knee, and hip joints. Data were collected using video cameras and force plate. Eight male recreational basketball players were tested during fast running (4.5m/s) and when cutting to the right or left off (+60, +30, 0, -30, and -60°). The inverse dynamics approach was used to integrate the body segment parameter, kinetic and force plate data, and to solve the resultant joint moments. Greater abduction moments of the ankle, adduction moments of the knee and external rotation and adduction moments of the hip were found compared to values for straight running. Greater inversion and adduction moments of the ankle, abduction moments of the knee and hip were found compared to values for straight running.

KEY WORDS: cutting movement, joint moment

INTRODUCTION: Often during sport a player may rapidly change direction: forward, backward, to the left or right sides. Fast medio-lateral movements which are frequent in basketball, volleyball, tennis, soccer, football, and baseball are often associated with lower extremity injuries. These injuries may occur as a result of excessive medio-lateral movement at the ankle, knee, and hip joint outside the normal range of motion. To turn in a certain direction during running, moments must be generated to rotate the body. These are created by the interaction of foot, shoe and ground but in addition muscle contraction and movement of the segments play an important role during turning. Although 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 are not well known. The purpose of this study was to investigate the effect of fast turning movement on the resultant joint moments of the lower extremity. It was hypothesized that the torsional moments (internal/external rotation and abduction/adduction) of ankle, knee, and hip joint would increase during fast turning movement.

METHODS: Subjects. Eight male recreational basketball players between the ages of 20 and to 22 were recruited for this study. Subject mean height was 181 (range, 175-188 cm), mean leg length was 91 cm (range, 84-98 cm), and mean weight was 710 N (range, 617-794 N). Each subject’s own basketball shoes were worn during experiment.

Protocol. Anthropometric measurements preceded the experimental trials of each subject for the purpose of estimation of segment mass, segment moments of inertia and joint centers. These measurements included body mass, foot length, malleolus height and width, shank length and circumference, thigh length and midthigh circumference, and anterior superior iliac spine width. Next, anatomical landmark calibration was performed using a technical frame of 12 skin markers. The technical frame was traced in 3 dimension (3D) over time. When combined with landmark calibration, global position-time data for anatomical landmarks was determined. Five trials were recorded at each direction condition for each subject. Running speed and turning direction were assigned randomly. All five trials were collected at one speed and direction before changing to the other condition. A protocol was accepted if the trial involved a speed within 0.2 m/s of 4.5 m/s and involved a direction change within 3 degrees of the appropriate testing direction (+60, +30, 0, -30, and -60°).

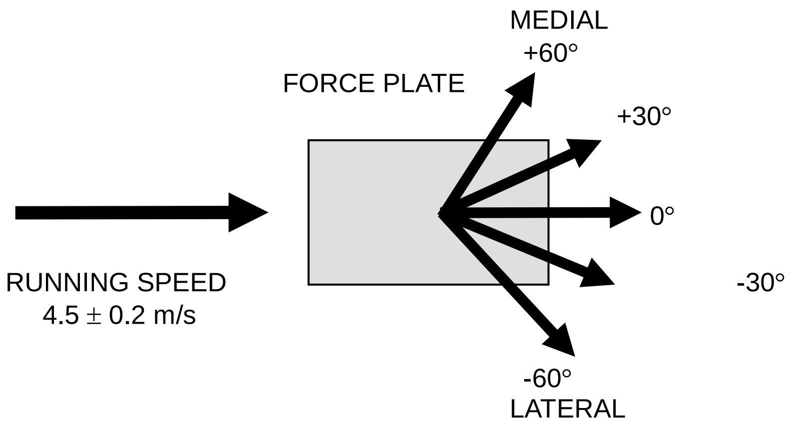

Figure 1 - Turning directions

Data processing. For each trial, 3D position data were determined from video analysis (60 Hz) and synchronized ground reaction forces were measured from on AMTI force plate at 240 Hz. An inverse dynamics approach was used to integrate the body segment parameter, kinematic and force plate data, and solve for the resultant forces and moments at the ankle, knee, and hip joints using Newton-Euler equations of motion.

Statistical analysis. To minimize variability due to body differences, joint moments were normalized to body weight times leg length. Statistical analysis used the mean of five trials for each direction to characterize a subject's performance. Repeated measures ANOVA was used to evaluate the effect of turning direction on maximum joint moments. The dependent variables were maximum value of each joint moment for each direction (+60, +30, 0, -30, and -60°). Follow-up comparisons were made with pared t-tests, controlling for Type I error by Holm's sequential Bonferroni procedure.

RESULTS: Flexion-extension moments measured during straight running corresponded well with joint moment patterns in the literature for running (Buczek & Cavanagh, 1990; Gordon & Robertson, 1985; Simpson & Bates, 1990; Winter, 1983). Mean 3D moments about the ankle, knee, and hip joint illustrating the effect of turning direction are shown in the following tables.

Ankle. Turning movement did not affect dorsi/plantar flexion moments. However, the maximum inversion moment increased 142% (33 Nm) during +60° turning compared to straight running. Maximum abduction moment increased 200% (36 Nm) during +60 turning while maximum adduction moment increased 300% (35 Nm) during -60° turning compared to straight running.

Knee. Maximum abduction and adduction moment increased with medial and lateral turning; 130% and 750% compared to straight running. Maximum internal rotation moment increased only slightly with medial turning movement. Maximum extension moment increased 60% (92 Nm) during +60 turning compared to straight running.

Hip. Flexion-extension moments were unchanged with turning while maximum internal rotation moment increased 140% (37 Nm) during -60° turning and maximum external rotation moment increased 280% (115 Nm) during +60° turning compared to straight running. Maximum abduction and adduction moments increased 300% with lateral and medial turning, respectively.

Table 1 Ankle Moments

Variable	+60	+30	0	-30	-60	p
Inversion	-7.38±2.54	-7.10±2.72	-12.09±3.03	-17.53±4.87	-17.22±3.25	.000
Eversion	2.74±2.77	2.08±2.31	0.12±0.15	0.14±0.13	0.14±0.21	.327
Dorsiflexion	-5.93±4.63	-3.26±2.26	-3.50±3.65	-2.64±3.37	-2.11±1.68	.308
Plantarflexion	15.01±3.87	17.29±5.72	15.54±4.27	13.64±4.24	10.54±4.97	.576
Abduction	7.09±2.67	7.42±2.20	1.71±1.36	1.63±1.49	0.66±1.16	.001
Adduction	-6.19±3.35	-2.53±2.17	-2.72±3.14	-6.00±3.37	-8.22±3.77	.048

Table 2 Knee Moments

Variable	+60	+30	0	-30	-60	p
Internal rotation	5.99±2.48	3.10±2.03	3.18±2.56	3.04±2.59	4.03±2.18	.293
External rotation	-4.56±7.05	-3.86±5.30	-2.46±3.62	-1.88±2.52	-0.69±0.96	.139
Flexion	1.35±1.57	2.17±1.98	1.13±0.96	3.05±4.53	2.17±2.51	.363
Extension	-37.10±10.44	-26.08±12.76	-22.83±10.80	-23.60±16.87	-20.14±8.51	.050
Abduction	0.27±0.52	2.92±4.11	4.74±5.16	11.29±5.60	10.75±2.79	.011
Adduction	-14.74±4.84	-6.28±4.51	-1.73±1.47	-0.95±1.41	-0.52±1.31	.004

Table 3 Hip Moments

Variable	+60	+30	0	-30	-60	p
Internal rotation	0.71±1.06	2.24±2.22	4.18±3.16	7.13±3.28	9.95±7.13	.029
External rotation	-24.26±9.20	-14.04±8.31	-6.41±8.31	-3.08±5.23	-4.32±7.46	.001
Flexion	2.44±2.20	4.63±3.05	7.30±7.46	7.54±5.70	1.01±1.64	.680
Extension	-18.74±8.30	-26.56±13.17	-22.77±10.58	-18.32±13.96	-14.09±4.30	.185
Abduction	0.73±1.04	1.95±2.38	5.75±3.38	14.19±8.82	22.90±5.33	.001
Adduction	-31.20±13.26	-21.13±9.27	-7.77±7.78	-5.00±4.92	-0.33±0.82	.003

DISCUSSION: Medial cutting movements. Greater abduction moments of the ankle, adduction moments of the knee and external rotation and adduction moments of the hip were found compared to values for straight running. Greater ankle abduction (external rotation) moments may help enable decelerating external rotation of the upper body and opposite leg. Greater adduction moments of the knee and hip may support the weight of the body which is medial to the knee and hip. These moments keep the body from moving toward the stance leg during medial turning. Greater hip external rotation moments may serve to slow external rotations of the pelvis and opposite leg.

Lateral cutting movements. Greater inversion and adduction moments of the ankle, abduction moments of the knee and hip were found compared to values for straight running. Greater ankle adduction (internal rotation) moments may help enable rotating of the upper body and opposite leg externally. During lateral turning there was greater movement of the upper body and opposite leg to the pivot leg producing larger translations of the whole body center of mass. Inversion movement at the ankle joint is produced by structures such as muscles (foot invertors) and ligaments. Although there was greater ankle inversion moment during lateral turning, the ankle was stabilized by external eversion moment of the vertical ground reaction force and shifted center of pressure to the right side of the foot and lateral ground reaction force.

CONCLUSION: One of the most common injuries of the foot is an ankle sprain that occurs in the lateral complex of the ankle during inversion. Parenteau, Viano, and Petit (1998) reported that ankle joint injury occurred at 34.1 ± 14.5 Nm and 34.3 ± 7.5° in inversion during quasi-static loading condition, while Begeman, Balakrishnan, and King (1993) reported 35.1 ± 15.6 Nm and 60.5 ± 6.0° during dynamic loading conditions. Maximum inversion moments of this study exceeded 80 Nm for all subjects during lateral turning. Under unstable conditions such as slipping or excessive inversion resulting from uneven surfaces, larger inversion moments are likely to occur which exceed physiological limits of the ligamentous structures. The maximum torsional moment in cadaver knees without ligament damage is 35-80 Nm in internal/external rotation, and the ultimate strength in abduction/adduction is 125-210 Nm (Piziali, Nagel, Koogle, & Whalen, 1982). Maximum torsional moment supported by the knee in this study was 40 Nm in internal/external rotation and 95 Nm for abduction/adduction moment during medio-lateral turning. Although these values are within the range of the ultimate strength of the knee, it is likely that faster and sharper cutting movements have a greater potential for knee injury. In summary, these findings reinforce the intuitive notion that fast medio-lateral turning movements produce substantially greater musculoskeletal stresses on joint structures than does straight running.

REFERENCES:

Begeman, P., Balakrishnan, P., & King, A.I. (1993). Dynamic human ankle response to inversion and eversion. *Symposium Proceedings-Centers for Disease Control*, 121-132.

Buczeck, F.L., & Cavanagh, P.R. (1990). Stance phase knee and ankle kinematics and kinetics during level and downhill running. *Medicine and Science in Sports and Exercise,* **22**, 669-677.

Gordon, D., & Robertson, E. (1985). Functions of the leg muscle during the stance phase of running. In B. Johnson (Ed.), *Biomechanincs X-B* (pp. 1021-1027). Champaign, IL: Human Kinetics.

Parenteau, C.S., Viano, D.C., Petit, P.Y. (1998). Biomechanical properties of human cadaveric ankle-subtalar joints in quasi-static loading. *Journal of Biomechanical Engineering,* **120,** 105-111.

Piziali, R.L., Nagel, D.A., Koogle, T., & Whalen, R. (1982). Knee and tibia strength in snow skiing. In R. J. Johnson, W. Hauser, & M. Magi (Eds.), *In Ski Trauma and Skiing Safety IV* (pp.24-31). Munich: TUV Publication Series.

Simpson, K.J., & Bates, T. (1990). The effect of running speed on lower extremity joint moments generated during the support phase. *International Journal of Sport Biomechanics,* **6**, 309-324.

Winter, D.A. (1983). Moments of force and mechanical power in jogging. *Journal of Biomechanics,* **16**, 91-100.