CONTRIBUTION OF THE LOWER EXTREMITY JOINTS TO MECHANICAL ENERGY IN ATHLETICS CURVE SPRINTING

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The purposes of this study were to identify differences of the three-dimensional joint kinetics between linear and curve sprinting and to quantify the asymmetrical loading of both legs during curve sprinting. Six male sprinters performed three linear and curve sprints. The energies of the ankle, knee and hip joint were determined during the ground contact phase with the aid of an adjusted multibody human model. The ankle joint was the largest energy absorber and generator in the sagittal plane while the hip joint was the largest energy absorber and generator in the frontal and transversal plane. Asymmetric functions of the inside and outside leg were determined during curve sprinting. The hip joint of the inside leg might be highly loaded in sprinting on a bend track.

KEY WORDS: sprint mechanics, joint energy, joint kinetics.

INTRODUCTION: The performance of the athletic 200 m sprint depends on various external factors, such as the radius of curvature. It influences the amount of the centripetal force that is necessary to follow the bend track. In comparison to the straight sprint, the generation of the centripetal force by the athlete leads to three-dimensional changes of ground-reaction forces, joint kinematics and joint kinetics. The asymmetric kinematic modulations seem to decrease the maximal sprinting velocity throughout the curve sprint (Chang & Kram, 2007; Hamill, Murphy, & Sussman, 1987; Ishimura & Sakurai, 2010; Nemtsev & Chechin, 2010; Smith, Dyson, Hale, & Janaway, 2006). While the trajectory of the athlete's center of mass cannot be influenced during the flight phase, the change of direction has to be realised during the ground contact phase of each leg. Different functionalities of the inside and the outside leg (Alt, Heinrich, Funken, & Potthast, 2015; Hamill et al., 1987; Ishimura & Sakurai, 2010; Smith et al., 2006) result in altered propulsive mechanisms due to changes in the non-sagittal planes of the lower extremity joints (Alt et al., 2015; Chang & Kram, 2007; Churchill, Salo, Trewartha, & Bezodis, 2012; Luo & Stefanyshyn, 2012). Thus, the purposes of the study were to identify differences of the three-dimensional joint kinetics between linear and curve sprinting and to quantify the asymmetrical loading of both legs during curve sprinting.

METHODS: Six male sprinters (20.2 ± 2.6 yrs; 1.86 ± 0.06 m; 76.3 ± 8.2 kg; 200 m personal best: 22.60 ± 0.33 s) performed six sprints (3 straight, 3 curve) with a constant submaximal velocity of 9.4 m/s. Anthropometric data were determined following the guidelines of the multibody human model Dynamicus (Alaska dynamicus 8.2, Institute of Mechatronics, Chemnitz, Germany). 32 spherical retro-reflective markers were put on anatomical reference points of the lower extremity. Four force plates (Kistler, Winterthur, CH) were placed tangential in the curve's vertex. Analog data (1250 Hz) and kinematic data were collected (250 Hz, 16 infrared cameras) using the software Nexus (Vicon Nexus 1.85, Oxford, UK). Joint angles, external joint moment, power and energy of the ankle joint (AJ), knee joint (KJ) and hip joint (HJ) were determined during the ground contact phase with the aid of the adjusted multibody human model Dynamicus. Positive joint power was defined as energy generation during concentric contraction, while negative joint power was defined as energy absorption. The sum of positive and negative energy was calculated for each joint in all planes. Descriptive and inferential statistics were conducted using PSPP (PSPP 0.8.4). Left and right stance of linear and curve sprinting were compared (Wilcoxon matched pairs signed ranks test).

RESULTS: The amount of all energy absorptions and generations are presented in Figure 1. The most significant differences were identified between the curve sprint (CS) and the linear sprint (LS). In the sagittal plane, the inside ankle joint (L_AJ) showed a significant higher energy generation during CS compared to LS. In the sagittal and transversal plane, the inside knee joint (L_KJ) showed significant higher energy generations during CS. In contrast to L_AJ and L_KJ the inside hip joint (L_HJ) showed higher energy generations in the frontal and transversal plane during CS. The outside hip joint (R_HJ) showed lower energy absorptions in the frontal plane and lower energy generations in the transversal plane during CS. The total energy at the end of stance phase is significant higher in L_HJ and lower in R_HJ in the transversal plane during CS.

Comparing the inside and outside leg during CS significant lower energy absorptions in L_AJ and significant higher energy absorptions in L_KJ could be found in the transversal plane. The L_HJ showed higher energy generations in the frontal and transversal plane and significant higher energy absorptions in the sagittal plane. The total energy at the end of stance phase is significant higher in L_HJ in the transversal plane.

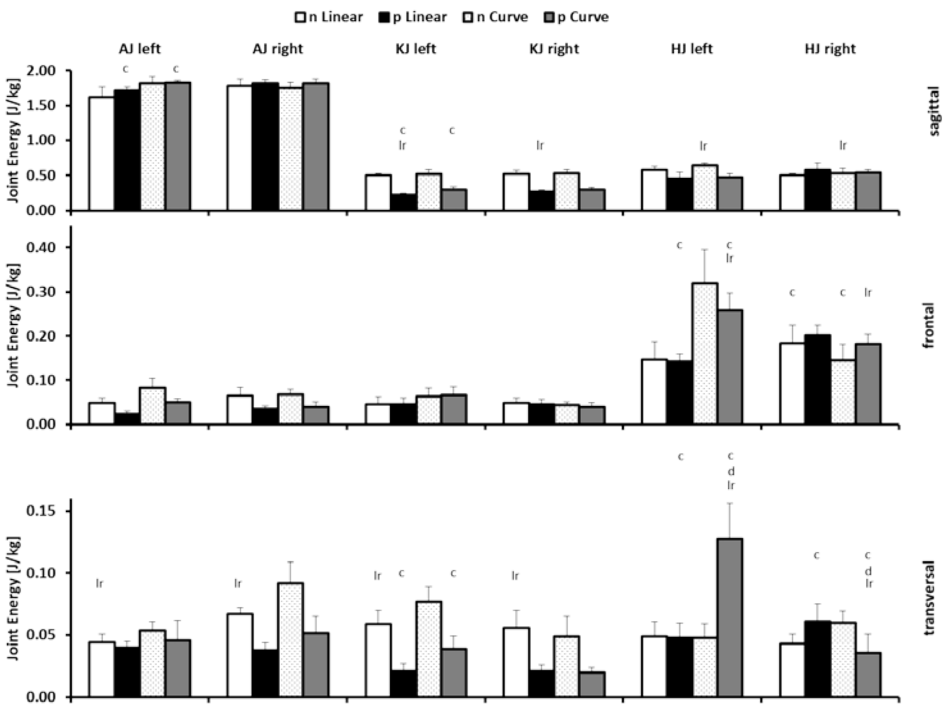

Figure 1: Energy absorption (n) and generation (p) of ankle joint (AJ), knee joint (KJ) and hip joint (HJ) for curve and linear sprinting in the sagittal, frontal and transversal plane.
c = significant difference between curve and linear sprinting
lr = significant difference between left (inside) and right (outside) leg
d = significant difference between the total energy at the end of stance phase between left (inside) and right (outside) leg and between curve and linear sprinting

DISCUSSION: The purposes of the study were to identify differences of the three-dimensional joint kinetics between linear and curve sprinting and to quantify the asymmetrical loading of both legs during curve sprinting. The determined differences in energy absorption and generation characteristics of the lower extremity joints between curve and linear sprinting might be caused by the additional force generation in medio-lateral

direction. Due to kinematic changes in the frontal plane (Alt et al., 2015) it could be expected that the energy absorption and generation in the frontal plane would be affected as well. However, only the energy generation of the inside and the energy absorption of the outside hip joint seem to be influenced by the curve sprinting. Most differences could be found in the transversal plane. Especially the energy generation of the hip joint of the inside leg stands out. The hip joint of the inside leg might be highly loaded during curve sprinting.
The functions of the ankle, knee and hip joints appear to be asymmetric in curve sprinting. The ankle joint could be confirmed as the largest energy absorber and generator in the sagittal plane (Stefanyshyn & Nigg, 1998). The hip joint is the largest absorber and generator in the frontal and transversal plane. The knee joint might only have a sub-unit function.
The inside leg seems to absorb and generate the same energies as the outside leg in the sagittal plane. The sprinting velocities between the inside and outside leg are not different during curve sprinting. In contrast to Chang et al. (2001) it could not be supposed that the running velocity in athletes curve sprinting is limited by the inside leg.

CONCLUSION: The results of the study underline the asymmetric functions of the inside and the outside leg during curve sprinting. A limitation of the curve sprinting by the inside leg could not be confirmed by energy absorption and generation characteristics of the lower extremity joint. Regarding the altered energy absorption and generation characteristic the hip joint, it might play a major role in generating the needed centripetal force.

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