COMPARISON OF SPRINTING MECHANICS OF THE DOUBLE TRANSTIBIAL AMPUTEE OSCAR PISTORIUS WITH ABLE BODIED ATHLETES

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The purpose of this study was to examine the overall kinetics and the kinetics at the joints of the lower limb while sprinting at maximum speed, and to compare the data of a double transtibial amputee (OP) and able-bodied controls running at the same level of performance. One double transtibial amputee, and five able-bodied sprinters participated in the study. The athletes performed submaximal and maximal sprints on an indoor track embedded with 4 Kistler force plates while recorded with a 12 camera Vicon 624 system. OP displayed lower mechanical work (stance phase), external joint moments and joint power at the hip and the knee joints while displaying higher values of joint power at the (prosthetic) ankle joint compared to able-bodied athletes. The mechanical work at the knee joints was 11 times higher in the negative phase and 8.1 times higher in the positive phase during stance in the able-bodied athletes compared to OP.

INTRODUCTION: On behalf of the International Association of Athletics Federations (IAAF) the biomechanics of maximal sprinting of the double below knee amputee Oscar Pistorius was analyzed in the phase of individual maximal running speed. In comparison to that, the sprinting mechanics of five able bodied athletes of a similar level of performance were analyzed. IAAF used that information for the decision making process whether or not Oscar Pistorius was allowed for participating at the Bejing Olympics 2008.

METHOD: Five able bodied sprinters were recruited as control group (CTR). Their average 400 m personal bests varied from 46.5 to 49.26 s, their average body mass was 78.67 ± 7.9 kg and, height 1.88 ± 0.05 m and their average age was 25.7 yrs. The personal best of the 22 years old double transtibial amputee (OP) was 46.3 s, his body mass was 83.3 kg and his body height was 1.85 m at the time of the measurement both with his dedicated sprinting prostheses (Cheetah, Össur, Iceland). Subjects performed maximal sprints over an indoor track of about 70 m. Ground reaction forces were measured using four 90 cm x 60 cm force plates (Kistler, Switzerland). Movement analysis was performed during stance phase. Sprinting kinematics were recorded using a twelve camera infrared high speed system (Vicon, UK). Segment kinematics of the lower extremities and inverse dynamic calculations were done using a three segment rigid body model (Stafilidis and Arampatzis, 2007). Therefore markers were placed on different anatomical landmarks of the able bodied sprinters and related points of the prosthesis (figure 1). Particularly joint power of the ankle and knee as well as the power generated and absorbed in the prostheses were calculated my multiplying angular velocity with joint torque component-by-component. Integrating the power time histories provided mechanical work produced in the particular structure.

Figure 1. Representation of the experimental setup. Left: Indoor running track, camera system and force plates. Middle and right: Marker placement.

A more comprehensive description of methods and material used in the measurement can be found elsewhere (Brüggemann et al., 2008).

RESULTS: Kinetics and kinematics of the sprints show clear differences between the able bodied group and OP. Figure 2 shows the vertical and anterior-posterior components of the ground reaction forces. Higher peak vertical and horizontal forces were found in the able bodied runners compared to the amputee. In addition the vertical as well as the horizontal breaking and propulsive impulses of OP were about 15% smaller than the impulses of CTR.

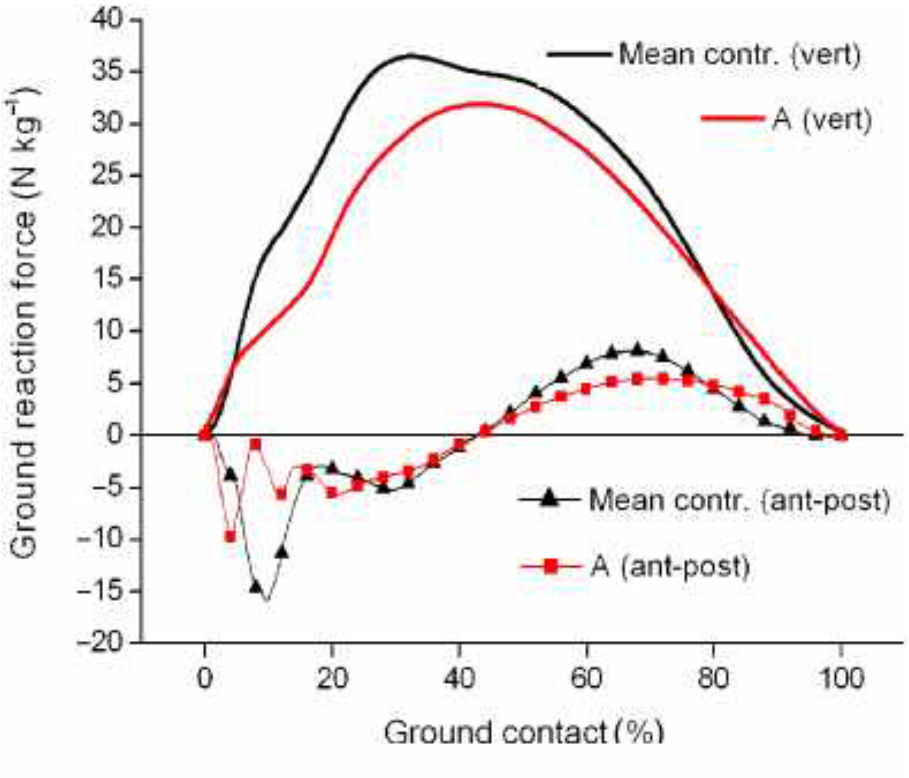

Figure 2. Vertical and anterior-posterior ground reaction force components for able bodied athletes (black) and OP (red).

Joint power and joint work in the prosthesis was much bigger compared to the ankle joint of the able bodied population (figure 3).

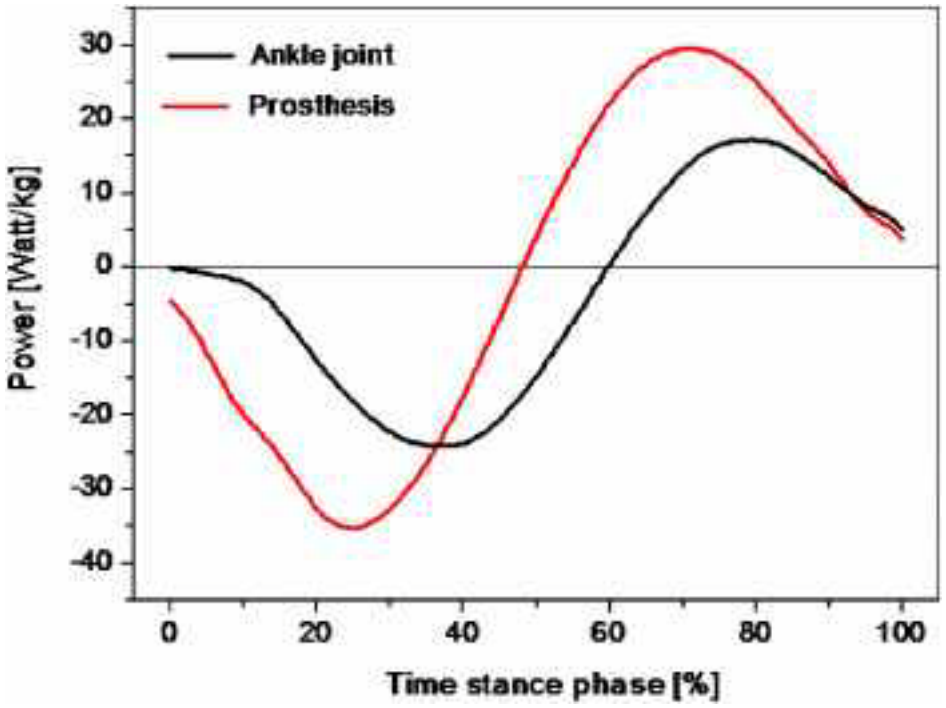

Figure 3. Time history of the joint power of the prosthesis of OP (red) and the ankle (black) of the able bodied controls.

The energy absorption of OP is about 40% higher for the artificial ankle joint compared to CTR. The almost elastic prosthesis keel returns about 90 to 95% of the stored energy. In the able bodied ankle joint only about 40 to 45% of the absorbed energy is generated in the second phase of the stance. The opposite situation occurs at the knee joint. Here OP does hardly any work, while the knee contributes remarkably (about 50% of the ankle) in CTR.

DISCUSSION: The biomechanics of double amputee sprinting shows differences to able bodied sprinting. The ground reaction forces indicate that OP runs with a smaller vertical displacement (smaller vertical impulse) in the phase of maximal speed than his able bodied counterparts. In addition he decelerates less in the first part of the stance phase and therefore has to generate a smaller propulsion impulse in the second phase of stance. The major part of the work of the lower extremity is done in the ankle joint in OP while the knee joint is contributing with less than 5%. This is completely different in able bodied sprinting, where the knee joint has a considerable contribution mechanical work production.

REMARK: Based on this and some additional data, IAAF decided to exclude OP from the Olympic Games 2008 in Beijing. The Court of Arbitration of Sports (CAS) overruled that decision essentially due to juristic reasons. OP did not participate in Beijing because he did not fulfil the qualification criteria for 400 m sprint.

REFERENCES:

Stafilidis, S. & Arampatzis, A. (2007). Track compliance does not affect sprinting performance. *Journal of Sport Sciences*, 25, 1479-90.

Brueggemann, G.-P., Arampatzis, A., Emrich, F. and Potthast, W. (2008). Biomechanics of double transtibial amputee sprinting using dedicated sprinting prostheses. *Sports Technology*, 1, 220 - 27.