BIOMECHANICS OF SPRINTING AMPUTEES ATHLETES

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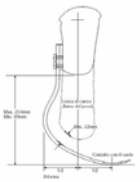
Knowledge Aided Engineering Manufacturing and Related Technologies

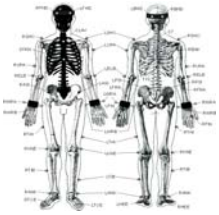
OBJECTIVE: This work presents the final part of an intense research activity related to the biomechanical analysis of sprinting amputees athletes by means of orthopaedic prostheses. The first session has been devoted to the comparison between the normal and amputee athletes in order to analyze the positioning of the amputee inside the sample of normal ones at different competitive level (pro, junior and amateur): it has been compared the kinematics parameters. The second session regarded the behavioural elastic-mechanic analysis of different feet which are on the market. The final part of this research regards a deepened analysis related to the kinetic one of a wider sample: it is made of five amputee athletes between them four below-knee amputation and just one above-knee, all paralympic athletes. The data gathered by the research will be used so as to optimize the performance of the athlete: the prosthesis has to be analyzed along the process of socket design and along the alignment components phase. It has to be considered as a functional evaluation tool in order to understand the athlete condition along the training session and in order to optimize the training type for Assen world championship 2006.

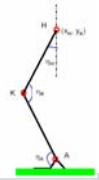
Key words: amputee sprinting, prosthesis design, kinetic analysis



INTRODUCTION ABOUT PROSTHESIS

The sprinting prosthesis for leg amputations are constituted by the following main parts: the **liner** made of soft and elastic material, has the task to guarantee the comfort of the stump preserving it from stresses during walking; the socket is the interface between the stump and the mechanical components of prosthesis; it is the custom part of the prosthesis, made for patient through manual acquisition; the carbon fiber **foot** with tipical "J" profile to optimize the propulsive force during sprinting. The class of the foot, chosen according to the weight and to the competitive level, establishes the stiffness and the elasticity of the foot itself. The alignment of the foot with the prosthesis depends on the length of the stump: in some cases, when stumps are long, the foot is attached to the socket in the back, if short they're fixed under the socket.





METHODS

LAY OUT: performance area is 12m long and 5m wide. It is 2m high and it is chosen according to the height of the athletes. Eight infrared cameras cover the entire volume of acquisition.

ANTHROPOMETRIC PARAMETERS: anthropometric parameters are: lower limb, ankle diameter, knee diameter, leg length (distance between iliac spine-medial malleolus) and distance between iliac spines.

MARKER SET: the optoelectronic VICON© system uses Kadaba's protocol. The landmarks of the lower limb are: **pelvis** (RASI, LASI, LPSI, RPSI) 4 iliac spines (left and right, front and posterior); **leg** (LKNE, LTHI, LANK, LTIB, RKNE,RTHI, RANK, RTIB) right and left femural epicondyle, 1/3 of the right and left femur, right and left lateral malleolus, 1/3 right and left tibia; **foot** (LTOE, LHEE, RTOE, RHEE) right and left second metatarsus, right and left heel. On the prosthesis, markers are sticked when the athlete is positioned on the tip-toe position. Two added markers are positioned to verify the alignment (one on under patella, the other at same height of the "T" attach).

TEST SESSIONS: it has been carried out three different acquisition sessions with different tests for the athletes. We analyzed the sprinting of amputee athletes referring to normal ones, which has been executed in each session for at least six times.

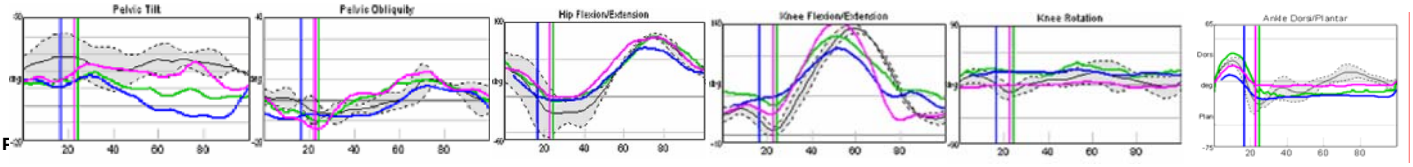
ANGLES: ZERO REFERENCE: thigh-leg segment aligned and perpendicularto the ground during stance phase.

Positive values: *Sagittal plane*: ankle dorsiflexion, knee flexion, hip flexion, pelvic tilt *Horizontal plane*: knee intrarotation, pelvic intrarotation, hip intrarotation *Coronal plane*: knee adduction, hip adduction, pelvic obliquity.

RESULTS AND DISCUSSION

Time–space parameters: **wide stride** of the amputee is greater than the normal one in order to find balance (it depends on stump length); **length stride** lower than the normal ones since knee and hip have a limited flexion and there's absence of plantarflexion in the ankle joint. Stance phase and contact time lower than normal athletes (search for adjustments due to the prosthesis comparing to the sound foot) **Cadence and sprinting velocity** of the amputees are lower than the normal athletes of pro and junior level, but greater than amateur ones**.**

KINEMATIC PARAMETERS OF BELOW AMPUTEES



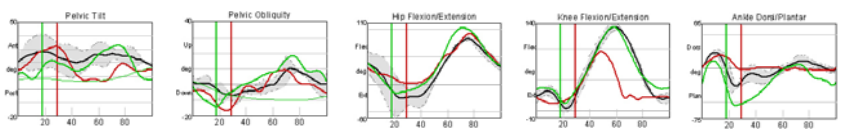
The range of motion of the **pelvic tilt** is proportional to the athlete energetic cost; as a matter of fact the sprinter maintains the body forwarded and in the case of normal athletes it assumes lower values. **Obliquity** it goes down on prosthesis side in loading phase (spring phase). Extrarotation during stance phase and low intrarotation during swing phase.

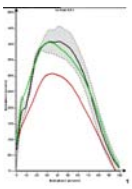
Hip *prosthesis side:* extension close to zero, lower than the normal athletes (60°) in relation to toe-off and a smaller value of the peak flexion during swing phase (about 10-20° less than normal ones). On the frontal plane, during the contact phase , the hip of the amputee limb, in opposition to the sound limb, gets in abduction in order to compensate knee intrarotation. On the horizontal plane it goes on extrarotation during swing phase).

Knee: *the knee of the amputee limb* gets a limited flexion due to socket ties and a limited extension for the alignement between socket and foot which maintains a flexion of about 10-20°. On the frontal plane it shows abduction during stance phase. On the horizontal plane it shows a constant intra-rotation due to the length and morfology of the stump (blue line presents shorter stump).

Ankle: *prosthesis ankle angle* lower dorsiflexion due to the shape and to the elasticity of the mechanical foot, close to the horizontal during swing phase due to the maintainance of the angle shaped by the foot profile.

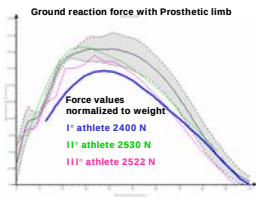
KINEMATIC PARAMETERS OF ABOVE AMPUTEE

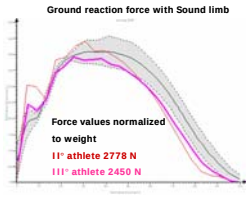


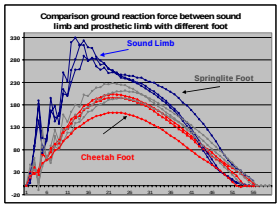


Above knee (AB) kinematics is different from normal and below-knee (BK) athletes. As far as the sound limb is concerned, it is close to the normal ones. As far as the prosthetic limb is concerned:

Hip: lower flexion and anticipation in reaching the maximum peak; **ankle**: angles depend on the "L" shape (modular OSSUR©) of the mechanical foot and its stiffness; **knee:** over-extension for a long period starting from 80% of the swing phase and it remains over-extended during stance phase.







KINETIC PARAMETERS

The force unloaded to the ground depends on some parameters:
Athlete muscle strength, physical attitude, type of prosthesis foot, class of prosthesis foot (stiffness).

Analysis of the same athlete:
1 sound limb (3234 N), 0,7 Springlite foot(2254 N), 0,6 Cheetah foot (1960 N)

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