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# Kinematic analysis of snowboarders with lower limb amputations

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## 1. Introduction

Snowboarding has made its first appearance at the Paralympic Winter Game in 2014. The popularity of this sport has accelerated the development of new devices, specifically for transfemoral amputee athletes. Such devices are composed of passive ankle and knee controlled by hydraulic or pneumatic cylinders. The mechanical characteristics of those cylinders influence the practice of snowboarding. Thus, there is a need to better understand how the devices operate during snowboard performances.

One challenge is the collection of biomechanical data in real conditions due to the limited number of athletes, the weather conditions, and the material. Some conducted experiment on simulator based on an optical system (Park et al., 2015). Others collected data on the slopes, using an electromagnetic Fastrak suits (Delorme et al., 2005) or Inertial Measurement Units (IMU) (Hirose et al., 2012). The comparison of amputee and non-amputee kinematics has been conducted indoors for one transfemoral subject (Gastaldi et al., 2011), and on the slopes for a transtibial subject (Minnoye & Plettenburg, 2009).

However, no work has been conducted on the slopes and for above knee amputee athletes. The objective of this study is therefore to describe the lower limbs kinematics for snowboarders with an amputation

during real training sessions. This work aims to bring information to develop new above-knee prosthesis and improve the performance of the athletes.

## 2. Methods

Four subjects with left-limb amputation participated in this study. Two of them were transtibial subjects, with one regular and one goofy. The two others were transfemoral subjects, with one regular and one goofy. One was an expert, two were recreational snowboarders and one was a novice. The following protocol has been validated by an ethics committee (CERSTAPS IRB00012476-2024-14-01-288).

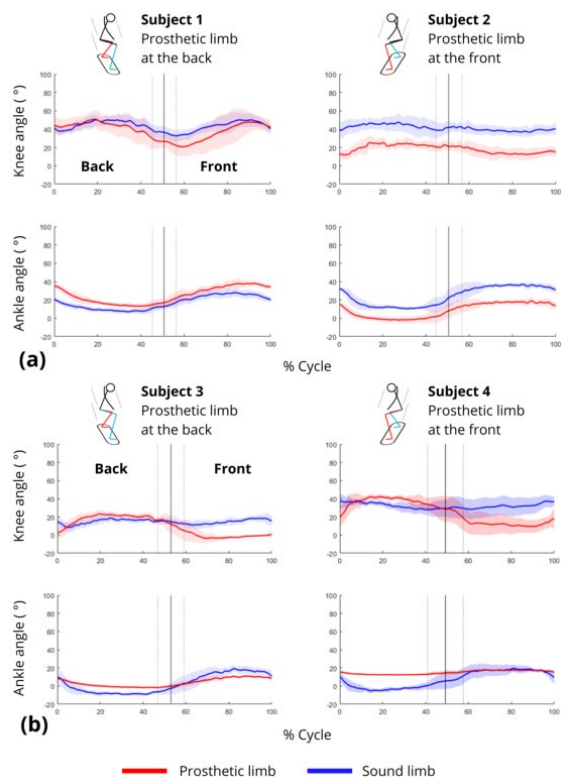
Kinematic data was collected with 8 IMU's (Awinda, Xsens Technologies, Enschede, The Netherlands). Sensors were placed on both feet, shanks, and thighs, one on the pelvis and one on the sternum. The acquisition frequency was set to 100 Hz. The IMU system calibration was realized on top of the slopes before the descent. The descent was a simple run, corresponding to a succession of backside and frontside turns. All trials were filmed with a synchronized webcam.

The kinematic data were processed on Matlab. A cycle has been defined as one backside turn followed by one frontside turn. Cycle determination has been based on the foot orientation in the sagittal plane, that also corresponds to the orientation of the board. A positive angle means that the board is on its front edge, corresponding to a frontside. A negative angle corresponds to a backside.

## 3. Results and discussion

The movements of flexion/extension of the knee and ankle are presented Figure 1. Results were similar for the two transtibial subjects (Figure 1-a): the ankle extended during the backside turns and flexed during the frontside, reaching an angle of 40° of dorsi flexion. The ankle range of motion was comparable to the one of non-amputee subjects (Delorme et al., 2005; Minnoye & Plettenburg, 2009).

Moreover, the kinematic patterns of the knee for the first subject were comparable to those of non-amputee: he bended the knee once in the backside turn before bending it a second time during the frontside turn. This double flexion also appeared with non-amputee subjects (Park et al., 2015). However, the kinematic of the knee was different for subject 2. He did not bend his residual knee, but the knee of the sound limb was more flexed.



**Figure 1.** Flexion/extension of lower limbs during a cycle for transtibial subjects (a) and transfemoral subjects (b). The 0° position match the athletes standing still.

For the transfemoral subjects (Figure 1-b), kinematic patterns of the two subjects were similar for both knee and ankle. The motion of the prosthetic ankle was limited: the range of motion was 11° for subject 3 and 6° for subject 4. The subjects relied on the other ankle, whose kinematics resembles the non-amputee, with dorsi flexion during the frontside turn.

The kinematic patterns of the knees were similar to non-amputee in the backside turn but different in the frontside turns. During the backside the knee flexion of the transfemoral subjects was inferior to the non-amputee subjects. The maximum flexion angle was 25° for subject 3 and 40° for subject 4. The knee flexion angle can reach 90° for expert snowboarders (Park et al., 2015). The main difference for the transfemoral subjects was the absence of flexion during frontside turns: the knee was fully extended during this phase. One explanation is the difficulty to flex the prosthetic knee during the frontside turn because of the knee joint axis position relative to the board. To compensate that loss of mobility, the subjects keep the sound knee flexed during the entire cycle (Bonnet et al., 2023).

## 4. Conclusions

Amputee snowboarders' kinematics differ by amputation type: transtibial resemble non-amputees, while transfemoral face more limitations. Thus, the type of amputation seems to be an important criterion in the study of kinematics. However, the subjects differ in other parameters: age, experience, style, equipment. Those differences provide an overview of the para snowboarding kinematics, bringing new information for the design of snowboard-specific prosthesis.

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## Conflict of Interest Statement

The authors declared no potential conflicts of interest.

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