Joint Efforts Calculation in the Gait of Incomplete Spinal Cord Injured Subjects

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Abstract

The present work is part of a project aimed to simulate the gait motion of incomplete spinal cord injured subjects wearing active orthoses. The inverse dynamic analysis of the actual motion of subjects walking with the aid of crutches, as the one shown in Figure 1a, is a required step that must be carried out before addressing the mentioned final objective. The approach to deal with this problem is basically coincident with the one considering the gait of healthy subjects, although there are some non-trivial differences: a) external actions come to the human body not only through the feet, but also through the crutches; b) typically, the crutch contacts the body at two points, i.e. the hand and the forearm.

These two differences demand some changes in both the model and the experimental setup. On the one hand, the model must include the crutches, and the connection between tool and body must be defined. On the other hand, the force plates that measure the foot-ground contact forces are no longer sufficient, since the contact forces between crutch and ground must also be experimentally obtained.

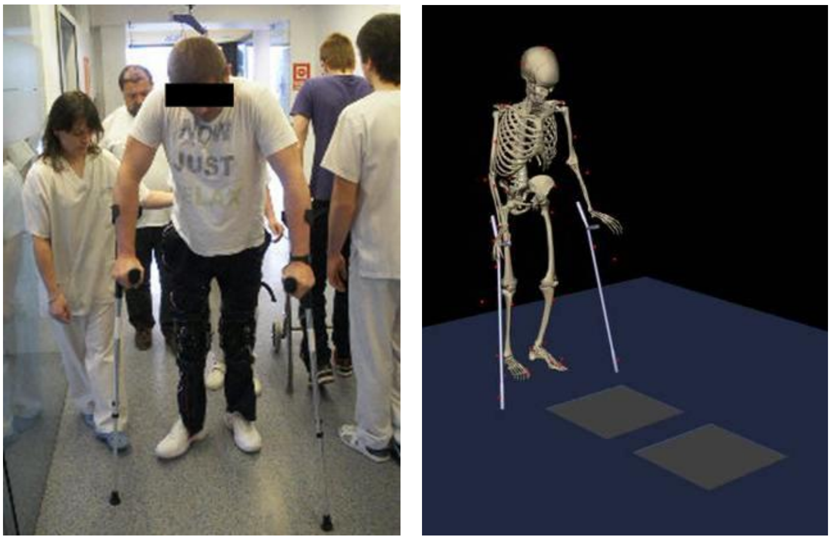

Figure 1: a) the patient; b) the model.

Regarding the modeling, the already existing 3D computational human-body model in natural and angular coordinates described in [2] has been extended with a couple of crutches, each of them rigidly connected to the corresponding hand, but with no kinematic connection at the contact between the upper support of the crutch and the forearm.

In what refers to the experimental side, three reflective markers have been rigidly attached to each crutch, thus allowing the capture of its motion by the optical system, and four Wheatstone bridges have been mounted on it, three aimed to provide the three components of the ground reaction at the tip, and one more devoted to measure the contact force between the upper support of the crutch and the human forearm. All these elements can be seen in Figure 2.

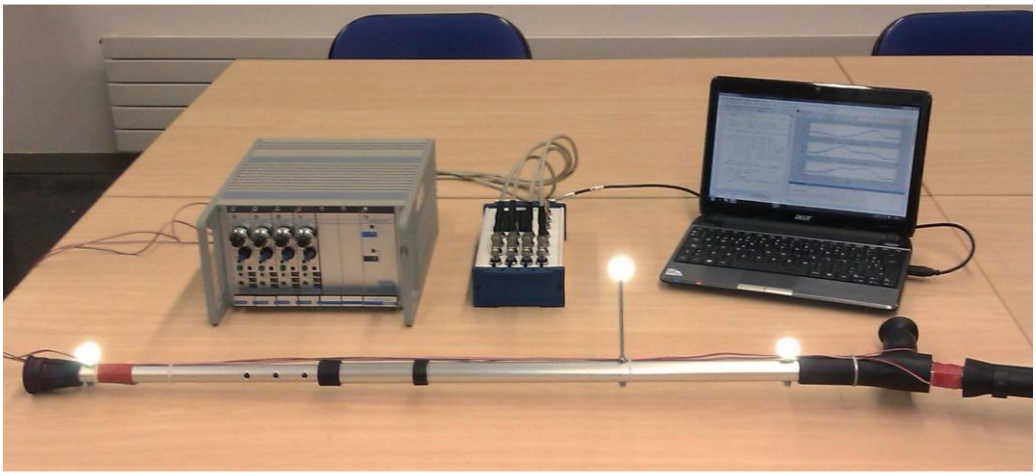

Figure 2: the experimental setup of the crutches.

As it is well known, a redundancy problem exists when analyzing the gait motion of a healthy subject, since the addition of the reactions measured by the force plates can also be derived from the motion by means of inverse dynamics, and both quantities should be equal to each other if the model and the experiment were perfect. Since they are not, the discrepancy is usually employed to minimize the errors [4]. In the case of crutch-assisted gait, it is the addition of the reactions measured by the force plates and the extensometry mounted at the tips of the crutches which must equal the total reaction obtained through inverse dynamics from the optically captured motion. Therefore, the previous minimization concept has been generalized to consider the four sources of reactions.

Another relevant issue that must be taken into account when building the model of the injured subject is the fact that, usually, the spinal cord injured subjects experience a loss of muscular mass due to inactivity. Consequently, the model inertias, obtained from correlation equations and tables for the model of healthy subject, were expected not to be valid as approximation, and densitometry data from the injured subjects has been considered instead.

Tests have been carried out with healthy and injured subjects, all of them walking with the aid of crutches. Healthy subjects were asked to mimic the motion strategy of their injured counterparts. Motions have been recorded and the corresponding reactions measured, so that the joint driving torques could be obtained by inverse dynamics calculation. Comparison of the results has allowed to observe the differences and the effect of the muscle weakness of injured subjects in the torque histories of the joints.

Some other works have been found in the literature that address crutch walking, like the one by Carpentier et al. [1] focused on the study of impacts on a simple planar model, and the paper by Slavens et al. [3] concerned by the efforts in the upper limbs.

References

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