In vivo Shoulder Joint Loads during Walking with Crutches

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INTRODUCTION
After injuries, following hip and knee surgery, or because of partial spinal cord lesion, people are dependent on walking aids like crutches to unload the lower extremities. However, the mechanical load, transferred to the shoulder, has only been calculated by mathematical models with strong varying results [1]. In vivo measurements of the shoulder joint loads are therefore necessary to improve these mathematical models, to instruct medical staff, and to advice patients in their everyday live. In this study we measured all six load components with an instrumented shoulder replacement during ambulation with forearm and underarm crutches (FC and UC) with different rates of weight bearing.

METHODS
A modified BIOMET Biomodular shoulder hemi-prosthesis was implanted in 4 patients (S1R, S2R, S3L, S4R) with different rates of weight bearing. These trials were excluded. Advised by the physiotherapist, measurements were taken at walking with partial (PWC) and full (FWC) weight on the crutches. Resultant peak forces and moments from 5-10 trials were averaged and are presented in percent bodyweight (%BW) and %BW*m (Figure 1). The X, Y, Z axes of the coordinate system point in anterior, superior and lateral direction (Figure 2). Values from the left shoulder at S3L are mirrored to the right side. All measurements were performed after complete recovery from shoulder surgery 6 to 18 month postoperatively with approval of the ethics committee and informed consent of the patients.

RESULTS
The peak forces in the shoulder joint with forearm crutches exceeded the bodyweight in all patients for FWC. The values of patients S1R, S2R, S3L were very similar between 115 and 130 %BW. Patient S4R had the weakest overall body constitution and much higher loads with 184 %BW, possibly explained by her very low bodyweight. The interindividual variation in the resultant moment was much larger between 0.2 and 0.90 %BW*m, corresponding to absolute values of 1.82 to 4.79 Nm. The same tendency appeared when walking with PWC. S4R showed the highest forces, about 30-40 % more than the others. Again the resultant moments varied much between the patients.

The use of underarm crutches during FWC led to lower forces in S2R and slightly higher forces in S3L. The moments had the same values as with FC. In both patients the angle to the long humeral axis in the frontal plane (αUC) was smaller than with forearm crutches (αFC) (Figure 2). During PWC with underarm crutches, patient S2R and partially S4R had considerable problems in exact loading and timing, accompanied by much lower forces (26.7 and 55.7 %BW) than with the forearm crutches.

DISCUSSION
When walking with complete load on the crutches, the glenohumeral contact force can rise higher than the body weight for both types of crutches. Nevertheless, the acting joint forces for both crutch types were not considerably higher than in other activities of daily living [2], and lower than calculated before [1]. The higher angle to the vertical axis using FC could indicate higher bending stresses in the proximal humerus as a risk for stabilized fractures. The high interindividual load variation, especially for PWC when using the -for our patients not familiar- underarm crutches, supports the opinion of many physiotherapists that crutch walking is a long term learning process. Measured contact moments can either be caused by an eccentric force application at the humeral head or by friction in the joint. Individual friction properties in the joint and different shapes of the glenoid could be a reason for the broadly varying moment values.

This study indicates that complete unloading of the lower extremities can be reached by both underarm and forearm crutches without overloading the shoulder joint. Even so, it needs intensive muscle effort and is exhausting in particular for elderly people. On the basis of measured forces and the small number of patients, we can not prefer one crutch type. For partial unloading of the lower extremities, and as an assistive device to avoid stumbling, the more accustomed kind of crutches seems to be preferably.

REFERENCES

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Figure 1: Glenohumeral contact loads during walking with crutches. Resultant peak forces with standard deviations are shown in the upper part and resultant peak moments in the lower part of the diagram.

Figure 2: Patients S2R and S3L at FWC with underarm and forearm crutches. The angles αUC and αUC indicate the direction of the resultant peak forces with ± one standard deviation shaded in grey.