SUMMARY
Patients suffering from an obstetric lesion of the brachial plexus have as a consequence of the lesion serious impairments in movement performance of the affected arm. Most of the children develop movement compensation strategies to increase the range of motion of the affected limb. However non-physiological movement patterns might result in additional forces and torques acting at the joints. In this work, a procedure for determination of net joint forces and torques in arbitrary upper extremity movement is presented. For calculation of net joint forces and torques via inverse dynamics, kinematic data, external forces and anthropometric parameters are used. A robot based 3D isokinetic tracking is introduced to standardize the movement path for kinematic movement analysis and to measure external forces. The procedure has been applied to different arbitrary upper extremity movement of healthy children and patients and net torque and forces have been calculated. The results show that due to compensational strategies in patients with brachial plexus lesion higher forces and torques act especially on the shoulder joint. This is in agreement with the fact that in this patient group frequently pathological deformations of the shoulder joint can be found.

INTRODUCTION
An obstetric lesion of the brachial plexus occurs approximately in 1 of 2000 newborns. As a consequence of the lesion most of the affected children have serious impairments in movement performance of the affected arm. Due to the fact that caused by the nerve lesion most patients show an abnormal muscular co-ordination pattern, the children have to develop movement compensation strategies to increase the range of motion of the affected limb as most as possible.

From clinical gait analysis it is known, that non-physiological movement patterns result in additional forces and torques acting at the joints which imply higher stress to the affected joints resulting in joint degeneration. However, it is questionable similar effects can be seen in upper extremities. In deed in patients suffering from brachial plexus lesion pathological deformation especially of the shoulder joint can be found, which might be a result of non-physiological forces acting at the joint during the compensation movements.

In this work, a procedure for determination of net joint forces and torques in arbitrary upper extremity movement is presented. It has been applied to patients with obstetric lesion of the brachial plexus in order to identify an individual risk for shoulder degeneration due to pathological movement compensation strategies.

METHODS
For calculation of net joint forces and torques via inverse dynamics, the assessment of kinematic data, external forces and anthropometric parameters is necessary.

Motion analysis system (Vicon 370) with 6 infrared cameras was used for acquiring kinetic data of upper extremity movement. Joint angles for hand, elbow and shoulder were calculated via a rigid body model for the upper extremities [1,2]. Since in the case of upper extremities there is a need to standardize the movement, which has to be reproducible, but does not constrain the patient’s movement strategies, a 7-DoF robot-arm presented a predefined 3D path that the subject should perform and which is repeatable and adaptable to the patient’s size and age [3] (Figure 1).

External forces and torques were measured using a 6-DoF force sensor attached at the robot’s end-effector. A force-feedback was used to predefine and help maintaining the desired force vector [3]. To detect the muscular
coordination, conventional surface EMG was used. The electrodes are placed on the muscles according to the SENIAM recommendations. Anthropometric data were obtained using the body segment parameters table [4]. For calculating kinetic data, anthropometric parameters, kinematic data as well as external forces and torques were used to calculate forces and torques in each joint (hand, elbow, and shoulder) via inverse dynamic method (Figure 2).

**Figure 2**: Concept for calculation of forces and torques via inverse dynamics

Different arbitrary upper extremity movement have been analysed in healthy children and patients suffering from a lesion of the plexus brachialis. For each trial the movement cycle has been repeated three times.

**RESULTS AND DISCUSSION**

Figure 3 shows exemplary the differences between healthy and affected subjects in the forces and the torques acting on the shoulder joint during a Flexion/Extension movement of the shoulder.

**Figure 3**: Example of pathology in joint forces and torques (left) compared to a healthy subject (right).

In the pathological case a clear internal rotation of the shoulder during flexion and extension movements can be found as a compensational movement strategy. As a consequence of this compensational movement, there is a significant increase in the net joint force along the flexion-and extension-axis, which leads to an increased pathological joint load. Figure 4 shows the effect of an increasing internal rotation of the shoulder on the forces acting along the Flexion- an Extension-axis as well as along the Abduction-Adduction axis of the shoulder joint. In addition to pathological forces the internal rotation of shoulder results in an additional torque in abduction/adduction axis which has to be compensated by the surrounding muscles.

**Figure 4**: Effect of internal shoulder rotation on the forces action on the shoulder joint during an Flexion-/Extension movement of the shoulder

Especially the existence of non-physiological forces acting on the shoulder joint is in agreement with the fact that in this patient group frequently pathological deformations of the shoulder joint can be found.

**CONCLUSION**

Patients suffering from an obstetric lesion of the brachial plexus show clear compensational strategies of upper extremity movements of the affected arm. Robot based 3D isokinetic tracking can be used to analyze these pathological movement patterns. In combination with inverse dynamics forces and torques acting on the joints of the upper extremity chain can be calculated. In this way a patient individual risk for shoulder degeneration due to pathological movement compensation strategies can be determined. Additionally, the introduced method can be used to evaluate operations, rehabilitation or treatment success.

**REFERENCES**