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GLENOHUMERAL CONTACT FORCE OF PATIENTS WITH TOTAL AND REVERSE SHOULDER ARTHROPLASTY

[1] Joelly Mahnic de Toledo, PhD, [1] Jefferson Fagundes Loss, PhD, Thomas W. Janssen, PhD [2,3], Tjarco D. Alta, MD [4], W. Jaap Willems, MD, PhD [4] , DirkJan (H.E.J.) Veeger, PhD [2,5]

[1] Physical Education School, Exercise Research Laboratory, Federal University of Rio Grande do Sul, Porto Alegre, Brazil. joellytoledo@hotmail.com
[2] Research Institute MOVE, Faculty of Human Movement Sciences, VU University, Amsterdam, The Netherlands.
[3] Amsterdam Rehabilitation Research Center/ Reade, Amsterdam, The Netherlands.
[4] Department of Orthopaedic Surgery and Traumatology, Onze Lieve Vrouwe Gasthuis, Amsterdam, The Netherlands.
[5] Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology, Delft, The Netherlands.

SUMMARY
The aim of this study was to determine the maximum glenohumeral contact force in patients with a total shoulder arthroplasty (TSA group) and a reverse shoulder arthroplasty (RSA group).The mathematical model used was the Delft Shoulder and Elbow Model (DSEM). Results showed that during anteflexion, the control group showed greater maximum glenohumeral contact force when compared to the TSA group, but no differences were found between groups of patients during both movements. Elastic resistance presented higher glenohumeral contact force in all groups. It can be concluded that both groups of patients had lower glenohumeral contact forces than controls and that these forces are influenced by the type of external load.

INTRODUCTION
Detailed information about shoulder joint forces has several applications, such as improving the design of prostheses, best description of joint and muscle damages, as well as improvement of rehabilitation programs for these lesions [1]. Biomechanical models are the only method to estimate joint forces in a non-invasive way and, to date, there is no knowledge of the use of models with data from patients with TSA and RSA when performing rehabilitation exercises with external load. However, there are studies that have done mathematical simulations of the reverse prosthesis using different shoulder models [2,3,4]. The aim of this study was to determine the maximum glenohumeral contact force in patients with a TSA, a RSA and in a control group during two movements (anteflexion and elevation in scapular plane) with different loads (no external load, 1 kg dumbbell and elastic resistance).

METHODS
Eighteen subjects divided in three different groups voluntarily participated in this study. Six patients had a total TSA , six subjects had no problems (pain or injury) in the shoulder (pilot group) and six patients (nine shoulders/three revisions) had a RSA group. The protocol was approved by the medical ethics committee and all subjects gave written informed consent before the experiment. A six degree-of-freedom electromagnetic tracking device, the Flock of Birds (Ascension Technology Inc., Burlington, Vermont, USA) was used to collect the kinematic data using the software *MotionMonitor* (Innovative Sports Training, Inc., Chicago, Illinois, USA) and following the ISB standardization proposal for the upper extremity (Wu et al., 2005). We measured two ROM tasks, which were performed actively in three different load situations (without external load, with 1kg dumbbell and with elastic band resistance). The ROM tasks consisted of elevation in the sagittal plane (anteflexion) and elevation in the scapular plane (at an angle of 30° anterior from the frontal plane). Since it is quite common for patients to have a severely limited ROM, subjects were instructed to reach up to 90° of elevation with both arms during the ROM task and these angles and the plane of elevation were maintained by using a semicircular board that subjects could follow as a reference. The data collection order was always the same for all subjects: 1) anteflexion without external load, 2) anteflexion with 1kg, 3) elevation in scapular plane without external load, 4) elevation in scapular plane with 1kg, 5) anteflexion with elastic resistance, 6) elevation in scapular plane with elastic resistance. The mathematical model used was the Delft Shoulder Elbow and Model [2]. Statistical analysis was performed using a two-way repeated measures analysis of variance with a Bonferroni post-hoc testing ($\alpha < 0.05$) and data processing was performed in Matlab® where the maximum glenohumeral contact force was determined for each repetition of each subject.

RESULTS AND DISCUSSION
The maximum glenohumeral contact force ranged from 442 to 1128 N during anteflexion and elevation in scapular plane without external load, with 1 kg dumbbell and elastic resistance. During anteflexion it was found a significant main effect of group and load (Figure 1). Kontaxis and Johnson [3] also found lower glenohumeral contact forces

based on prosthesis simulation when compared with normal articulation. These authors reported a mean decrease of 31.6% in glenohumeral contact force during the anteflexion, abduction and elevation in scapular plane.

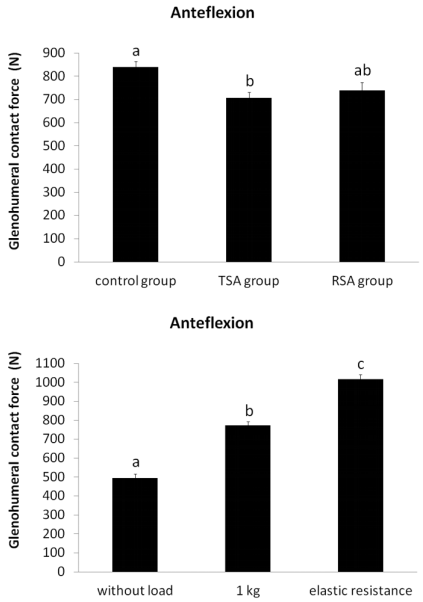

Figure 1: Maximum glenohumeral contact force during anteflexion. Different letters represent statistical differences among factors level ($p<0,05$). TSA: total shoulder arthroplasty. RSA: reverse shoulder arthroplasty.

During elevation in scapular plane, there was a significant interaction between group and load factors ($p = 0.003$). In the situation without external load, there was no statistically significant difference among groups, but with 1 kg dumbbell RSA group showed higher glenohumeral contact force than the TSA group and with elastic resistance the control group presented higher peak than the TSA group. Regarding differences caused by different external loads, TSA and control groups showed no statistically significant difference between the three loads analyzed, and elastic resistance presented higher peak than situation with 1 kg dumbbell and without external load. In the RSA group, both situations with external load (1 kg and elastic resistance) showed no significant differences, but compared to the situation without external load glenohumeral contact force was significantly higher (Figure 2). Regarding effects of different loads on glenohumeral contact force, the results of this study corroborate with other previously described in the literature [2,6]. However, even existing studies with similar results, no studies were found evaluating the influence of elastic resistance on glenohumeral contact forces. In this study, the elastic resistance was the load situation that presented higher peak glenohumeral contact force in all groups. Based on these results, it can be suggested that the elastic resistance must be used after free weights during the rehabilitation process of a patient with shoulder prosthesis, whereas larger contact forces are not indicated in the early phase and which must be applied progressively throughout the healing process.

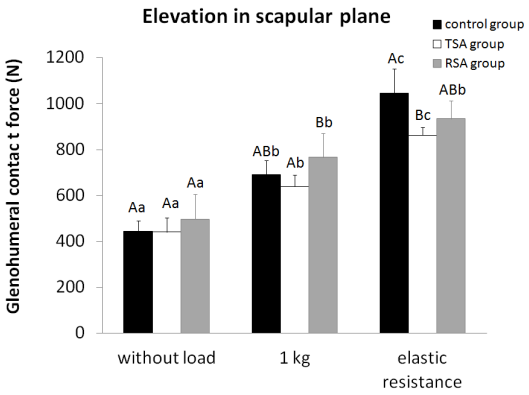

Figure 2: Maximum glenohumeral contact force during elevation in scapular plane. Different capital letters represent statistical differences among groups for a same load situation and different lower case letters represent statistical differences among load situations for a same group ($p<0,05$). TSA: total shoulder arthroplasty. RSA: reverse shoulder arthroplasty.

CONCLUSIONS

The control group showed greater glenohumeral contact force during anteflexion when compared with TSA group, but there were no statistically significant differences between groups of patients during both movements. Elastic resistance was the load situation that presented higher peak glenohumeral contact force for all groups.

ACKNOWLEDGEMENTS

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