Scapular resting orientation and scapulo-humeral rhythm in paraplegic and able-bodied males

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ABSTRACT - The mean scapular resting orientation and the mean scapulo-humeral rhythm (SHR) during anteflexion of seven male SCI subjects (lesion level below T2) and nineteen able-bodied (AB) males were compared. The co-ordinates of bony landmarks of the scapula, humerus and thorax were recorded with the palpation technique. The SHR was determined in a quasi-static situation. Data were analyzed according to Pronk (1991). No difference in scapular resting orientation and SHR between the groups could be shown in this study, which is probably due to the large inter-individual differences especially within the SCI group. This could imply that the position of the scapula is lesion level dependent. This notion which needs further investigation.

INTRODUCTION

There is a high prevalence in musculo-skeletal injuries in the shoulder region of wheelchair users (Woude, 1989; Pentland & Twomey, 1994). To understand the causes for these complaints, insight is needed in the functioning of the shoulder. Therefore modeling is required. Modeling requires kinematic input.

Since in vivo measurements of scapular movements are impossible, it is very difficult to collect kinematic information. Previous studies already revealed that there is a consistent relationship between the position of the scapula and the position of the humerus (scapulo-humeral rhythm (SHR) (Inman et al, 1944; Pronk, 1991; van der Helm, 1991) a solution to this problem can be found. In these studies static positions were extrapolated to dynamic movements. When the position of the humerus (which can easily be measured during movement) is known, the position of the scapula can be estimated and movements like manual wheelchair propulsion can be simulated and analyzed (Veeger et al, 1993).

The question, however, is whether the resting orientation of the scapula and the SHR of specific wheelchair user groups are identical to these kinematic aspects in able-bodied (AB) persons. Therefore in this comparison study between spinal cord injured (SCI) males (lesion level below T2) and AB males two hypotheses were tested:

- There is a difference in the resting position of the scapula between wheelchair dependent SCI males with a lesion below T2 and AB males. The resting position is the position in which the arms are hanging aside the body (palms facing medially).
- There is a difference in the SHR during ante- and retroflexion of the humerus (as expressed in Euler angles) between wheelchair dependent SCI males with a lesion below Th2 and AB males.

METHODS

Seven male SCI subjects (lesion level below T2) and nineteen AB males without present arm or shoulder complaints were measured. The lesion level below T2 was chosen to exclude subjects with a malfunctioning brachial plexus, which would directly influence the kinematics of the shoulder girdle.

Following Pronk (1991), for each subject 3D-co-ordinates of ten standard bony landmarks of the thorax, scapula and humerus were recorded with the palpation technique (Pronk, 1991; Six Dijkstra et al, 1996). A disadvantage of this method is that measurements can only be performed in static situations and measuring of the scapula during movement, in order to determine the SHR, clearly is not possible. Therefore the SHR is measured as a 'quasi-static' situation. This means that a series of static positions is measured and related afterwards.

A special experimental set-up was designed to position the subjects (Figure 1). Since the SHR had to be measured during anteflexion of the humerus, the two rims were positioned bilateral of the chair in the sagittal plane. Every fifteen degrees between -30° and +180° a marker was set on the rims, with the 0° marker indicating the position in which the arms are hanging aside the body. This position was defined as the actual resting position. The subjects were pointing actively bilaterally to the markers. During each position, the co-ordinates of 10 standard bony landmarks were recorded.

Table 1 - *Mean Euler angles of the scapula during the resting position, the standard deviations (sd) and the T-values.*

Euler angle	Able-bodied group (n = 19)	SCI group (n = 7)	T-value
beta	26.64 (7.06)	30.50 (19.64)	-0.76^{ns}
gamma	174.52 (5.02)	173.29 (4.10)	0.58^{ns}
alpha	7.09 (4.22)	11.25 (5.43)	-2.07^{ns}

ns = not significant, $p > 0.05$

The data were processed according to Pronk (1991): the thorax, scapula and humerus are expressed as local Cartesian co-ordinate systems fixed to these rigid bodies, relative to a global co-ordinate system which is oriented to a fixed thorax position. To form these co-ordinate systems the co-ordinates of the bony landmarks were used. The orientation of the scapula was expressed as rotations about the Y-, Z'- and X''- axis of the global Cartesian co-ordinate system (the Euler angles).

The orientation of the scapular resting position is defined by the local co-ordinate system of the scapula with reference to the global co-ordinate system. The orientation of the scapula during anteflexion was expressed as a rotation relative to its resting position. The rotations were decomposed in the order Ys-Zs'-Xs'', corresponding to respectively pro-retraction (ß), medio-lateral rotation (γ) and tilt around the scapular spine (α).

The SHR of each person could now be described as three relationships between actual ante/retroflexion of the humerus and the matching α-, ß-, and γ- Euler angles of the scapula. These relationships were calculated with regression analysis. Finally group mean equations were calculated.

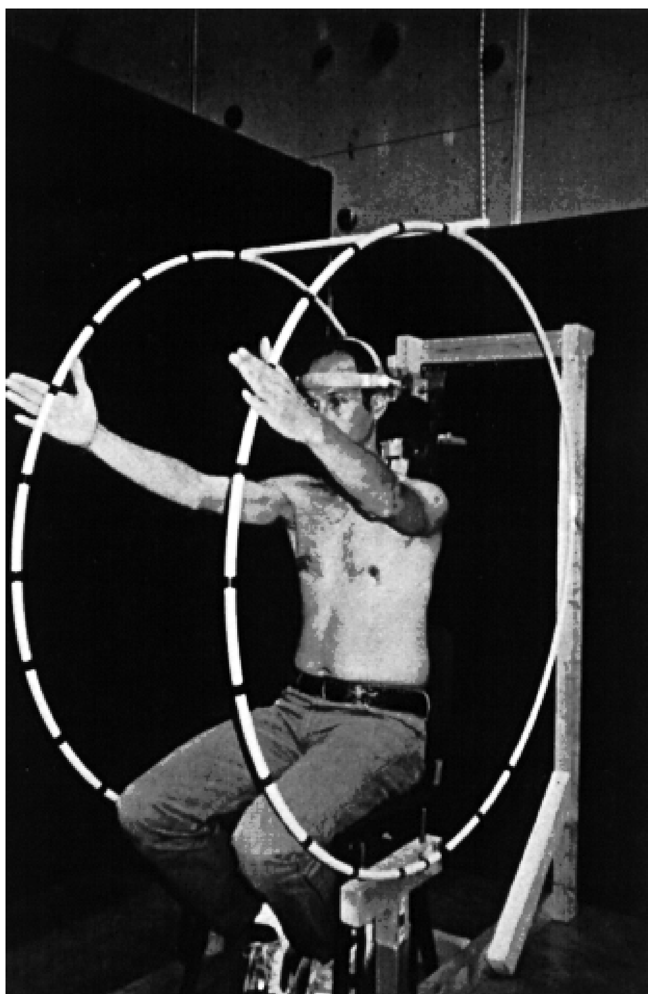

Figure 1 - *Experimental set-up.*

RESULTS

As mentioned earlier, the scapular resting orientation was expressed as three Euler angles for each individual. As indicated in Table 1, large standard deviations were found within both groups. T-test results showed that there was no significant difference in resting position between the groups (Table 1).

The individual regression equations describing the SHR of the AB and the SCI group are shown in Figure 2. The mean quadratic regression equations of both groups are presented in Table 2. The mean scapular rotations about the Ys-axis can be described as the pro-retraction movement of the scapula. At the maximal angle of retroflexion of the humerus, the scapula is retracted. As the humerus rotates forward, the scapula becomes more protracted till on average 77° of anteflexion in the AB group and 60° of anteflexion in the SCI group, after which the scapula is retracted again.

The range of mean scapular lateral-medial rotation is about 80 degrees which is larger than the ranges of rotations about the Xs"- and Ys-axis. The scapula moves to a more laterally rotated position as the humerus moves forward.

The mean rotation about the Xs"-axis (tipping forward/backward) has a small range of 20° in both groups and the regression lines are close to linear. From maximal retroflexion to maximal

anteflexion of the humerus, the scapula rotates backwards.
The SHR was statistically tested with the use of serial measurements and summary measures according to Matthews et al. (1990). After calculating the individual regression equations these summary measures were treated as if they were the original data: coefficients of the equations of the AB group were compared with the equations of the SCI group using a T-test. Using this method, it is taken into account when measurements at different points are from the same subject. The T-tests revealed that the rotations about respectively. the Ys- and the Xs-" axis do not differ significantly between the studied AB and SCI group, possibly due to the large standard deviations. The quadratic term of the equation describing the rotation about the Zs-' axis however, does differ significantly between the two groups (Table 2).

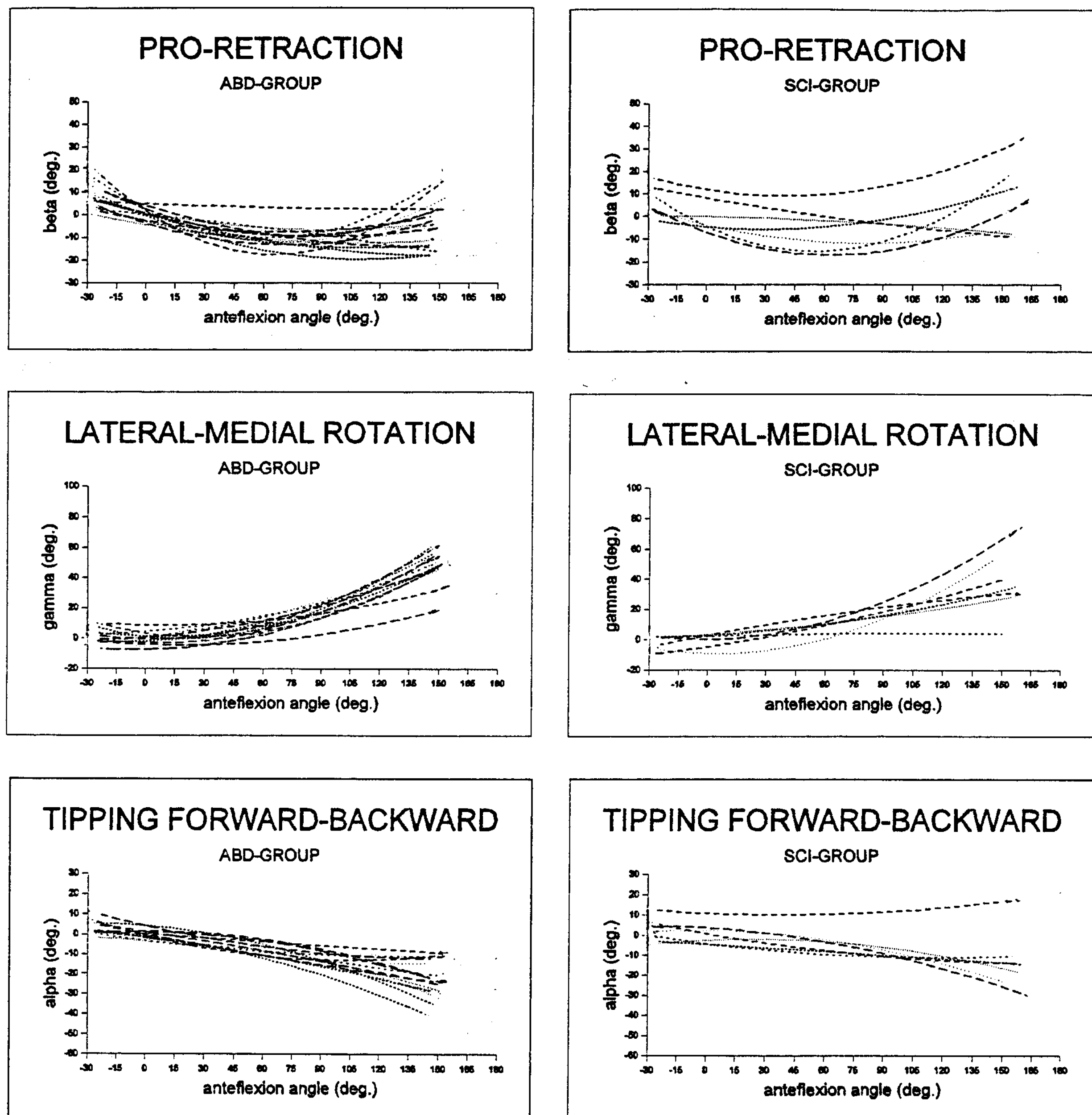

Figure 2 - *Individual regression equations describing the SHR for both tested groups.*

Table 2 - *Mean regression equations describing the SHR of the SCI and AB group. Euler angles are described as a function of humeral elevation angle (Ø).*

Scapular rotation	regression terms	SCI group	SE	AB group	SE	pooled SE	T-value
protraction	constant	-0.08	2.72	0.33	0.58	1.86	0.22^{ns}
-	linear	-0.18 Ø	0.05	-0.26 Ø	0.03	0.06	1.28^{ns}
retraction	quadratic	0.0015 $Ø^2$	0.00	0.0016 $Ø^2$	0.00	0.00	0.16^{ns}
	(sd)	(10.87)		(7.16)			
lateral	constant	-0.60	1.82	-0.83	0.90	1.84	0.13^{ns}
-	linear	0.09 Ø	0.04	0.001 Ø	0.02	0.04	2.28^{ns}
medial	quadratic	0.0011 $Ø^2$	0.00	0.0022 $Ø^2$	0.00	0.00	2.73^{*}
	(sd)	(12.97)		(7.31)			
foreward	constant	0.87	2.06	-0.37	0.50	1.46	0.85^{ns}
-	linear	-0.06 Ø	0.03	-0.100 Ø	0.02	0.03	1.37^{ns}
backward	quadratic	-0.002 $Ø^2$	0.00	-0.0003 $Ø^2$	0.00	0.00	0.04^{ns}
	(sd)	(9.46)		(6.24)			

sd = standard deviation = mean residual
^{ns} = not significant, alpha > 0.0167
* = significant, alpha < 0.0167

DISCUSSION AND CONCLUSIONS

A difference in mean scapular resting position between SCI and AB males could not be shown in this study (Table 1). This can be due to the large standard deviations that were found in both groups, which indicate large inter-individual differences.
The SHR was described as three group mean regression lines for pro-retraction, latero-medial rotation and tipping forward-backward. Again large standard deviations were found which could be the result of inter-individual differences. The T-test showed a difference between the two groups, but only on the quadratic term of the latero-medial rotation of the scapula. Since the slope of the individual regression equations strongly differed, it is dubious to draw conclusions on basis of the mean regression equations of the groups (Matthews et al, 1990). Figure 2 shows the plots of the individual regression equations describing the SHR for both tested groups. Especially within the SCI group there is a large variation in the slope of the lines that describe the SHR, although the lines also vary within the AB group.
In the current study, it was assumed that different lesion levels under T2 would not result in extremely different scapular orientations within the groups, since the brachial plexus functions well. Though the tested group was rather small, the large variation of the SHR within the SCI group, could implicate that the lesion level does have an effect on the SHR. The effect could be the result of a difference in hypertrophy of the muscles in the SCI group as a result of training, a different trunk stabilization or a different neural adaptation of the active muscles (McComas, 1994).
Comparison of the AB group with a study of Pronk (1991) on the SHR during an ante/retroflexion movement, did show some differences, which might have been the result of the measurement errors, slightly different measurement techniques or inter-observer differences (Six Dijkstra et al, 1996). To compare the results of the current study with the studies of Inman et al (1944) and van der Helm (1991), data were recalculated as the 2D spino-humeral rhythm (Inman et al, 1994). Similarities in shape of the curves are remarkable, but the inter-individual differences are larger in the current study, probably due to the same factors as mentioned earlier.
On the outcome of this study it is concluded that no difference in scapular resting orientation and SHR between AB and SCI subjects could be shown. This was probably due to the large inter-individual differences in especially the SCI group.

In conclusion, the following recommendation can be made:

- The large inter-individual differences within the SCI group are interesting. To separate 'normal' inter-individual variation from 'lesion level-dependent' variation, further studies are required with a control mechanism and more specific groups of paraplegic subjects.

- The large inter-individual differences within the SCI group that were found in this study, implicate that to simulate the shoulder of paraplegic persons with the shoulder girdle simulation model, information about the specific population is needed to serve as input.

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