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Activation of shoulder muscles in healthy men and women under isometric conditions

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Abstract

Purpose: Due to the low osseous lead of the shoulder joint a large portion of the shoulder muscles, in addition to executing movements, deals with stabilising tasks. This requires a permanent readjustment of the intermuscular co-ordination of all involved muscles. The aim of the study was to verify the existence of gender dependent differences in intramuscular co-ordination patterns of shoulder muscles.

Method: Fifteen healthy men and nine healthy women, who executed 24 isometric exercises in sagittal, frontal and horizontal planes with a loading of 50% of their individual isometric maximum force, were investigated. In every plane, four angular positions were chosen and both opposite force directions were measured, respectively. SEMG was taken from 13 muscles of the shoulder and the upper arm. Due to inter-individual differences SEMG amplitudes were normalised. *Results*: Gender specific differences of functional intermuscular co-ordination patterns could be proven systematically. Women showed less activation of muscles acting in the main force direction. In addition, those muscles less necessary for the actual force production were more activated in women than in men.

Conclusions: Functionally comparable shoulder function showed a gender dependency in terms of functional intermuscular co-ordination.

Keywords: SEMG (surface electromyography); Shoulder muscles; Gender differences

1. Introduction

Throughout the animal world, the shoulder joint is the connecting element between thoracic cage and upper extremity. The vertical posture of humans and our extreme reliance on the use of the arms and hands, and thus the shoulder, necessitates a high degree of structural protection as well as functional control. The shoulder's mobility characteristics make it the most mobile joint of the human body [11].

This is already clear in the anatomical construction [13,28]: the small and plain glenoid cavity contrasts to a proportionally larger articular condyle of the glenohumoral joint (relationship 1:4). The required stability is reached by a complex of static components (head of humerus, glenoid cavity, labrum and capsular ligamentous structures) and dynamic components (muscles). The dynamic components are of utmost importance.

The musculature of the shoulder joint can be divided into intrinsic (centering and stabilising) and extrinsic (mobilising) muscle groups [14]. In addition, further muscles, for example M. serratus anterior and M. teres major are involved in the positioning and the fixation of the scapula, respectively. Thus, these muscles have influence on shoulder joint function as well.

Due to the low osseous lead, many muscles of the shoulder show a bifunctional behaviour. In addition to the execution of movements, they also deal with stabilising tasks, i.e. the optimal positioning of the articular condyle. Therefore, even more than with other joints,

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shoulder movements require a control system for constant readjustment of the intermuscular co-ordination of all muscles involved. The postural information necessary for this is reached by reflex circuits between ligaments [5,9] and muscles [14].

Formerly, attempts to describe muscle movement dynamics were strictly limited to cadaver analyses [23], which enabled inferences of muscle function only. Recently, dynamic imaging methods and three-dimensional models [29] have become available. Such technologies provide for direct measurement of actual function of the different components of the shoulder joint [11] in vivo. To take it a step further and investigate intermuscular co-ordination, the application of electrophysiological methods is possible. Up to now there exist only a few systematic examinations to this purpose [1,17,26]. These investigations were done using wire electrodes. Due to its non-invasive characteristic surface electromyography (SEMG) is particularly dedicated for such functional investigations. Nevertheless, the application of SEMG has the disadvantage that an evaluation of muscles not lying directly under the skin surface is limited.

Currently, more in depth analyses of muscle function requires consideration of new results concerning the functional characteristics of the so-called "muscle systems" [3]. The local system is responsible for stability (i.e. limitation of movements) and the global system is responsible for mobility (i.e. initiation of movements) [3].

The results of trunk muscle investigations [3,7,10] showed that stabilising muscles are characterised by a tonic activation and lower strength levels. In contrast, mobilising muscles are activated phasically at measurably higher force levels. These conjunctions should be considered as general. Correspondingly, the fiber composition of the two muscle groups should differ. Histochemical investigations have demonstrated a predominant proportion of type II fibres in limb muscles [20] whereas back muscles contained a higher fraction of type I fibres [24]. This corresponds with the main functional requirements of the analysed muscles whether the activation is more phasic (limb muscles) or more tonic (autochthonous back muscles).

In the literature, gender differences in muscle fiber composition are still discussed controversially. Some authors found no statistically significant differences [20,24,27]. Others have demonstrated gender specific differences in the back muscles [18]. Results in patients with chronic low back pain showed correlations between reduced endurance capacity and a reduced fraction of type I muscle fibres [19]. In accordance with these findings, the endurance capacity of women compared to men is higher in fatigue experiments of the back muscles [18]. Own unpublished examinations yielded different intermuscular activation patterns in the lower back area between men and women. If one considers the different pelvic architectures these results are not really surprising.

We assume that in general in order to assess intermuscular co-ordination patterns in body regions in addition to the back, such as the shoulder, gender dependent influences need to be determined as well. To this purpose no systematic investigations exist. Biomechanical differences can be excluded primarily [4].

Therefore, the aim of the study was to identify muscular co-ordination patterns during isometric tasks and, if verifiable, to show gender differences in muscle activation during isometric tasks of the shoulder joint. In cases of injuries such differences would give hints towards more specific therapeutic strategies.

2. Method

Nine women (age: mean 29.9 SD ± 5.6 years) and 15 men (age: mean 34.2 SD ± 7.7 years) without past medical histories or clinically distinctive features were investigated for the present study. All volunteers gave their informed consent. The investigations were carried out using an equipment for three-dimensional diagnostics and training of shoulder muscles (Ikarus, BFMC®, Germany, Fig. 1). This device permits analysis at arbitrary angles of the shoulder joint. For the three possible planes, the corresponding force directions were isometrically tested in the following joint positions (Fig. 2):

sagittal plane:

- anteversion angles: 0°, 45°, 90°, 120°
- force direction: anteversion (an) and retroversion (re)

frontal plane:

- abduction angles: 0°, 45°, 90°, 120°
- force direction: abduction (ab) and adduction (ad)

horizontal plane:

- extension angles at 90° anteversion: 0°, 30°, 60°, 90°.
- force direction: horizontal extension (horizontal abduction, he) and horizontal flexion (horizontal adduction, hf).

Exercises were carried with the arms held straight out. During the tasks in sagittal and horizontal planes the forearms were pronated. In frontal plane the forearms were in neutral position. All exercises were carried out for both sides simultaneously.

Isometric force was defined at 50% of the previously determined maximum force level using biofeedback for each arm separately. Although the observed side differ-

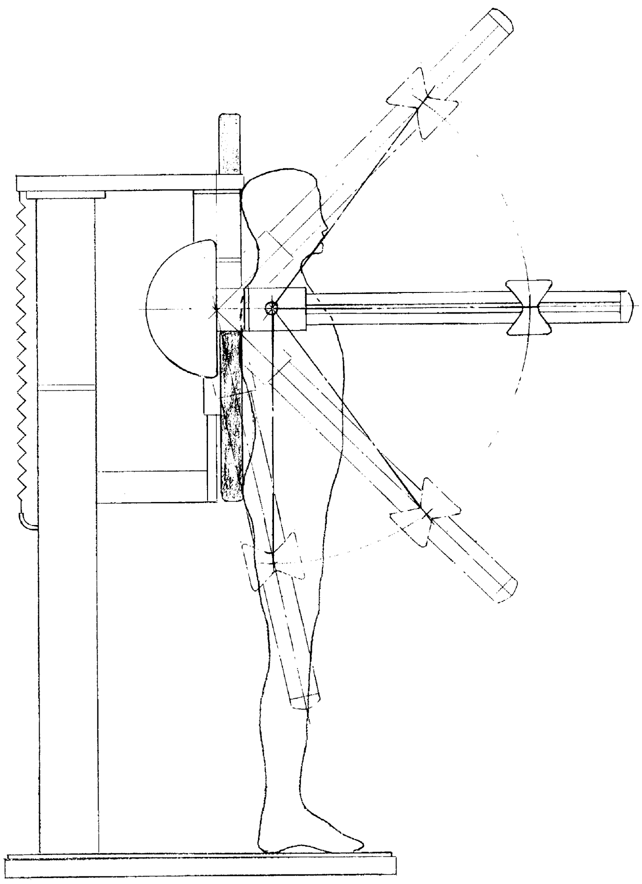

Fig. 1. Schematic view of the used training device (Ikarus, BFMC®, Germany).

ences were comparably low (median: 8.8%) the level of the target force was taken from the weaker side to avoid excessive levels.

Subjects were asked to attain the target level within 1–2 s and hold it for 5 s. Every task was performed three times.

After gently preparing the skin with abrasive paste (Epicont, marquette Germany) and shaving of hair, SEMG was recorded bipolarly from 13 localisations symmetrically for both sides (see Table 1). Disposable Ag–AgCl electrodes (rectangular shape: H93, Arbo ltd. Germany) with a circular detection area of 1 cm diameter, filled with solid gel were used. Inter-electrode distance was 2.5 cm. Raw SEMG was recorded using a mobile SEMG measuring system (biovision, Germany) and directly stored on hard disk for offline analysis. The used amplifiers had a gain of 1000. Input impedance was 10 GΩ with a noise level of $\leq$ 800 nV and a common mode rejection ratio of >130 dB. Cut-off frequencies were 10 and 700 Hz, respectively (3rd order filters, RC). AD conversion was carried out at 2000/s with an amplitude resolution of 2.4 μV/bit (12 bit, Daq-Card 700, National Instruments, USA). Stationary data from the 50% plateau phase were used for SEMG analysis using simultaneously measured force data. Only signal parts without any artefacts like the ventricular activity of the heart were chosen for analysis. For every task three to five segments without overlap were used for the calculation of the representative activity of this single task.

Because the registration of the signals was done by using bipolar montages cross talk cannot be excluded, especially for the rhomboid and ascending trapezius muscles. By attaching the electrodes strictly along fibre direction, using anatomical landmarks systematic errors were reduced. Electrode placement for all subjects was carried out by the same experienced investigator. Only for some of the investigated muscles international accepted recommendations [12] for electrode locations exist.

Data analysis was performed using spectral analysis. The square root of the band power between 10 and 500 Hz was used as amplitude parameter. From this mean values for every task were calculated from the three single tasks. SEMG data from both sides were pooled, because no systematic side differences could be found (men: 13 cases = 4.17%, women: 19 cases = 6.09 % of all 312 muscle-task combinations, non-parametric Wilcoxon test for paired samples). Except one woman all subjects were right handers.

These pooled amplitude levels for each muscle were then normalised. The normalisation was done individu-

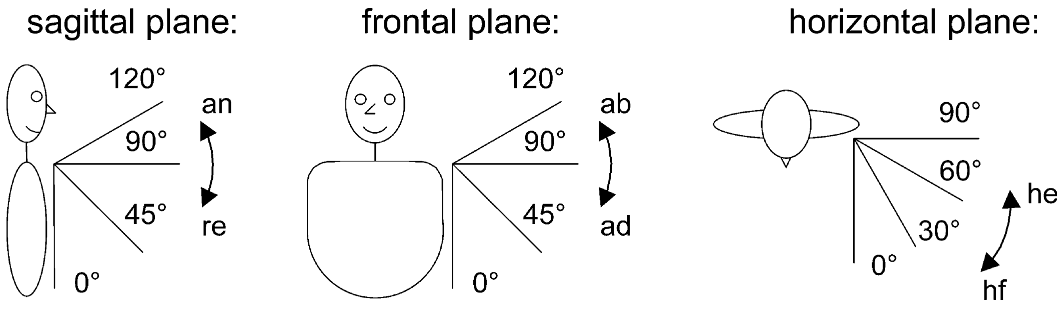

Fig. 2. Schematic demonstration of the used arm positions in the corresponding movement planes (an, anteversion; re, retroversion; ab, abduction; ad, adduction; he, horizontal extension; hf, horizontal flexion). Force direction was upward or downward, respectively, inwards or outwards. The arms were always straight during the exercise.

Table 1
Electrode localisations

Muscle (left/right)	Localisation, orientation
Pectoralis major (mobilising)	Half distance shoulder fold-sternum, horizontal
Biceps brachii (centering)	Centre/centre brachium, vertical
Triceps brachii (centering)	Upper third/centre brachium, vertical
Deltoideus clavicularis (mobilising)	Half muscle/front, vertical, level shoulder fold
Deltoideus acromialis (mobilising)	Half muscle/lateral, vertical, level shoulder fold
Deltoideus spinalis (mobilising)	Half muscle/back, vertical, level shoulder fold
Trapezius descendens (scapula)	Half muscle/cranial contour, following this
Trapezius ascendens (scapula)	Half distance, inner third spina scapulae-Th7, along line
Latissimus dorsi (mobilising)	Upper third line shoulder fold-L1, along line
Teres major (mobilising)	Half line lower scapula angle-shoulder fold, along line
Rhomboideus major (scapula)	Half 45°-line Th3-medial border scapula, along line
Serratus anterior (scapula)	Level Xiphoid, lateral body contour, 45° rising to dorsal, along line
Infraspinatus (centering)	Below spina scapulae, along line 45° aiming at shoulder, middle of Scapula

ally by calculating relative amplitudes (ratio). As the reference value for these ratios, the cumulative SEMG amplitude of all 24 performed exercises was used. The calculation was done for every single muscle separately. With this different absolute SEMG levels were balanced and comparisons between the examined individuals, especially between men and women were possible. For statistical analysis, the non-parametric Mann–Whitney test was used. Numeric values will always be displayed as median and upper and lower quartiles, respectively.

3. Results

3.1. Mobilising muscles

For the *M. pectoralis major* men showed markedly higher absolute SEMG as well as ratio levels for the horizontal flexion at 0°, which was the exercise with the highest amplitude in both groups (Table 3). In contrast, for the opposite force direction (horizontal extension) women reached higher ratios for this muscle (significant levels for all positions, Table 2).

The three parts of the *deltoid muscle* showed functional differences. For the clavicular part, the highest ratio was found for abduction at 120° abduction angle in both groups without significant differences (men: 12.0%; women: 10.2%). However, at 90° abduction angle men reached significantly higher ratios. During retroversion and adduction women almost always demonstrated higher ratios than men did (Table 2).

The acromial part of the deltoid muscle showed a similar trend. No group differences could be found during horizontal extension which in general exhibited the highest ratios and therefore could be considered as the main force direction during this investigation procedure. Statistically detectable differences with higher levels for the woman's group could be observed for the adduction tasks and retroversion.

The spinal part of the deltoid muscle demonstrated different characteristics in men and women (Fig. 3). In women, the highest ratio was found during retroversion at 0° anteversion angle (9.9%), whereas men produced the highest ratio during horizontal extension at 90° extension angle (12.0%). Therefore, men showed statistically higher ratios for all positions during horizontal extension and women during retroversion (details see Table 2).

In eight of the total 12 exercises during anteversion, abduction and horizontal flexion, in which the *M. latissimus dorsi* was characterised by only low ratios, men exhibited only slightly, but statistically significant, higher ratios than women (Table 2). In contrast, during adduction, the force direction showing the highest ratios for both sexes, women demonstrated higher ratios than men, statistically significant at two positions. Absolute SEMG levels did not differ for this task (Table 3).

The highest ratios for the *M. teres major* were seen during retroversion at 0° anteversion angle in both groups. For this exercise, men generated significantly higher ratios than women (men: 10.5%; women: 8.1%; $p < 0.05$). In the force directions with low ratios only during anteversion at two positions significant differences could be proven with higher ratios for the investigated women.

3.2. Centering and stabilising muscles

Again, for the *biceps* muscle, similar to the main tendency for the mobilising muscles, men showed higher ratios in the main force producing exercises in comparison to women (horizontal flexion). Except for abduction and adduction where ratio levels were comparable, women represented higher ratios in all other force directions proven as significant at seven positions out of 12 (Table 2).

For the *triceps* muscle differences could only be found for horizontal flexion, where women showed higher ratio levels than men.

The *M. infraspinatus* reached its highest ratio levels during horizontal extension, but group differences could not be proven. A tendency towards higher levels for men in all exercises in the horizontal plane could be

Table 2
Ratio differences between women and men for all muscles

Force direction angle	Pectoralis major	Biceps brachii	Triceps brachii	Deltoid clavicularis	Deltoid acromialis	Deltoid spinalis	Trapezius descendens	Trapezius ascendens	Latissimus dorsi	Teres major	Rhomboideus	Serratus anterior	Infra-spinatus
an 0°	0.3	0.5	−0.6	−1.9	−0.2	−0.1	−0.9	−1.3	0.3	−0.8**	−0.7	−1.2	−0.5
an 45°	1.3*	−1.4*	−0.7	−1.6	−0.4	−0.1	−0.4	−0.4	0.5*	−0.9*	−1.7	0.5	−0.8
an 90°	1.0	−2.2	−0.1	0.7	0.8	0.0	0.9	−0.4	1.0*	−1.4	−2.5**	1.5	−0.4
an 120°	2.4	−0.5	0.2	2.2	1.3	0.9	2.3	**0.4**	0.6	0.1	−2.4	**2.3**	0.0
re 0°	−0.9**	−1.0**	−0.2	−0.7	−1.8	0.2	−1.0	−1.1	**1.2**	**2.4***	0.4	−1.4*	1.4
re 45°	−0.4	−0.4**	1.5	−0.3*	−1.2**	−1.1	−0.5	−0.4	−0.4	0.5	0.2	−0.9	−0.4
re 90°	−0.9	−0.4	0.7	−0.1*	−0.5**	−1.3*	0.1	−0.1	0.1	−1.1	−0.1	−0.7	−0.2
re 120°	−1.6**	−0.6**	0.5	−0.3**	−0.3*	−1.7*	0.1	0.2	0.4	−0.6	0.2	−0.7*	−0.3
ab 0°	−0.3	−0.9	−0.4	−0.5	0.2	1.2	1.2	0.1	0.1	−0.3	−0.4	0.0	−0.2
ab 45°	−0.1	0.0	−0.4	2.0	1.1*	1.2	0.8	2.4**	0.4*	−0.2	1.6	0.7	0.4
ab 90°	−0.1	−1.3	−1.2	2.2**	1.3	0.8	1.4*	1.5	0.5*	−0.5	1.7	1.5*	−0.5
ab 120°	1.2	−1.1	−1.4*	**1.8**	0.0	0.8	**4.5****	1.9	0.8*	−0.3	1.3	3.9**	−0.7
ad 0°	−0.6	0.7	−0.6	−0.4**	−0.8**	−3.2*	−1.2*	−1.2**	−3.7**	−0.8	−0.5	−4.1**	−1.0
ad 45°	0.0	0.4	−0.7	−0.2**	−0.6**	−2.4*	−1.3**	−0.6	−3.0*	0.6	−0.2	−2.5**	0.1
ad 90°	−0.6	0.2	1.0	−0.1*	−0.3	−1.6	0.2	−0.3	−0.4	0.9	0.4	−0.9	0.5
ad 120°	−1.6**	0.4	0.7	−0.2*	−0.1	−1.0	−0.1	−0.1	−0.4	−0.6	−0.1	−1.1*	0.0
he 0°	−0.2*	−0.5*	0.1	0.9	0.4	2.6*	−2.9**	0.6	0.9*	0.3	1.2	−0.3	0.7
he 30°	−0.6**	−0.4	0.6	1.9	1.2	1.7*	−2.5**	1.9	0.3	0.1	1.6	0.0	0.7
he 60°	−0.9**	−0.7*	0.9	2.0	−0.8	3.7**	−2.5*	2.1	−0.3	−0.8	2.1	−0.6*	1.5
he 90°	−1.7**	−0.8*	**1.8**	2.4	**−0.1**	**2.4***	−3.0	0.4	−0.9	0.0	0.1	−0.7*	**0.3**
hf 0°	**5.6****	**2.0***	−0.5*	−0.5	−0.2	−0.2	0.9**	0.2	0.5*	0.5	**0.1**	2.1**	0.3
hf 30°	0.9	3.6*	−0.6**	−0.4	−0.2	−0.1	1.3**	0.0	0.3*	0.5	0.2	0.4	0.5
hf 60°	0.1	2.0*	−0.5**	−0.1	−0.1	0.0	1.5**	0.2	0.2	0.1	0.2	−0.3	0.5
hf 90°	0.5	3.2	**−0.3	−0.8	0.0	0.0	2.1**	0.1	0.3*	0.1	0.1	0.5	0.5*

Positive values, ratio of men > women; bold, force direction/angle showing the highest relative amplitude; an, anteversion; re, retroversion; ab, abduction; ad, adduction; he, horizontal extension; hf, horizontal flexion.

[*] $p < 0.05$.

[**] $p < 0.01$.

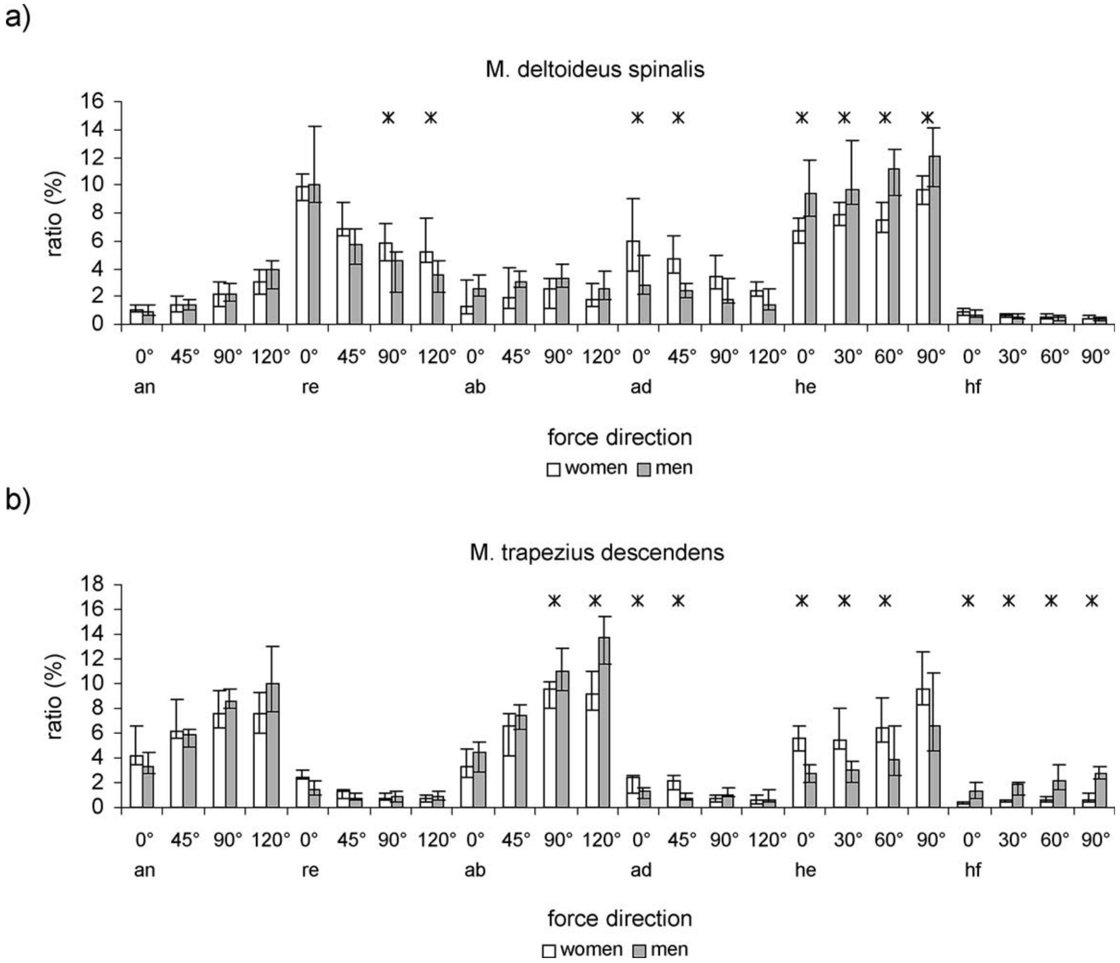

Fig. 3. Relative amplitudes of the M. deltoideus spinalis (a) and M. trapezius descendens (b) for all performed exercises. Significant differences (*U*-test) are assigned by asterisks.

Table 3
Comparison of measured maximal SEMG amplitudes and force levels between women and men. Force directions and positions with the highest relative activation of the examined men served as the reference level

Muscle	SEMG maximum (men)	SEMG amplitudes (μV)			Strength values (Nm)		
		Women	Men	*U*-test	Women	Men	*U*-test
M. pectoralis major	hf 0°	110.9	314.0	$p < 0.01$	47.0	78.8	$p < 0.01$
M. biceps brachii	hf 30°	187.4	396.5	$p < 0.01$	49.1	81.7	$p < 0.01$
M. triceps brachii	he 90°	204.8	309.3	$p < 0.05$	25.3	42.1	$p < 0.01$
M. deltoideus clavicularis	ab 120°	349.4	524.4	n.s.	28.2	42.9	$p < 0.01$
M. deltoideus acromialis	he 90°	373.2	405.2	n.s.	25.3	42.1	$p < 0.01$
M. deltoideus spinalis	he 90°	278.4	317.9	n.s.	25.3	42.1	$p < 0.01$
M. trapezius descendens	ab 120°	264.9	326.5	n.s.	28.2	42.9	$p < 0.01$
M. trapezius ascendens	an 0°	265.5	387.0	n.s.	48.3	74.8	$p < 0.01$
M. latissimus dorsi	ad 0°	349.9	247.7	n.s.	25.4	43.1	$p < 0.01$
M. teres major	re 0°	224.2	344.3	$p < 0.05$	39.9	60.3	$p < 0.01$
M. rhomboideus	he 90°	299.4	224.3	n.s.	25.3	42.1	$p < 0.01$
M. serratus anterior	an 120°	174.8	340.8	$p < 0.05$	34.8	74.8	$p < 0.01$
M. infraspinatus	he 90°	263.5	292.2	n.s.	25.3	42.1	$p < 0.01$

seen but, except for one position never reached statistically significant levels.

3.3. *Muscles acting on the scapula*

The activation characteristics for the two examined parts of the *M. trapezius* were very similar. The highest ratio levels were reached during anteversion, abduction and horizontal extension. During anteversion men showed higher ratios than women in both parts of the muscle. The descending part is characterised by opposite ratio levels in both groups during the exercises in sagittal plane. Higher ratio levels for the women were produced while performing horizontal extension exercises, whereas men showed higher ratio levels during horizontal flexion (Fig. 3, statistics see Table 2).

The *M. rhomboideus* was most strongly activated during the anteversion and the horizontal extension. Again, opposite tendencies between the groups were visible. Women tended to reach higher ratios during anteversion (statistically significant at 90° anteversion angle: $p < 0.01$). Although statistically significant levels were not reached men tended to demonstrate higher ratio levels during horizontal extension.

The main force directions of the *M. serratus anterior* were anteversion and abduction. During these exercises, men showed higher ratios than women at two angle positions. In principle women produced higher ratio levels for the opposite force direction: retroversion and adduction. This could be proven statistically at various angle positions (Table 2).

4. Discussion

The description of the results of the examination on hand yielded unexpectedly explicit differences in the activation characteristics of single muscles for many of the examined force directions.

A general systematics could be identified resulting in a difference between the sexes concerning how intensely the shoulder muscles are activated in the different force directions. While the muscles were acting directly in their force directions in general the men's group showed a tendency for a higher relative activation level. If these muscles were acting not in the direction of action it was the woman's group which demonstrated a tendency for higher relative activation. In other words, shoulder muscle activation in men could be described as being more precise than for women. This salient feature was independent of the clearly different force levels of women and men because by the standardisation of the measured SEMG activity over all force directions amplitude differences were compensated.

This more goal driven co-ordination pattern together with the much larger forces acting at the shoulder joint in men on the other hand may lead to a higher risk for injuries because of a relatively less stabilised functional situation. Although work related influences, especially monotonous work were scientifically proven [2] the question of gender specific differences is still in discussion [6].

To analyse the data inter-individual differences in SEMG amplitudes were compensated by the normalisation method which calculated relative amplitude levels (the so-called ratio) as a profile of all performed exercises. Although the known gender related differences in muscle mass [16] would lead one to expect differences in absolute level of the SEMG, it gives no hint about different activation strategies of men and women during similar movement tasks. With the use of SEMG analysis, single muscles showed statistically significant differences in their relative activation between both investigated groups.

Inter-individual differences in SEMG amplitudes may originate multifariously. In this study, a bipolar montage technique was used. This technique can be affected by deviations of electrode positions from suggested localities (see for example [12]), by different skinfold thickness [25], deviations from the fiber direction, varying inter-electrode distances [30] as well as different localisation of the electrodes according to the innervation zone of the respective muscle [15,21]. Since electrode localisation was assessed by the same investigator and electrode application was done by highly experienced personnel, application dependent errors could be minimised. The observed differences in amplitude levels for the pectoralis muscle between men and women most probably originates from the interference of the female breast which results in an increase of the distance between electrodes and this muscle. A greater skinfold thickness can also be assumed for the brachial muscles in women. Furthermore, the brachial muscles are measurably stronger and larger in men than in women. The amplitude differences for the teres and serratus muscles cannot be interpreted clearly, but may also result from the different muscle mass of men and women [8,16]. Furthermore, although fiber composition seems to be unaffected by gender [20], muscles in men are characterised by larger cross-sectional areas of the type II fibres [22]. This, again, may aid in understanding overall SEMG amplitude differences between men and women whereby forces are obviously higher in men than in women for all exercises.

Another dimension of data analysis, however, could be reached by the use of individually calculated relative amplitudes. In order to do this longitudinal sections for each muscle were calculated, including all investigated exercises. Therefore, every single exercise could be judged independently from inter-individual amplitude differences. From this perspective clear differences between men and women could be observed again. In principle men showed higher ratios for the respective muscles in exercises which correspond to the main force direction of these muscles. This could be seen very clearly for the pectoralis, the biceps and the descending trapezius muscles for instance. However, as already mentioned above for the case of the pectoralis the observed difference at the 0° flexion angle in horizontal plane may result from a more pronounced skin displacement in women compared to men. The absence of significant differences for the other angle positions argues for this possibility. Such arguments cannot be found for the other investigated muscle sites, therefore, gender specific co-ordination strategies can be assumed.

In contrast, the more pronounced activation in the women's group in trapezius descendens muscle activation during the exercises in the sagittal plane may result from a less clean task performance in terms of conditional co-activation: activity increased clearly for the horizontal extension in contrast to the men. Less clean task performance in the maximum strength exercise may result in more than a 50% effort level during the investigated situation also. Furthermore, during the horizontal extension a number of other muscles such as the triceps brachii, the middle and the posterior part of the deltoideus, the rhomboideus and the infraspinatus muscle were also considerably activated. All of them showed higher levels in men.

Nevertheless, for the ascending trapezius and the rhomboid muscles gender differences of their activation characteristics were not present.

Unexpectedly, the distribution of latissimus ratios showed a somehow inverse characteristic—for this muscle men were characterised by higher ratios during low level tasks whereas women exhibited higher ratios for the main force directions. Therefore, during direct force production women used this muscle in a more isolated manner. The higher ratios for men during the antagonistic force directions could be interpreted cautiously as co-activation aimed at stabilising the joint mechanics. With this, the observed less stabilising muscle activation might be compensated somehow.

Although in general, different strategies could be observed for most investigated muscles a clear systematic for the "outliers" cannot be seen up to now.

5. Conclusions

In summary, during isometric shoulder exercises men showed less co-activation of stabilising muscles, but a more precise force directed activation if compared to women. This observed difference in co-ordination pattern may act as an additional factor for shoulder joint injuries in men. Therefore, therapeutic strategies for injured patients in general should not only be directed on force increase of the stabilising muscles but also on a graded and controlled training of these muscles. With this a change in co-ordination patterns towards a more stabile functional situation may be achieved. This has to be proven in therapeutic interventional studies.

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