Acta orthop. scand. 52, 299–306, 1981

SHOULDER PAIN IN INDUSTRY: AN EPIDEMIOLOGICAL STUDY ON WELDERS

PETER HERBERTS, ROLAND KADEFORS, GUN ANDERSSON & INGEMAR PETERSÉN

Departments of Orthopaedic Surgery I and Clinical Neurophysiology, University of Göteborg, Projekt Lindholmen Center and Occupational Health Center, Arendal Shipyard, Göteborg, Sweden.

The occurrence of supraspinatus tendinitis in a group of welders at a shipyard was investigated, and compared with the occurrence of this condition in a group of office clerks. The study showed a prevalence ratio of 18 per cent in the welders, significantly higher than in the clerks. The average age (39 years) in the group with pain did not differ significantly from the average age in the entire group of welders. It is concluded that supraspinatus tendinitis is not exclusively an aging phenomenon, but that welding as an occupation plays an etiological role.

Key words: biomechanics; epidemiology; occupational health; shoulder pain supraspinatus tendinitis; welders

Accepted 23.xi.80

Pain in and dysfunction of the shoulder are common causes of impaired quality of life in the general population. Two per cent of the age group 42–46 years report shoulder pain (Allander 1974). Hammond et al. (1971) stated that shoulder pain is, second to low back pain, the most frequent reason for visits to orthopaedic clinics. In Sweden, this incidence varies between 6–10 per cent (Rössler 1976) and 2–3 per cent (Sahlstrand 1980).

Several investigations have also shown frequent occurrence of shoulder pain among industrial workers (Hult 1954, Andersson 1971, Jansson 1978, Bjelle et al. 1979). On the other hand, Partridge & Duthie (1968) could not find any difference in complaints between workers with light work and those with arduous work. It is obvious that epidemiological research on shoulder pain in industry is hampered by the inability to agree on classification and diagnosis, by uncertainty about the causes of shoulder pain and by difficulties encountered in objectively measuring load on the shoulder. With full knowledge of these problems the present investigation was undertaken to study the occurrence of shoulder pain in a group of experienced welders as compared with a group of office clerks. Age and welding experience was related to the presence of shoulder pain.

Clinical and pathologic considerations

Despite the frequency and importance of shoulder lesions in producing disability they are still incompletely diagnosed and classified. This confusion of terminology is in part related to our incomplete understanding of the basic pathophysiology underlying shoulder pain. The "painful shoulder" includes a variety of conditions with different etiologies. This fact complicates all calculation of frequency and makes comparison between different studies less reliable.

The vast majority of cases of shoulder pain can

0001-6470/81/030299-08 $02.50/0

be classified into two groups of conditions, those with normal range of motion and those with a limited range of motion. Lesions paired with a normal range of motion are by far the most common and this group includes such diagnoses as acute and chronic tendinitis of the supraspinatus, rupture of the supraspinatus, tenosynovitis of the long biceps, and acromioclavicular degenerative arthritis.

With increased understanding of the pathophysiology of the shoulder it has become evident that chronic inflammation and degenerative changes in the rotator cuff (supraspinatus tendon), the biceps tendon and the acromioclavicular joint are the predominant causes of shoulder pain (Richardson 1975, Bateman 1978). The pain is caused by chronic inflammation of the viable tendinous tissue surrounding a degenerated zone in the rotator cuff with secondary inflammation of the overlying subdeltoid bursa. These changes encroach upon the small space between the tuberosity and the acromion and coracoacromial ligament, resulting in increased impingement and pain (Neer 1972).

Diseases in the supraspinatus tendon thus dominate and they constitute approximately 75 per cent of the shoulder complaints in several investigations (Harmon 1958, Pasila 1965, Bateman 1978, Sahlstrand 1980). Less than 10 per cent are reported as biceps tenosynovitis (Harmon 1958, Pasila 1965) and isolated acromioclavicular arthrosis is also uncommon (Zanca 1971).

Conditions associated with limited range of motion are more rare and they constitute about 15 per cent of the cases with shoulder pain (Harmon 1958, Pasila 1965). Adhesive capsulitis or frozen shoulder account for the majority of these cases. The cause of this syndrome is unknown, the course is usually self-limiting and this disease is of no interest with respect to physical load and working conditions.

The unique anatomy of the shoulder joint contributes to the physiologic degeneration that gradually develops in the musculotendinous cuff after the age of 40 years (Ingelmark 1948). This degeneration, which mainly occurs in the supraspinatus tendon, means that the tendinous fibers become frayed, fibrillated, avascular, and even necrotic.

A tear of the cuff may subsequently occur in this deteriorated area. Complete and incomplete ruptures of the supraspinatus tendon are common among elderly people and most frequent close to its bony insertion (Olsson 1953). The degenerative changes occur without violence and are postulated by most writers to be caused by daily repeated minor trauma (Codman 1934) or to be the result of frictional wear between the acromion and the humeral head as the arm is elevated (Meyer 1937, Bateman 1978). The relative avascularity of the supraspinatus tendon associated with advancing age has, however, also been discussed as a possible etiological factor. The presence of such an avascularity has been clearly demonstrated (Lindblom 1939, Moseley & Goldie 1963). In a combined microangiographical and histological study, Rathburn & Macnab (1970) found a constant avascular zone in the area of the supraspinatus tendon where the ruptures frequently occur. The other rotator cuff tendons showed normal vessels or minor changes. Rathburn & Macnab suggested that the longitudinal disposition of the vessels in the long and flat supraspinatus may render this vascular bed more susceptible to traction and compression exerted by elevation of the arm.

Biomechanics of the shoulder

With four separate joints and fifteen attaching muscles, the shoulder is a complicated biomechanical unit. Its movements require synchronized activity in all these joints and muscles (Inman et al. 1944, Lucas 1973, deLuca & Forrest 1973, Saha 1971 and 1973, Poppen & Walker 1976).

A stable fulcrum at the glenohumeral joint is necessary for contraction of the deltoid muscle to produce the motion of arm elevation. This stabilization of the humeral head in the glenoid socket is mainly achieved by active muscular forces exerted by the rotator cuff musculature. In the absence of these stabilizing forces the deltoid muscular fibers, which essentially are parallel with the axis of the humerus, would only lift the humerus along its axis into conflict with the acromion. In describing this simultaneous, smooth deltoid and rotator cuff muscle action the terms "lifters" and "steerers" have been used. The

muscles of the rotator cuff are unique in their twofold function. In addition to producing joint motion by approximating their origins and insertions, they are oriented so that their tendons and muscle masses may press and push on the head of the humerus to create a stable fulcrum for the glenohumeral motions.

Because of the large number of muscles involved in the action of arm elevation, and the variability in the force contributions of each of these muscles with different loads, planes of elevation, and amounts of elevation, the calculation of joint reaction forces at the glenohumeral joint is a great problem. Inman et al. (1944) estimated the deltoid force at 90 degrees of abduction to be 70 per cent of the body weight and a corresponding joint reaction force to be 90 per cent of the body weight. In a recent study of forces in isometric abduction, Poppen & Walker (1978) assumed that the force in a muscle was proportional to its cross-sectional area times the integrated electromyographic signal. They calculated that the resultant glenohumeral force reached a maximum of 90 per cent of body weight at 90 degrees of abduction. Great muscular forces are thus necessary to keep the arm elevated especially in working postures when the hand is positioned at or above shoulder level, perhaps even with a hand tool adding to the load.

Welding work

Localized shoulder muscle fatigue in welders was studied in typical working situations by Kadefors et al. (1976). Here quantitative electromyography was used to investigate the fatigue in a number of muscles in the shoulder. Three groups of welders were incorporated into the study: inexperienced, experienced and elderly welders with shoulder pain. It was found that inexperienced welders generally showed fatigue in a greater number of muscles than did experienced welders. Localized muscle fatigue was particularly common in overhead work. In one of the muscles under study, the supraspinatus muscle, fatigue in overhead welding was found in the experienced as well as in the inexperienced group. Experience thus helps to lower muscle fatigue through training and improved working techniques, but without eliminating the load on the supraspinatus muscle. It was concluded that this muscle in certain welding situations is strained continuously.

Elderly welders with shoulder pain show a muscular fatigue picture similar to that found in the experienced welders (Herberts & Kadefors 1976). This indicates that pains localized to the supraspinatus tendon do not cause a redistribution of the muscle load to other, synergestically operating muscles. Clinical examination and soft tissue radiography revealed that these elderly welders with shoulder pain had a chronic supraspinatus tendinitis.

In the course of these ergonomic studies many elderly welders reported that in their experience shoulder pain was a common and important problem in the shipyard industry. The present study was thus undertaken in order to check the validity of this commonly made statement.

MATERIAL AND METHOD

The investigation was carried out at Arendal shipyard in Göteborg. It comprises the following parts.

1. A questionnaire covering the experience of shoulder pain was directed as part of a health check-up to all welders at the shipyard with more than 5 years of welding experience. The relevant part of the questionnaire is found in Figure 1. The number of welders participating in the check-up and filling in the

Questionnaire

1. Have you had pain in the neck for more than 3 days in a row during the last 12 months?	☐ yes	☐ no
2. If yes, did you then feel pain extending into either one or both arms?	☐ yes	☐ no
3. Did you feel weakness or numbness in your arm and/or hand?	☐ yes	☐ no
4. Have you had low back pain for more than 3 days in a row during the last 12 months?	☐ yes	☐ no
5. If yes, did you then feel pain extending into either one or both legs?	☐ yes	☐ no
6. Did you feel weakness or numbness in your leg?	☐ yes	☐ no
7. Have you had repetitively periods with pain in your loaded shoulder joint during work?	☐ yes	☐ no
8. If yes, did you then have a feeling of stiffness in your shoulder to the extent that the work was hampered?	☐ yes	☐ no
9. Did you feel weakness in your shoulder to the extent that the work was hampered?	☐ yes	☐ no

Figure 1. Part of the questionnaire employed.

questionnaire was 131. The age and the number of years as an active welder was registered as well as the working area (an organizational and usually geographical definition). The questionnaire was filled in with the aid of a nurse. Whenever needed, questions and answers were translated into Finnish or Serbocroatian.

2. In conjunction with health check-ups of office personnel at the age of 40 and above, the same questionnaire was directed to 56 male office clerks, i.e., all those called in over a certain period of time.
3. Those who had answered any one of the questions number 7, 8 or 9 (see Figure 1) in the affirmative were called in for clinical examination. Those who had answered question number 3 with "yes" were also included in this group, unless questions number 1 and 2 were also answered positively. The clinical examinations were carried out with a delay of approximately 1 year, due to administrative reasons. The following components were included in the clinical examination:

- Interview concerning shoulder pains at the time of the clinical examination and at the time of the questionnaire.
- Estimation of the range of movement of the joint actively and passively with simultaneous pain analysis.
- Rating of the gross power in flexion, abduction, and rotation according to the method described by Zadig (1963).
- Assessment of palpation tenderness of the joint.

This part of the investigation was carried out by a physiotherapist.

4. From the group who had responded negatively to all questions according to item 1 above, a corresponding number of individuals were called in for clinical examination according to item 3 above.

Statistical evaluation was carried out as follows:

1. Calculation of the prevalence ratio of supraspinatus tendinitis in shipyard welders.
2. Comparison of prevalence ratios in welders and clerks.
3. Comparison between the age distribution in the group of welders with supraspinatus tendinitis and the entire group of shipyard welders.
4. Comparison between the group of welders with supraspinatus tendinitis and the entire group of shipyard welders concerning the number of years as active welders.
5. Selection of age-matched pairs of welders from the groups of welders with and without supraspinatus tendinitis. Comparison between the individuals concerning:

- Number of years as a welder.
- Estimated work-load on the basis of assessment of the work-place. Rating of shoulder load into three classes: very high, high or low load was carried out by an experienced physiotherapist.

RESULTS

The results of the questionnaire are summarized in Table 1. The table shows that out of a total of 131 welders, 35 reported shoulder pain (27 per cent) compared with only 1 out of 57 clerks.

Out of the 35 welders who were called in for clinical examination and who had reported subjective symptoms, 12 had finished their work at the company or were for other reasons unavailable at the time of the examination. Table 2 summarizes the results. It was found that a group of those investigated were free from symptoms at the clinical examination, but reported that they at the time of the questionnaire had experienced shoulder pain. Only in those cases where the physiotherapist could confirm without doubt that periods of shoulder pain combined with palpation tenderness had been present, and that the pain had disappeared only after relaxation or change to lighter work, was the subject included in the group of verified tendinitis. In all, the group of verified tendinitis comprised 16 subjects. Taking into account the missing data in the investigation and assuming that the drop-out group does not deviate from the examined group, proportionation is possible and the number of cases of supraspinatus tendinitis in the entire group (131) is

Table 1. Shoulder pain complaints from the questionnaire

	Yes	No	Total
Welders	35	96	131
White collar workers	1	56	57

Table 2. Number of cases with supraspinatus tendinitis according to clinical investigation

	Yes	No	Total
Positive questionnaire	16	7	23
Negative questionnaire	1	17	18

set to 24. The prevalence ratio obtained is 18.3 per cent with 14.7–22.1 per cent as a 90 per cent confidence interval.

Comparison between the occurrence of pain in the welding and in the clerk groups entail $\chi^2 = 7.75$ and the significant difference between the two groups ($P < 0.25$ per cent).

From Table 2 it can be seen that in the group who had answered the questionnaire negatively, 1 out of 18 at the clinical examination turned out to have shoulder pain of the supraspinatus tendinitis type. Additionally, three new cases of tendinitis were found in subjects who had been free from symptoms at the time of the questionnaire, but the pains had evolved later on. This can give an approximation of the rate of incidence; it should be of the order of 15–20 per cent based on the group of welders under study over a time period of 1 year.

Figure 2 shows the age distribution of the entire material compared with the cases where supraspinatus tendinitis had been verified. The mean age in the two groups was $m_1 = 39.3$, $\sigma = 10.7$ years and $m_2 = 41.5$, $\sigma = 9.8$ years, respectively. Even if a tendency towards higher age is found in the group with pain, the hypothesis that the mean age is identical cannot be rejected (80 per cent confidence interval for the difference $\pm$ 3.4 years).

Figure 3 shows the distribution of the number of welding years in the group with pain compared with the entire material. The mean value for the entire group is $m_1 = 12.8$, $\sigma = 8.7$ years and for

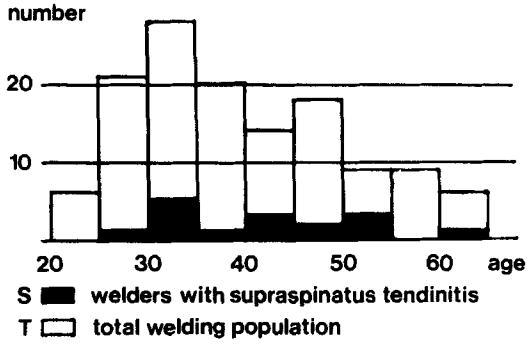

Figure 2. Age distribution of the group of welders studied.

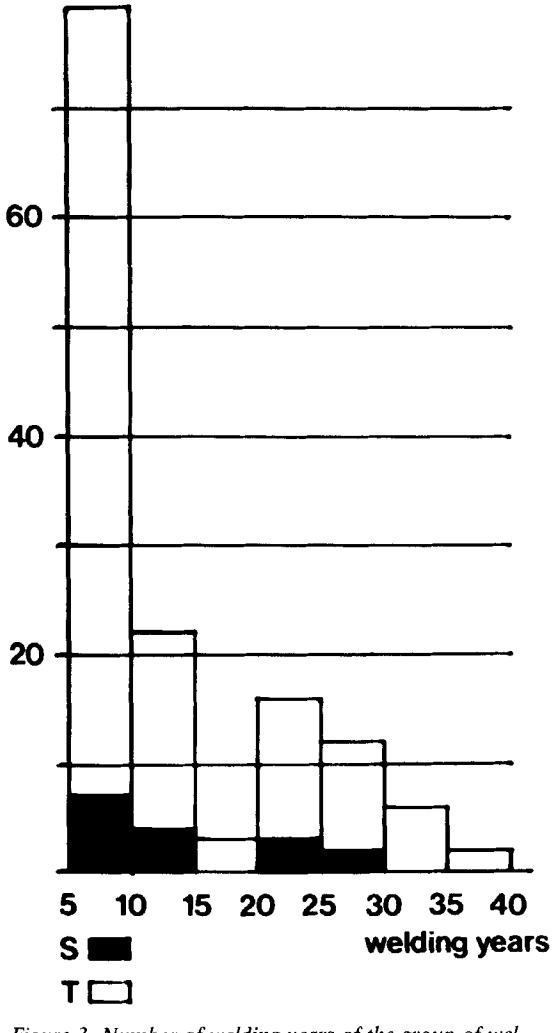

Figure 3. Number of welding years of the group of welders studied. S: welders with supraspinatus tendinitis, T: total welding population.

Table 3. Number of welding years and nominal shoulder load in welders with and without tendinitis, matched for age

Age		Number of welding years		Nominal shoulder load	
T	NT	T	NT	T	NT
60	61	24	30	2	1
50	49	27	12	3	3
48	48	12	21	1	1
45	46	6	10	2	3
41	40	5	8	3	1
38	39	11	5	3	1
34	34	10	5	3	3
32	34	7	6	3	1
31	30	5	5	3	3
30	29	6	5	3	2
29	29	5	6	3	3

T: tendinitis; NT: no tendinitis
Nominal shoulder load: 1 = low load, 2 = high load; 3 = very high load.

the group with pain $m_2 = 12.9$, $\sigma = 8.1$. Hypothesis testing with the Wilcoxon signed ranks test entails no significant difference between the subsample compared to the entire material.

Table 3 shows the results obtained in the case control study, where the number of welding years as well as an ergonomic rating of the working area with regard to shoulder load, are given for individuals with and without supraspinatus tendinitis. The subjects were matched with regard to age within a range of 2 years. Statistical evaluation for number of welding years gives an average difference between the two groups of 0.5, $\sigma = 6.7$ years, which does not imply that there is any difference between the two groups. Concerning rated shoulder load there is a tendency towards a heavier load in those cases with shoulder pains; however, the difference (after application of a signed ranks test) is not significant.

DISCUSSION

In conclusion, the following results were arrived at in this investigation:

1. Supraspinatus tendinitis is a common disorder in shipyard welders, with a prevalence ratio of about 18 per cent.
2. The prevalence ratio of supraspinatus tendinitis in welders is significantly higher than that in office clerks.
3. The mean age in a group of shipyard welders with supraspinatus tendinitis does not deviate from that of the entire group of shipyard welders (with more than 5 years of welding experience).
4. The number of welding years in the group of shipyard welders with supraspinatus tendinitis does not deviate from the number of welding years in the entire group of shipyard welders.
5. The incidence ratio for supraspinatus tendinitis in shipyard welders can be estimated to around 15–20 per cent.
6. Neither the number of welding years nor the rated level of shoulder muscle load were found to be important etiology factors for the development of supraspinatus tendinitis; on the other hand such a linkage cannot be ruled out.

The lack of knowledge about the etiology of shoulder pain makes it difficult to find objective methods for assessing clinical manifestations. Furthermore, when pain is present the difficulties obtaining objective values increase, since the methods for registering pain are inadequate. However, it is our belief that the standardized clinical examination used in this study does demonstrate the presence of an inflammatory disease in the upper part of the rotator cuff. No effort was

made to quantify or describe the different underlying pathologic changes. All subjects with pain had a pure shoulder pain syndrome and objective signs of mixed syndromes with shoulder, neck or arm pain excluded any subject from the group studied.

The turnover of welders in the shipyard industry is very high (about 33 per cent) (Jutvik 1974); this means that it is difficult to totally eliminate missing data in the investigation. However, there is no reason to believe that the drop-out group should have pain to a lesser extent than the group who underwent clinical investigation. Even if work-load factors do not dominate, they are one of several reported reasons for shipyard welders quitting.

From the group of welders, who at the time of the questionnaire reported pain, but who were without pain at the clinical examination, we have found reason to include seven persons under the heading of verified tendinitis. It is of interest to note that even if this classification is not employed, the prevalence of tendinitis in the welding group is significantly higher than in the control group ($\chi^2 = 2.77$; one-tailed test).

The groups of welders and office clerks are not matched for age; the average age of the office clerks is higher. This does not invalidate the conclusions, since a larger number of age inflicted tendinitis in the office clerk group can be expected, whereas the hypothesis is that welders have a higher prevalence of tendinitis (Harmon 1958) than do office clerks.

The investigation of the age distribution has clearly shown that the supraspinatus tendinitis in welders is not exclusively an age-dependent phenomenon. The disorder is common also in younger welders, which implies that welding work as such is an important etiological factor in this type of pain. Nevertheless, age has probably an important influence on the course of the tendinitis. In the younger welders pain decreases after relaxation and/or change of work; in the elderly, the modifications become in the long run chronic (Herberts & Kadefors 1976).

The investigation has not revealed any clear connections between the occurrence of tendinitis and the number of welding years, or the type of welding work, respectively. This can be explained as follows. Disorders of this nature depend, in a certain working situation, on individual factors which are difficult to trace. The training level and the working technique as well as anatomical factors make the load on the tendon variable over a period of time (Petersén & Kadefors 1977). To arrive at an assessment of the actual amount of shoulder load on the basis of an occupational anamnesis must be considered extremely difficult.

Welding is an example of work which is at times arduous, and where the static muscular load is an important component. To what extent the static load is an etiological factor in the development of tendinitis can not be determined within the framework of the present study. This aspect will be the subject of a subsequent investigation comprising plate workers as well, an occupation in which static load on individual muscles is less common than in welders.

In conclusion, we have found that welding work entails a risk for the development of supraspinatus tendinitis, even in young persons who have been active in their occupation for a comparatively short time only.

REFERENCES

Allander, E. (1974) Prevalence, incidence and remission rates of some common rheumatic diseases or syndromes. *Scand. J. Rheumatol.* **3**, 145–153.

Andersson, J. A. D. (1971) Rheumatism in industry: A review. *Br. J. Ind. Med.* **28**, 103–121.

Bateman, J. (1978) The shoulder and neck. W. B. Saunders Company, Toronto.

Bjelle, A., Hagberg, M. & Michaelsson, G. (1979) Clinical and ergonomic factors in prolonged shoulder pain among industrial workers. *Scand. J. Work Environ. Health,* **5**, 205–210.

Codman, E. A. (1934) *The shoulder.* The Author, Boston.

de Luca, C. J. & Forrest, W. J. (1973) Force analysis of individual muscles acting simultaneously on the shoulder joint during isometric abduction. *J. Biomech.* **6**, 385–393.

Hammond, G., Torgerson, W., Dotter, W. & Leach, R. (1971) The painful shoulder. Instructional Course Lectures. The American Academy of Orthopaedic Surgery **20**, 83–90. The C. V. Mosby Company, Saint Louis.

Harmon, P. (1958) Methods and results in the treatment of 2580 painful shoulders. *Am. J. Surg.* **95**, 527–544.

Herberts, P. & Kadefors, R. (1976) A study of painful shoulders in welders. *Acta Orthop. Scand.* **47**, 381–387.

Hult, L. (1954) Cervical, dorsal and lumbar spinal syndromes. *Acta Orthop. Scand.*, Suppl. 17, 100 p.

Ingelmark, B. E. (1948) The structure of tendons at various ages and under different functional conditions. II. *Acta Anat. (Basel)* **6**, 193–225.

Inman, V. T., Saunders, J. B. de C. M. & Abbot, L. C. (1944) Observations on the function of the shoulder joint. *J. Bone Joint Surg.* **26**, 1–30.

Jansson, L. (1978) Skuldertendiniter hos pelarborrare. Examensarbete vid SAF-LSR:s kurs i företagshälsovård.

Jutvik, C. (1974) Vart tar varvsarbetare vägen efter varvet? Report, Department of Sociology, University of Stockholm.

Kadefors, R., Petersén, I. & Herberts, P. (1976) Muscular reaction to welding work: an electromyographic investigation. *Ergonomics* **19**, 543–558.

Lindblom, K. (1939) On pathogenesis of ruptures of the tendon aponeurosis of the shoulder joint. *Acta Radiol. (Stockh.)* **20**, 563–577.

Lucas, D. B. (1973) Biomechanics of the shoulder joint. *Arch. Surg.* **107**, 425–432.

Meyer, A. W. (1937) Chronic functional lesions of the shoulder. *Arch. Surg.* **35**, 646–674.

Moseley, H. F. & Goldie, I. (1963) The arterial pattern of the rotator cuff of the shoulder. *J. Bone Joint Surg.* **45**-B, 780–789.

Neer, C. (1972) Anterior acromioplasty for the chronic impingement syndrome in the shoulder. *J. Bone Joint Surg.* **54**-A, 41–50.

Olsson, O. (1953) Degenerative changes of the shoulder joint and their connection with shoulder pain. *Acta Chir. Scand.*, Suppl. 181.

Partridge, R. E. M. & Duthie, J. J. R. (1968) Rheumatism in dockers and civil servants. A comparison of heavy manual workers and sedentary workers. *Ann. Rheum. Dis.* **27**, 559–567.

Pasila, M. (1965) Periarthritis glenohumeralis. *Duodecim*, Suppl. 14.

Petersén, I. & Kadefors, R. (1977) *Svetsning undersökt med kliniskt neurofysiologiska mätmetoder.* Nordeström & Hellgren Tryckeri AB, Göteborg.

Poppen, N. K. & Walker, P. S. (1976) Normal and abnormal motion of the shoulder. *J. Bone Joint Surg.* **58**-A, 1–4.

Poppen, N. K. & Walker, P. S. (1978) Forces at the glenohumeral joint in abduction. *Clin. Orthop.* **135**, 165–170.

Rathburn, J. B. & Macnab, I. (1970) The microvascular pattern of the rotator cuff. *J. Bone Joint Surg.* **52**-B, 540–553.

Richardson, A. T. (1975) The painful shoulder. *Practitioner* **215**, 27–35.

Rössler, H. (1976) Rupturen in der Rotatorensehnenplatte. *Z. Orthop.* **114**, 282–294.

Saha, A. K. (1971) Dynamic stability of the glenohumeral joint. *Acta Orthop. Scand.* **42**, 491–505.

Saha, A. K. (1973) Mechanisms of elevation of glenohumeral joint. *Acta Orthop. Scand.* **44**, 668–678.

Sahlstrand, T. (1980) Patienter med skulderbesvär – en sjukvårdsanalys. *Läkartidningen* (In press).

Zadig, A. (1963) Objektiv mätning av muskelkraft med en ny dynamometer. *Läkartidningen* **60**, 2937–2953.

Zanca, P. (1971) Shoulder pain: involvement of the acromioclavicular joint. *Amer. J. Roentgenol.* **112**, 493–506.

Correspondence to: Peter Herberts, M.D., Department of Orthopaedic Surgery, Eastern Hospital, S-416 85 Göteborg, Sweden.