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Isometric strength and occupational muscle disorders

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Summary. In two longitudinal studies, initial muscle strength and endurance of the shoulder-forearm muscles were related to deterioration of shoulder-neck-arm disorders after one year. Group I ($n=32$) worked in the automobile industry assembling car motors. Their work was performed when standing and walking, and implied varied postures and exertion of external forces. Group II ($n=96$) worked in the electronics industry assembling printed circuit boards. They worked sitting down and were exposed mainly to postural static loads. Muscle strength was negatively related to deterioration in group I but no such relationship was found in group II. The mechanism of occupational muscular injury is discussed, and it is suggested that mechanical overstress of the musculoskeletal system causes injury in occupations where external forces are exerted. The mechanism of injury in static, postural loads remains to be explained.

Key words: Automobile manufacturing — Electronics manufacturing — Muscle strength — Occupational shoulder-neck disorders — Static endurance

Introduction

A low muscle strength has been assumed to be an important risk factor for occupational musculoskeletal disorders. This assumption is based on theoretical considerations as well as on results from epidemiological studies.

The theory is based on the fact that a given occupational work load is usually the same independant of the individual worker's muscle strength. In individuals with a high maximal muscle strength the occupational work load may demand only a low relative strain, whereas the relative work load in the same job will be high in individuals with a low muscle strength. Given the relationship between static endurance and relative muscle strength as described by Rohmert (1960) and as later adjusted by Björkstén and Jonsson (1977), it is reasonable to assume that the individual with high muscle strength will run a lower risk of anaerobic intramuscular conditions and fatigue than the individual with a low muscle strength.

Epidemiological studies that identify a low muscle strength as a risk factor have been performed in fire-fighters by Cady et al. (1979), in industrial workers by Keyserling et al. (1980), and in a general population by Biering-Sørensen (1984). These prospective studies are all concerned with muscular capacity and its relationship to low back disorders. Cady et al. and Keyserling et al. used maximal static strength as the independant variable, whereas Biering-Sørensen used static endurance.

The relationship between musculoskeletal disorders in the neck-shoulder region and muscular capacity has been studied in a cross-sectional study by Kvarnström (1983). He found a negative relationship between shoulders disorders and maximal static strength in extension-abduction of the upper arm. However, since measurements of muscle strength require that the subjects are symptom free, a longitudinal study design is preferable. This paper deals with the possible importance of static muscle strength as a risk factor for cervico-brachial disorders in two longitudinal studies. Both were performed in the manufactur-

Table 1. Age and body size of subjects. Mean values, SDs and ranges are given

	n	Age, years			Weight, kg			Height, m		
		Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Group I	32	27	4	19–39	56	13	40–80	1.63	5	1.51–1.72
Group II	96	31	11	17–57	63	10	43–99	1.64	6	1.45–1.81

ing industry in female workers, but the work tasks of the two groups differed in several significant ways.

Methods and procedure

Subjects and their work tasks. The ages and body size data of the subjects are given in Table 1. Group I consisted of female automobile industry workers who assembled car engines. They worked standing and walking, using balanced tools like pneumatic screw-drivers, and the maximum weight to be handled was 10 kg. Thus their work implied the exertion of significant external forces. Their working postures varied continuously over the work cycle, which lasted for 30–60 min dependant on the kind of engine assembled. Their wage was calculated on the basis of group productivity, but the number of engines to be assembled during the day was limited.

Group II worked in the electronics manufacturing industry. Their main tasks were preparing, assembling, soldering and inspecting printed circuit boards. The work was performed sitting down, with little variation in working posture. The weight of tools and parts used was very low, and usually they were mounted on fixtures. Thus the musculoskeletal loads were mainly postural. Work cycle time varied from a few seconds to 30 min (average 5.7 min). Their wage was based on individual productivity.

Study design. At the onset of the study a medical history was taken and a thorough examination of the musculoskeletal system was performed by a physiotherapist. Static muscle strength of the shoulder and forearm muscles was measured together with muscular endurance.

After one year the clinical status of the musculoskeletal organs was again evaluated, emphasizing the shoulder-neck region. In the subsequent analysis deterioration in shoulder-neck-arm status was used as the dependant variable, with initial muscle strength data as independant variables.

Both groups were studied separately, as part of larger research projects where other possible risk factors were also recorded. In group I heart rate and rating of perceived exertion during arm bicycle exercise were obtained, as well as the workload chosen by the subjects during the "Preferred Settings Test". These results have been published separately by Edgren (1986). In group II several other independant variables, such as working technique, productivity, sick-leave and leisure time habits were also recorded. All these data, including those on muscle strength, were used for a multivariate analysis, with clinical status at the onset of the study, or outcome after one or two years as dependant variables. The results of the cross-sectional study as well as some of the follow up results have been published separately (Kilbom et al. 1986 a, b).

Thus this paper focuses on the importance of muscle strength in two occupational groups, using χ^2 analysis or Fisher's exact test.

Clinical assessment. Initially all the subject's medical records from the Occupational Health Service were reviewed, and those who had recently sought medical aid or been on sick-leave due to shoulder-neck-arm disorders were excluded from the study. Similarly subjects who were undergoing treatment at the time of the initial examination were excluded. Nevertheless, some subjects during the examination reported having had slight to moderately severe problems from the shoulder-neck-arm region. These subjects were included in the study group, provided they did not report pain during the muscle strength measurements.

The clinical assessment was carried out by a physiotherapist at the onset of the study and after one year, according to a standardized procedure. Previous and current disorders from the neck, shoulder, upper thoracic spine, arm and hand were recorded. Inspection, tests of mobility — active and passive — and palpation of the same body regions were carried out. Moderate discomfort or fatigue occurring during working hours and relieved after work was not considered a disorder, whereas severe discomfort or pain occurring regularly was. In group II the symptoms were coded in four degrees of severity (Kilbom et al. 1986a) where degrees I and II roughly correspond to those states in group I not considered disorders. Occurrence of new clinical findings, or deterioration of previously existing ones, during the following year was used as the dependant variable. In group II these criteria for deterioration corresponded to the transition into degree III or IV. Nearly all "disorder" cases also had objective signs like decreased mobility, tenderness on palpation or pain on movement.

Muscle strength measurements. The maximum static muscle strengths (MVC = maximum voluntary contraction) of the handgrip, and of shoulder elevation (performed unilaterally),

Table 2. MVC and static endurance at onset of study. Mean values and SDs

	Handgrip (N)		Upper arm abduction (Nm)		Shoulder						Upper arm abduction, static endurance (min)	
					elevation (N)		inward rotation (Nm)		outward rotation, (Nm)			
Group I	322	53	34	9	480	121	25	6	18	3	3.7	2.1
Group II	304	57	35	9	502	160	25	6	16	3	6.2	3.3

shoulder inward and outward rotation and of upper arm abduction were determined. Moreover, static endurance of upper arm abduction was measured at a force of 60 N (13 Nm), corresponding to 20—50% of individual MVC. The same external force was chosen for all subjects, rather than a constant fraction of MVC. Muscle strength was tested on the right side, with the subjects fastened in a chair where an unchanged body position could be maintained throughout the experiments. MVC was defined as the greatest force and/or corresponding torque that the subject could sustain for one second. Each test was repeated at least three times for each muscle group, with a short rest of 2 min between contractions, and the highest value was used. The force was measured using strain gauges, which had been calibrated with known weights. The measurements were performed with the upper arm vertical and the forearm horizontal and resting on a support.

Results

Muscle strength

The results of muscle strength measurements at the onset of the study are given in Table 2. The two groups did not differ in maximal strength data, but group II had a longer endurance time for upper arm abduction than group I. This is mainly an effect of the age distribution of the groups; group II consisting of 15 subjects above 40 years of age, with a longer endurance time.

Clinical outcome

Group II was reduced to 84 subjects during the first year due to change of job, childbirth or studies. At the initial examination 10 subjects in group I and 19 in group II had disorders in the shoulder-neck-arm region. During the first year some subjects acquired shoulder-neck disorders and the disorders of others were worsened, so that altogether 14 and 18 subjects respectively had deteriorated after the first year. The symptoms in some subjects were reversible (Fig. 1), and altogether 6 and 11 subjects respectively improved.

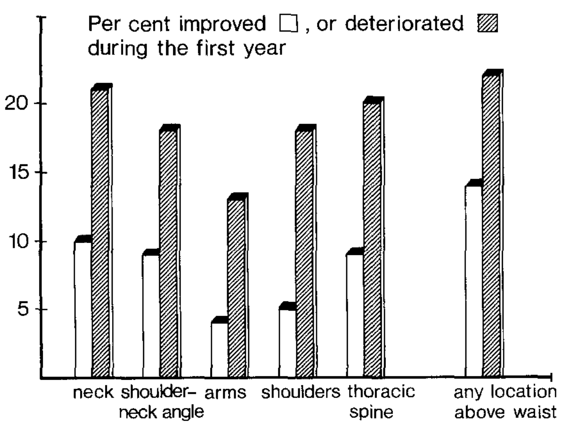

Fig. 1. Percent of group II ($n = 84$) whose clinical status of the cervicobrachial region improved from degree III—IV to degree I—II or deteriorated in the opposite way during one year. The shoulder-neck angle corresponds to the Trapezius muscle

Clinically the disorders were diagnosed as myofascial syndromes with extreme tenderness on palpation and sometimes trigger points, mainly of the trapezius and neck muscles, or as tendinitis, mainly in the shoulder-neck region.

Relationship between deterioration and muscle strength

The individual clinical outcome after one year was divided into deterioration or improved/unchanged, and the muscle strength data were divided into results above or below the mean value of the respective group. In group II no relationships ($p > 0.05$) between muscle strength variables and the dependant variable deterioration were obtained (χ^2 analysis or Fisher's exact test). In a stepwise multiple regression analysis all other independant variables were also used, together with the muscle strength data, in an attempt to explain the outcome. In this analysis MVC at shoulder elevation appeared as positively related to deterioration, although the relationship was weak (manuscript in preparation). In another analysis an attempt was made to relate muscle strength to the dependant variable "healthy", i.e. those subjects who remained without symptoms over the first year. This analysis did not disclose any relationship with muscle strength.

In group I the results revealed that MVCs of handgrip, shoulder elevation, upper arm abduction and outward rotation were negatively related to deterioration ($p < 0.05$ χ^2 analysis or Fisher's exact test), whereas upper arm inward rotation and static endurance were not significantly related to the outcome.

Discussion

The results clearly indicate that low muscle strength was a risk factor for deterioration of shoulder-neck-arm disorders in group I, who performed motor assembly work in the automobile industry. In group II, however, no such relationship could be demonstrated. In fact, one of the multivariate analyses indicated that a high static muscle strength (at shoulder elevation) was a risk factor. The two groups were similar with regard to initial muscle strength and body size data, although group II had a wider distribution of ages. The longer endurance in the older subjects of group II may be ascribed to either a selection or a training effect.

In both groups the strain on the shoulder-neck-arm muscles appeared to be severe, as the incidence and prevalence of symptoms from these areas were high. Sick-leave and reallocation to other work tasks due to symptoms in these industries are reported to be common (Edgren 1986; Melin 1987; Westgaard and Aarås 1984). Thus available data, including those from the official statistics on work injuries (ISA 1984) do not indicate differences in the risk of acquiring shoulder-neck disorders between the two groups.

The work tasks in the two groups, however, differed in many important respects. The subjects in group II were exposed to prolonged, static, postural loads but handled no heavy objects and exerted no large peak forces. The subjects in group I had more varied and dynamic tasks. They too were exposed to some static loading when working with elevated arms for brief periods of time, but the main characteristic of their work was the exertion of significant external forces. An EMG analysis in group II might have yielded the average static load level. Due to the large number of subjects, another method for postural analysis was used instead. Using a standardized video technique, VIRA, the posture of the upper arm, shoulder and neck was analyzed (Kilbom et al. 1986a and b). The results revealed that on average the subjects kept their neck in forward flexion by more than 20° during 44% of the work cycle. Corresponding data for upper arm abduction and flexion by more than 30° were 16 and 18% respectively, and for abduction and flexion by less than 30° were 36 and 33% respectively (Kilbom et al. 1986). Thus the subjects in group II were exposed to some static loading, although it was not quantitatively assessed by EMG. In group I EMG recordings, calibrated against static contractions, would hardly have been reliable, as the range of motion was so wide. In conclusion inspection of the work tasks revealed large differences in load pattern, although the work loads were not quantified as % MVC. These different work load patterns suggest that the mechanism of injury differed between group I and group II.

The two most commonly advanced theories concerning work related cervicobrachial disorders ascribe the injury to either *hypoxia* leading to structural damage via unknown mechanisms, or to *mechanical rupture* caused by sudden peak loads or eccentric contractions (cf. Hagberg 1984).

The difference between the groups, as regards muscle strength as a risk factor, also suggests different injury mechanisms in the two groups. Peak loads and eccentric contractions, as in dynamic work tasks where external forces are exerted, may occasionally tax the muscles beyond their maximal tensile strength, with ensuing mechanical damage. Therefore the risk of overstraining the musculoskeletal system is larger in physically weak subjects. This injury mechanism may have been at work in group I, and explains the relationship obtained between static strength and deterioration.

In group II no high peak loads or eccentric contractions seem to have occurred, so another injury mechanism must have been active. According to the hypoxia theory mentioned above, the static load levels in postural tasks are related to a low endurance and give rise to anaerobic conditions in the muscles. As suggested by Jonsson (1982), static strain levels of about 5% MVC held for prolonged periods must not be exceeded. The muscle strength of the subjects in group II varied from the weakest to the strongest by a factor of 2—4, and the static postural strain must have varied accordingly. Therefore subjects with a low static strength were expected to deteriorate more than the strong ones. As mentioned above no such result was obtained — it rather seemed as if the strong subjects were at an increased risk. Even though other risk factors, like productivity, were more powerful predictors of injury, the multivariate analysis should have disclosed valid relationships between a low muscle strength and deterioration. It may be argued that maximal static strength is not an accurate measure of static endurance, because of the relatively large interindividual variation above and below the mean endurance — strength curve (Rohmert 1960). However, static endurance time was not related to the outcome. Thus neither of the two theories concerning injury mechanisms can adequately explain the findings in group II. The possibility remains that static work loads in themselves are prerequisites for injury, but that the relative work load is of minor importance. Work organizational factors, like work-rest regimes, i. e. the duration of static work loads, may play a more decisive role for the individual outcome.

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