Hand and shoulder ailments

among laboratory technicians using modern plunger-operated pipettes

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Laboratory technicians working with plunger-operated pipettes have a monotonous work task loading the arm. A study was performed to evaluate the prevalence of hand and shoulder ailments among laboratory technicians in relation to the 'dose' of pipetting and in relation to some psychosocial factors. A comprehensive questionnaire regarding musculoskeletal ailments and psychosocial factors was used to compare a cohort of 128 females employed by university research laboratories with reference data obtained from 25,378 female Swedish state employees in general. The prevalence of hand ailments among the laboratory assistants was found to be twice that among female state employees in general. In the cohort a nested case-control study indicated that an increased risk of hand (OR = 5, 0) and shoulder (OR = 2, 4) ailments was associated with more than 300 h/year pipetting. Suggestions for permissible exposure levels for pipetting are presented.

Keywords: Laboratory technicians, plunger-operated pipettes, hand ailments, shoulder ailments, dose-response, monotonous movements

Introduction

Many research projects conducted at university-based laboratories require pipetting, often at an intensive pace. Individual research projects may entail short series but numerous projects taken together form the routine work of the laboratory technicians involved. Laboratory technicians may perform repetitive pipetting tasks for a full working day several days a week throughout the year.

During recent decades there has been a change in the design of laboratory pipettes, with glass pipettes being replaced in favour of plunger-operated pipettes. Modern pipettes are manoeuvred by a tangent for one or more fingers or the thumb (Figure 1). The handling of these pipettes demands a high degree of precision and a considerable amount of static work for the muscles of the whole arm and shoulder.

A meta-analysis performed by Stock (1991) included several studies showing that workplace ergonomics factors are related to the development of disorders in the neck and upper limb. Stock concluded that there is strong evidence of a causal relationship between repetitive forceful work and the development of musculoskeletal disorders of the neck and upper limbs.

A recent study by Dimberg et al (1989) has shown that there is risk for problems in the cervicobrachial region even in light physical work. Dimberg reported that manual repetitive work tasks are prone to give the workers pains in the neck, shoulders, arms and hands. In his study, women had about double the rate of cervicobrachial symptoms compared with men.

Lundgren (1990) edited a comprehensive report from a Nordic project entitled 'Work-related musculoskeletal disorders, prevalence, causes and prevention', in which the Standardized Nordic Questionnaire concerning musculoskeletal problems was developed and evaluated. In the report it is postulated that there is a higher risk for getting pains in the neck, shoulders and arms in seated, monotonous, 'tensed' work tasks. Ergonomists in the pharmaceutical industry in Sweden have noticed that the prevalence of ailments is high among laboratory technicians using pipettes. Two studies have been performed and reported in Swedish (Fredriksson, 1987; Wallin, 1990).

Laboratory technicians at several universities in Sweden, working with manual pipetting, have complained about hand and shoulder problems when visiting their local occupational health units (State Employer OHS). Therefore a systematic evaluation of the influence of pipetting tasks upon complaints regarding the musculoskeletal ailments was initiated.

The first aim of this study was to evaluate the prevalence of hand and shoulder ailments among female laboratory technicians with pipetting tasks compared with the prevalence of such ailments among female state employees in general. The second aim was to assess the influence of the 'dose' of pipetting and of some psychosocial factors upon the prevalence of hand and shoulder ailments within the studied group of laboratory technicians.

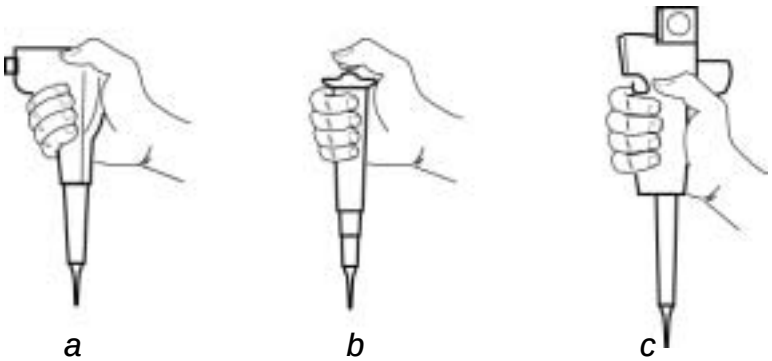

Figure 1 Examples of different types of design of plunger-operated laboratory pipettes: a & b, thumb-operated, c, finger-operated

Subjects and methods

All female laboratory workers at the University of Uppsala were invited to participate. Information about the study was given at their workplaces by the State Employee OHS ergonomist. The two criteria for participating in the study were: employment at the time of the inquiry, and currently working with pipettes.

A questionnaire including a total of 110 questions was sent to the home addresses of 218 female laboratory employees. Sixty did not meet the criteria owing to long-term sick leave, leave of absence or because they did not work with pipettes. The number of laboratory technicians who fulfilled the inclusion criteria for the study was 158. The questionnaire comprised five groups of questions covering the following areas:

1. *Demographic data.* Besides the traditional demographic factors (age, weight, height and weekly working time), a question concerning the dominant working hand was to be answered.
2. *Pipetting tasks.* To determine the amount of time spent with pipetting tasks, subjects were questioned about the duration and number of periods during the work day, the number of days per week and the number of weeks per year with pipetting tasks. In addition, the total number of years with pipetting was reported. The amount of time spent with pipetting was converted into hours per year and lifetime exposure was calculated for each subject. The exposure values were used in the data analysis.
3. *Other regular work tasks.* These questions concerned microscopy, VDU and administrative work.

4a. *Musculoskeletal ailments.* We used the Standardized Nordic Questionnaire (Lundgren, 1990), which is also used by the State Employee OHS for the database from which the referent data drawn.

4b. *Specific problems in the hands.* This section concerned specific disorders in the hands: location of pain, numbness and weakness of hand and / or finger grip. Subjects were asked to note the type and location of complaints on sketches of both hands.

5. *Psychosocial factors in the workplace.* The 10 questions on psychosocial conditions were grouped according to the procedure used by the State Employee OHS to form the three main question groups:

– *Work content* included four detailed questions: whether the work tasks are engaging and stimulating: whether the work tasks are alternating: whether there is a possibility to influence work conditions: and whether the employee gets to know if she performs a good job.

– *Social support* included three questions: extent of contact and cooperation with management; contact and togetherness at work; and whether the employee receives help and support when necessary.

– *Workload* included three questions: whether there is too much work: too high demands: and whether the employee worries about changes in their work situation.

The questions in each group represented points from 1 to 4. Work content, which consisted of four questions, could receive a score ranging from 4 to 16: social support and workload scores ranged from 3 to 12. Answers were considered indicating satisfaction under the mid point of the scales: ≤ 8 for work content and ≤ 6 for social support and workload.

Reference data for the prevalence of musculoskeletal problems were obtained from a database on 25,378 Swedish female state employees (Statshälsan Referens data, 1990), representing several occupations. The State Employee OHS in Sweden performs continuous examinations of state employees as a screening for health status. The references had answered the same questions in the Standardized Nordic Questionnaire and the laboratory technicians regarding musculoskeletal ailments (Group 4a) and psychosocial factors (Group 5). This group was used as a reference group for comparison with the laboratory technicians. According to the State Employee OHS, the possibility of getting more information about data than presented in Table 1 is limited.

A 'nested case control' study in the cohort of laboratory technicians was performed to study the influence of the 'dose' of pipetting. The cases were those pipetting a mean of > 300 h yearly, and the controls were those with a mean of ≤ 300 h yearly which is close to the median of yearly exposure for pipetting (313 h). The data were used for cross-tabulation for estimating risks (odds ratios, OR) and 95% confidence intervals and tests of significance by chi-square. The analysis of odds ratios for developing hand and shoulder problems due to the dose and psychosocial factors was calculated for the right-hand side, as 92% of the laboratory technicians were pipetting with that hand. Statistical analyses were performed with the QUEST program (Gustafsson, 1987).

Results

Of the 158 female laboratory technicians receiving the questionnaire and who fulfilled the inclusion criteria, 128 (81%) answered the questionnaire. The mean age of responders and non-responders was 41 years. The responders worked in many different laboratories (N=49). All kinds of laboratories were represented also by the non-responders (N=20).

Demographic data of the 128 subjects and the 25,378 female state

Table 1 Demographic data for laboratory technicians (*N*=128) and for female state employees (*N*=25,378) from the database

	Laboratory technicians			State employees	
Variables	Mean	SD	Range	Mean	SD
Age (years)	41.1	8.4	22-62	41.8	11.1
Postural height (cm)	167.0	5.7	153-184	166	-
Body weight (kg)	62.6	9.4	48-99	63.5	-
Work (hours week)	33.8	7.7	10-50	35	-
No of years pipetting	15.0		2-39		
Pipetting hours total	6904		20-46371		
yearly	495		1-2016		
	N	(%)		*N*	(%)
Right-handed	118	92		24,109	95
Pipetting hand					
right	114	90			
left	9	7			
both	4	3			

employees in general are demonstrated in Table 1. In the studied group, mean postural height was 167 cm, mean body weight was 62.6 kg, and 92% of the subjects were right-handed. Data for the state employees concerning age, body height, weight and handedness showed only slight differences. One hundred and fourteen of the laboratory technicians (89%) used their right hand for pipetting, while the others used the left or both hands (7% and 3% respectively).

The laboratory technicians had worked with pipetting for a mean of 15 years (median = 15, range = 2–39). The mean time spent pipetting per year was 495 h (median = 313, range 1–2016). The total amount of pipetting during their whole career was estimated to a mean value of 6904 h (median = 3180, range 20–46,371). Many of them also worked with microscopy (53%), VDUs (43%) and administration (68%) in addition to their pipetting tasks. They worked at the time of the injury for a mean of 34 h a week. The state employees worked a mean of 35 h a week. The total work time for the state employees was not available.

Hand and shoulder ailments

Prevalence. Forty-four percent of the technicians reported hand problems, 58% shoulder problems and 44% neck problems (Table 2). Compared with female state employees in general, hand problems especially ($p < 0.001$) but also shoulder problems ($p = 0.03$) were significantly more frequent among the total group of 128 laboratory technicians (Figure 2). Low-back problems were significantly less among the laboratory technicians than among the state employees ($p = 0.04$).

Estimated risks. Among the 128 laboratory technicians the median value of annual exposure time was 313 h. Those laboratory technicians who reported >300 h of mean annual exposure for pipetting had a significant, five-fold risk of hand ailments compared with those exposed for ≤ 300 hours as a mean (Table 3). The prevalence of ailments among the subgroup with mean exposure time ≤ 300 h per year did not differ from the group of female state employees in general (Figure 3). The number of years, with pipetting or not, in the profession per se was not of importance. Psychosocial factors were not found to be related to the development of hand ailments.

As is shown in Table 4, shoulder ailments were also significantly more frequent in the 'annually high exposed' group than in the 'annually low exposed' group, with an OR = 2.4 (CI 95% = 1.1-5.2). As for hand ailments, there was no difference in prevalence of shoulder ailments between those exposed for <300 h per year and female state employees in general.

The laboratory technicians had as a group significantly more positive ratings for their work content than the state employees in general (Table 5). In spite of that there were differences within the group of laboratory technicians. Those with a value of 9 points or more, which means that they evaluated their 'work content' (for details see Group 5 questions in Methods) to be less satisfactory, had an eight-fold risk (OR = 7.7, CI 95% = 1.7-28.1) of reporting shoulder ailments compared with those more satisfied with their work content (Table 4). The two other psychosocial factors did not show any significant relation to shoulder ailments.

Many of the laboratory technicians complained about both hand and shoulder problems (OR = 5.1, CI 95% = 2.4-11.2).

Other work tasks also performed by the laboratory technicians, such as microscopy, administrative activities and VDU work, did not influence the prevalence of hand or shoulder ailments.

Discussion

Hand ailments in the subjects' preferred hand for pipetting are remarkably prevalent: almost twice as frequent as hand problems among female state employees in general (44% and 24%, respectively). The amount of hours pipetting influenced the prevalence of both hand and shoulder problems. The 'low exposed' group showed the same prevalence of problems as the female state employees in general. This indicates that specific activities in the laboratory are causing strain and ailments.

There is a considerable difference in size between the group of laboratory technicians (N = 128) and the population of female state employees (N = 25,378). As a routine, all state employees are offered a health screening by the

Table 2, Percentage of female laboratory technicians (N = 128) and female state employees (N = 25,378) reporting musculoskeletal ailments. Note that an individual may report multiple ailments.

Localization	Laboratory technicians (%)	State employees (%)	Significance of difference
Neck	44	47	NS
Shoulders	58	48	$p = 0.03$
Elbows	18	13	NS
Hand/wrists	44	24	$p < 0.001$
Thoracic back	25	21	NS
Lumbar back	34	43	$p = 0.04$
Hips	20	16	NS
Knees	19	23	NS
Feet/ankles	12	16	NS

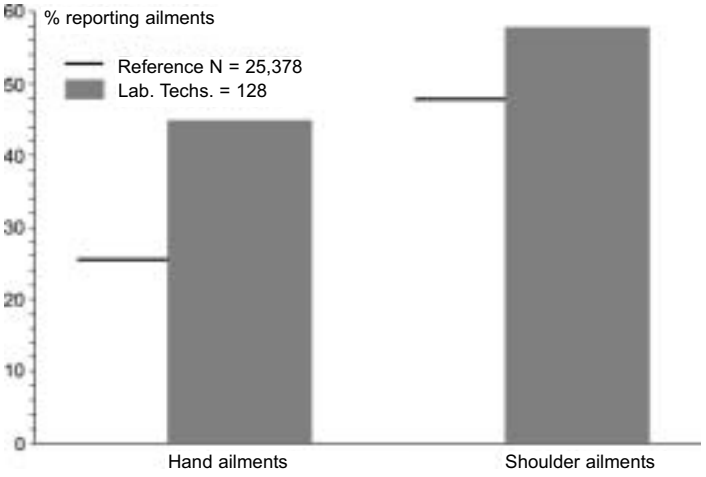

Figure 2 Percentage of female laboratory technicians (*N* = 128) and female state employees (*N* = 25,378) reporting hand and shoulder ailments.

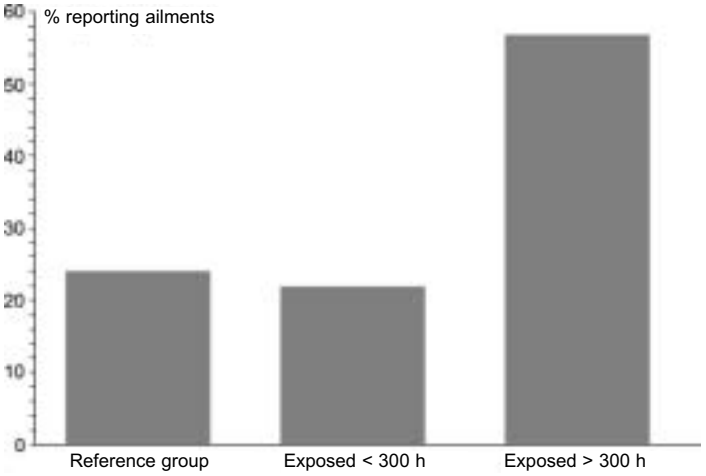

Figure 3 Percentage reporting hand ailments among female state employees (*N* = 25,378), female laboratory technicians (*N* = 128) pipetting less than 300 hrs/year (*N* = 56) and more than 300 hrs/year (*N* = 58)

Table 3, Odds ratios (OR) and 95% confidence intervals (CI) of reporting hand ailments: as a function of hours working with pipettes, expressed as mean annual exposure: as a function of work content, expressed as satisfactory/not satisfactory

	Number of laboratory technicians			
	With ailments	Without ailments	OR	95% CI
Exposure for pipetting				
≤ 300 h/year	11	40		
> 300 h/year	30	22	5	2.1 - 11.5 $p < 0.001$
Work content				
Satisfactory	38	59		
Not satisfactory	9	5	2.8	0.9 - 8.7 NS

Table 4, Odds ratios (OR) and 95% confidence intervals (CI) of reporting shoulder ailments: as a function of hours working with pipettes, expressed as mean annual exposure: as a function of work content, expressed as a satisfactory/not satisfactory

	Number of laboratory technicians			
	With ailments	Without ailments	OR	95% CI
Exposure for pipetting				
≤ 300 h/year	20	32		
> 300 h/year	31	21	2.4	1.1 - 5.2 p = 0.03
Work content				
Satisfactory	57	51		
Not satisfactory	15	2	7.7	1.7 - 28.1 p = 0.01

Table 5, Percentage of the laboratory technicians (N = 128) and female state employees (N = 25,378), rating their psychosocial work environment as satisfactory or not

	Laboratory technicians		State employees		
	Satisfactory (%)	Not satisfactory (%)	Satisfactory (%)	Not satisfactory (%)	Significance of difference
Work content	87	13	74	26	p = 0.001
Social support	93	7	91	9	NS
Workload	41	59	35	65	NS

Work content: sum of the questions = 4-16, social support and work load: sum of the questions = 3-12. Answers are considered indicating satisfaction under the mid point of the scales, which for work content is ≤ 8 and for social support and work load is ≤ 6

StateEmployee OHS. The Standardized Nordic Questionnaires are also used in this screening. We chose this available large population as a reference group. We consider them to be representative of Swedish female state employees. The differences between laboratory technicians and referents regarding age, postural height, body weight and work hours were small and cannot account for the difference in prevalence.

A cross-sectional study design may have certain drawbacks due to selection processes and the number of available employees, thereby limiting the validity of the study. The most obvious drawback is a possible underestimation of a true effect because people with pronounced symptoms or effects have left their jobs: it is a health-based selection of workers. It was not possible to determine whether those who were on sick leave or did not work with pipetting had previously worked with pipetting or whether they suffered from hand or shoulder problems.

Fredriksson (1987) provides a detailed description of the physical strain upon the shoulder, arm and hand when pipetting. The pipette most commonly used by laboratory technicians in our study was described by Fredriksson: length 29 cm, hand grip diameter 2.0–2.9 cm, weight 104 g. Fredriksson observed the posture of laboratory technicians performing pipetting tasks. She found that they kept the neck bent forward 30° with the neck muscles isometrically contracted. The upper arm was held in 20° abduction and each time the fluid was transferred into test-tubes the arm was flexed forward 45°. When the tubes were held in the opposite hand they adducted and rotated the upper arm inward. The elbow joint was held in 90° flexion and the lower arm was supinated 30°. The wrist was kept in 30° dorsal flexion and also flexed radially. The thumb was abducted radially and rotated inward in the CMC joint. The MCP joint was extended according to the length of the thumb and the height of the tangent. The IP joint was flexed 90°. The tangent was pushed down by flexing the MPC joint. The depression of the plunger to the first position (transferring the fluid) required a force of 4.2 N and to the second position (releasing the tip) a force of 14.2 N. In this study, the female subjects used 5.4% and 18.4%, respectively, of their maximal voluntary capacity (MVC) to depress the tangent to the two positions. The work of the thumb was characterized by Fredriksson as continually dynamic with the possibility of micro-pauses.

The character of the task is such that the neck and shoulder muscles have to work statically when the head and neck are beyond the neutral position (bent forward more than 30°) and the arm is elevated without support for lengthy periods. Many studies have suggested that static work is harmful (Larsson *et al*, 1988; Byström, 1991; Hägg, 1991; Lindman, 1992; Sundelin, 1992). It has not been possible, however, to quantify the 'dose' or limit that is harmful to human structures. Wallin (1990) found

that the perceived strain on the shoulder was correlated with the time spent pipetting. Higgs *et al*'s (1992) study of upper extremity impairment in workers performing repetitive tasks showed that subjects performing the job type requiring the least number of repetitions per hour were the least impaired. Fredriksson (1987) found that the amount of time spent pipetting influenced the prevalence of thumb ailments among females. Those who pipetted daily had more problems than those who pipetted less frequently.

It could be argued that there is a difficulty in reporting pipetting time. Laboratory technicians are, however, educated to count and record most of the procedures during their daily work. Therefore there was an assumption that they could adequately record their amount of pipetting.

Our study shows that the prevalence of hand ailments among the 128 laboratory technicians is correlated with the 'dose' of pipetting. A dose of more than 300 h per year is associated with an increased risk of hand and shoulder ailments. Based on the assumption of 44 work weeks per year, a permissible exposure level of 1–2 h of daily pipetting should be considered. This value coincides with the results of Fredriksson (1987) for the thumb. Subjective ratings by laboratory technicians also show that perceived fatigue increases as a function of time spent pipetting (Wallin, 1990).

The psychosocial factor 'work content' was found to be of importance for the prevalence of shoulder ailments. The risk of shoulder problems when work content is less satisfactory is high compared with the risk for hand ailments (Table 4). One possible interpretation is that hand ailments are more directly related to the physical loading according to the sequence physical strain – somatic disturbance – pains. Shoulder ailments might also be generated via another mechanism: physical strain / experience of poor work content – somatic disturbance – pains, ie a psychosomatic connection. Repetitive, monotonous work, in addition to the direct physical strain, is experienced as boring and mentally inactivating, which workers interpret as poor work content. This interpretation is relevant to current discussions about the relative importance of the psychosocial and physical loading as explanations for musculoskeletal problems. Workers may express symptoms in different ways depending on the questions put in an inquiry. In Figure 4(a) and (b) the hypothetical covariation is presented graphically.

Our results indicate that the 'dose' of pipetting influences the prevalence of hand and shoulder ailments.

In many laboratories, it may not be feasible at present to follow our suggestion for limiting time spent pipetting. Nonetheless, those responsible for laboratory work should take into consideration the increased risk of developing musculoskeletal ailments when pipetting for more than two hours per day for extended periods of time. Our findings provide further support for the claim that a work organization that promotes task variety is necessary to provide a physically and mentally good work environment.

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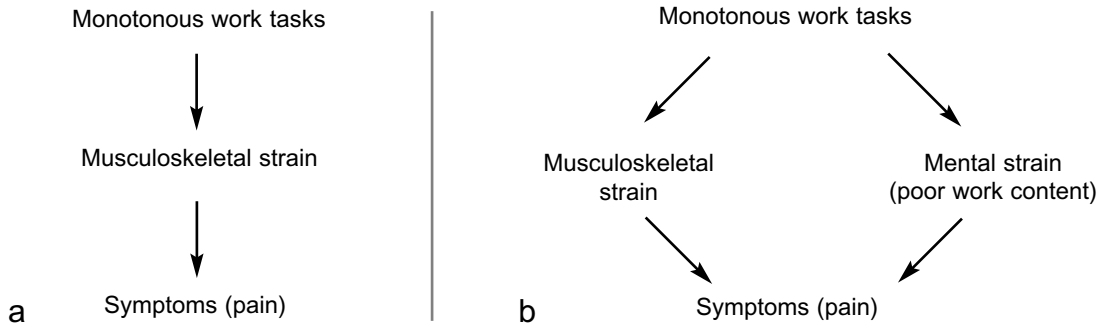

Figure 4 Hypothesis for generation of pains: (a) hand ailments: (b) shoulder ailments

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