ORIGINAL ARTICLE

Relationship Between Selected Health Problems and Exposures Among Women Semiconductor Workers in Malaysia

H L Chee, PhD*, K G Rampal, PhD**

*Department of Community Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, **Department of Community Health, Faculty of Medicine, Universiti Kebangsaan Malaysia, 56000 Cheras, Kuala Lumpur

Summary

A study conducted between 1998-2001 on the semiconductor industry in Penang and Selangor found that irregular menstruation, dysmenorrhea and stress were identified as the three leading health problems by women workers from a checklist of 16 health problems. After adjusting for confounding factors, including age, working duration in current factory, and marital status, in a multiple logistic regression model, wafer polishing workers were found to experience significantly higher odds of experiencing irregular menstruation. Dysmenorrhea was found to be significantly associated with chemical usage and poor ventilation, while stress was found to be related to poor ventilation, noise and low temperatures.

Key Words: Semiconductor industry, Women workers, Irregular menstruation, Dysmenorrhea, Stress

Introduction

The electronics industry in developed countries started setting up off-shore plants in developing countries in the early 1970s. In Malaysia, this process coincided with the advent of the New Economic Policy, as well as a new industrialization strategy that emphasized export orientation instead of import substitution. Consequently, the active encouragement of the industry in this country led to its rapid rise and entrenchment in the economy.

The identification of health problems that are associated with the electronics industry, in particular, semiconductor production, began as early as the 1970s[1]. In 1980, it has been pointed out, the incidence rate of occupational illness among semiconductor workers in California was more than three times the rate among workers in the general manufacturing industry[2]. Based on Californian Workers' Compensation statistics from 1980-84, occupational illnesses were found to account for 19.9% of all lost-work-time injuries and illnesses among semiconductor workers compared to an average of 6.5% for workers of all manufacturing industries. Furthermore, semiconductor workers showed a 46.7% incidence of occupational illnesses attributable to exposure

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Corresponding Author: Chee Heng Leng, BT 11-2, Prima 16, No. 2, Jalan 16/18 46350 Petaling Jaya, Selangor

to toxic materials, as compared with 21.0% for all manufacturing industries. More recent data confirms these earlier conclusions, as analysis of the United States Department of Labour statistics for the whole country has shown that in 1995, occupational illnesses among semiconductor workers accounted for 30.2% of all reported injuries and illnesses, as compared to 20.5% among other electronics workers, and an average of 14.3% among all manufacturing workers [3].

Other studies have been carried out to identify the exposures that are associated with specific health problems, with recent work focussing on reproductive effects of chemical exposures [4,5]. In Malaysia, however, the occupational health of semiconductor workers has rarely been studied, with the notable exception of a 1983 study of five semiconductor factories in Singapore and Penang, Malaysia [6].

Localized studies are important because the semiconductor industry consists of a long and complex production process, different parts of which are carried out in different countries. In general, the initial processes of wafer fabrication are primarily located in developed countries, while the lower stream processes of semiconductor assembly are in developing countries. Wafer fabrication is a capital intensive process involving sophisticated technology and high chemical usage, while semiconductor assembly, on the other hand, has historically been more labour intensive, although this is changing due to increasing automation. In Malaysia, the semiconductor industry is primarily made up of semiconductor assembly factories, although there are a few wafer fabrication factories.

This paper is based on data collected in a study conducted between 1998-2001 on the semiconductor industry in Penang and Selangor. The objectives are to identify the health problems (from a checklist of 16 selected health problems) most commonly cited as experienced by the workers in the last one year, and the workplace exposures that are associated with these health problems in the semiconductor industry.

Materials and Methods

All 24 semiconductor factories listed in two geographical clusters, Bayan Lepas, Penang and Selangor, were selected from the Malaysian Industrial Development Authority list (31st August 1998). However, the management of six factories withheld cooperation, resulting in a participation rate of 75%. Six participating factories were located in Selangor, while 12 were in Bayan Lepas, Penang.

The study consisted primarily of a workers' survey. The management of each factory was requested to provide a 10% random sample of women workers with the criteria that they be Malaysian citizens, had worked for one year or more in the present factory, and were direct production line workers up to the level of line leaders only. Factories with fewer that 300 women workers were asked to select at least 30 workers, and those with more than 2,000 workers were asked to select only 200 workers. As limitations imposed by the factory management did not make it possible for the researchers to carry out random selection, it was emphasised to the factory personnel involved that the selection should be random, and that every work process should be represented.

Workers participating in the survey were allowed to leave their work temporarily. The survey took part in an allocated room or space in the factory, usually with groups of 10 to 15 workers at a time. Research assistants briefed the participating workers on the survey and requested them to fill in a self-administered questionnaire while in their presence, so that any problems in understanding the questions may be clarified by them. The workers were not required to provide individual identification in the questionnaire, and were assured of confidentiality. All data was collected between July 1999 and March 2000.

The questionnaire included questions on socio-demographic characteristics, work characteristics, physical working conditions, chemical usage, and health problems. The outcome variables were obtained from a question on whether or not the worker had experienced, in the last one year, any of the following health problems (yes or no): diabetes, high blood pressure, tuberculosis, sexually transmitted diseases (including AIDS), severe backache, goitre, varicose veins, kidney illness, bladder illness, cancer, stress, injury outside work, injury at work, irregular menstruation, dysmenorrhea, early menopause (before age of 40 years), or any other health problem (to be stated by worker).

The exposure variables used in this paper were number of years worked in factory, work section, and exposure to chemical and physical hazards. Exposure to chemical hazards was defined by answers to two separate questions (i) whether any chemical or dust was used in work processes that the worker was involved in (yes or no), (ii) whether or not there was any smell of any chemicals or dust while working (yes or no). Exposure to physical hazards was defined by a combination of two questions. First, whether or not the workers felt themselves to be exposed to various physical hazards (yes or no), and second, whether they felt satisfied with various aspects of their physical working conditions (satisfied, dissatisfied, or not relevant). Only workers who answered yes to the first question and dissatisfied to the second were considered as being exposed to the particular physical hazard. Age and marital status were considered as potential confounding variables.

Data analysis was carried out using the SPSS (Version 10.0) software package. The t-test, chi-square, and odds ratio were used to test for significant relationship between health problems and exposure variables. Multivariate analysis was carried out by logistic regression, the models of which only included exposure and confounding variables that were found to be significantly related in the bivariate analysis.

Results

Socio-demographic and Work Characteristics

The total sample of women workers in this study was 968 (Table I). Their ages ranged from 18 to 54 years, with a mean of 30.5±7.9 years, and spread quite evenly over three age groups, that is 31.3% in the <25 year age group, 33.9% in the 25-34 year age group, and 30.3% in the 35-44 year age group. The majority were Malay (75.8%), and most had achieved either upper secondary education and above (66.0%) or lower secondary education (26.9%). Just over half of the group (51.1%) were currently married, while 45.1% were unmarried.

The number of years that the workers had worked in their present factory ranged from one to 31 years, with a mean of 8.9±7.5 years and a median of 6.0 years (Table II). The distribution is skewed with lower proportions in the categories of longer work duration. Thus, 23.9% had worked for 1-2 years, and 25.4% for >2-5 years, making a total of 49.3% who had worked for one to five years compared to 16.6% who had worked for >5-10 years.

The workers were selected as direct production operators, but 8.1% had additional duties as line leaders. The majority of the workers (60.6%) were on a rotating eight-hour shift, but 30.1% were on a rotating 12-hour shift. The fixed and rotating eight-hour shifts are based on a six-day work week with a fixed rest day on Sunday; while the rotating 12-hour shift is based on a fortnightly work schedule, usually consisting of four days of work followed by three rest days, and then three days of work and four rest days.

The largest proportion of workers (47.6%) came from the end of line semiconductor assembly section, which consisted primarily of chip testing processes, including electrical and memory testing, burn-in testing, and final visual inspection. There were 18.5% who were from the semiconductor assembly front of line section, where imported wafers were diced, processed, attached, bonded to wires, and tested, all of which

were carried out by machines in clean rooms. Clean rooms are for establishing a dust-free or low-dust environment with controlled temperatures so as to protect the semiconductors that are being produced. Workers in clean rooms have to wear bunny suits, apparel that covers them completely from hand to foot.

Another 18.8% of the workers were in the semiconductor middle of line section, where the exposed chips were encapsulated so as to prevent contamination. After encapsulation, the chips go through processes of forming and trimming, soldering and marking. A small proportion of the workers were in lines that were carrying out parts assembly, that is the assembly of diodes, transistors, and other electronics components.

There was also 9.6% of the workers who were in wafer polishing. These processes begin with crystal ingots being mounted onto rods, and then sliced into wafers. The wafers are then put through various processes - etching, lapping, annealing, grinding, sand-blasting - in order to achieve clean and smooth mirror surfaces. Wafer polishing is part of wafer fabrication, but the factories that were in this study did not carry out the complete wafer fabrication process. Ingots were imported from other countries, sliced and polished, and then shipped out again.

It was also found that a relatively large proportion of the workers had worked for 1-2 years in their present work section (35.8%), while 29.2% had worked for >2-5 years. The mean number of years worked in present work section was 6.0±5.8 years. Most of the workers worked at fully automated tasks (49.2%), where they loaded and unloaded units into and out of machines, looked after the machines, fixing the computerised settings, and checking when warning buzzers go off. Workers in semi-automated work tasks constituted 14.3%, and their work involved handling units manually in between machine-operated processes.

Exposures and Health Problems

The workers who said that chemicals were used in their work process constituted 41.8%, while those who said that they could smell chemicals while working constituted 31.9% (Table III). Among the physical exposures, the most commonly cited was noise (39.6%), followed by cold (27.5%). Considerably lower proportions cited insufficient ventilation (9.7%), heat (8.7%), insufficient lighting (5.9%) and radiation (5.8%). Although close to 40% of the workers had said that they were exposed to noise, only 29.1% expressed dissatisfaction with the noise level in their working environment as well. Likewise, although 27.5% were exposed to cold temperatures, 16.0% were at the same time dissatisfied with it.

The health problem identified from the checklist by the largest number of workers was irregular menses (107 per 1,000) (Table IV). This was followed by dysmenorrhea (100 per 1,000), and then stress (82 per 1,000). Health problems associated with ergonomics, varicose veins (34 per 1,000) and severe back pain (21 per 1,000) were also identified by substantial proportions of workers.

Relationship Between Exposure Variables and Three Main Health Problems

The three main health problems identified by the workers were further analysed in relation to selected exposure factors. It was found that the workers who had irregular menses were significantly younger (28.0 years vs 30.8 years, $p<0.001$) and had shorter working duration (6.8 years vs 9.2 years, $p<0.01$) compared to those who did not have the problem in the last one year (Table V). Mean age (26.8 years vs 30.9 years, $p<0.001$) and working duration (5.6 years vs 9.3 years, $p<0.001$) were also significantly lower for those who experienced dysmenorrhea within the last one year. Marital status, however, was significantly associated with dysmenorrhea only ($p<0.01$), with higher proportions of single women (14.0%) reporting the problem compared to married women (6.5%) (Table VI).

The odds ratios for irregular menses were computed for the selected exposure variables (Table VII). It was found that workers in wafer polishing (OR 2.72, CI=1.27-5.79) and semiconductor assembly middle of line (OR 2.12, CI=1.07-4.18) work sections had significantly higher odds of experiencing irregular menses in the last one year. Significantly higher odds were also found for those in work processes where chemicals were used (OR 1.96, CI=1.30-2.96), and those who smelt chemicals while working (OR 2.16, CI=1.43-3.26), as well as those who were exposed to high temperatures (OR 2.20, CI=1.10-4.42), poor lighting (OR 3.72, CI=1.40-9.89), and poor ventilation (OR 2.17, CI=1.11-4.23). From the multiple logistic regression, however, only the adjusted odds ratio for workers in wafer polishing were found to be significantly higher (OR 2.65, CI=1.21-5.79).

The odds ratios for dysmenorrhea in the last one year were significantly higher for those who were in work processes that used chemicals (OR 1.78, CI=1.17-2.71), and those exposed to poor ventilation (OR 2.37, CI=1.21-4.63) (Table VIII). These odds remained elevated even after adjusting for confounding effects (chemicals OR 1.58, CI=1.02-2.46; poor ventilation OR 1.46, CI=1.02-2.08). The adjusted odds ratios of experiencing stress within the last one year were significantly higher for exposure to poor ventilation (OR 2.56, CI=1.24-5.28), noise (OR 2.02, CI=1.22-3.32), and low temperatures (OR 1.80, CI=1.03-3.13) (Table IX).

Table I: Socio-demographic Characteristics of Study Population

	% Distribution (N=968)
Age, mean (years) (±SD)	30.5 ± 7.9
Age group (years)	
<25	31.3
25-34	33.9
35-44	30.3
45-54	4.5
Ethnicity	
Malay	75.8
Non-Malay	24.2
Education level	
No formal education	0.6
Primary	6.5
Lower secondary	26.9
Upper secondary and higher	66.0
Marital Status	
Unmarried	45.1
Married	51.1
Divorced & widowed	3.8

Table II: Working Profile of Study Population

	% Distribution (N = 968)
No. of years worked in present factory	
1-2	23.9
>2-5	25.4
>5-10	16.6
>10-20	25.3
>20	8.8
Mean (± SD)	8.9 ± 7.5
Job designation	
Operator	91.9
Line leader	8.1
Work schedule	
Fixed shifts	9.3
Rotating 8-hr shift	60.6
Rotating 12-hr shift	30.1
Work section	
Wafer polishing	9.6
Semiconductor assembly	
Front of line	18.5
Middle of line	18.8
End of line	47.6
Parts assembly	5.5
No. of years worked in present section	
1-2	35.8
>2-5	29.2
>5-10	18.0
>10-20	14.2
>20	2.8
Mean (±SD)	6.0 ± 5.8
Type of work task	
Automated	49.2
Semi-automated	14.3
Manual	13.0
Inspection	19.8
Supervisory	3.7

Table III: Exposure to Chemical and Physical Hazards

	Distribution of respondents (N = 968)	
	No.	%
Exposed to chemical hazards		
Chemicals used in work process	405	41.8
Smell chemicals while working	309	31.9
Exposed to physical hazards		
Noise	383	39.6
Cold	266	27.5
Insufficient ventilation	94	9.7
Heat	84	8.7
Insufficient lighting	57	5.9
Radiation	56	5.8
Exposed to physical hazards as well as dissatisfied with physical working conditions:		
Noise	282	29.1
Temperature / too cold	155	16.0
Poor ventilation	61	6.3
Temperature / too hot	55	5.7
Poor lighting	20	2.1

Table IV: Prevalence of 10 Selected Health Problems in the Last One Year

	Health problems in the last one year	
	No.	Prevalence (Per 1,000)
Irregular menses	104	107
Dysmenorrhea	97	100
Stress	79	82
Varicose veins	33	34
Severe back pain	20	21
Injury outside workplace	17	18
High blood pressure	17	18
Diabetes	9	9
Thyroid problems	9	9
Injury at the workplace	8	8

Table V: Association between Age, Working Duration and Three Main Health Problems

	Mean age (years)	t	p	Mean no. of year worked in factory	t	p
Irregular menses						
Yes (n=104)	28.0	4.0	0.000***	6.8	3.3	0.001**
No (n=864)	30.8			9.2		
Dysmenorrhea						
Yes (n=97)	26.8	5.3	0.000***	5.6	5.7	0.000***
No (n=871)	30.9			9.3		
Stress						
Yes (n=79)	30.9	0.4	0.694	10.2	1.5	0.140
No (n=889)	30.5			8.8		

** $p < 0.01$
*** $p < 0.001$

Table VI: Association between Marital Status and Three Main Health Problems

	Single (n=437)	Married (n=495)	Divorced / widowed (n=36)	χ^2	p
Irregular menses				3.0	0.227
Yes (n=104)	54 (12.4)	45 (9.1)	5 (13.9)		
No (n=864)	383(87.6)	450 (90.9)	31 (86.1)		
Dysmenorrhea				14.5	0.001*
Yes (n=97)	61 (14.0)	32 (6.5)	4 (11.1)		
No (n=871)	376 (86.0)	463 (93.5)	32 (88.9)		
Stress				3.4	0.187
Yes (n=79)	28 (6.4)	48 (9.7)	3 (8.3)		
No (n=889)	409 (93.6)	447 (90.3)	33 (91.7)		

** $p < 0.01$

Table VII: Odds Ratios for Exposure Variables and Irregular Menses Experienced within the Last One Year (N=968)

Exposure Variables	Odds Ratio	95% Confidence Interval	Adjusted Odds Ratio	95% Confidence Interval
Work section:				
Wafer polishing	2.72	1.27-5.79	2.65	1.21-5.79
Semiconductor assembly				
Front of line	1.00	-	-	-
Middle of line	2.10	1.07-4.18	1.64	0.80-3.33
End of line	1.12	0.59-2.12	2.06	0.76-5.59
Parts assembly	2.10	0.79-5.46	1.15	0.60-2.20
Chemical hazards:				
Use chemicals in work process	1.96	1.30-2.96	0.97	0.45-2.10
Smell chemicals (N=405)	2.16	1.43-3.26	1.89	0.87-4.12
Exposed to physical hazards as well as dissatisfied with physical working conditions:				
Temperature / too hot	2.20	1.10-4.42	1.56	0.70-3.46
Temperature / too cold	1.03	0.59-1.78	-	-
Noise	1.53	1.00-2.34	-	-
Poor lighting	3.72	1.40-9.89	2.26	0.71-7.26
Poor ventilation	2.17	1.11-4.23	1.09	0.49-2.45

Adjusted odds ratios were obtained from logistic regression with the covariates that were significantly related to irregular menses. These were age, no. of years worked in factory, work section, use of chemicals, smelt chemicals, temperature too hot, poor lighting and poor ventilation.

Table VIII: Odds Ratios for Exposure Variables and Dysmenorrhea Experienced within the Last One Year (N=968)

Exposure Variables	Odds Ratio	95% Confidence Interval	Adjusted Odds Ratio	95% Confidence Interval
Work section:				
Wafer polishing	1.71	0.78-3.72	-	-
Semiconductor assembly				
Front of line	1.00	-	-	-
Middle of line	1.22	0.61-2.46	-	-
End of line	1.08	0.59-1.97	-	-
Parts assembly	1.50	0.55-4.07	-	-
Chemical hazards:				
Use chemicals in work process	1.78	1.17-2.71	1.58	1.02-2.08
Smell chemicals (N=405)	1.43	0.93-2.20	-	-
Exposed to physical hazards as well as dissatisfied with physical working conditions:				
Temperature / too hot	1.58	0.72-3.44	-	-
Temperature / too cold	0.72	0.38-1.35	-	-
Noise	1.29	0.83-2.01	-	-
Poor lighting	1.60	0.46-5.57	-	-
Poor ventilation	2.37	1.21-4.63	1.46	1.02-2.46

Adjusted odds ratios were obtained from logistic regression with the covariates that are significantly related to dysmenorrhea. These are age, marital status, no. of years worked in factory, use chemicals and poor ventilation.

Table IX: Odds Ratios for Exposure Variables and Stress Experienced within the Last One Year (N=968)

Exposure Variables	Odds Ratio	95% Confidence Interval	Adjusted Odds Ratio	95% Confidence Interval
Work section:				
Wafer polishing	1.99	0.98-4.02	-	-
Semiconductor assembly				
Front of line	1.36	0.74-2.52	-	-
Middle of line	1.12	0.58-2.15	-	-
End of line	1.00	-	-	-
Parts assembly	1.22	0.41-3.61	-	-
Chemical hazards:				
Use chemicals in work process	1.56	0.98-2.47	-	-
Smell chemicals (N=405)	1.59	1.00-2.55	-	-
Exposed to physical hazards as well as dissatisfied with physical working conditions:				
Temperature / too hot	3.97	2.03-7.77	1.95	0.90-4.22
Temperature / too cold	2.36	1.40-3.96	1.80	1.03-3.13
Noise	2.74	1.72-4.37	2.02	1.22-3.32
Poor lighting	2.91	0.95-8.93	-	-
Poor ventilation	4.30	2.27-8.11	2.56	1.24-5.28

Adjusted odds ratios were obtained from logistic regression with the covariates that are significantly related to stress. These are temperature too hot, too cold, noise and poor ventilation.

Discussion

Lin's study [6] of 773 production workers and 130 clerical workers had identified the main problems reported by production workers to be respiratory, skin, eye, gastro-intestinal, and general complaints such as headache, giddiness, and fever. Our study, however, is not entirely comparable to Lin's study because different checklists were used for identifying health problems. Nevertheless, Lin's study did include menstrual problems, defined as pain, irregularity and heavy flow, experienced for several days in a row since working in electronics, and she found that production workers were more likely to report more menstrual problems compared to clerical workers. Furthermore, she showed that production workers using solvents regularly were more likely to experience menstrual problems.

A prospective study that was carried out as part of the Semiconductor Industry Association study had found that menstrual cycle lengths were longer and varied to a greater extent among wafer fabrication clean room workers as compared to non-fabrication workers[7]. This study also reported that photolithography workers who were potentially exposed to organic solvents had greater variability in menstrual cycle lengths and a higher risk of short cycles compared to non-fabrication workers. In our present study, irregular menstruation was found to be significantly higher among wafer polishing workers, and dysmenorrhea was significantly associated with

chemical usage and poor ventilation, both of which are congruent with the findings of these two previous studies cited here.

A study of 170 premenopausal women employed in the United States Air Force (USAF) had found the prevalence rate of dysmenorrhea to be 31.2%, hypermenorrhea 17.9%, and abnormal cycle length 12.0% [8]. In comparison, the prevalence rates (irregular menstruation 10.7%, dysmenorrhea 10.0%) in our current study are lower. The definition of menstrual problems differs in the two studies, which are therefore not directly comparable. In the USAF study, the period of recall was three months compared to one year in our study, and dysmenorrhea was defined as needing bedrest or missing work because of menstrual pain, while in our current study, it was less stringently defined as experiencing pain during menstruation.

The prevalence of dysmenorrhea in our present study are more comparable to a study of 415 women aged 15-54 residing in government flats in Singapore [9]. Defined as one or more episodes of menstrual cramp or pain in the previous year, the prevalence was found to be 51.3%, while 10% of all employed women reported having been sick absent because of dysmenorrhea.

The USAF study also studied job strain, which was experienced as 'high' by 55.3% of the women employees, but when the definition of job strain was refined as being 'high demand, low control and low social support', only 6.5% were found to be in this category 8. The present study found the prevalence of stress, as crudely measured by a yes or no answer to a checklist containing 'stress' as one of the items, to be 8.2%.

The present study also found significant associations between self-reported stress and exposures to poor ventilation, noise and low temperatures. Lin [6] had also interviewed a subsample of 83 production workers and had found low temperatures to be a common complaint; while in her survey, she had found an association between exposures to hot/cold and illness/ no illness in the previous 6 months. Lin did not examine stress, but data was collected on psychological complaints, which were found to be significantly related to time pressure as well as migration.

In the present study, those experiencing irregular menstruation and dysmenorrhea were found to be significantly younger and to have worked for a shorter duration in their current factory. Although the number of years worked in present factory could have been used as a general exposure variable, it was found in the present study to have a similar trend as age, and therefore was acting more like a confounding variable. The relationship between older age and reduced likelihood of dysmenorrhea is consistent with the Singapore study cited earlier [9] and a longitudinal study of young women in Sweden [10]. Nevertheless, the inverse relationship between working duration and menstrual problems could also be reflecting a healthy worker effect, where those who experience problems tend to leave employment earlier, and those with fewer problems continue employment longer. The finding that there is more dysmenorrhea among single women than ever married women is consistent with these other two studies which show a higher frequency of dysmenorrhea among nulliparous women [9, 10].

Conclusion

Irregular menstruation, dysmenorrhea and stress were identified as the three leading health problems by women workers in the present study from a checklist of 16 specified health problems. After adjusting for confounding factors, including age, working duration in current factory, and marital status, in a multiple logistic regression model, wafer polishing workers were found to experience significantly higher odds of experiencing irregular menstruation. Dysmenorrhea was found to be significantly associated with chemical usage and poor

ventilation. These results were found to be congruent with previous studies that linked irregular menstruation and dysmenorrhea to exposures to chemicals, in particular, solvents. Nevertheless, this needs to be further investigated, and in particular, environmental measurements of wafer polishing factories need to be determined.

The finding that stress is related to poor ventilation, noise and low temperatures also require further investigation. More detailed research should measure stress by a validated instrument, and investigate relationships with more stressor-specific exposures.

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