Health Survey of Workers Exposed to Mixed Solvent and Ergonomic Hazards in Footwear and Equipment Factory Workers in Thailand

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A cross-sectional health study was performed at four footwear and one equipment factory in Thailand to evaluate the prevalence of chemical- and ergonomic-related symptoms in Thai factory workers and to investigate associations between these symptoms and exposures to organic solvents, isocyanates and ergonomic risks. A 10-page health questionnaire was administered to 1784 workers across the four footwear and equipment factories. A total of 1675 questionnaires were returned, yielding a 94% response rate. The questionnaires asked about age, gender, use of chemicals, use of personal protective equipment and health outcomes. Without exception, the percentages of workers reporting symptoms after being hired were higher than those reporting symptoms before being hired for all the factories. The highest symptom percentages were related to ergonomic stressors. Multiple logistic regression was used to calculate adjusted prevalence odds ratios and 95% confidence intervals. This study showed that adverse health effects experienced by footwear and equipment factory workers are associated with occupational exposures to chemicals (volatile organic solvents and water-based adhesives) and ergonomic hazards.

Keywords: equipment factories; ergonomics; exposure assessment; footwear factories; isocyanates; questionnaires

INTRODUCTION

Workers in athletic footwear and athletic equipment manufacturing factories in developing countries are exposed on a daily basis to water-based isocyanate mixtures, complex mixtures of organic solvents and ergonomic hazards. The chemical exposures occur through both the respiratory and dermal routes and can adversely affect many physiological systems.

The primary chemical exposures to organic solvents in footwear manufacturing and equipment factories come from the hand application of glues, cements and degreasing and cleaning solvents to the footwear and equipment pieces as they are assembled. Because these chemicals are hand applied, using a variety of brushes, both inhalation and dermal routes of exposure are important. The mixtures of chemicals can include n-hexane, toluene, methyl ethyl ketone, acetone, xylene, ethyl acetate, hexane and cyclohexane. A number of epidemiological studies have found associations between chemical exposure in footwear factories and adverse health effects. Associations between exposure to these solvents and an excess risk of leukemia and stomach, bladder and kidney cancers were found in an epidemiological study of footwear factory workers in Florence, Italy (Fu et al., 1996). Exposure to these organic solvents may also induce other genotoxic effects, including chromosomal aberrations, DNA strand breakage and protein cross-links (Popp et al., 1992; Karacic et al., 1995). Associations were found between solvent use and peripheral and central nervous system (CNS) damage (Buiaatti et al., 1978; Cavalleri and Cosi, 1978; Dyro, 1978; Governa et al., 1987).
In addition, chronic exposure to hexane from glue has been linked to neurobehavioral and neurophysiological changes among shoe manufacturing workers (Perbellini et al., 1981; Mutti et al., 1982; Lee et al., 1998).

Organic solvent use has been associated with adverse effects on the respiratory system, including chronic airway impairment (Oleru and Onyekwere, 1992). Mixtures of organic solvents and plasticizers have been associated with dermatitis, mucous membrane irritation, eye irritation and sore eyes (Vidovic and Kansky, 1985; Oleru and Onyekwere, 1992; Yasugi et al., 1994; Zavalic et al., 1998; Nijem et al., 2001).

Job functions and workstations in footwear and athletic manufacturing factories can present ergonomic risks due to repetitive movements, fixed and awkward body positions, vibration and the exertion of undue force when assembling shoe and equipment parts. Operation of sewing machines with rapid speed performance and fixed working positions create risks for musculoskeletal disorders, especially low-back pain and shoulder pain (Serratos-Perez and Mendiola-Anda, 1993). Workers, who remained seated for long periods of time, have experienced adverse effects on their spinal segments and shoulders and occupational fatigue (Grieco, 1986; Kristjuhan, 1995). Clinical studies of footwear workers have reported that operation of vibrating tools with hand–arm systems have been linked to carpal tunnel syndrome and the development of local aneurysms in the hands of shoemakers (Pelnar, 1973).

To reduce exposures to volatile organic solvents in the contract factories, multinational companies have begun substituting water-based adhesives for the organic solvent-based adhesives. These water-based substitutes require the addition of highly reactive and toxic isocyanate cross-linkers that have been associated with impaired pulmonary function and occupational asthma (Akbar-Khanzadeh and Rivas, 1996; Bernstein, 1996). Diisocyanates are the most commonly identified cause of occupational asthma in industrialized countries (Redlich et al., 2002). Once sensitized, very low level exposures can induce the clinical onset of symptoms (Lemiere et al., 2002). Patients can develop persistent airway hyperreactivity and the complete recovery of lung function may never be achieved (Saetta et al., 1995; Piirila et al., 2000; Padoan et al., 2003). The most commonly used diisocyanates include HDI (1,6-hexamethylene diisocyanate), methylene bisphenyl diisocyanate and toluene diisocyanate. In footwear and equipment factories, direct contact of isocyanates with the skin can occur during mixing of water-based cements, application of the cements on shoe and equipment parts, handling of isocyanate-contaminated tools and cleaning of contaminated work surfaces.

This paper reports on a cross-sectional health study that was performed at four footwear and one equipment factory in Thailand that are contract factories for a large multinational corporation with headquarters in the US that has >700 contract factories worldwide. The objectives of the study were to (i) evaluate the prevalence of chemical- and ergonomic-related symptoms in Thai footwear and equipment factory workers and to (ii) investigate associations between these symptoms and exposures to organic solvents, isocyanates and ergonomic risks.

METHODS

Overall description of the factories

In 1999 (27 July–19 August), a health survey was conducted at four footwear factories (A, B, C and D) and one equipment factory that were all located within a few hours of Bangkok, Thailand. Factories B and C were physically separated from one another and produced different shoes; however, they were owned by the same parent corporation. The four footwear factories had an average of 2500 employees (2076–3476) and the equipment factory had ~500 employees. Approximately 75% of the employees at the factories were women. The factories had long assembly lines, where workers performed most of their jobs throughout the day. The shoes and balls (equipment factory) were all cut, stitched, cemented, assembled and painted by hand. The parts were transported on conveyor belts and the workers manually applied the adhesives, primers, paints and cleaners using a variety of hand tools. The workstations at the factories all had hard seats that could not be adjusted. Job rotation was not employed as a control strategy at any of the factories.

Two to three days were spent at each footwear factory; one day was spent at the equipment factory. On the first day, a walk-through survey was performed to identify job tasks based upon potential for chemical exposure and/or ergonomic risks. The questionnaires were distributed on the second day of the study for the footwear factories and the first day for the equipment factory (see Table 1 for the departments evaluated and number of different job tasks represented). In the footwear factories, the primary job tasks having direct exposure to chemicals included cleaning, cementing, priming, gluing, mixing, laminating, painting, repairing and screening. In the equipment factories, the primary job tasks having direct exposure to chemicals included cleaning, cementing, gluing, mixing, laminating, painting, repairing, screening and vulcanization.

In the footwear factories, the primary job tasks with ergonomic risk factors included pressing, cutting, grinding, buffing, lasting, sole laying, de-lasting, trimming, gauge marking, rubber sheeting, rubber milling and mixing, strobel stitching, stitching, trimming and using a precision skiving machine.
to sew leather parts. In the equipment factories, the primary job tasks with ergonomic risk factors included forming, mixing, screening, mixing, winding and cutting.

Questionnaires

A 10-page health questionnaire was first developed in English in the US and was then translated into Thai by graduate students and faculty from the Occupational Health and Safety Department of Mahidol University in Bangkok, Thailand. The questions were designed to require minimal translation back into English and to be easily understood by workers. The questionnaires included questions regarding the demographics of the workers (age, sex, smoking, education, marital status and duration of employment), job title, use of chemicals, use of personal protective equipment, engineering controls, workplace conditions and health outcomes. The questionnaire was designed to evaluate the health status of the workers with regard to occupational exposures to chemicals and ergonomic hazards. Symptom questions were based upon chemical use in factories provided by the parent company and through review of the literature.

Symptoms were divided into six physiologic categories: eye, upper respiratory system (nasopharyngeal region), lower respiratory system (pulmonary region), CNS, skin, and musculoskeletal system, giving a total of 28 different symptoms. For each symptom, the workers identified whether or not they ever had any of the symptoms. For each symptom they identified ‘yes before starting employment’, ‘yes after starting employment’, ‘yes in the last month’ or ‘never’.

For each factory visited, trained Thai graduate students gathered groups of workers together; explained the purpose of the study; obtained voluntary consent for participation; explained how to fill out the questionnaires and then distributed the questionnaires, pencils and fact sheets. All the workers in each job function were invited to participate in the study. All job functions were invited, including those that involved chemical or ergonomic exposures as well as job functions such as office work that, in theory, had no direct contact with chemicals. Each questionnaire was assigned a personal identification number (PID) and a factory ID. The PID number could not be used to track the questionnaire back to any specific worker. The workers returned the questionnaires on the following day either to the students or by placing them in boxes located on the factory floor. A limited number of workers were interviewed to evaluate their understanding of the purpose of the study, their ability to fill out the questionnaires and their use of personal protective equipment.

Case identification

A case was categorized as ‘before-hired’ for workers who had a symptom history before starting employment at the factory. A case was categorized as ‘after-hired’ for workers who developed symptoms after starting employment at the factory. If a worker checked ‘never’ plus any other responses, their responses to that symptom was considered unclassifiable and was not used in data analyses. A worker who had symptoms before and after starting employment could be categorized as a both before-hired and after-hired case.

Exposure classification

A combination of questionnaire responses and observation was used to classify exposed and reference groups. For chemical exposures, if the workers noted direct use of chemicals, they were considered ‘exposed’. Job practices were observed to identify which workers had potential ergonomic hazards. Ergonomic hazards included repetitive motion, forceful exertions, awkward work positions, use of vibrating equipment and standing on hard surfaces for long periods of time.

In these factories there were no traditional unexposed reference groups because of the widespread low-level exposures to airborne chemicals throughout the factories and the moderate to high work demands. Therefore, workers at the factory with low levels of exposures had to be used as the reference group. Workers were classified as reference workers if they did not directly work with chemicals and/or did not encounter obvious ergonomic hazards. Exposed was defined by the presence of ergonomic hazards for musculoskeletal symptoms and chemical exposure for other symptoms.

Statistical analysis

For the footwear and equipment factories, symptom percentages were calculated for cases occurring

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**Table 1. Departments and number of job tasks represented in the questionnaires**

| Factory | Departments (number of questionnaires per department) | Number of tasks |
|---------|-------------------------------------------------------|-----------------|
| A, footwear | Assembly (185), stockfit (177), cutting (60), office (20) and stitching (71) | 44 |
| B, footwear | Assembly (398), rubber (7), cutting (13) and autoclave (10) | 46 |
| C, footwear | Assembly (128), cutting (5), stitching (25), packing (19) and rubber room (19) | 47 |
| D, footwear | Assembly (200), stockfit (123), upper stitching (12), stitching (19) and rubber room (63) | 60 |
| E, equipment | No specific department names (111) | 14 |
prior to hiring and after hiring and for all workers, regardless of exposure status.

For the footwear factories, the prevalence of symptoms developing before and after beginning employment was calculated separately for workers directly exposed and workers not directly exposed. These two groups were then compared against each other with respect to the before-hired and after-hired symptoms. In the equipment factory the cases were not further divided into exposure groups because only six of the workers were not directly exposed to chemicals.

Multiple logistic regression was used to calculate adjusted prevalence odds ratios (PORs) and 95% confidence intervals (CIs) describing relationships between exposures and symptoms that developed after employment in the four footwear factories combined (Kleinbaum et al., 1982, 1997). PORs >1.0 indicate a positive association between the exposure and symptoms. The covariates age (in years), sex, smoking status (never, former or current) and symptoms before hire (yes, no) were included in all models. SAS® software (Version 8.2, SAS Institute Inc., Research Triangle Park, NC, USA) was used to calculate regression coefficients, PORs and 95% CIs.

RESULTS

Health questionnaires were administered to 1784 workers across the four footwear and equipment factories. A total of 1665 questionnaires were returned to the research team, yielding a 93% response rate. The number of questionnaires returned for Factories A, B, C, and D and E were 513, 428, 196, and 417 and 111, respectively. The factory response rates were 97, 90, 94, and 93 and 90, respectively. Table 2 shows the demographics of all study workers in the footwear and equipment factories. Workers were primarily non-smoking females in their mid-20s, the majority of whom had worked <5 years in the factories. Most

| Characteristics     | Footwear factories | Equipment factory |
|---------------------|--------------------|-------------------|
|                     | A (N = 513) No. (%)| B (N = 428) No. (%)| C (N = 196) No. (%)| D (N = 417) No. (%)| E (N = 111) No. (%)|
| Age (years)         |                    |                   |                   |                   |                   |
| <20                 | 63 (12.5)          | 41 (9.9)          | 15 (8.1)          | 43 (10.7)         | 6 (5.4)           |
| 20–25               | 176 (34.9)         | 119 (47.8)        | 74 (39.8)         | 160 (39.7)        | 48 (43.2)         |
| 26–31               | 171 (33.9)         | 111 (26.7)        | 59 (31.7)         | 128 (31.7)        | 34 (30.6)         |
| >31                 | 95 (18.8)          | 65 (15.6)         | 38 (20.4)         | 72 (17.9)         | 19 (17.1)         |
| Employment (years)  |                    |                   |                   |                   |                   |
| <1                  | 123 (25.3)         | 146 (35.3)        | 42 (21.8)         | 63 (15.4)         | 16 (14.4)         |
| 1–3                 | 92 (18.9)          | 149 (36.0)        | 72 (37.3)         | 131 (32.0)        | 45 (40.5)         |
| 3–5                 | 63 (12.9)          | 40 (9.7)          | 37 (19.2)         | 63 (15.4)         | 22 (19.8)         |
| 5–7                 | 43 (8.8)           | 35 (8.5)          | 18 (9.3)          | 49 (12.0)         | 16 (14.4)         |
| >7                  | 166 (34.1)         | 44 (10.6)         | 24 (12.4)         | 104 (25.4)        | 12 (10.8)         |
| Sex                 |                    |                   |                   |                   |                   |
| Female              | 471 (92.0)         | 297 (70.1)        | 138 (71.1)        | 344 (82.7)        | 94 (84.7)         |
| Male                | 41 (8.0)           | 127 (30.0)        | 56 (28.9)         | 72 (17.3)         | 16 (14.4)         |
| Smoking             |                    |                   |                   |                   |                   |
| No                  | 413 (90.6)         | 271 (78.6)        | 145 (79.7)        | 316 (85.9)        | 85 (76.6)         |
| Former              | 30 (6.6)           | 30 (8.7)          | 14 (7.7)          | 20 (5.4)          | 6 (5.4)           |
| Current             | 13 (2.9)           | 44 (12.8)         | 23 (12.6)         | 32 (8.7)          | 5 (4.5)           |
| Marital status      |                    |                   |                   |                   |                   |
| Single              | 203 (40.0)         | 159 (38.4)        | 84 (43.1)         | 220 (54.7)        | 46 (41.4)         |
| Married             | 266 (52.5)         | 227 (54.8)        | 93 (47.7)         | 162 (40.3)        | 55 (49.5)         |
| Separated/divorced  | 21 (4.1)           | 8 (1.9)           | 6 (3.1)           | 10 (2.5)          | 2 (1.8)           |
| Widowed             | 17 (3.4)           | 20 (4.8)          | 12 (6.2)          | 10 (2.5)          | 4 (3.6)           |
| School              |                    |                   |                   |                   |                   |
| College             | 14 (2.7)           | 0 (0.0)           | 0 (0.0)           | 0 (0.0)           | 0 (0.0)           |
| Academic high       | 60 (11.7)          | 32 (7.6)          | 14 (7.3)          | 40 (9.6)          | 16 (14.4)         |
| Commercial high     | 41 (8.0)           | 7 (1.7)           | 4 (2.1)           | 4 (1.0)           | 0 (0.0)           |
| Secondary           | 154 (30.1)         | 127 (30.2)        | 54 (28.3)         | 141 (34.0)        | 23 (20.7)         |
| Elementary          | 242 (47.4)         | 255 (60.6)        | 119 (62.3)        | 230 (55.4)        | 65 (58.6)         |
workers had completed at least secondary school and almost half the workers were married.

**Symptom percentages for all factory workers**

Figure 1 shows the prevalence of symptoms reported before and after hire for the four footwear factories combined, and Fig. 2 shows prevalence’s for the equipment factory. The specific symptoms measured by the bars correspond to the symptom numbers in Table 3. Without exception, the percentages of workers reporting symptoms after being hired were higher than those reporting symptoms before being hired for all the factories. The average percent of workers reporting symptoms beginning after being hired ranged from an average of 4 to 53% for the four footwear factories combined and from 4 to 60% for the equipment factory. Highest prevalences were for physically tired (CNS); pain/stiffness in back, shoulders and neck (musculoskeletal); pain/stiffness in hands, fingers and wrist (musculoskeletal); pain in waist, legs, knees and feet (musculoskeletal) and headaches (CNS). The prevalence of these after hire ranged from 37 to 50% in the combined footwear factories and from 34 to 61% in the equipment factory.

For the footwear factories the prevalence of symptoms reported after being hired were ranked from highest to lowest in the six physiological categories as follows: musculoskeletal, CNS, upper respiratory, eyes/skin and lungs. This ranking was relatively consistent across the different departments within the four footwear factories. The ranking of the four factories from highest to lowest percent of after-hired symptoms was Factories D, A, C and B (Table 3). For the equipment factory, the prevalence of symptoms reported after being hired was ranked from highest to lowest in the six physiological categories as follows: musculoskeletal, upper respiratory, skin, CNS, eye and lungs. All the symptoms in the musculoskeletal category were reported in >43% of the workers, and all three symptoms in the skin category were reported in >24% of the workers.

**Symptom percentages related to exposure**

For the four footwear factories, the reference (indirect exposure) and exposed groups were compared for demographics and before-hired symptoms, see Table 4. The age distribution was similar between the reference and the exposed groups with a mean age of 26 years. The distribution of age, sex, smoking and before-hired symptoms was also similar between the two groups. The percentages of workers who ever had symptoms before starting work at their footwear factories ranged from 0.5 to 19.3% in the reference group and from 1.0 to 19.3% in the exposed group. Headache was the highest (19.3%) reported symptom in both groups. Coughing symptoms were present in 11.8% of both groups.

The reference (indirect exposure) and exposed groups were compared for percentages of after-hired symptoms. Table 3 shows the percentages of workers with each symptom in the exposed and reference groups.

![Fig. 1. Prevalence of symptoms reported before- and after-hired at four footwear factories.](image-url)
groups. The exposed group had higher percentages of symptoms (up to 11%) than did the reference group for all 28 symptoms. The largest difference between these groups was seen for the three musculoskeletal symptoms, physically tired and headaches.

**Adjusted PORs**

PORs for the four combined footwear factories are shown in Table 5. The PORs for the 28 symptoms, adjusted for age, sex, smoking and symptoms before hire ranged from 1.11 (wheezing) to 1.74 (eye irritation). Nineteen PORs are >1.4, including at least one symptom in each physiological category. Ten PORs for chemical-related symptoms, all in the eye, upper respiratory, lung and CNS categories, are >1.5. The average of adjusted PORs in each category range from 1.53 for upper respiratory symptoms to 1.37 for musculoskeletal conditions. CIs are wider for symptoms such as ‘wheezing or whistling sounds’ that are infrequently reported and narrower for symptoms such as ‘physically tired’ that are reported more frequently.

**DISCUSSION AND CONCLUSIONS**

This study found associations between exposure to both chemical and ergonomic hazards in footwear factories and all adverse health outcomes. PORs >1.1 were found for all symptoms. In all, 16 of the 18 symptoms associated with chemical exposure and 2 of the 3 symptoms associated with ergonomic hazards were statistically significant (two-tailed test) using the normative criterion of \( P < 0.05 \).

Significant associations were found for all physiological categories.

While significant, the adjusted PORs in this study may be underestimating the actual health impacts of working in the footwear factories. This study used workers in the factories as the unexposed reference group. These unexposed workers were actually workers indirectly exposed to chemicals and exposed to some ergonomic hazards. Most of the employees who did not work with chemicals were in close proximity to employees who worked directly with chemicals. In addition to chemicals, most of the jobs in the factories involved repetitive motions and awkward working positions. These factors could have increased symptom prevalence in the reference worker group and therefore reduced the differences between the two groups. This would bias the results toward the null hypothesis (no association). Furthermore, like many studies of occupational exposure, our results may reflect biases from the ‘healthy worker effect’. Workers who are most acutely sensitive to chemicals or ergonomic hazards would tend to leave jobs more quickly than workers who are insensitive to the same exposures. Over 85% of workers in this study had been employed for >1 year. Workers with acute symptoms severe enough to cause substantial discomfort would be more motivated to seek alternative employment or to move from exposed to unexposed jobs. This pattern of selection out of exposed jobs would tend to reduce the ability of a prevalence study, which lacks information on workers who left their jobs prior to the date of the survey, to detect an effect of occupational exposures.
Although lack of a true unexposed reference group and the healthy worker effect would lead to underes-
timates of effects, recall bias could lead to over- or
underestimates of effects. If workers did not remem-
ber symptoms that occurred in the more distant past
as well as those that occurred after being hired, or if
they noticed symptoms more after they became occu-
ployally exposed to chemicals and ergonomic haz-
ards, this could bias PORs upward. Alternatively,
workers may have been reluctant to report symptoms
if they thought these reports could have affected their
jobs. However, workers were cooperative and clearly
differentiated in the levels of symptoms, suggesting
that they were not uniformly reporting or not report-
ing symptoms.

Comparisons of exposed and reference workers
were not made for the equipment factory because
only seven of the 111 workers completing question-
naires were indirectly exposed to chemicals, resulting
in a reference group that was too small for analysis. However, the significance of the footwear
factory results highlights the importance of evaluat-
ing athletic equipment factory workers as well. Many
of the chemicals and application methods were sim-
ilar in the footwear and equipment factories, and air
concentrations were orders of magnitude higher in
the equipment factory. Some of the chemicals were
found to spike up to six times their occupational ex-
posure limits. The equipment factory workers were
observed to have significantly poorer work practices
and housekeeping than any of the footwear factories.

Reported prevalence of symptoms after being
hired was much higher than the prevalence of symp-
ptoms before being hired for workers in both the

Table 3. Percentage of people reporting symptoms after employment at the four footwear factories

| Symptoms                                      | A    | B    | C    | D    | Combined |
|-----------------------------------------------|------|------|------|------|----------|
| **Eye**                                       |      |      |      |      |          |
| 1. Dry, itching or irritated eyes             | 13.3 | 0.9  | 3.6  | 23.5 | 11.4     |
| 2. Tired or strained eyes                     | 21.6 | 3.3  | 7.1  | 3.1  | 16.2     |
| 3. Blurred vision                             | 10.9 | 1.6  | 7.1  | 14.9 | 8.9      |
| **Upper respiratory system**                 |      |      |      |      |          |
| 4. Sore or dry throat                        | 26.7 | 4.0  | 14.8 | 34.1 | 20.9     |
| 5. Stuffy or runny nose or clogged sinuses   | 25.5 | 5.8  | 18.4 | 25.9 | 18.7     |
| 6. Sneezing                                  | 19.5 | 5.8  | 13.8 | 16.1 | 8.7      |
| **Lungs**                                     |      |      |      |      |          |
| 7. Wheezing or whistling sounds coming from chest | 3.1  | 0.9  | 3.1  | 3.8  | 2.7      |
| 8. Coughing                                  | 14.0 | 3.7  | 11.7 | 16.3 | 11.5     |
| 9. Coughing that produces something from lungs | 7.6  | 1.4  | 4.1  | 6.7  | 5.2      |
| 10. Breathing problems that wake you up       | 5.5  | 0.7  | 5.6  | 6.5  | 4.4      |
| 11. Chest tightness                          | 10.9 | 2.6  | 8.7  | 20.9 | 11.0     |
| 12. Shallow breathing                        | 17.2 | 2.8  | 8.7  | 20.9 | 13.1     |
| 13. Pain with deep breaths                   | 9.6  | 2.8  | 7.1  | 14.1 | 8.6      |
| 14. Sneezing                                 | 19.1 | 5.6  | 12.8 | 13.2 | 13.0     |
| **CNS**                                      |      |      |      |      |          |
| 15. Headaches                                | 29.4 | 9.6  | 26.0 | 39.6 | 26.3     |
| 16. Unusual tiredness or drowsiness          | 29.4 | 8.4  | 20.9 | 40.0 | 26.8     |
| 17. Tension, irritability or nervousness     | 18.3 | 4.0  | 18.4 | 31.2 | 17.8     |
| 18. Short attention span                     | 11.7 | 1.6  | 5.6  | 15.8 | 9.3      |
| 19. Faint easily                             | 18.5 | 4.4  | 10.7 | 25.7 | 15.6     |
| 20. Nausea and vomiting                      | 13.5 | 2.6  | 8.2  | 16.8 | 10.7     |
| 21. Clumsiness                               | 4.1  | 0.5  | 3.1  | 3.1  | 2.7      |
| 22. Physically tired                         | 52.4 | 15.7 | 42.9 | 64.0 | 44.2     |
| **Skin**                                     |      |      |      |      |          |
| 23. Dry or itchy skin on hands or arms       | 16.8 | 1.6  | 11.2 | 23.0 | 13.6     |
| 24. Redness on hands or arms                 | 13.8 | 3.0  | 10.7 | 22.8 | 12.9     |
| 25. Inflammation of hands or arms            | 5.1  | 1.6  | 5.1  | 10.6 | 5.6      |
| **Musculoskeletal system**                   |      |      |      |      |          |
| 26. Pain or stiffness in back, neck or shoulders | 50.5 | 12.6 | 44.4 | 61.4 | 42.2     |
| 27. Pain or stiffness in hands, fingers or wrists | 39.0 | 11.4 | 28.6 | 50.8 | 33.3     |
| 28. Pain in waist, legs, knees or feet       | 45.4 | 10.7 | 38.3 | 53.5 | 37.1     |
footwear and equipment factories. This implies that adverse health impacts were associated with working at the factories. The general profile of the symptoms was similar between the factories; however, Factory B reported significantly lower after-hired cases than Factories A, D and C. This result is surprising given that the workplace conditions and air sampling results in Factory B were not different from the other factories. The lower prevalence of symptoms after hired was observed in all the departments in this factory. It is possible that the workers participating in the study from Factory B may have reported fewer symptoms because they were concerned about job security. Such reporting bias could have affected responses in other factories as well.

Within a factory, symptom prevalence varied between departments. This would be expected if symptoms were caused by occupational exposures because chemical mixtures and job tasks varied between departments. Although differences in symptom prevalence between departments may also be due to preemployment differences in symptoms between people who go to work in different departments, the comparisons of exposed and unexposed workers

| Symptom history | Before-hired Reference No. (%) | Exposed No. (%) | After-hired Reference No. (%) | Exposed No. (%) |
|-----------------|-------------------------------|----------------|-------------------------------|----------------|
| Eye             |                               |                |                               |                |
| 1. Dry, itching or irritated eyes | 14 (2.3) | 30 (4.0) | 66 (10.9) | 133 (17.6) |
| 2. Tired or strained eyes | 8 (1.3) | 19 (2.6) | 115 (18.8) | 149 (20.4) |
| 3. Blurred vision | 17 (2.8) | 26 (3.6) | 62 (10.2) | 101 (13.9) |
| Upper respiratory system |               |                |                               |                |
| 4. Sore or dry throat | 63 (10.2) | 72 (9.5) | 138 (22.3) | 230 (30.3) |
| 5. Stuffy or runny nose or clogged sinuses | 85 (13.9) | 120 (16.2) | 139 (22.7) | 216 (29.1) |
| 6. Sneezing | 66 (11.0) | 95 (13.1) | 97 (16.1) | 178 (24.5) |
| Lungs            |                               |                |                               |                |
| 7. Wheezing or whistling sounds coming from chest | 8 (1.3) | 7 (1.0) | 21 (3.5) | 26 (3.6) |
| 8. Coughing     | 71 (11.8) | 85 (11.8) | 87 (14.4) | 145 (20.1) |
| 9. Coughing that produces something from lungs | 9 (1.5) | 21 (2.9) | 32 (5.4) | 56 (7.8) |
| 10. Breathing problems that wake you up | 17 (2.9) | 13 (1.8) | 27 (4.6) | 49 (6.9) |
| 11. Chest tightness | 15 (2.5) | 27 (3.7) | 69 (11.6) | 115 (16.0) |
| 12. Shallow breathing | 18 (3.0) | 28 (3.9) | 94 (15.5) | 140 (19.3) |
| 13. Pain with deep breaths | 14 (2.4) | 10 (1.4) | 53 (8.9) | 89 (12.4) |
| 14. Sneezing | 64 (10.8) | 85 (11.8) | 88 (14.9) | 163 (22.6) |
| CNS              |                               |                |                               |                |
| 15. Headaches    | 118 (19.3) | 147 (19.3) | 198 (32.4) | 313 (41.0) |
| 16. Unusual tiredness or drowsiness | 20 (3.3) | 41 (5.7) | 169 (28.0) | 249 (34.3) |
| 17. Tension, irritability or nervousness | 22 (3.7) | 39 (5.5) | 128 (21.4) | 188 (26.3) |
| 18. Short attention span | 19 (3.3) | 25 (3.6) | 65 (10.9) | 104 (14.8) |
| 19. Faint easily | 30 (5.1) | 45 (6.3) | 100 (17.0) | 176 (24.4) |
| 20. Nausea and vomiting | 29 (5.0) | 39 (5.6) | 73 (12.6) | 123 (17.6) |
| 21. Clumsiness | 14 (2.4) | 19 (2.8) | 20 (3.5) | 35 (5.1) |
| 22. Physically tired | 39 (6.3) | 60 (7.9) | 290 (46.8) | 435 (57.4) |
| Skin             |                               |                |                               |                |
| 23. Dry or itchy skin on hands or arms | 12 (2.0) | 20 (2.7) | 79 (13.0) | 141 (19.0) |
| 24. Redness on hands or arms | 9 (1.5) | 13 (1.8) | 78 (12.9) | 127 (17.6) |
| 25. Inflammation of hands or arms | 3 (0.5) | 8 (1.2) | 33 (5.6) | 57 (8.2) |
| Musculoskeletal system |               |                |                               |                |
| 26. Pain or stiffness in back, neck or shoulders | 62 (6.1) | 27 (6.9) | 486 (48.1) | 210 (54.0) |
| 27. Pain or stiffness in hands, fingers or wrists | 27 (2.7) | 7 (2.0) | 368 (37.0) | 162 (45.9) |
| 28. Pain in waist, legs, knees or feet | 58 (5.9) | 25 (6.5) | 419 (42.8) | 205 (53.5) |

Before-hired and after-hired as categorized by questionnaire for Symptoms 1–25 and as observed by the research team for Symptoms 26–28.
Central nervous system

Six of the eight symptoms in the CNS category were significantly associated with chemical exposure. Most of the chemicals that the workers are exposed to during painting, cementing, priming and cleaning contain volatile organic chemicals (VOCs) that can adversely affect the CNS. Workers in footwear factories are exposed to these chemicals through both inhalation and dermal absorption. An industrial hygiene sampling study of workers in these factories performed along with this cross-sectional study (Todd et al., 2008) found overexposures to mixtures of CNS depressants. Some of the CNS depressants that were measured in the air included n-hexane, methyl ethyl ketone, toluene, xylene, ethyl acetate, cyclohexanone and trichlorethylene. Most of these chemicals can cause headaches, drowsiness, nausea, lethargy and vomiting, symptoms that were all significantly associated with chemical exposure.

Eye, skin and respiratory system irritation

In all, 10 of the 17 symptoms associated with the eyes, skin and respiratory system were significantly associated with chemical exposure. This is consistent with the findings that many of the VOCs found in footwear factories can cause irritation of the eyes, skin and respiratory system. In addition to VOCs, many workers in these factories used water-based cements that contained HDI. Isocyanate exposure can result in irritation as well as debilitating effects including asthma and dermatitis. Isocyanates can be absorbed into the body through both the inhalation and dermal route. In the assembly and stockfit departments of the footwear factories and throughout the equipment factory, there was regular skin contact with these isocyanate-containing water-based cements. The workers applied the cements to the footwear or equipment parts by hand using sponge tools, toothbrushes or paintbrushes. While the tools differed between the factories, the overall application process was similar. The tools were replaced at regular intervals throughout the day because they would become unusable, caked with hardened cement. Workers in the equipment factory did not wear gloves when mixing or applying the water-based cements. In the industrial hygiene study of these factories, surface sampling and hand sampling for free isocyanates were performed. They were detected on over half of samples taken on surfaces, hand tools and on the workers’ hands. Over 40% of samples taken underneath gloves were also positive for isocyanates (Todd et al., 2008).

Musculoskeletal symptoms

Adjusted PORs were significantly elevated for two musculoskeletal symptoms: ‘pain or stiffness in hands, fingers, or wrists’ and ‘pain in waist, legs,
The workers at the four footwear and equipment factory all wore gloves that were inappropriate for protecting them against dermal absorption of chemicals. Cotton gloves were the most commonly used gloves across the footwear factories to protect their hands when handling warm shoe parts. Workers would wear a clear plastic glove over the cotton gloves when working with chemicals. When this was done, chemicals that penetrated the outer glove could then sit against the skin, causing greater skin absorption. A few of the workers wore latex surgical gloves. Fingertips were often cut off of these gloves to increase dexterity. Some of the chemicals used in the factories can be absorbed through the skin; frequent skin contact with chemicals can result in increased body burden of chemicals. Workers in the equipment factories rarely wore gloves for personal protection even when washing basketballs in open solvent baths. Across all the factories, there were no gloves used that could protect against exposure to isocyanates.

All the factories primarily used dilution ventilation through use of fans or open windows. The footwear factories had large exhaust hoods for some of the processes. The fans on these hoods were inadequate for removing vapors from the building. Factories D and A primarily used dilution ventilation for the organic vapor removal. Factories B and C used dilution ventilation and local exhaust ventilation for some of the cementing processes. Small hoods were used in Factory B when glue was applied to footwear parts. The effectiveness of these hoods was diminished as workers often removed shoe parts from the hoods, held them close to their faces and applied glue. The equipment factory only used dilution ventilation.

**Significance**

This study showed that footwear and equipment factory workers experienced adverse health effects due to exposures to chemicals (volatile organic solvents and water-based adhesives) and ergonomic hazards. The musculoskeletal symptoms were the highest across all the factories. The controls present in all the factories were not adequate to protect workers from exposure to organic vapors or isocyanates. In particular, workers in the equipment factory had the poorest controls.

These results point to the urgent need for extensive health effect and intervention studies of footwear and athletic equipment factory workers in developing countries. Health effect studies could motivate companies that are currently resistant to controlling exposures to chemicals. This study is particularly important due to the increasing use of water-based isocyanates in these factories. The potential health impacts from isocyanates could be devastating for tens of thousands of workers. The present study looked at only five contract factories; this is a small
fraction of the hundreds of contract factories associated with this one company alone. Well-targeted intervention studies should be conducted to determine which control measures will be most effective for reducing health hazards to chemicals and ergonomic hazards. In particular, new chemical application methods need to be developed to eliminate dermal and inhalation exposures from solvents and glues.

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