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A Model to Analyze Ergonomics Working Conditions

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An ergonomics and safety model to assess and evaluate the most critical industrial improvement areas in a developing nation. This study was initiated and supported by a Fortune 500 Corporation interested in improving its global operations in developing nations. This initiative was also fully supported by an emerging nation that was concerned with its ergonomics and safety problems. The model was tested and validated in the emerging nation and the results were used to further enhance the model so that it can be implemented and adapted to other similar work environments. The model provides a practical methodology that analyzes and evaluates an emerging nation's current work environments, suggests practical solutions, and recommends effective remedies.

ergonomics work environment design systems engineering
developing nations

1. INTRODUCTION

A comprehensive industrial ergonomics and safety (E&S) model was developed to recognize, evaluate, and analyze the most urgent industrial improvement areas in a developing nation. This study was undertaken as a research project for a Fortune 500 Corporation that has undertaken major global industrial

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initiatives. Due to the nature of the project and sensitivity of the results, this developing nation's name will not be mentioned throughout this analysis. To effectively develop a universal model, a developing nation was targeted as an alpha and beta testing ground. From the outset, the study had full support of the government regulatory officials and its environmental activists. The primary purpose of the corporation's effort was to develop and implement a practical E&S model that was capable of improving working conditions of its international employees, and subsequently enhancing work environments of other emerging economies (Chavalitsakulchai, 1992). This model prioritized E&S problems, suggested workstation re-engineering, developed solution processes, recommended resource allocation, and addressed other pertinent critical issues.

To help occupational ergonomists and safety practitioners, the paper follows systems engineering (SE) approach that leads its readers through various stages of the model and analyzes each situation by example. The model was based on a checklist that incorporated eight groups of hazards or risks (Wiker & Stultz, 1992). The classifications of the hazards were gathered from a comprehensive list of workstations and manufacturing environments commonly used in developing nations. E&S experts with various backgrounds were employed to develop the model and to validate its effectiveness (Hoque & Adalla, 1993). The model was intended to be practical, easy to use, and simple to understand. The model prioritizes different hazard categories and provides intuitive tables, charts, and figures that enable E&S subject matter experts to remedy the problems (Dickinson et al., 1992). The model incorporated ratings of seven alternatives that were ranked with numerical values ranging from 0 (*factor not known to be present*) to 6 (*imminent danger, immediate action required*).

2. BACKGROUND

The SE approach implemented in the analysis was carried out in order to identify most important and critical hazards and problems in the emerging country. The study was initiated by a Fortune 500 Corporation to design and develop an E&S model that could be adapted to other developing economies. The objective was to provide a basic recognition for setting up priorities for the model. Another objective was to assist the targeted nation in solving its E&S problems using the priorities. The model was tested and validated using the targeted nation's E&S statistical data, surveys, question

TABLE 1. Industrial Injuries in the Targeted Country

Number	Type of Industry	Number of Units	Employees (E)	Industrial Injuries (N)	Frequency Rate of Injuries (F)
1	Mining, quarry, gravel, sand, and clay	65	31,484	2,478	32.794
2	Food, beverages, and tobacco	420	159,678	978	2.552
3	Textiles and wearing apparel products	615	189,657	678	1.489
4	Wood and wood products	302	43,895	4,523	42.934
5	Paper and paper products	195	634,566	1,678	1.102
6	Chemicals and petroleum products	521	83,145	4,567	22.889
7	Non-metallic mineral products	156	27,865	3,467	51.843
8	Basic metal industries	167	24,587	7,345	124.473
9	Fabricated metal products and machinery	609	67,897	8,935	54.831
10	Production and transportation equipment	170	35,678	4,562	53.278
11	Construction	156	35,678	3,412	39.847
12	Transportation and communications	2,567	58,956	3,698	26.131
13	Trade, restaurants, and hotels	892	265,789	897	1.406
14	Other manufacturing industries	12	26,435	2,346	36.978
15	Government industries	87	786	87	46.120
16	Other occupations	6,895	126,423	871	2.871
	TOTAL	13,829	1,812,883	50,522	

Notes. $F = \dfrac{(N)\times(1{,}000{,}000)}{(E)\times(2{,}400)}$ for 2,400 working hours/employee/year.

naires, qualitative, and quantitative responses. Information was gathered from 80 industrial units covering about 40,000 employees (Brass, 1990).

In 1994, the population of the focused country was about 65 million, out of which about 6 million were living in the capital or its surrounding areas. Most of the heavy and modern industries were located in or around the capital (Bongers, de Winter, Koimpier, & Hildebrandt, 1993). The labor force was about 28 million, of which about 5.5 million were working in various industrial enterprises. The nation's statistics pertaining to E&S injuries were obtained from the country's Workmen's Compensation Fund Organization (WCFO), a branch of the government supported by the United Nations and World Bank (Tubich, 1991). Table 1 is a summary of the country's industries with most common injuries, number of employees, industrial injuries, and percentage frequency rate of the injuries for each industry for 10 years (1983 to 1993). Rankings shown in the table were based on an industry's importance to the country's economy and needs. The government bureau of statistics provided most of the information incorporated in this study.

The WCFO statistics covered more than 60% of the country's workforce. Small enterprises of fewer than 20 employees were not covered by the WCFO and, therefore, were not used in this study (Burdorf & Zondervan, 1990). The E&S injuries were available from WCFO covering more than 1,457,000 employees in 1994. During the 10-year period, 45,658 enterprises were inspected, including about 4,456 million employees. The statistics also revealed that, during the same 10-year period, the government's E&S laws and policies resulted in 4,674 warnings, 3,654 court orders requesting immediate improvements, and 79 court cases that resulted in severe fines and business closures. At the time of the study, the number of government inspectors enforcing E&S laws and regulations was 678 for the entire country (United Nations, 1992).

3. METHODOLOGY

Survey forms were prepared to address various E&S issues in various businesses. These surveys included (Chavalitsakulchai & Shahnavaz, 1989)

- 12 items of general factory data;
- 17 items of working conditions data;
- 60 items of work environment data;
- 70 items of E&S data; and
- 8 items for recommendations, priorities, and references.

The survey also contained a checklist of workstation E&S requirements and a database containing 12 different groups of hazards or risks. The E&S classification of certain hazards was taken from a comprehensive list of OSHA and NIOSH regulations, policies, practices, and guidelines. Due to time and resource constraints, only a limited number of the most common and critical hazards were identified and analyzed (National Institute for Occupational Safety and Health [NIOSH], 1993).

The data collected was from 82 enterprises. The hazard ratings consisted of seven different alternatives. The ratings ranged from 0 (*factor not known to be present*) to 6 (*imminent danger, immediate action required*; Chavalitsakulchai & Shahnavaz, 1991). The E&S information gathered was further divided into two categories: establishments with fewer than 100 employees and those with more than 100 employees. To identify and prioritize E&S hazards and to determine their associated risks, seven different industry groups were analyzed and compared (Karasek & Theorell, 1990).

4. SAFETY AND ERGONOMICS HAZARDS

The priority rating used to analyze the E&S data consisted of the following measurements (Ekberg et al., 1994):

0—*factor known not to be present*;
1—*factor not observed, not expected*;
2—*factor expected but not observed*;
3—*factor observed but considered under control*;
4—*factor is of concern, requires investigation*;
5—*factor is serious, requires action in near future*;
6—*imminent danger, immediate action required to prevent accident.*

Following are criteria used to identify, analyze, and evaluate the country's working conditions and hazards (Christiani, 1990):

- Mechanical and structural hazards
  1. Stationary dangerous parts;
  2. Falling or unstable structures, work pieces, loads, machines, objects;
  3. Moving parts;
  4. Cuts and bruises;
  5. Ejection of parts or particles;
  6. Risk of falling from elevated workplaces;
  7. Stumbling caused by waste or by slippery floor;

8. Unexpected burst of hydraulic or pneumatic pressure; and
9. Other.

- Noise and vibration (Wiker & Stultz, 1992)
  1. Too high noise level,
  2. Exposure to vibration, and
  3. Impulsive noise.
- Hazards of electrical current and charges
  1. Risk of electrical shock,
  2. Hazard caused by electric arc, and
  3. Electrostatic sparks.
- Hazards by environmental temperature and climatic conditions (Colombia, Colombini, & Occhipinti, 1993)
  1. Direct contact, burns;
  2. Radiant heat;
  3. Fire;
  4. Humidity; and
  5. Insufficient protection against climatic conditions (e.g., cold, heat, solar rays).
- Chemical hazards (Ekberg et al., 1994)
  1. Skin exposure to harmful substances,
  2. Risk of splashes (e.g., in the eye),
  3. Risk of chemical explosion,
  4. Incorrect labeling of chemicals, and
  5. Inhalation of
     - Organic solvents,
     - Other harmful gases and vapors,
     - Lead,
     - Other harmful smokes and fumes,
     - Silica dusts,
     - Asbestos dust,
     - Cotton and other fumes,
     - Other harmful dusts.
- Biological hazards
- Ergonomic disorders (Ohlsson, Attewall, Johansson, Ahlm, & Skerfving, 1994)
  1. Physical overload,
  2. Highly repetitive tasks,
  3. Compulsorily unchanging position of long duration,
  4. Insufficient lighting,
  5. Inadequate workstation designs, and
  6. Poor furniture.

- General
  1. Unsatisfactory personal protection,
  2. Lack of training, and
  3. Lack of personal hygiene and sanitary facilities.

5. ANALYSIS OF THE RESULTS

As previously was discussed, Table 1 represents a summary of the country's industries with most common injuries. Table 1 also highlights the number of employees in these industries, industrial injuries, and percentage frequency rate of the injuries for the 10 years. The ranking of Table 1 industries was based on an industry's importance to the country's economy as well as its present and future needs.

The prevalence of E&S hazards and their risks was at the level of about 50%. These hazards are identified in Table 2. This table ranks hazards according to their frequency and the percentage of factories with scores of more than 2. Table 2 identified the 15 E&S problem areas that required immediate attention and remedies (Getty, 1994). In this table, serious hazards were ranked according to their frequency—highest frequency of occurrence was rated as first, lowest as last.

Table 3 is similar to Table 2 in content. But this table further divided the country's E&S hazards into two categories, small enterprises with fewer

TABLE 2. Prioritization of the Serious Hazards Prevailing in the Workplace

Hazard Number	Factor	Factories With Score >2 (%)	Serious Hazard
10	Skin exposure	55	145
12	Cuts and bruises	54	139
4	Moving parts	61	137
7	Stumbling	57	129
14	Ejection	47	127
3	High level noise	62	125
8	Electricity	56	120
13	Labeling	49	115
5	Repetitive work	59	115
9	Unchanging position	56	114
6	Insufficient lighting	58	113
1	Personal protection	69	113
11	Workplace hygiene	55	112
15	Physical stress	45	111
2	Lack of knowledge	65	108

than 100 employees and large enterprises with more than 100 employees (Forget, 1992).

TABLE 3. Prioritization of the Serious Hazards in the Workplace for Small and Large Enterprises

Hazard Number	Factor	Serious Hazards	
		Small Enterprises	Large Enterprises
10	Skin exposure	38	107
12	Cuts and bruises	34	105
4	Moving parts	33	104
7	Stumbling	21	108
14	Ejection	20	107
3	High level noise	20	105
8	Electricity	19	101
13	Labeling	17	98
5	Repetitive work	16	99
9	Unchanging position	15	99
6	Insufficient lighting	15	98
1	Personal protection	14	99
11	Workplace hygiene	14	98
15	Physical stress	13	98
2	Lack of knowledge	13	95

TABLE 4. Hazard Factors Based on Industry Categories

Hazard Number	Factor	Industry Category			
		Textile	Chemical	Metal	Food
10	Skin exposure	50	37	41	17
12	Cuts and bruises	41	39	38	21
4	Moving parts	42	36	37	21
7	Stumbling	38	35	38	18
14	Ejection	30	36	39	22
3	High level noise	48	30	32	15
8	Electricity	29	37	38	16
13	Labeling	27	39	36	13
5	Repetitive work	23	38	35	19
9	Unchanging position	39	37	22	16
6	Insufficient lighting	42	31	27	13
1	Personal protection	43	30	26	14
11	Workplace hygiene	41	29	30	12
15	Physical stress	44	28	28	11
2	Lack of knowledge	38	29	27	14

Table 4 is also similar to the previous tables. This table further categorizes the nation's serious hazards into four primary industries: textile, chemical, metal, and food. The statistics presented in this table greatly assisted the E&S efforts (Harris, 1992).

Comparative analysis of Tables 1, 2, 3, and 4 indicates that large industries had the majority of serious hazards due to their lack of adherence to the E&S practices policies and guidelines. Analyses of these tables also indicate that among all industries with serious problems, textile had more E&S injuries than chemical, metal, and food industries. In comparison to other injuries, skin exposure was the most predominant E&S problem in this country's industries.

6. DISCUSSION OF THE RESULTS

As a result of this study, E&S problems could be effectively analyzed, and accurately identified using the model with a relatively small sample size of enterprises. The SE approach to the problem recognized priorities and focused on the high-risk areas. Our research indicated that the developing nation's E&S problems were identical to other similar nations, but with different emphases. Our model concluded that, in an emerging nation, training and information were the first criteria to stress, improve, and upgrade standards (Linton, 1990).

Figure 1 is a presentation of the country's frequency of industrial injuries for the previous 10 years based on different types of industries. This figure is a supplement to Table 1 and is based on the same statistical data. As this figure illustrates basic metal industries (No. 8) had the highest frequency number of injuries and E&S violations (Kivi & Mattila, 1991). This relatively high number of injuries was due to employees working near smelting furnaces and constantly being exposed to heat, fumes, chemicals, and hazardous operating equipment. The second highest percentage of injury frequency corresponded to fabricated metal products and machinery industry (No. 9). The contributing factors to the high-level percentage of injury frequency in No. 9 were similar to the No. 8 industries. The third highest percentage of injury frequency pertained to production and transportation equipment industry (No. 10). In this industry the workers had to work with sharp objects, heavy pieces of equipment, and moving machinery. Other frequency rates were also high because of the lack of safe and healthy work environments and insufficient E&S policies and practices in the industries (Oxenburgh, 1991).

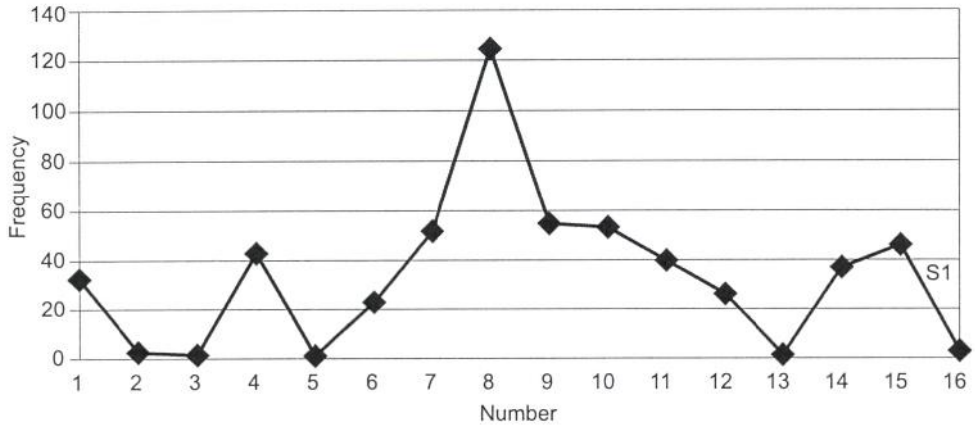

Figure 1. Frequency (%) and number of injuries in different industries. *Notes.* S1 represents one unit size or dimension—to help graph identification and presentation

Figure 2 is a presentation of a number of critical hazards in the targeted nation with respect to different environmental, physical, and psychological factors (e.g., cuts and bruises, moving parts, lack of knowledge). The most serious prevailing hazard was skin exposure to environmental elements such as extreme variation in temperature (e.g., heat and cold), chemicals, and so forth. In most cases, employees had no knowledge of their workplace safety laws, regulations, procedures, guidelines, and policies. In most workplaces employees lacked safety glasses, helmets, and other protective devices (Sen, 1984). Most of the factories visited had no ventilation systems (e.g., air conditioning and heating systems). Workstations were very confined and had poor lighting conditions. Fire safety was a major problem in most places of work. Assembly lines lacked fire protection equipment and most areas were prone to fire hazards. Most factories could not afford first aid facilities and had no knowledge of first aid procedures.

Figure 3 is a comparative analysis of most commonly found hazards in four primary industries: textile, chemical, metal, and food. Predominantly the textile industry has had the largest number of hazards, complaints, and injuries. This was primarily due to outdated equipment and highly stressful working conditions (Karasek & Theorell, 1990). Other reasons for the increased number of hazards, complaints, and injuries in the textile industry have been predominant use of children and their availability in most remote locations. Unfortunately, enforcing child labor laws in the textile industry by the country's law enforcement agencies has not been a national priority due to remoteness of most locations, lack of education, insufficient funds, and poor personal hygiene.

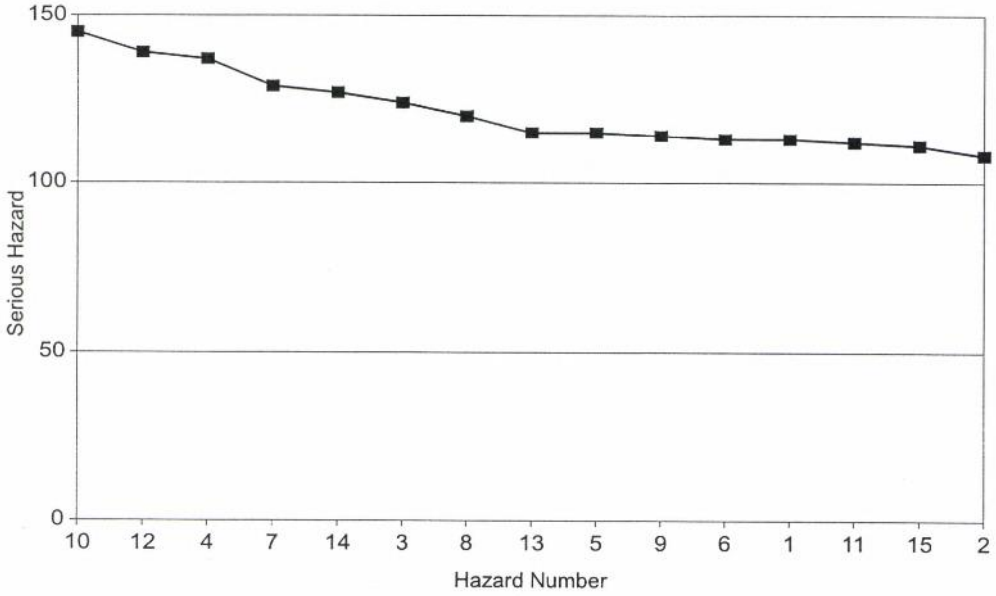

Figure 2. Prevalence of critical hazards and risks in industries.

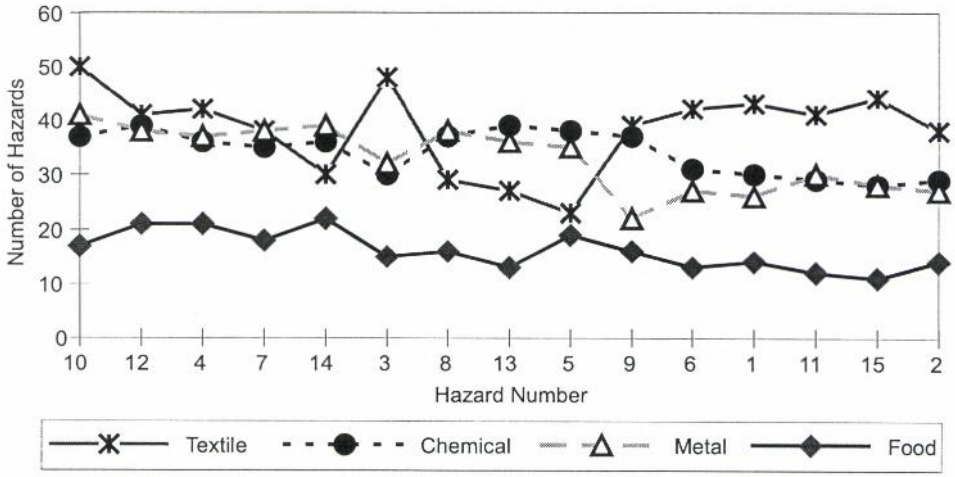

Figure 3. Prevalence of most common hazards and risks in four major industries.

7. CONCLUSIONS

This paper discussed an ergonomics model that analyzes working conditions and safety problems of developing nations. The model was based on a checklist that incorporated nine E&S groups of hazards and risks. The checklist was used as a blueprint and a foundation to evaluate and guide E&S activities in most developing nations. The model had two primary

purposes: to help professional ergonomists and safety engineers in the developing nations to effectively answer their E&S problems, and to initiate preventive measures that would eliminate root causes of the problems so that they would not occur again. The model was designed to be user friendly and practical (Hendrick, 1991). The process incorporated ratings of seven alternatives that were ranked with numerical values and ranged from 0 (*factor not known to be present*) to 6 (*imminent danger, immediate action required*).

The model was developed for a Fortune 500 Corporation to improve its work environments in various emerging nations. To validate accuracy, and integrity of the results, the model was implemented in an emerging nation, and the focused country was used for alpha and beta testing. The model identified the most common injuries and hazards in various industries and their frequency rate of occurrence (Sen, 1984). The study further analyzed E&S hazards by categorizing them into small and large enterprises. It also grouped serious hazards into industry type category (e.g., textile, chemical, metal, and food). Besides, the model determined the most frequent hazards prevailing in the workplace, prioritized serious hazards, and ranked hazards for small and large enterprises (Waersted & Westgaard, 1991).

REFERENCES

Bongers, P.M., de Winter, C.R., Koimpier, M.A.J., & Hildebrandt, V.H. (1993). Psychosocial factors at work and musculoskeletal disease. *Scandinavian Journal of Work, Environment and Health, 19*, 297–312.

Brass, P. (1990). Endemic placenta accreta in a population of remote villagers in Papua New Guinea. *British Journal of Obstetrics and Gynecology, 97*(2), 167–174.

Burdorf, A., & Zondervan, H. (1990). An epidemiological study of low-back trouble over a one-year period. *Spine, 9*(2), 106–119.

Chavalitsakulchai, P. (1992). *Ergonomics for the improvement of health and safety of female workers in industrially developing countries*. Doctoral dissertation (1992:109), Luleå University of Technology, Department of Human Sciences, Sweden. Available: http://epubl.luth.se/avslutade/0348-8373/109/index.html

Chavalitsakulchai, P., & Shahnavaz, H. (1989). A study of health, working conditions and working life of female shift workers in a large textile industry in Thailand. *Occupation Accidents, 12*, 245–250.

Chavalitsakulchai, P., & Shahnavaz, H. (1991). Problems of ergonomics in five different industries in Thailand. In Y. Quéinnec & F. Daniellou (Eds.) *Proceedings of the 11th Congress of International Ergonomic Association, Paris, France, 1991* (pp. 1565–1567). London, UK: Taylor & Francis.

Christiani, D.C. (1990). Occupational health in developing countries. *American Journal of Industrial Medicine, 17*, 393–401.

Colombia, A.M., Colombini, D., & Occhipinti, E. (1993). Ergonomic analysis and redesign of materials handling tasks in a chemical plant: A field study. In W.S. Maras, W. Karwowski, J.L. Smith, & L. Pacholski (Eds.), *The ergonomics of manual work* (pp. 667–670). London, UK: Taylor & Francis.

Dickinson, C.E., Campion, K., Foster, A.F., Newman, S.J., O'Rourke, A.M.T., & Thomas, P.G. (1992). Questionnaire development: An examination of the Nordic Musculoskeletal Questionnaire. *Journal of Applied Ergonomics, 23*, 197–201.

Ekberg, K., Bjorkqvist, B., Malm, P., Bjerre-Kiely, B., Karlsson, M., & Axelson, O. (1994). Case-control study of risk factors for disease in the neck and shoulder area. *Occupational and Environmental Medicine, 51*, 262–266.

Forget, G. (1992). Occupational health and development: An overview of the situation. *IDRC Reports: Perils in the Workplace, 20*(1), 4–7.

Getty, R.L. (1994). Physical demands of work are the common reference for an integrated ergonomics program. In *Proceedings of 38th Human Factors and Ergonomics Society Annual Meeting* (pp. 683–687). Santa Monica, CA, USA: Human Factors and Ergonomics Society.

Harris, C. (1992). Working to stay alive. *IDRC Reports: Perils in the Workplace, 20*(1), 7–10.

Hendrick, H. (1991). Ergonomics in organizational design and management. *Ergonomics, 34*, 743–756.

Hoque, M.M., & Adalla, C.B. (1993). Integrated gender issues into farmer-participatory research: The case of vegetable IPM technology generation in Calamba, Laguna, Philippines. *Journal of Farming Systems Research-Extension, 3*, 1–11.

Karasek, R., & Theorell, T. (1990). *Healthy work, stress, productivity, and the reconstruction of working life*. New York, NY, USA: Basic Books.

Kivi, P., & Mattila, M. (1991). Analysis and improvement of work postures in the building industry: Application of computerized OWAS method. *Applied Ergonomics, 22*(1), 43–48.

Linton, S.J. (1990). Risk factors for neck and back pain in a working population in Sweden. *Work and Stress, 4*, 41–49.

National Institute for Occupational Safety and Health (NIOSH). (1993). *Health hazard evaluation report*. Cincinnati, OH, USA: U.S. Department of Health and Human Services, NIOSH.

Ohlsson, K., Attewall, R.G., Johansson, B., Ahlm, A., & Skerfving, S. (1994). Assessment of neck/upper extremity disorders by questionnaire and clinical examination. *Ergonomics, 37*, 891–897.

Oxenburgh, M.S. (1991). *Increasing productivity and profit through health and safety*. North Ryde, NSW, Australia: CCH International.

Sen, R.N. (1984). Application of ergonomics to industrially developing countries. *Ergonomics, 27*(10), 1021–1032.

Tubich, G.E. (1991). The foundry—Its real potential health hazards. In *Proceedings of the Symposium on Occupational Health Hazard Control Technology in the Foundry and Secondary Non-Ferrous Smelting Industries* (NIOSH Publication No. 81–114, pp. 1–13). Cincinnati, OH, USA: U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health (NIOSH). (National Technical Information Service [NTIS] No. PB 167–710)

United Nations. (1992). *Statistical yearbook* (37th issue). New York, NY, USA: Author.

Waersted, M., & Westgaard, R.H. (1991). Working hours as a risk factor in the development of musculoskletal complaints. *Ergonomics, 34*(3), 265–276.

Wiker, S.F., & Stultz, M. (1992). NIOSH work practices guide or manual lifting: Significance of posturally-based differences in perceived stress in lifting tasks of equivalent merit. In S. Kumar (Ed.), *Advances in industrial ergonomics and safety IV* (pp. 607–614). London, UK: Taylor & Francis.