American Journal of Industrial Medicine 19:433–445 (1991)

Reproductive Hazards of Fire Fighting I. Non-Chemical Hazards

Jacqueline Agnew, RN, PhD, Melissa A. McDiarmid, MD, MPH, Peter S.J. Lees, PhD, CIH, and Richard Duffy, MS

Fire fighters are regularly exposed to chemical and non-chemical agents that have known or suspected adverse effects on reproductive health. Although chemical agents have received some attention, non-chemical hazards such as heat, noise, and physical exertion have only recently been examined for their reproductive effects. There is evidence that heat, noise, and physical exertion may affect various endpoints of reproductive health, including fertility, fetal loss, and growth parameters of the offspring. In particular, hyperthermia, a major fire fighting hazard, has been shown to impair male fertility and may also be teratogenic. Further study of the potential reproductive effects of this and other common non-chemical agents in the fire environment is needed to ensure the reproductive health of male and female fire fighters.

Key words: reproductive health, hyperthermia, noise, physical activity, stress, radiation, biological agents, fire fighting exposures

INTRODUCTION

Awareness of the existence of potential reproductive hazards in the workplace has increased dramatically in recent years. Attention has focused primarily on hazards facing pregnant women workers, although issues concerning male reproductive risk are beginning to be appreciated. The spectrum of potential reproductive hazards includes: physical hazards, such as temperature extremes and ionizing radiation; ergonomic and psychological stress; biological agents; and chemical agents, including irritant gases, asphyxiant gases, and other toxins such as mutagens and teratogens. Assessment of the effects of these classes of agents on reproductive outcome is essential to the development of administrative policy options that minimize the risk of adverse reproductive outcome in workers while protecting the employment opportunities of the affected worker. The chemical hazards in this work setting are reviewed in the accompanying article by McDiarmid et al. [1991].

Department of Environmental Health Sciences, School of Hygiene and Public Health, The Johns Hopkins University, Baltimore, MD (J.A., M.A.M., P.S.J.L.).
Office of Occupational Safety and Health, International Association of Fire Fighters, Washington, DC (R.D.).
Address reprint requests to Dr. Jacqueline Agnew, Department of Environmental Health Sciences, School of Hygiene and Public Health, The Johns Hopkins University, 615 N. Wolfe Street, Baltimore, MD 21205.
Accepted for publication August 28, 1990.

The fire service poses a unique work environment wherein all classes of reproductive hazards may be found. The health impact of these hazards on fire fighters, however, is not clear. As the number of female fire fighters increases, and as knowledge of both male and female reproductive toxins expands, attention must be directed to reconciling the scientific evidence for and interpreting the presence of reproductive toxins in the fire fighting environment with fair and equitable employment policies.

The magnitude of reproductive dysfunction is significant, spanning infertility, fetal loss, and malformations. The proportion of infertile couples in the United States is estimated to range from 8% to 13% [Mosher, 1988; Pratt et al., 1984]. The demand for physician consultation regarding infertility rose by 30% between 1968 and 1980 [Arab and Cates, 1983]. Infertility is typically defined as the inability to conceive after one or more years of intercourse without contraception. The conception rate per menstrual cycle of normal couples of reproductive age having unprotected intercourse approaches 50%. However, the viable pregnancy rate, i.e., pregnancy resulting in the birth of a viable child, is about 25% [Soules, 1985]. Estimates of total pregnancy loss, including very early pre- and post-implantation embryonic losses, are as high as 75% of all conceptions [Arab and Cates, 1983; Kline and Stein, 1985]. Major fetal malformations occur in about 3% of liveborn babies, and other impairments such as low birth weight occur in many more [Kalter and Warkany, 1983].

Studies of infertility have not specifically examined the fire fighting profession, although several have assessed the effects of agents to which fire fighters are subjected. Spontaneous abortion rates, a complex area of research, have not been examined in this group. A recent Canadian investigation, however, has suggested that the risk of certain birth defects is higher in children whose fathers are fire fighters than in children whose fathers are policemen [Olshan et al., 1990].

Until recently, the study of occupational reproductive hazards has focused primarily on female reproductive health. This focus has probably been stimulated by the entrance of women into traditional male sectors of the workforce. There is good evidence, however, that workplace hazards to male reproductive health have been previously overlooked. For the few reproductive toxins that have been well studied, evidence demonstrates effects mediated through both males and females [Paul and Himmelstein, 1988]. In fact, one author has suggested that males may be more sensitive to exposure to reproductive toxins [Meistrich, 1986]. It is now clear that effects in both males and females need to be considered when studying an agent's potential as a reproductive hazard.

This paper summarizes the potential effects on reproductive health of non-chemical hazards in the fire fighting environment (Table I). It is recognized that the frequency and intensity of exposure to these agents by fire fighters varies widely and that non-chemical exposures have not been characterized quantitatively for fire fighting to the same extent as many chemical exposures. However, for the sake of completeness, a wide range of exposures is addressed. When information is available, both male and female effects are considered, but for most agents the need for further research is strikingly apparent.

HEAT

Exposure to heat is an obvious hazard of fire fighting. Even when ambient temperatures are not extreme, wearing turnout gear and other protective clothing

TABLE I. Summary of Potential Reproductive Effects of Non-Chemical Exposures*

	Animals		Human		
Agent	Male	Female	Male	Female	Comments
Hyperthermia	Decreased sperm [Henderson et al., 1986)	Fetal malformations [Edwards, 1986]	Decreased sperm [Henderson et al., 1986]	Birth defects, with maternal fever [Pleet et al., 1981; Clarren et al., 1979]	Sperm decreases can resolve with time
			Abnormal sperm [Procope, 1965]	Hearing loss in children of exposed mothers (?) [Lalande et al., 1986]	Some fire fighting tasks may elevate pregnant women's body temperatures to levels dangerous to the fetus
Physical activity	—	Few effects noted on fetus [Lotgering et al., 1985]	Trauma: testicular damage, hormonal change, impotence [Steeno and Pangkahila, 1984]	Amenorrhea [Armstrong, 1986; Warren, 1983] strenuous job: prematurity and low birth weight [Naeye and Peters, 1982; Mamelle et al., 1984; Saurel-Cubizoles et al., 1987; Saurel-Cubizoles and Kaminski, 1987]	
				Heavy lifting or standing on job: miscarriages (?) [Taskinen et al., 1986; McDonald et al., 1988]	
				At 20+ weeks pregnant: problem with balance and agility [AMA Council Sci Affairs, 1984b]	
Noise	—	Increased litter resorption and fetal mortality, decreased fetal weight [Kimmel et al., 1976; Nawrot et al., 1980]	—	Increased rates of birth defects and low birth weight (?) [Edmonds et al., 1979; Jones and Tauscher, 1978; Knipschild et al., 1981; Schell, 1981]	Animal studies at ≥ 100 db (very loud); human studies near airports only
		Fetal malformations (?) [Kimmel et al., 1976; Cook et al., 1982]			Evidence weak for noise as a reproductive hazard
Psychological stress	Decreased testosterone level [McGrady, 1984]	—	Decreased testosterone levels [McGrady, 1984]	Amenorrhea [Fries et al., 1974]	
			Negative behavioral effects [U.S. Congress, OTA, 1985]	Negative behavioral effects [U.S. Congress, OTA, 1985]	
Ionizing radiation	Decreased sperm, infertility [Meistrich, 1986]	Infertility [Baker, 1971]	Decreased sperm, infertility [Meistrich, 1986]	Infertility [Baker, 1971]	Prenatal exposure can cause childhood cancer [Harvey et al., 1985]
	Sperm abnormalities [Young et al., 1982]	Fetal malformations [Russell, 1950]		Birth defects [Miller, 1956; Yamazaki et al., 1954]	Postnatal exposure can cause cancer [Warren and Mays, 1983]

*,? indicates that strength of study design or results do not justify definite conclusions.

under conditions of physical exertion can contribute to a rise in core body temperature [White and Hodus, 1987; Duncan et al., 1979].

Heat is a non-chemical agent that affects both males and females. Its toxicity in males derives from impairment of spermatogenesis. The location of the testes within the scrotum provides the thermoregulation and reduced temperature necessary for spermatogenesis. High ambient air temperatures may inhibit thermal loss through the scrotum, leading to a rise in testicular temperature [Procope, 1965]. Infertile men without varicocele have been noted to have significantly higher intrascrotal temperatures than men without fertility problems, although the reasons for this temperature difference are not fully understood [Zorgniotti and Sealfon, 1988; Mieusset et al., 1987b].

Both animal and human studies have confirmed the sensitivity of sperm production to extrinsic heat [Henderson et al., 1986]. Studies of male animals in elevated environmental temperatures have indicated that levels of reproductive hormones can be altered significantly, a factor that may be related to observed decreases in sperm production [Bedrak et al., 1980]. Sperm production in humans is known to decrease when testicular temperature is raised by experimental techniques; under the same conditions, the number of abnormal sperm also tends to increase [Mieusset et al., 1987a; Procope, 1965]. Normal sperm production eventually resumes after return to baseline temperature, but the timing depends on the duration and extent of hyperthermia experienced. Similar transient effects have been noted in men who have suffered a febrile illness [Lazarus and Zorgniotti, 1975].

Although one epidemiological case-control study has suggested that occupations in which men are exposed to heat are associated with male infertility [Rachootin and Olsen, 1982], the fire fighting profession was not specifically included. Currently, there is disagreement regarding the potential for hot working conditions to cause adverse effects on male fertility [AMA Council on Scientific Affairs, 1984a; Levine, 1984]. There is, however, general agreement that further research on this question is warranted.

In some animal studies, teratogenesis has been associated with exposure to hot environments. One review presents evidence that temperature elevations of 1.5–2.5°C are teratogenic in several animal species and cautions that the study of hyperthermia as a potential human teratogen has been neglected [Edwards, 1986]. Congenital anomalies of the central nervous system have occurred in children born to women who had been febrile during pregnancy [Pleet et al., 1981; Clarren et al., 1979], but it is unknown whether these effects have been due to fever or to the infectious agents responsible for the illness. The use of saunas and hot tubs by pregnant women provides additional evidence of the effect of hyperthermia, and at least one study has suggested an association with neural defects [Miller et al., 1978]. Sauna use, in contrast to fire fighting, allows women to leave voluntarily when temperature elevations become uncomfortable [Harvey et al., 1981]. Based on the available evidence, a limit of 38.9°C has been considered to be the minimum core temperature likely to pose a teratogenic hazard to the human embryo or fetus [AMA Council on Scientific Affairs, 1984a].

Some investigators have concluded that hot working environments encountered by women workers in general [AMA Council on Scientific Affairs, 1984a], and more specifically by women fire fighters [Evanoff and Rosenstock, 1986], probably do not increase the risk of adverse pregnancy outcomes. Recent studies suggest, however, that routine fire fighting duties can pose a risk of hyperthermia. A comparison of the physiologic effects of different types of turnout clothing (typical fire fighting outfits) was conducted in the Southwestern United States [Veghte, 1987]. Five fire fighters completed a set of relevant fire fighting tasks in hot ambient temperatures of 38.1–41.2°C. Although the highest average core temperature on completion of testing was 38.5°C, a maximum temperature of 39°C was recorded for one participant and two others reached maximums of 38.8°C. In a structural fire, a fire fighter might spend up to 30 min in temperatures ranging from 60°C to 300°C [Veghte, 1987].

Most thermal regulation research has been directed at protective clothing required for response to hazardous materials incidents. This specialized duty can be associated with significant increases in body temperature. The core temperatures of experienced male fire fighters rose to a mean of 38.3°C while performing typical tasks for an average of only 37 min while wearing impermeable protective suits and self-contained breathing apparatus (SCBA) in cool (2°C), non-fire conditions [Smolander et al., 1985]. In another study, nine moderately fit men performed treadmill exercise classified as low work intensity in a neutral environment (22.8°C, 55% relative humidity) while wearing various types of protective clothing and respirators [White et al., 1987]. Subjects wearing impermeable clothing and SCBA exhibited an average increase in core temperature to 38.5°C, the highest of all the test groups. Under these conditions, testing had to be terminated for three of the men because their core temperatures rose above the established safety criterion of 39°C. Subjects wearing turnout gear and SCBA in this same neutral environment exhibited an average increase in core temperature to 37.9°C, with one case exceeding the 39°C limit.

Whereas the above experiments were performed on moderately fit fire fighters, the effects of working in protective clothing and/or hot environments are not well understood for unconditioned individuals or for pregnant women, who are known to have decreased heat tolerance. If one accepts 38.9°C as the core temperature threshold for human teratogenesis, the experimental evidence cited above suggests that routine fire fighting tasks could pose a risk to the developing fetus.

PHYSICAL ACTIVITY

In addition to effects on sperm production due to the contribution of exercise levels to hyperthermia, male fire fighters can experience job-related injuries that result in pelvic or intrascrotal trauma. Depending on severity, injuries can result in impaired fertility from testicular damage, hormonal disruption, or impotence [Steeno and Pangkahila, 1984]. With the exception of these effects, study of the reproductive effects of physical activity has concentrated on females and pregnancy outcome.

Women who engage in rigorous exercise sometimes develop amenorrhea due to hypothalamic-pituitary axis effects [Armstrong, 1986]. This effect has been reported in ballet dancers, long-distance swimmers, runners, and other athletes. This condition generally reverses when the intensity of training is reduced and is not thought to have permanent consequences [Cumming and Rebar, 1983]. Although it is unlikely that normal fire fighting duties alone would account for activity levels sufficient to cause amenorrhea, women fire fighters who engage in intensive physical conditioning programs to achieve high levels of fitness may experience transient amenorrhea.

An extensive review of the effects of exercise on pregnant animals (primarily sheep) has concluded that physiological changes in the fetus during maternal exercise are slight, suggesting that acute exercise does not represent a major fetal stress [Lotgering et al., 1985]. The reviewer noted, however, that in humans, significant differences in uterine contractility and the upright position may affect fetal responses differently. Little is known with regard to the effects of long-term exercise training on pregnancy in animals or humans [Lotgering et al., 1985].

A limited number of epidemiological studies of pregnancy outcome for working mothers have addressed physical job demands. Spontaneous abortions were found to be associated with continuous heavy lifting in one study [Taskinen et al., 1986] and with lifting and standing in another [McDonald et al., 1988]. Rates of pre-term delivery and low birth weight have been associated with arduous working conditions such as standing, carrying heavy loads, and performing tiring jobs [Naeye and Peters, 1982; Mamelle et al., 1984; Saurel-Cubizolles et al., 1985; Saurel-Cubizolles and Kaminski, 1987]. When assessing these studies, it is important to consider whether socioeconomic factors associated with arduous work were adequately controlled. Another study indicated that moderate physical activity may protect against preterm delivery [Berkowitz et al., 1983]. Well designed epidemiological studies are needed to resolve this issue.

Safety is a concern during the second and third trimesters of pregnancy as weight, center of gravity, and musculoskeletal changes make it more difficult to perform some activities. The American Medical Association has published guidelines for various job tasks during pregnancy [AMA Council on Scientific Affairs, 1984b]. According to these guidelines, limitations are justified fairly early in a pregnancy for fire fighting tasks such as climbing ladders and poles, repetitive heavy lifting, and repetitive stooping (at 20 weeks of gestation) and for prolonged standing (at 24 weeks).

NOISE

Sources of noise in a fire fighter's work environment include sirens, air horns, vehicles, and auxiliary power equipment. Noise surveys, performed by the National Institute for Occupational Safety and Health (NIOSH) in several U.S. fire departments during investigations of hearing loss in fire fighters, have revealed time-weighted average (TWA) noise exposures in the 60–85 dBA range [NIOSH, 1982, 1990]. Although this is below the current Occupational Safety and Health Administration (OSHA) standard of 90 dBA for an 8 hr TWA exposure, established to prevent hearing loss, noise levels emitted during simulated response calls average in the mid-90 dBA range for most riding positions on pumpers and ladder trucks, and range up to 118 dBA [NIOSH, 1985]. Findings of hearing loss in fire fighters also strongly suggest that noise exposure is a hazard in this occupation [NIOSH, 1988].

There is no evidence to suggest the existence of any male reproductive effects resulting from noise exposure [OTA, 1985]. Most studies have concentrated on potential adverse effects of noise on pregnancy outcome. Several laboratory investigations have been carried out on pregnant rodents, exposed in most cases to very loud levels (usually >100 dB) of continuous or intermittent noise. Findings have supported an exposure effect manifested most often by increased litter resorption, increased fetal mortality, and decreased fetal weight [Kimmel et al., 1976; Nawrot et al., 1980]. Fetal malformations have been demonstrated less consistently [Kimmel et al., 1976; Cook et al., 1982]. It is unknown whether these observations are due to a direct effect on the developing embryo or fetus or if they are caused by the maternal physiologic response to the stress of noise exposure. The appropriateness of these species as models for the prediction of human reproductive response to noise is similarly unknown [Meyer et al., 1989].

Relevant epidemiologic studies on the reproductive effects of noise have dealt predominantly with the association between pregnancy outcome and noise levels near major airports [Ando and Hattori, 1977; Edmonds et al., 1979; Jones and Tauscher, 1978; Knipschild et al., 1981; Schell, 1981]. Although these studies have provided some suggestion that high levels of community noise may be associated with increased rates of birth defects and low birth weight, they must be interpreted with caution. Results have been inconsistent and are subject to criticism for methodologic problems [Meyer et al., 1989].

The association between occupational noise exposure and reproductive outcome has not been thoroughly investigated, although one group [Lalande et al., 1986] has reported an increased risk of high-frequency hearing loss (>10 dB at 4,000 Hz) in children whose mothers were exposed during their pregnancy to 8 hr TWA of 85–95 dBA. Another study found an increased risk of hormonal disturbances and infertility in women who reported exposure to noise on the job [Rachootin and Olsen, 1982]. Studies to date have concentrated on industrial job exposures and have not consistently addressed possible socioeconomic influences. However, if their results are confirmed, they could be relevant to the pregnant fire fighter whose field noise exposures are comparable to those demonstrated by NIOSH in the above investigations.

PSYCHOLOGICAL STRESS

Fire fighters may experience stress related to the characteristics or demands of the job, including the unpredictable and emergency nature of the work, erratic work schedules, and prevalent hazards. Various indicators of psychological distress have been documented for fire fighters involved in major disasters [McFarlane, 1988] and potentially toxic exposures [Markowitz et al., 1987]. Psychological stress has been examined in a limited number of studies for its potential reproductive effects on both males and females.

Psychological stress has been demonstrated to cause depressed testosterone levels in both humans and rodents, but the relationship of this effect to infertility is not clear [McGrady, 1984]. In women, hormonal responses to stress can bring about amenorrhea, thereby affecting fertility at least temporarily [Fries et al., 1974]. A well recognized effect of psychological stress, whether from the job or other sources, is interference with sexual relationships through behavioral changes. Significant degrees of stress can bring about impotence in men or vaginismus in women [OTA, 1985]. More commonly, stress is likely to bring about a general decrease in interest in sexual activity.

The literature regarding work-related psychological stress and pregnancy outcome is sparse. Shift work, one factor that could contribute to the level of job stress of a fire fighter, was found in one study of Swedish laboratory workers to be associated with increased rates of miscarriage [Axelsson et al., 1984]. Further study of this possible relationship is warranted.

RADIATION

Sources of ionizing radiation may be encountered during response to calls at medical care facilities, laboratories, certain industries, or some environmental spills. Although radiation is very uncommon in the fire fighting environment, it is discussed here because of its well recognized and potentially serious reproductive effects. Although radiation has been shown to cause heritable genetic mutations in insects and some mammals, mutagenesis in humans has been difficult to characterize, primarily due to study size limitations [Ritenour, 1986]. Chromosomal abnormalities have been induced, however, by in vitro exposure of human white blood cells to low-dose gamma radiation [Uchida, 1979].

High doses of ionizing radiation impair testicular function. Effects on the particularly sensitive spermatogonia result in decreased sperm production in humans and experimental animals [Meistrich, 1986], an outcome that is often transient depending on the dose of radiation received. At very high doses, such as those used for treatment of certain types of cancer, complete sterility may result [Lushbaugh and Casarett, 1976]. Abnormalities in sperm morphology have also been demonstrated in animals exposed to X-rays [Young et al., 1982].

In female animal studies, radiation has been shown to be capable of affecting all tissues of the reproductive tract. Because a female's full complement of oocytes is established before birth, these cells are susceptible to cumulative damage throughout their existence from the prenatal period until ovulation. Oocyte sensitivity to radiation differs among animal species, but there is evidence that humans may be among the most radio-resistant [Baker, 1971]. High doses of radiation, however, can cause sterility in women and can induce menopause [OTA, 1985].

Animal experiments have demonstrated that exposure to radiation can produce major malformations in the fetus [Russell, 1950; Lione, 1987]. Depending on the timing of the exposure, irradiation of pregnant mice and rats has resulted in growth retardation and abnormal development of the eyes, skeleton, and kidneys [Russell, 1950]. Human teratogenesis due to radiation has been studied primarily in children born to women who received substantial doses of radiation while pregnant, including pregnant survivors of the atomic bombs. Findings among these populations include microcephaly, mental retardation, and growth retardation [Yamazaki et al., 1954; Miller, 1956; Miller et al., 1972]. Although somewhat controversial, recent investigations have provided evidence that the risk of childhood cancers, such as leukemia, is higher in children who were exposed prenatally to relatively low doses of diagnostic X-rays [Harvey et al., 1985].

The well documented human reproductive effects of ionizing radiation justify protection of any potentially exposed worker and pregnant workers in particular. It must be stressed, however, that exposure opportunities in fire fighting are very uncommon, thus constituting only an infrequent and relatively unusual hazard for the fire fighter.

Although there is considerabe controversy regarding the reproductive effects of sources of non-ionizing radiation, such as communication equipment and video display terminals, there is no conclusive support to date for their direct effect in humans. In that fire fighter exposure to these sources is not greater than that of the general population, it is unlikely that non-ionizing radiation is a significant reproductive hazard for fire fighters.

BIOLOGICAL AGENTS

Although not predominantly a hazard of fire fighting, exposure to biological agents frequently arises out of fire fighters' emergency medical response duties and thus deserves mention in this review. Much attention has been directed recently to emergency response personnel and their potential exposure to blood-borne infectious agents, primarily to the hepatitis B virus (HBV) and human immunodeficiency virus (HIV). The United States Fire Administration (USFA) of the Federal Emergency Management Agency (FEMA) has issued recommendations regarding notification of health care workers and emergency response personnel on a "need to know" basis after exposure to a patient with a blood-borne disease [USFA/FEMA, 1988]. Fire service health and safety personnel have also been actively involved with the development of policy regarding no-cost availability of the hepatitis B vaccine for emergency response personnel.

Emergency medical personnel are at increased risk for HBV infection [Kunches et al., 1983; Valenzuela et al., 1985; Pepe et al., 1986], thereby increasing their risk of transmission of the virus to offspring and/or sexual partners. In a study of infants born to HBV-infected mothers, 10–50% of the children became infected perinatally with the virus [Chan et al., 1985]. Administration of hepatitis B immune globulin to the newborn is thought to decrease the risk of postnatal infection [Centers for Disease Control, 1990].

The potential for HIV transmission in the emergency medical setting is considerably less than for hepatitis B, and no cases of HIV have been conclusively determined as having been acquired during the performance of emergency medical service or public-safety job duties [CDC, 1989]. The likelihood of emergency response personnel developing AIDS from a work-related exposure is therefore believed to be remote, especially with the use of universal precautions. If a pregnant woman is infected, however, HIV is capable of crossing the placenta to infect the child [LaPointe et al., 1985]. Contact of the newborn during birth with infected maternal blood and secretions may also transmit the virus to the child [Cowan et al., 1984]. The risk of HIV transmission from an infected mother to her infant is estimated at 30–50% [CDC, 1987].

CONCLUSIONS

Several non-chemical agents in the fire service environment are known or suspected reproductive hazards. There has been only limited scientific assessment of the reproductive effects of the most frequently encountered agents, including heat, noise, physical activity, and psychological stress. Of the non-chemical reproductive hazards, ionizing radiation is the most thoroughly studied and understood, but fire fighter exposure is rare. Similarly, there is strong evidence that some viral agents pose a significant risk to the unborn fetus, but exposure opportunities for pregnant fire fighters are limited and are minimized through procedural and hepatitis B vaccination policies.

Current research findings for the agents reviewed above suggest that hyperthermia may pose a significant reproductive hazard for male fire fighters and fire fighters who are pregnant. Although this issue needs further exploration, it has implications for all fire fighting tasks that require physical exertion in protective clothing. Training, especially in hot weather conditions, has the potential for raising core body temperatures and, therefore, should be addressed along with active fire suppression when designing hyperthermia prevention strategies for pregnant fire fighters. There is also sufficient evidence to warrant further study of the relationship of occupational hyperthermia and male infertility.

The reproductive risks to male or female fire fighters of physical activity (except perhaps during late pregnancy) or psychological stress are less clear. The relationship of research findings on sustained noise exposure during pregnancy and subsequent hearing loss in children to the intermittent noise-exposure scenario encountered in fire fighting also needs to be clarified.

Further study of the reproductive risk of non-chemical agents is limited by the inadequate characterization of fire fighter exposures to many of these agents. Quantitative exposure data would markedly enhance the quality of risk assessment determinations and would facilitate better understanding of the hazards to the reproductive health of both male and female fire fighters.

REFERENCES

American Medical Association Council on Scientific Affairs (1984a): Effects of physical forces on the reproductive cycle. JAMA 251:247–250.

American Medical Association Council on Scientific Affairs (1984b): Effects of pregnancy on work performance. JAMA 251:1995–1997.

Ando Y, Hattori H (1977): Effects of noise on human placental lactogen (HPL) levels in maternal plasma. Br J Obstet Gynaecol 84:115–118.

Arab SO, Cates W (1983): The increasing concern with infertility: Why now? JAMA 250:2327–2331.

Armstrong DT (1986): Environmental stress and ovarian function. Biol Reprod 34:29–29.

Axelsson G, Lutz C, Rylander R (1984): Exposure to solvents and outcome of pregnancy in university laboratory employees. Br J Ind Med 41:305–312.

Baker TG (1971): Radiosensitivity of mammalian oocytes with particular reference to the human female. Am J Obstet Gynecol 110:746–761.

Bedrak E, Chap Z, Fried K (1980): Factors for consideration in the interpretation of the adverse effects of elevated environmental temperatures on reproduction in the male rat. Int J Biometeor 24: 117–128.

Berkowitz GS, Kelsey JL, Holford TR, Berkowitz RL (1983): Physical activity and the risk of spontaneous pre-term delivery. J Reprod Med 28:581–588.

Centers for Disease Control, U.S. Department of Health and Human Services (1987): Human immunodeficiency virus in the United States: A review of current knowledge. MMWR 36, No. S-6.

Centers for Disease Control, U.S. Department of Health and Human Services (1989): Guidelines for prevention of transmission of human immunodeficiency virus and hepatitus B virus to health care and public safety workers: A response to P.L. 100-607.

Centers for Disease Control, U.S. Department of Health and Human Services (1990): Protection against viral hepatitis: Recommendations of the Immunization Practices Advisory Committee (ACIP). MMWR 39, No. RR-2.

Chan SH, Tan KL, Goh KT, Lim C, Tsakok M, Oon JN, Ratnum SS (1985): Maternal child Hepatitis B virus transmission in Singapore. Int J Epidemiol 14:173–177.

Clarren SK, Smith DW, Harvey MA, Ward RH, Myrianthopoulos NC (1979): Hyperthermia: A prospective evaluation of a possible teratogenic agent in man. J Pediatr 95:81–83.

Cook RO, Nawrot PS, Hamm CW (1982): Effects of high frequency noise on prenatal development and maternal plasma and urine catecholamine concentrations in the C-1 mouse. Toxicol Appl Pharmacol 66:338–348.

Cowan MJ, Hellmann D, Chudwin D, Wara DW, Chang RS, Ammann AJ (1984): Maternal transmission of acquired immune deficiency syndrome. Pediatrics 73:382–386.

Cumming DC, Rebar RB (1983): Exercise and reproductive function in women. Am J Ind Med 4: 113–125.

Duncan HW, Garner GW, Bernard RJ (1979): Physiological responses of men working in fire fighting equipment in the heat. Ergonomics 22:521–527.

Edmonds L, Layde P, Erickson J (1979): Airport noise and teratogenesis. Arch Environ Health 34: 243–247.

Edwards MJ (1986): Hyperthermia as a teratogen: A review of experimental studies and their clinical significance. Teratogen Carcinogen Mutagen 6:563–582.

Evanoff BA, Rosenstock L (1986): Reproductive hazards in the workplace: A case study of women firefighters. Am J Ind Med 9:503–515.

Fries H, Nillus SJ, Pettersson F (1974): Epidemiology of secondary amenorrhea: A retrospective evaluation of etiology with special regard to psychogenic factors and weight loss. Am J Obstet Gynecol 118:473–479.

Harvey EB, Boice JD, Honeyman M, Flannery JT (1985): Prenatal exposure and childhood cancer in twins. N Engl J Med 312:541–545.

Harvey MA, McRorie MM, Smith DW (1981): Suggested limits to the use of hot tub and sauna by pregnant women. Can Med Assoc J 125:50–53.

Henderson J, Baker HWG, Hanna PJ (1986): Occupation-related male infertility: A review. Clin Reprod Fertil 4:87–106.

Jones FN, Tauscher J (1978): Residence under an airport landing pattern as a factor in teratism. Arch Environ Health 33:10–12.

Kalter H, Warkany J (1983): Congenital malformations—Etiologic factors and their role in prevention. N Engl J Med 308:491.

Kimmel CA, Cook RO, Staples RE (1976): Teratogenic potential of noise in mice and rats. Toxicol Appl Pharmacol 36:239–245.

Kline J, Stein Z (1985): Very early pregnancy. In Dixon RL (ed): "Reproductive Toxicology." New York: Raven Press, pp 251–265.

Knipschild P, Meijer H, Salle H (1981): Aircraft noise and birthweight. Int Arch Occ Environ Health 48:131–136.

Kunches LM, Craven DE, Werner BG, Jacobs LM (1983): Hepatitis B exposure in emergency medical personnel: Prevalence of serologic markers and need for immunization. Am J Med 75:269–272.

Lalande NM, Hetu R, Lambert J (1986): Is occupational noise exposure during pregnancy a risk factor of damage to the auditory system of the fetus? Am J Ind Med 10:427–435.

LaPointe N, Michaud J, Pekovic D, Chasseau JP, Dupuy JM (1985): Transplacental transmission of HTLV-III virus (letter). N Engl J Med 312:1325–1326.

Lazarus B, Zorgniotti A (1975): Thermoregulation of the human testis. Fertil Steril 26:757–759.

Levine RJ (1984): Male fertility in hot environment (letter). JAMA 252:3250–3251.

Lione A (1987): Ionizing radiation and human reproduction. Reprod Toxicol 1:3–16.

Lotgering FK, Gilbert RD, Longo LD (1985): Maternal and fetal responses to exercise during pregnancy. Physiol Rev 65:1–36.

Lushbaugh CC, Casarett GW (1976): The effects of gonadal irradiation in clinical radiation therapy: A review. Cancer 37:1111–1120.

Mamelle N, Laumon B, Lazar P (1984): Prematurity and occupational activity during pregnancy. Am J Epidemiol 119:309–322.

Markowitz JS, Gutterman EM, Link B, Rivera M (1987): Physiological response of firefighters to a chemical fire. J Hum Stress 13:84–93.

McDiarmid MA, Lees PSJ, Agnew J, Midzenski M, Duffy R (1991): Reproductive hazards of fire fighting II. Chemical hazards. Am J Ind Med 19:447–472.

McDonald AD, McDonald JC, Armstrong B, Cherry NM, Cote R, Lavoie J, Nolin AD, Robert D (1988): Fetal death and work in pregnancy. Br J Ind Med 45:148–157.

McFarlane AC (1988): The longitudinal course of posttraumatic morbidity: The range of outcomes and their predictors. J Nerv Ment Dis 176:30–39.

McGrady AV (1984): Effects of psychological stress on male reproduction: a review. Arch Androl 13:1–7.

Meistrich ML (1986): Critical components of testicular function and sensitivity to disruption. Biol Repro 34:17–28.

Meyer RE, Aldrich TE, Easterly CE (1989): Effects of noise and electromagnetic fields on reproductive outcomes. Environ Health Perspect 81:193–200.

Mieusset R, Bujan L, Mansat A, Pontonnier F, Grandjean H (1987a): Effects of artificial cryptorchidism on sperm morphology. Fertil Steril 47:150–155.

Mieusset R, Mansat A, Bujan L, Pontonnier F, Mondinat C, Grandjean H (1987b): Association of scrotal hyperthermia with impaired spermatogenesis in infertile men. Fertil Steril 48:1006–1011.

Miller P, Smith DW, Shepard NH (1978): Hyperthermia as one possible etiology of anencephaly. Lancet 1:519–521.

Miller RW (1956): Delayed effects occurring within the first decade after exposure of young individuals to the Hiroshima atomic bomb. Pediatrics 18:1–17.

Miller RW, Blot WJ (1972): Small head size after in-utero exposure to atomic radiation. Lancet 2: 784–787.

Mosher WD (1988): Fecundity and infertility in the United States. Am J Public Health 78:181–182.

Naeye RL, Peters EC (1982): Working during pregnancy: Effects on the fetus. Pediatrics 69:724–727.

Nawrot PS, Cook RO, Staples RE (1980): Embryotoxicity of various noise stimuli in the mouse. Teratology 22:279–289.

National Institute for Occupational Safety and Health, Centers for Disease Control, U.S. Public Health Service (1982): Newburgh Fire Department, Newburgh, New York, Health Hazard Evaluation Report HETA 81-059-1045.

National Institute for Occupational Safety and Health, Centers for Disease Control, U.S. Public Health Service (1985): The City of New York Fire Department, New York, New York. Health Hazard Evaluation Report HETA 81-459-1603.

National Institute for Occupational Safety and Health, Centers for Disease Control, U.S. Public Health Service (1988): International Association of Fire Fighters, Cincinnati, Ohio. Health Hazard Evaluation Report HETA 84-454-1890.

National Institute for Occupational Safety and Health, Centers for Disease Control, U.S. Public Health Service (1990): Memphis Fire Department, Memphis, Tennessee. Health Hazard Evaluation Report HETA 86-138-2017.

Office of Technology Assessment, United States Congress (1985): "Reproductive Health Hazards in the Workplace." Washington, DC: United States Government Printing Office, p 199.

Olshan AF, Teschke K, Baird PA (1990): Birth defects among offspring of firemen. Am J Epidemiol 131:312–321.

Paul M, Himmelstein J (1988): Reproductive hazards in the workplace: What the practitioner needs to know about chemical exposure. Obstet Gynecol 71:921–938.

Pepe PE, Hollinger FB, Troisi CL, Heiberg D (1986): Viral hepatitis risk in urban emergency medical services personnel. Ann Emerg Med 15:454–457.

Pleet HG, Graham JM, Smith DW (1981): Central nervous system and facial defects associated with maternal hyperthermia in four to 14 weeks gestation. Pediatrics 67:785–789.

Pratt WF, Mosher WD, Bachrach CA, Horn MC (1984): Understanding U.S. fertility findings from the National Survey of Family Growth, Cycle III. Popul Bull 39:3–42.

Procope BJ (1965): Effect of repeated increase of body temperature on human sperm cells. Int J Fertil 10:333–339.

Rachootin P, Olsen J (1982): The risk of infertility and delayed conception associated with exposures in the Danish workplace. J Occup Med 11:245–249.

Ritenour ER (1986): Health effects of low level radiation: Carcinogenesis, teratogenesis, and mutagenesis. Semin Nucl Med 16:106–117.

Russell LB (1950): X-ray induced developmental abnormalities in the mouse and their use in the analysis of embryological patterns. J Exp Zool 114:545–602.

Russell LB (1950): X-ray induced environmental abnormalities in the mouse and their use in the analysis of embryological patterns. J Exp Zool 114:545–602.

Saurel-Cubizolles MJ, Kaminski M (1987): Pregnant women's working conditions and their changes during pregnancy: A national study in France. Br J Ind Med 44:236–243.

Saurel-Cubizolles MJ, Kaminski M, Llado-Arkhipoff J, Du Mazaubrun C, Estryn-Behar M, Berthier C, Mouchet M, Kelfa C (1985): Pregnancy and its outcome among hospital personnel according to occupation and working conditions. J Epidemiol Community Health 39:129–134.

Schell L (1981): Environmental noise and human prenatal growth. Am J Phys Anthropol 56:63–70.

Smolander J, Louhevara V, Korhonen O (1985): Physiological strain in work with gas protective clothing at low ambient temperature. Am Ind Hyg Assoc J 46:720–723.

Soules MR (1985): The in vitro fertilization pregnancy rate: Let's be honest with one another. Fertil Steril 43:511–513.

Steeno OP, Pangkahila A (1984): Occupational influences on male fertility and sexuality. Andrologia 16:5–22.

Taskinen H, Lindbohm ML, Hemminki K (1986): Spontaneous abortions among women working in the pharmaceutical industry. Br J Ind Med 43:199–205.

Uchida IA (1979): Radiation-induced nondisjunction. Environ Health Perspect 31:13–17.

United States Fire Administration, Office of Fire Health and Safety, and Federal Emergency Management Agency (1988): Forum on Communicable Diseases. July 27–29, 1988, Emmitsburg, MD.

Valenzuela TD, Hook EW, Copass MK, Corey L (1976): Occupational exposure to hepatitis B in paramedics. Arch Intern Med 145:1976–1977.

Veghte JH (1987): "Physiologic Response of Fire Fighters Wearing Bunker Clothing (Phase 2)." Biotherm. Inc., Beaver Creek, Ohio.

Warren ME, Mays CW (1983): Ionizing Radiation. In Rom WN (ed): "Environmental and Occupational Medicine." Boston: Little Brown and Company, pp 676–679.

Warren MP (1983): Effects of undernutrition on reproductive function in the human. Endocrine Rev 4:363–377.

White MK, Hodus TK (1987): Reduced work tolerance associated with wearing protective clothing and respirators. Am Ind Hyg J 48:304–310.

Yamazaki JN, Wright SW, Wright PM (1954): Outcomes of pregnancy in women exposed to the atomic bomb in Nagasaki. Am J Dis Child 87:448–463.

Young IT, Gledhill BL, Lake S, Wyrobeck AJ (1982): Quantitative analysis of radiation induced changes in sperm morphology. Anal Quant Cytol 4:207–216.

Zorgniotti AW, Sealfon AI (1988): Measurement of intrascrotal temperature in normal and subfertile men. Reprod Fertil 82:563–566.