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Heat Stress Associated With the Use of Vapor-Barrier Garments

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Use of personal protective devices in the workplace, while intended to diminish risk of injury, may in some cases increase personal risk from environmental hazards. A case of a juvenile diabetic with complaints of near syncope while working in a plastics laminating process is analyzed. Although his symptoms might be attributed to a variety of causes, they were traced to the effects of heat stress related to wearing vapor-barrier disposable coveralls in a warm environment (85°F). A field study of asbestos workers involved in abatement of asbestos steam pipe insulation illustrates how clothing impermeable to sweat may result in elevation of core body temperature. When workers use vapor-barrier coveralls, work practices or wet bulb globe temperature limits may need to be revised to prevent heat-related injury.

The potential for adverse interactions between protective devices and their users must be considered when plastic-lined vapor-barrier coveralls are used to prevent skin contact with absorbable substances. In toxic-waste cleanups involving considerable physical activity (and hence the generation of metabolic heat through muscular contraction), vapor-barrier coveralls may lead to elevated body temperature and increased risk for heat stress. These lightweight garments cause minimal restriction to movement, can be worn over other clothes, and may effectively prevent the passage of most liquids and dusts through their surface. They are well-known to the public as the white "space suits" seen in depictions of toxic-waste cleanups, and are usually shown in use with full-face respirators and heavy boots. Protective garments do not increase risk for heat stress in all situations. Under some environmental conditions they may protect from radiant heat, or be used to cool the wearer. However, the quality of impermeability to vapor puts the user of these garments at risk for heat stress because the vapor barrier effectively prevents sweat evaporation and thus limits the most important heat dissipation mechanisms under conditions of heavy muscular work in a warm environment. In addition, like other garments, they may increase risk for heat stress by preventing convective heat loss. Their light weight, disposability, relatively low cost, and impermeability to liquids and vapors makes them applicable to a broad range of tasks. They are used with increasing frequency under conditions where engineering controls cannot meet current standards of protection such as in asbestos abatement projects where air concentrations of asbestos may be high and the disposable suits prevent contamination of work clothes with asbestos fibers.

The physiologic abnormalities associated with elevated core body temperature, collectively known as heat strain, may be viewed as a continuum beginning at slightly elevated temperatures with heat exhaustion and heat syncope, and progressing, at core temperatures above 105°, to heat stroke with permanent organ damage or death.

Diagnosis of heat-related disorders may be difficult because of the rapid return of core temperature to normal when the employee leaves the workplace. Diagnosis is essential because it identifies the employee at risk for more serious heat-related disorders, and permits early intervention and prevention of heat-stroke deaths.

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The following case studies highlight points of differential diagnosis and illustrate some of the conditions where the use of vapor-barrier clothing for protection against toxic hazards results in the potential for heat strain.

Case Report 1

A 25-year-old diabetic male employed in a polymer laminating production process came to the Johns Hopkins Occupational Medicine Clinic complaining of lightheadedness and disorientation occurring while handling an organic diamine derivative in a plastics process.

Juvenile onset diabetes had been diagnosed when he was 16 years of age. He had been treated with subcutaneous insulin and continued an active life. At 20 years of age he had the first of three symptomatic hypoglycemic episodes, which were treated by adjusting his insulin dose.

One year before he came to the clinic, electrodiagnostic studies performed as part of his routine evaluation showed borderline motor and sensory neuropathy of both lower extremities. In addition to insulin the patient received routine potassium supplementation (20 mEq daily), because serum potassium had been measured at 2.9 mEq/L after one previous hypoglycemic episode.

The patient's symptoms of light-headedness and disorientation occurred only while he was weighing and mixing the chemical, a task he performed once a week. Because a similar substance, ethylene diamine, is known to cause allergic contact dermatitis and occupational asthma, the patient routinely wore a vapor-barrier suit, air-supply respirator, and gloves while weighing the chemical in an enclosed room equipped with local exhaust ventilation. The task usually required 1½ hours. The room was maintained at a temperature of approximately 85°F, and during the work period the patient stood at a worktable moving only his arms and shoulders. His symptoms were highly reproducible, occurring on each occasion after approximately 45 minutes at the worktable, and beginning with light-headedness which progressed to near-syncope and disorientation. On several occasions, suspecting an insulin reaction, he checked his blood glucose when these symptoms occurred using a self-monitoring glucose system (Accu-Check). In each case he measured his blood glucose at greater than 90 mg/dL. These symptoms rapidly resolved when he left the enclosed area and removed the vapor-barrier suit.

There was a past history of a recurrently draining perineal abscess. He had no history of orthostatic intolerance, impotence, urinary hesitation, dysphagia, abdominal bloating, diarrhea, or abnormal distribution of sweating.

On physical examination he was a muscular and fit-appearing young man. Neurologic examination demonstrated minimally impaired proprioception in the lower extremities and the remainder of the examination was unremarkable.

Laboratory examination disclosed the following values: urine pH, 7.5 with no proteinuria, casts, or red cells; serum sodium, 138; potassium, 4.3; chloride, 100; bicarbonate, 27; serum urea nitrogen, 11; glucose, 367. After one hour supine, plasma renin activity was 2.0 ng/mL/h (0.2 to 2.1).

This initial history and physical examination in the Occupational Medicine Clinic raised five possible sources for the patient's symptoms: exposure to chemicals, hypoglycemia due to insulin reaction, orthostatic intolerance due to the volume depletion of type IV renal tubular acidosis (hyporeninemic hypoaldosteronism), heat stress, diabetic autonomic neuropathy involving the cardiovascular system, or a combination of these. The differential diagnostic field was narrowed by a review of the effects of organic diamine derivatives, which are not known to cause CNS effects or syncope. The patient's own monitoring of his blood glucose also ruled out symptomatic hypoglycemia. Normal urine pH, serum HCO_3^-, and plasma renin activity ruled out type IV renal tubular acidosis.

Because the presence of sensorimotor neuropathy may be associated with subtle autonomic neuropathy, an evaluation for abnormal cardiovascular responses was performed. Diabetics with autonomic neuropathy involving the cardiovascular system experience postural hypotension[1] and have a reduced duration of tolerance for motionless standing before the onset of syncope. The presence of autonomic neuropathy may be demonstrated by tests of heart rate and blood pressure responses to postural changes, the Valsalva maneuver, and the use of lower body negative pressure. All of these maneuvers reduce right-sided cardiac filling pressure, increase the firing rate of carotid sinus and aortic baroreceptors, and lead to increased heart rate and peripheral arterial tone. The diabetic with autonomic neuropathy involving the cardiovascular system will have blunted heart rate and blood pressure responses to these stimuli.

Because of the possibility of subnormal heart rate and vascular responses to prolonged, near-motionless standing in this patient, autonomic testing was performed. On postural change from the supine to the upright position, his heart rate increased from 64 to 88, and his blood pressure went from 112/72 to 102/78. He experienced no symptoms with postural change.

A Valsalva maneuver was performed for ten seconds at a pressure of 40 mmHg at the mouth. Heart rate increased appropriately from 65 to 115 during the maneuver, and brachial artery cuff pressure increased appropriately from 118/80 to 142/78, the normal "pressure overshoot" response to the Valsalva maneuver. Lower-body negative pressure, perhaps the best means to test for cardiovascular autonomic neuropathy, was administered using a rigid box around the legs and pelvis. This lower-body negative pressure box was evacuated in 8-mmHg steps to a constant pressure of −50 mmHg. At each level of negative pressure, heart rate and blood pressure responses were greater than those in four age-matched nondiabetic control subjects, indicating an intact cardiovascular autonomic response. Orthostatic intolerance due to diabetic neuropathy was thus ruled out by these tests. The patient's symptoms could be attributed entirely to the heat stress produced

by warm environmental conditions and the use of a vapor-barrier suit, rather than to any increased susceptibility to heat stress associated with diabetes. This finding is consistent with a previous study of thermal regulation in young diabetics[2] whose skin blood flow and sweating responses to exercise-induced increase in core temperature were not different from those of control subjects. A work recommendation was made to reduce the ambient temperature of the workroom to prevent further episodes of near syncope in this patient.

Discussion

Heat-related disorders in the workplace are usually associated with both very high ambient temperatures and with heavy workloads. Healthy workers have a remarkable ability to dissipate the metabolic heat generated by muscular work and to maintain body temperature in the face of high environmental temperatures. Only where prolonged heavy work in severe environmental conditions is required is there a high risk for heat disorders in most healthy workers. In the present case report, however, another variable was added: the vapor-barrier garment, which inhibited sweat evaporation, the most important temperature-regulating mechanism in conditions of high air temperature where convection and conduction are insufficient means to dissipate body heat. Without the ability to sweat, this patient's core temperature may have risen sufficiently to cause marked peripheral vasodilation and near-syncope. The air-supplied respirator may have played a role in reducing the patient's discomfort (by "fanning" the face) while his core temperature was rising, so that his first symptom was the near-syncope of marked peripheral vasodilation and volume redistribution. Even in a relatively mild condition of heat exposure (85°F, stationary work using arms and shoulders), the inability to dissipate heat by sweating led to heat-related symptoms. Because of the relatively moderate environmental conditions, it was at first thought that this patient was unusually susceptible to the effects of heat by virtue of a blunted cardiovascular autonomic response. In fact, his response to autonomic testing was normal and his diabetes did not produce a condition of enhanced susceptibility to heat. A study of young and otherwise healthy diabetics similar to the present patient, performed under controlled laboratory conditions, also found no increased susceptibility to heat. Fortney et al[2] studied a group of four male insulin-dependent diabetics between the ages of 21 and 37. They compared the core temperatures, skin temperatures, and skin blood-flow responses to exercise to those of nondiabetic age-matched control subjects in a room maintained at 35°C. The responses of the diabetics were not different from the control subjects. In more marked stages of diabetic neuropathy, some diabetics have been found to have abnormal sweating distribution, believed due to the loss of sympathetic cholinergic fibers innervating dermal sweat glands in the affected parts of the body. This loss of sudomotor fibers has been associated with a compensatory excessive sweating in unaffected regions. The most common area of loss of sweating is over the lower extremities. For the patient under discussion, however, diabetes was not a factor in his susceptibility to heat stress.

Case Report 2

The interaction between vapor-barrier suits and heat stress may be a widespread problem in industry. We recently conducted a field study of healthy plumbers, insulators, and welders who were removing asbestos insulation from underground pipes carrying steam from a central generating plant to large steam-heated buildings.[3] Measurements were made on 16 subjects, and were made both in summer and winter months. Wet bulb globe temperature (WBGT) measurements were as high as 107°F. Because of the asbestos exposure risk, these workers were advised to wear vapor-barrier suits to prevent contamination of clothing, but in some cases they were reluctant to do so because of the added heat discomfort associated with their use. A subject studied while wearing a vapor-barrier suit over conventional clothing had a heart rate at 164 beats per minute and oral temperature at 100.6°F. When wearing conventional clothing alone at the same WBGT, his heart rate was 112 beats per minute and oral temperature was 98.3°F. Metabolic heat production may not have been identical during these two sets of measurements, but was probably similar because he was performing the identical task. The markedly elevated oral temperature suggests an impairment of heat dissipation due to the impermeable suit. On the basis of these findings, a recommendation for the entire work force was made to substitute lightweight cotton clothing for the vapor-barrier coveralls. The cotton uniforms would be removed and washed at the end of each work shift to prevent transporting asbestos fibers away from the workplace.

Conclusions

Current guidelines for occupational heat exposure[4] use wet bulb globe temperature measurements and assume the worker is wearing light clothing, but do not provide standards for other circumstances such as the use of heavy or impermeable garments. As with other conditions of heat stress, injury control may be approached through the adjustment of work-rest schedules, the provision for time off to remove the garment and cool the skin, the use of special cooling areas, and, where feasible, the substitution of vapor-permeable garments for impermeable ones. Where environmental air temperatures are high, impairment by these garments of the ability to sweat may result in significantly higher

core body temperatures and high risk for heat-related disorders.

Acknowledgments

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References

1. Hosking DJ, Bennett T, Hampton JR: Diabetic autonomic neuropathy. *Diabetes* 1978;27(10).
2. Fortney S, Koivisto V, Felig P, et al: Circulatory and temperature regulatory response to exercise in a warm environment in insulin-dependent diabetes. *Yale J Biol Med* 1981;54:101–109.
3. Fortney S, Lees P, Beckett W, et al: *Asbestos Exposure and Heat Stress of GSA Steam Tunnel Personnel.* General Services Administration, 1981.
4. Dukes-Dubos FN, Henschel A: Development of permissible heat exposure limits for occupational work. *ASHRAF J* 1973;15(9):57–62.

Search for Truth

If the reader is not at risk, he is not reading. And if the writer is not at risk, he is not writing. As a rule, a writer and a book or a poem are no good if the writer is essentially unchanged morally after having written it. If the work is really a holding operation, this will show in a closed or flat quality in the prose and in the scheme of the thing, a logiclessness, if you will pardon the neologism, in the writing. Writing always tends toward a kind of moral stance—this is because of the weight of logic and of truth in it—but judging the ways in which it is moral is hard for people who are not cultivated. Profoundly educated persons make the best judges.

The general risk in being a man or woman of cultivation is then very high, and this is so in any culture, and perhaps requires too much strength for even a small group to practice in ours. But should such a guerrilla group arise, it will have to say that cultivation and judgment issue from the mouths of books and can come from no other source. Over a period of centuries, ignorance has come, justifiably, to mean a state of booklessness. Movie-educated people are strained; they are decontextualized; they are cultivated in a lesser way. Television and contemporary music are haunted by the search for messiahs; the usual sign of mass inauthenticity is a false prophet (which usually means a war will shortly break out and be lost). The absence of good sense signals the decline of a people and of a civilization. Shrewdness without good sense is hell unleashed.

—From "Reading, the Most Dangerous Game" by Harold Brodkey in *The New York Times Book Review*, November 24, 1985.