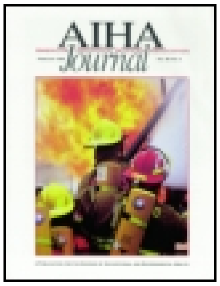

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APPLIED STUDIES

A study was conducted to assess the ergonomic hazards of ironwork job tasks associated with concrete reinforcement work at a large highway construction site. PATH (posture, activity, tools, and handling) analysis, a work-sampling method, was used to provide task-based estimates of the percentage of time ironworkers spent in specified postures of the trunk, arms, and legs; performed activities; used tools; and handled loads. A total of 2128 PATH observations were made of 17 ironworkers performing 5 job tasks: (1) ground-level reinforcement bar (rebar) construction, (2) wall rebar construction, (3) ventilation rebar construction, (4) preparation work, and (5) supervising. Nonneutral trunk postures were observed frequently (exceeding 30%) and manual material handling (MMH) was the most commonly observed activity (exceeding 20%) for all job tasks except supervising. The percentage of time workers spent in specific postures, activities performed, tool use, and MMH activities differed significantly between the five main job tasks, even when supervising was excluded from the analysis. It was concluded that ironworkers are exposed to significant ergonomic hazards when performing concrete reinforcing tasks, and that opportunities exist for the implementation of ergonomic interventions. Further, the results of this study can be used to target specific hazardous tasks for ergonomic interventions and confirms the need to use a task-based exposure assessment strategy to properly assess ergonomic risk profiles for nonstructured jobs such as construction.

Keywords: concrete reinforcement, ergonomics, highway construction, ironwork

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In the ironwork trade, construction ironwork (commonly referred to as "outside" ironwork) is divided into four main specialties: (1) structural ironwork, (2) ornamental ironwork, (3) rigging ironwork, and (4) reinforcing ironwork. Ironworkers engaged in reinforcing ironwork (also referred to as rod-work, rebar work, or concrete reinforcement work) are responsible for placing and connecting steel rods (rebar) that reinforce concrete structures on construction sites. Carpenters then build forms around the steel rods and construction laborers pour concrete into the forms. Once the concrete has set, the forms are removed and the finished structure remains.

Reinforcing ironwork is physically demanding, often requiring awkward postures and heavy manual material handling (MMH). Most studies of reinforcing ironwork have focused on the prevalence of low-back pain among such workers.[1–7] These studies have found that concrete reinforcement work is associated with high rates of musculoskeletal problems, particularly those of the back.

The strongest epidemiologic evidence linking concrete reinforcement work to musculoskeletal disorders originated from a cohort study of concrete reinforcement workers in Finland.[1–3,8–10] The original study group consisted of 295 male Finnish concrete reinforcement workers, of whom 167 were followed prospectively over a 5-year period. Health and demographic data were obtained with written questionnaires, interviews, clinical examinations, and radiographic examinations. Exposure data (percentage of time the workers worked in nonneutral trunk postures and frequency in which the workers handled loads) were obtained from 32,620 observations made at regular intervals at two building construction sites.

The results clearly demonstrate that concrete reinforcement workers have a high prevalence of musculoskeletal problems, particularly those of the back. Eighty percent of the concrete reinforcement workers had back trouble sometime during their lives, 51% had daily symptoms of backache,[3] 38% had some restriction of forward lumbar bending,[3] and 24% had some diminished capacity of the abdominal muscles.[1] There was also a high prevalence of disc degeneration[10] and evidence of a relatively high risk of knee degeneration.

Concrete reinforcing ironworkers also had a high prevalence of minor accidents resulting in injuries to the back, legs, and arms, of which half were thought to be caused by overexertion.[12] Lifting and carrying of rebar and nets, placing rebar, and tying rebar were thought to be the most common causes of accidents.[12] Lifting and carrying reinforcement bars were also considered to be the heaviest job activities by the workers.[4]

When compared with a cohort of about 200 house painters who performed lighter manual handling tasks, concrete reinforcement workers had a higher risk of minor accidents of the musculoskeletal system and higher risk of sciatica.[12,13] The increased risk of back injury was thought to be linked to the observed higher frequency of severely stooped postures, 5–20 kg lifts, toe-to-hip lifting, and poor walking surfaces.[12]

Dababneh and Waters[14] described five different methods for tying rebar and the physical risk factors associated with each one. As part of this study, alternatives to manual tying were examined. The advantages and disadvantages of each method are compared.

Beyond these studies there is very little information about the ergonomic hazards of concrete reinforcement work, and even less about the ergonomic hazards associated with specific tasks in highway concrete reinforcement work. One of the reasons the ergonomic hazards of concrete reinforcement work and construction work in general have not been more fully characterized is because such work is difficult to evaluate due to its dynamic nature (i.e., the work constantly changes both in terms of content and duration due to the ever-evolving nature of the work site and environmental conditions). Ironworkers, like most construction tradespeople, will perform a variety of tasks, and each most likely will have its own set of ergonomic exposures. Therefore, a task-based exposure assessment method, as opposed to a method that characterizes exposure for a given trade or job title, may provide more information for identifying hazardous conditions and insight for controlling these hazards. Therefore, the objective of this study was to quantitatively assess some of the ergonomic hazards for several concrete reinforcement job tasks at a large heavy highway construction site.

METHODS

Study Site

The study took place at a highway construction site in Boston, Mass., where a "cut-and-cover" tunnel was being constructed. This tunnel is part of the South Boston access road to the recently completed Ted Williams tunnel underneath Boston Harbor. Cut-and-cover tunnels are built by excavating a trench in the ground and building a reinforced concrete box in the trench. Ducts needed for ventilation are constructed within the concrete structure. This particular cut-and-cover tunnel was approximately 0.4 miles long and consisted of two traffic lanes in each direction separated by a dividing wall. It took approximately 6 months to complete.

The study took place during the fall, when the weather was usually dry and sunny with daily temperatures ranging from approximately −1 to 13°C (30–55°F).

Study Population

A group of 17 ironworkers, which included one foreman, were observed during the study. This group represented greater than 60% of the workers that were responsible for the concrete reinforcement work on the cut-and-cover and worked during the day (7 a.m. to 3 p.m.). The group consisted of 16 men and 1 woman, ranging in age from 20 to 50 years. Two of the concrete reinforcement workers were apprentices; the remainder were experienced journey-level ironworkers.

Description of Concrete Reinforcement Work

Bundles of rebar were loaded into the "cut" with a tower crane. Smaller cranes were used to move rebar within the cut. Ironworkers helped secure and guide these crane loads. Individual pieces of rebar were then positioned manually or positioned with a crane and guided manually. Rebar was precut and prebent to specifications and was rarely altered during the construction process.

Workers wore tool belts that held a reel of wire, folding rule, tape measure, and a pair of pliers. The pliers, alternatively called side cutters or togs, are used to twist the wire around the rebar and cut the wire after tying. Equipped belts weighed about 10 lbs (~45 N), a reel of wire weighed about 5 lbs (~20 N), and the pliers weighed approximately 1 lb (~5 N). Ironworkers generally used two different ties when securing reinforcement bars. A "figure 8," which wraps around the bars from all directions, was used when a strong tie was needed and was used most commonly during the reinforcing of walls. The "snap" tie wraps around the intersecting bars only once and was used most frequently when the reinforcement bars would remain horizontal (i.e., ground-level rebar). In some cases, a "double wrap," in which wire is first doubled then wrapped around the reinforcement bars, was used to create a stronger tie. Workers explained that they had the freedom to decide on the appropriate type of tie.

Taxonomy

A hierarchical taxonomy has been developed to describe the construction process and to systematically categorize construction work into small units, so that ergonomic hazards of specific job tasks and activities can be evaluated.[15] Construction projects are broken into a series of stages. Each stage is further broken down into two or more operations. Definitions for the stages and operations for this study were adapted from state highway specifications.[16] Each operation is comprised of one or more job tasks that are each performed by a specific trade, which is defined jurisdictionally for unionized construction work. In addition to state highway specifications, information about operations and job tasks was obtained from contractor documentation, direct observation, and interviews with contractor personnel, foremen, and workers.

TABLE I. Interobserver Agreement (Number of Observations)

Job Task	Trunk	Legs	Arms	Grasp	Activity	Tools	Load
Ground-level rebar construction	0.95	1.00	1.00	1.00	1.00	1.00	1.00
	(20)	(20)	(20)	(18)	(27)	(22)	(20)
Wall rebar construction	0.81	0.94	0.87	0.91	0.88	0.89	0.95
	(38)	(38)	(38)	(33)	(62)	(37)	(38)
Caisson construction	0.89	0.91	0.95	0.94	0.82	0.87	0.97
	(66)	(66)	(66)	(82)	(95)	(76)	(66)
Preparation work	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	(5)	(5)	(5)	(10)	(6)	(2)	(5)

Stage and Operation

The cut-and-cover construction was categorized as part of the "structures" construction stage, which includes construction of bridges, culverts, walls, steps, and so forth. The operation of interest for this study within the structures stage was cement concrete masonry, which includes concrete reinforcement, form building, and concrete pouring.

Job Tasks and Activities

Six concrete reinforcement job tasks for the cement concrete masonry operation were defined: (1) ground-level rebar construction, (2) wall rebar construction, (3) ventilation rebar construction, (4) caisson construction, (5) preparation work, and (6) supervising. Ground-level rebar construction involved the reinforcing of the subbase surface of the cut. Wall rebar construction reinforced the walls of the cut. Ventilation rebar construction consisted of reinforcing the concrete structures surrounding the ventilation ducts, which are below the road surface. Caisson construction involved building reinforcement for caissons that form the foundation for the subbase. For this job task rebar normally was positioned on saw horses to elevate the caissons between shoulder and waist height. Preparation work included moving materials, guiding crane loads, erecting scaffolding along rebar walls, and clearing debris. Finally, supervising consisted of the planning and directing of the work. Common activities for all job tasks except supervising included tying and manual handling of rebar.

PATH Data Collection

PATH (posture, activities, tools, and handling),[15] an observational work sampling-based analysis method,[17] was used to collect task-based quantitative ergonomic exposure data for the six concrete reinforcement job tasks defined for the cement concrete masonry operation. The PATH posture (trunk, leg, arms) codes are modifications of the posture codes used in the Ovako Work Posture Analyzing System.[18,19] In addition to postures, the activities performed, tools or materials used, and estimated loads handled are coded. Many of the activity codes are based on work elements (e.g., reach, grasp, and move) taken from the time study methodology traditionally employed by industrial engineers.[20,21] More than one activity may be coded for each observation. Activity codes include (1) MMH activities, (2) activities that are common to most trades and operations, (3) trade/operation-specific activities, and (4) hand postures/activities.

The key activities were determined before actual PATH data collection. The loads handled were ascertained prior to PATH sampling either by direct measurement of the tool or object weight with a force gauge or by accessing standard construction material data. A PATH coding template and data collection sheets were then customized for use in this study.

Interobserver agreement was checked before formal PATH data collection. Two observers coded PATH data of one or two workers during the job tasks of ground-level rebar construction, wall rebar construction, caisson construction, and preparation work. Interobserver agreement for each PATH code was calculated by dividing the number of observations for which observers agreed by the total number of observations. Interobserver agreement was calculated for postures (trunk, arms, and legs), grasp type, activities performed, tools used, and loads handled. Interobserver agreement was evaluated for each of the tasks except supervising, because characteristics of task (e.g., task complexity, speed of movement) were hypothesized to affect measurement reliability. Interobserver reliability was not tested for supervising because the posture, activity, and tool codes were thought not to change very often.

Three observers collected PATH data on 13 days over a 1-month period. All the ironworkers were assigned a number, and each observer selected a group of between 6 and 10 ironworkers at the beginning of each shift. The specific worker for any given observation was randomly determined for the observer from among those that were in the selected group. Observations were made at 1-min intervals. For each observation the worker number and job task were coded. This strategy resulted in a specific ironworker being observed at random intervals over approximately 3 hours on a given day of observation. Each worker was observed on multiple days.

Data Analysis

PATH field data were then scanned from coding sheets into a personal computer using optical mark recognition software (Remark Office OMR, Principia Products, West Chester, Pa.). Scanning errors were identified and corrected. The data were analyzed using SAS (Statistical Analysis System, version 6, SAS Institute, Cary, N.C.). Obstructed views were not included in the analysis.

Descriptive data for specific postures, activities, tools, and loads handled were obtained to provide task-specific estimates of the proportion of time workers were exposed to these factors. Chi-square tests were performed to determine which exposures varied between tasks. Because the physical activity during supervising was much less than during other job tasks, the chi-square tests were repeated with supervising omitted.

RESULTS

Interobserver Agreement

Interobserver agreement was relatively high for all variables for which tests were made, ranging between 0.81 and 1.00 for all coding categories (Table I). Agreement for the postural codes was

TABLE II. Number of Ironworkers Observed, Number of Observations Made, and the Percentage of Total Observations for Each Job Task

Job Task	Number of Workers	Number of Observations	Percentage
Ground-level rebar construction	17	623	29.3
Wall rebar construction	15	516	24.2
Ventilation rebar construction	11	172	8.1
Preparation work	16	651	30.6
Supervising[A]	5	166	7.8
Total	17	2,128	100

Note: All ironworkers were observed performing more than one task.
[A]Of the 166 observations, 121 were made on 1 worker (the foreman).

greater than 0.87, except for the trunk posture coding during wall rebar (0.81). Interobserver reliability of activities performed and tools used was perfect for two of the tasks and greater than 0.88 for a third task, indicating that the activities and tools used for tasks were well defined. Interobserver reliability of the activity codes for caisson construction was 0.82, but this task was rarely performed after formal PATH data collection began, and no additional training could be performed to improve the reliability of activity coding for that task.

Job Tasks

A total of 2128 observations were made on 17 ironworkers performing concrete reinforcement job tasks during the cut-and-cover tunnel operation (Table II). On average, each worker was observed at random intervals over 15 hours. The most common job tasks were preparation work (31%), ground-level rebar construction (29%) and wall rebar construction (24%). Caisson construction initially was observed and used to determine and evaluate PATH observer interrater reliability. Thereafter, caisson construction was observed so infrequently during the formal PATH data collection that no further analysis of this job task is reported. Ventilation rebar construction and supervising were each observed approximately 8% of the time.

Trunk Postures

Overall, nonneutral trunk postures were observed frequently. Moderate flexion was observed 10% of the time, severe flexion 9%, twisting or lateral flexion 9%, and simultaneous flexion and twisting 14%. Trunk postures differed significantly between job tasks (chi-square on 16 degrees of freedom [d.o.f.], $p < .001$). Neutral trunk postures were observed most frequently during supervising (81%) and preparation work (68%) and least frequently during ventilation rebar construction (42%) (Figure 1). Severe flexion and simultaneous flexion and twisting were observed most frequently during ventilation rebar construction. When supervising was excluded from the analysis of variance, trunk postures remained significantly different between job tasks (chi-square on 12 d.o.f., $p < .001$).

Arm Postures

Arm postures at or above shoulder height were observed infrequently (5% for one arm at or above shoulder level and 1% for both arms above shoulder level). Arm postures differed significantly between job tasks (chi-square on 8 d.o.f., $p < 0.05$). Arm postures at or above shoulder height (one or both) were observed

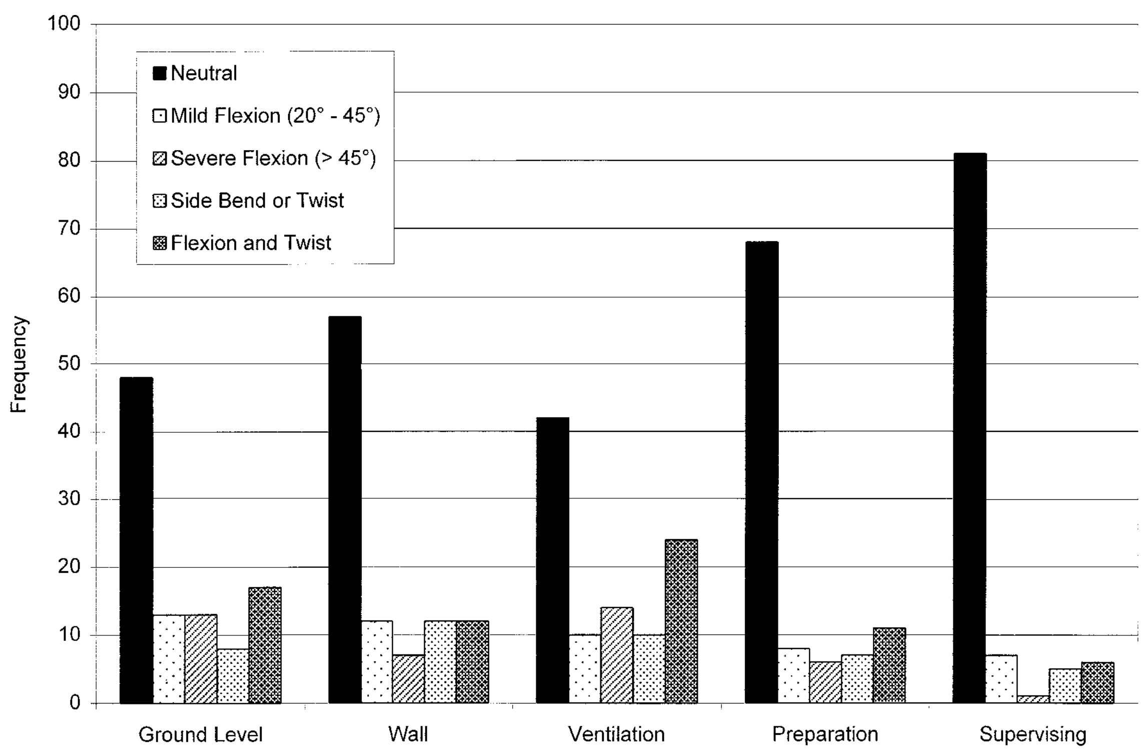

FIGURE 1. Estimate of the proportion of time that ironworkers (given as a percentage) were observed in various trunk postures during concrete reinforcement job tasks

TABLE III. Percentage of Time Activities were Performed by Ironworkers While Engaged in Five Concrete Reinforcing Job Tasks

Activity	Ground Level	Wall Rebar	Ventilation	Preparation	Supervising	Overall
MMH[A]	35	22	30	21	5	25
Walking	12	11	11	20	23	15
Tying rebar	11	14	22	0	0	8
Guiding crane	2	2	0	12	2	5
Between activities	25	24	18	23	50	26
Other	15	27	19	24	20	21

[A]Lifting, lowering, carrying, pushing/pulling, moving

most frequently during wall rebar construction (9%) and least frequently during ground-level rebar construction (4%). Arm postures remained significantly different between job tasks when supervising was excluded (chi-square on 6 d.o.f., $p < .05$).

Leg Postures

Awkward leg postures were also rare. The most frequently observed were neutral leg postures (53%), walking or moving (19%), and one leg bent at least 35° (17%). Kneeling was observed 3% of the time. Leg postures differed significantly between job tasks (chi-square on 36 d.o.f., $p < .001$). This remained true when supervising was excluded (chi-square on 24 d.o.f., $p < .001$). Neutral leg postures were least frequent (46%) and kneeling postures were most frequent (4%) during ground-level rebar construction. Workers were supported in a harness 11% of the time during wall rebar construction.

Activities

MMH activities (lifting, lowering, carrying, moving, and pushing/pulling) were among the most commonly observed activities (Table III). Of the five job tasks, all except supervising had MMH frequencies greater than 20%. The percentage of time workers lifted, lowered, moved, or pushed/pulled material differed significantly between job tasks (chi-square on 4 d.o.f., $p < .005$). The percentage of time workers carried material did not differ significantly between tasks (chi-square on 4 d.o.f., $p > .05$). When supervising was omitted from the analysis, the percentage of time workers devoted to manual handling activities (except carrying) remained significantly different between job tasks (chi-square on 3 d.o.f., $p < .005$). MMH activities were most frequent during ground-level rebar construction (35%) and ventilation rebar construction (30%).

Walking (15%) and tying rebar (8%) were also among the most frequently observed activities (Table III). Walking often required workers to walk across secured rebar or temporary plywood flooring, posing a potential slip/trip and fall hazard. The percentage of time workers were observed walking differed significantly between job tasks (chi-square on 4 d.o.f., $p < .001$), and remained unchanged when supervising was omitted from the analysis (chi-square on 3 d.o.f., $p < .001$). Workers were observed walking least frequently during ventilation rebar construction and wall rebar construction (11% each) and most frequently during supervising (23%) and preparation work (20%). The percentage of time workers devoted to tying rebar differed significantly between tasks (chi-square on 4 d.o.f., $p < .001$), and remained unchanged when supervising was omitted (chi-square on 3 d.o.f., $p < .001$). Workers tied rebar most often during ventilation rebar construction (22%) followed by wall rebar construction (14%) and ground-level rebar construction (11%). Workers rarely tied rebar during supervising and preparation work.

Tool Use

Workers held or operated tools approximately 19% of the time. The percentage of time workers were observed using hand tools or holding tools differed significantly between job tasks (chi-square on 4 d.o.f, $p < .05$), and differed similarly when supervising was excluded (chi-square on 3 d.o.f., $p < .05$). Hand tools were used most frequently during ventilation rebar construction (22%) and least during preparation work (3%) and supervising (1%). Hand tool use was similar for ground-level rebar construction (13%) and wall rebar construction (12%). Workers held a tool (without operating) most often during supervising (10%) and least often during ventilation rebar construction (4%). Power tool use was too infrequent for valid chi-square tests.

Pliers were the most frequently used or held tool during the job tasks of ventilation rebar construction (26%), ground-level rebar construction (17%), and wall rebar construction (15%). A communication radio was the tool used or held most often during preparation work (12%) and supervising (11%). Although most tools were used too infrequently for valid chi-square tests, use of pliers and communication radio differed significantly between job tasks (chi-square on 4 d.o.f., $p < .001$). When supervising was excluded this difference remained unchanged (chi-square on 3 d.o.f., $p < .001$).

Loads Handled

Loads were handled 46% of the time (Figure 2). Heavy loads (greater than 30 lbs [135 N]) were handled infrequently (3%). Loads exceeding 50 lbs (227 N) were observed most frequently during ventilation rebar construction (2%). When the load categories at or above 30 lbs (135 N) were combined, loads handled differed significantly between job tasks (chi-square on 24 d.o.f., $p < .001$) and remained unchanged when supervising was omitted (chi-square on 21 d.o.f., $p < .001$).

DISCUSSION

Interobserver agreement of the PATH codes for concrete reinforcement work was quite favorable. PATH analysis requires the observer to record three body postures, the activities performed, tools or materials used, and grasp types while holding tools or materials for workers simultaneously. Other observational ergonomic hazard assessment techniques such as TRAC use two coders to achieve similar observational data.[22] One coder records postures while another codes the activities and weights handled. Such a procedure requires observers to remember fewer codes to reduce code misclassification. Such a technique also requires less time between observations (as little as 15 sec). Because interobserver agreement was relatively high for all codes in this study, random misclassification of codes did not appear to be a major problem.

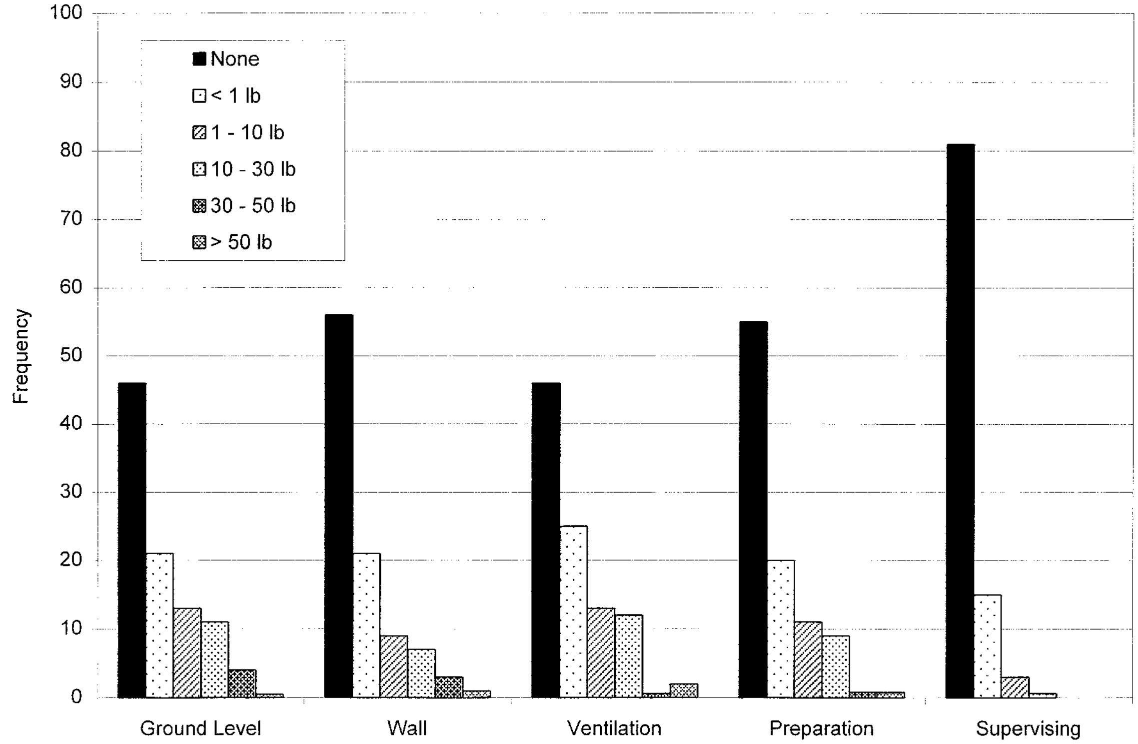

FIGURE 2. Estimate of the proportion of time that ironworkers (given as a percentage) were observed handling loads during concrete reinforcement job tasks

The agreement between observers, at least in part, can be attributed to comprehensive observer training and a clear understanding of posture, activity, and tool definitions prior to data collection. Tools and materials handled also were weighed prior to data collection to help reduce error in load estimation. This study demonstrates that observers can code relatively large amounts of information with careful preparation. PATH analysis also eliminates the errors in coding caused by inconsistencies in coding times between observers coding different aspects of the job.

In this study the most obvious ergonomic hazards identified for concrete reinforcement job tasks other than supervising were the large percentage of time workers spent in nonneutral trunk postures (particularly flexed and twisted, and severely flexed) and highly frequent MMH activities. Although loads handled during MMH activities were usually light, in some cases loads exceeding 50 lb. (227 N) were recorded. Lifts of this magnitude exceed maximum recommended weight limits under "ideal" lifting conditions and may increase a worker's risk of back injury.[23,24]

The frequency of ergonomic exposures varied significantly among the job tasks evaluated in this study. This is thought to be the result of differences in both task requirements and work area layout. Although all of the tasks except supervising had MMH activities as the most commonly performed activities, actual tying of rebar was performed only in the ground-level, wall, and ventilation rebar construction tasks. The frequency of awkward trunk postures varied in these three tasks, but ironworkers were observed in nonneutral trunk postures greater than 40% of the time for all three. Punnett et al.[25] found an association between back disorders and nonneutral trunk postures in a study of workers in automobile manufacturing. The risk increased with exposure to multiple postures and when the duration of exposure increased to over 10% of the work shift. Burdorf et al.[26] found the same relationship in a comparison of concrete workers and maintenance engineers. Concrete workers were exposed to nonneutral trunk postures in 37% of the observations and maintenance engineers were exposed for 27%, whereas the prevalence of back pain was 59 and 31%, respectively.

Because ground-level rebar construction is performed at ground level, this task required a flexed trunk posture a large proportion of the time (43%). Ventilation rebar construction had an even higher proportion of awkward trunk postures, including a high frequency of side bending and/or twisting (34%). This was because this task was performed inside the rebar structures that formed the ventilation ducts. In addition to differences in work area layout and job requirements between tasks, possible reasons exposures often differed among ground-level, wall, and ventilation rebar construction might include the following: rods for each task often had different diameters, rebar mats for each task had a different number of intersections (and therefore a different number of ties) per unit area, and tie type differed between tasks.

Others have found that ergonomic exposures (such as trunk posture) vary considerably within a shift.[27] Perhaps one of the reasons exposures vary within a shift is because the amount of time devoted to different job tasks changes within a day. For example, workers may devote more time to cleanup tasks toward the end of a shift. Other factors that may be important are differences in exposures between workers and between days.[27] More detailed analysis of the data collected in this study is necessary to determine the relative importance of factors such as worker or day for concrete reinforcing operations.

Exposures within a job task may also vary with each activity performed within the job task. For example, workers were rarely

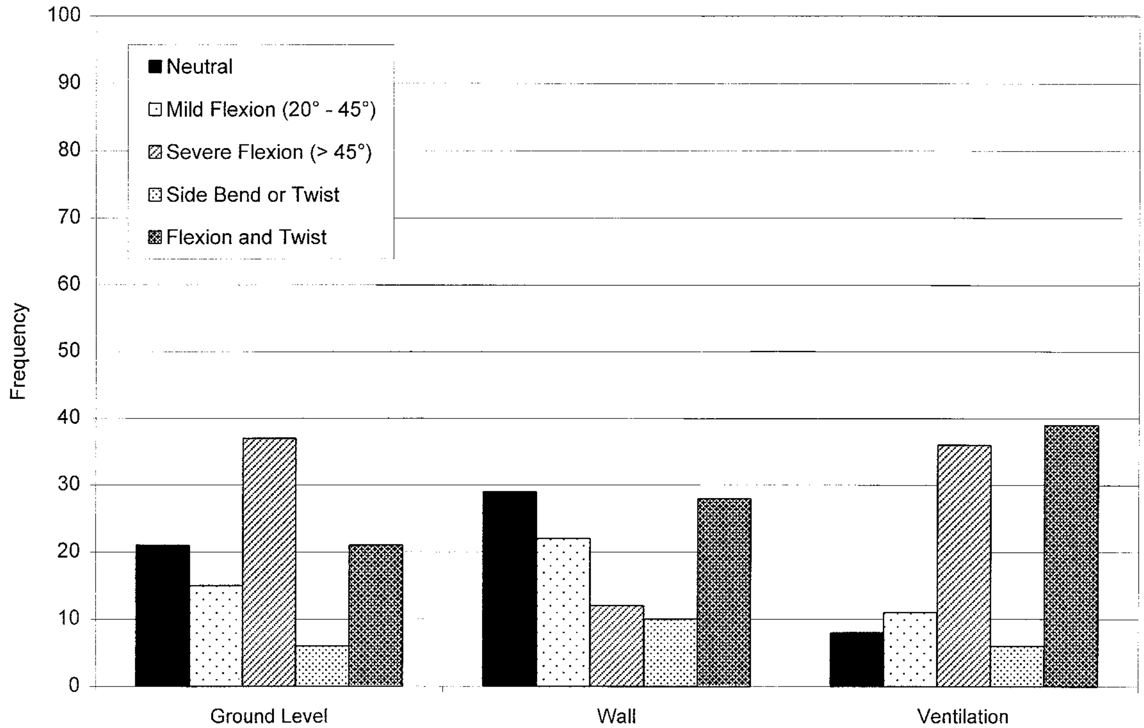

FIGURE 3. Estimate of the proportion of time that ironworkers (given as a percentage) were observed in different trunk postures while performing the activity "tying rebar" during ground-level, wall, and ventilation rebar construction.

observed in nonneutral trunk postures while walking but were in nonneutral trunk postures more than 66% of the time while tying rebar. In some cases ergonomic exposures for an activity (e.g., the percentage of time devoted to nonneutral trunk postures while tying rebar) varied considerably among job tasks (Figure 3), whereas in other cases they did not (e.g., walking). Therefore, it may be important to characterize the ergonomic exposures of an activity for each job task.

There are numerous potential interventions for the ergonomic hazards found in this study. For example, the use of cranes to position rebar could reduce the amount of MMH currently experienced by ironworkers doing concrete reinforcing tasks, though this control may be viewed as too costly. An administrative control would require the use of two-person lifts on heavier pieces of rebar.

Interventions recommended by Riihimaki et al.[12] included the use of ready cut and prebent reinforcement bars to reduce manual work and the use of prefabricated elements (matrix structures) to reduce the amount of tying and manual handling on site. They did not discuss the effectiveness of such recommendations for reducing ergonomic hazards further. Ready cut and prebent reinforcement bars were used in this study, but this probably increased the routineness of the job tasks. The frequency of MMH and rebar tying were increased, whereas no time was spent on cutting, which may have enlarged the tasks by transferring stress to other body locations.

A tool for tying ground-level rebar from an erect standing posture has been developed and used in Sweden for more than 25 years. The tool works like a giant staple gun, but weighs approximately 15–20 lb. (75 N). Attempts to implement this device in the United States and Canada have not been successful, possibly because the tool is cumbersome and possibly because the tool deskills the tying job.[28] The use of such a tool was discussed with several ironworkers, whose responses were not favorable. They thought the tool would lower the quality of the ties and possibly reduce the number of jobs for ironworkers.

Walking was a commonly identified activity. Much of this occurred on ground-level rebar, a difficult surface on which to walk. A simple method for improving the walking surfaces would be to lay plywood sheets over the rebar.

CONCLUSIONS

Concrete reinforcement work during heavy highway construction can and does pose several ergonomic risks to ironworkers. The PATH data indicate that nonneutral postures varied by job task from 19% for supervising to more than 58% for the ventilation rebar construction task. Similarly, the data indicate that ironworkers spend a large proportion of time performing MMH tasks. Because the ergonomic hazards clearly differed among job tasks, the data from this study clearly illustrate the importance of considering the hazards of individual tasks when prioritizing hazards and developing interventions for any given operation. These results can be used to identify and target specific tasks and activities that pose large ergonomic hazards. They also provide insight into what intervention and control strategies would be most appropriate to eliminate or minimize these hazards.

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