Original Article

An ergonomic study in building demolition: Assessment of musculoskeletal disorders risk factors by PATH method

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ABSTRACT

Aims: The aim of this study was the investigation of musculoskeletal disorders risk factors among building demolition workers.
Materials and Methods: Posture, activity, tools, and handling (PATH) method as a work sampling method was applied to record the postures, activities, and handling of building demolition workers in four tasks. The percentage of working time is reported for each item to compare the risk factors in tasks. Nordic musculoskeletal questionnaire also was used to study the prevalence of musculoskeletal disorders over 12 months.
Results: Trunk, leg(s), and arm(s) postures differed significantly among tasks. Neutral arm posture and non-neutral leg(s) and trunk postures were observed frequently. Manual materials handling (MMH) activities are distributed differently among tasks. Moving was the most observed (35%) and carrying was the less observed (11.8%) MMH activity. Gross grasp was the most observed (78.5%) hand activity in building demolition workers. The most observed weight category was 0 kg≤load<5 kg. Low back had the highest prevalence of MSDs symptoms (91.1%) and hip had the lowest prevalence of symptoms (6.7%).
Conclusions: PATH is applicable to building demolition process. Ergonomic intervention is necessary in high prevalence body regions such as lower back and wrist to decrease the symptoms. With respect to the results of PATH method, ergonomic interventions for trunk and leg(s) are necessary in all tasks, but only task #3 is in the priority of arm(s) intervention.

Key words: Building demolition, ergonomic risk assessment, musculoskeletal disorders, posture, activity, tools, and handling

INTRODUCTION

Most ergonomic assessments have focused on office and manufacturing sections.[1-3] Recently, some studies have highlighted ergonomic exposures in construction trades.[4-8] Demolition of building is one of the most dangerous sectors of the construction industry. If demolition of buildings is performed manually musculoskeletal disorders (MSD_s) risk factors require systematic assessment. There is little ergonomic exposure and MSDs symptoms data of workers population in building demolition. The profile of ergonomic exposures in building demolition might have similarities to construction process, but because of the growing nature of this industry in developing countries

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such as Iran, ergonomic assessments are necessary in this industry.

Awkward postures, physical excretion, and frequent use of hand tools have been related with lost-time injuries.[9] These risk factors are the main characteristics of construction trades and are expected in building demolition. Demolition of buildings manually is not a static job and cycles of activities and postures vary due to the dynamic nature of the job.

Low back, knee, and wrist have been reported as a body regions with high prevalence of symptoms in construction workers. One year prevalence of low back pain has been reported 65% in semi-skilled construction workers.[10] In a Thai survey, 97% of 531 construction workers have experienced numerous MSDs symptoms over the 12 months. Half of the symptoms have received medical treatment.[7]

Several methods have been applied to ergonomic risk assessment of different jobs.[11-15] Most of them are reliable for static tasks. Posture, activity, tools, and handling (PATH), a work sampling based approach, was developed specifically to characterize the ergonomic exposures in construction trades.[4] PATH method has been used in agriculture setting and caisson cage construction successfully.[16] In this study, PATH was applied to building demolition process. Postures, activities, and handling were recorded and discussed in four tasks. Critical tasks in terms of awkward postures were identified and highlighted for ergonomic interventions. The nordic musculoskeletal questionnaire (NMQ) was filled in by interview to record MSDs symptoms over 12 months [Table 1].

Table 1: Standardized nordic questionnaire for analysis of musculoskeletal symptoms. Please answer the questions by putting a cross in the appropriate box. Please answer every question, even if you have never had trouble in any part of body

Have you at any time during the last 12 months had trouble (ache, pain, discomfort) in:	Have you at any time during the last 12 months received medical treatment for trouble in:
Neck	Neck
1 ❐ No 2 ❐ Yes	1 ❐ No 2 ❐ Yes
Shoulders	Shoulders
1 ❐ No 2 ❐ Yes	1 ❐ No 2 ❐ Yes
Elbows	Elbows
1 ❐ No 2 ❐ Yes	1 ❐ No 2 ❐ Yes
Wrists/Hands	Wrists/hands
1 ❐ No 2 ❐ Yes	1 ❐ No 2 ❐ Yes
Upper back	Upper back
1 ❐ No 2 ❐ Yes	1 ❐ No 2 ❐ Yes
Low back	Low back
1 ❐ No 2 ❐ Yes	1 ❐ No 2 ❐ Yes
One or both hips/thighs	One or both hips/thighs
1 ❐ No 2 ❐ Yes	1 ❐ No 2 ❐ Yes
One or both knees	One or both knees
1 ❐ No 2 ❐ Yes	1 ❐ No 2 ❐ Yes
One or both ankles/feet	One or both ankles/feet
1 ❐ No 2 ❐ Yes	1 ❐ No 2 ❐ Yes

MATERIALS AND METHODS

This study took place at 8 building demolition sites in Tehran, Iran. Postures, manual materials handling activities, Hand grasps/activities and loads handled were recorded for 45 workers. A total of 920 observations were made on four job tasks.

PATH, firstly was developed to characterize the ergonomic risk factors of heavy high way construction work. More recently, PATH has been generalized to building construction and to work in agricultural settings and should be easily adapted to other non-repetitive work.[4]

PATH method evaluates the postures, activities, tools and weight of tools and loads handled. The PATH posture (trunk, legs, and arms) codes are modification of the posture codes used in the ovako working posture analysis system (OWAS). Definitions of postures and their illustration were shown in detail elsewhere.[4] Activity codes include manual material activities, and hand postures/activities. Lifting, lowering, carrying, moving/placing, and pushing/pulling are the manual material activities classification in this method. Hand activities are categorized in gross grasp, pinch grasp, and empty hand. The weight of tools and handled objects is recorded according to prior measurement and estimation during assessment. Before data collection, a specific data collection sheet is prepared for desire tasks. During data collection, each observer selects a group of workers at the beginning of the work shift. Observations are made at fixed 1 min intervals. In each observation, required data such as postures, activities, and weight of tools and materials are recorded in the data collection sheet.

The nordic musculoskeletal questionnaire (NMQ) also was used to study of the musculoskeletal disorders symptoms in this study.[17] The prevalence of musculoskeletal disorders symptoms in one last year was recorded by interview in nine regions of the body (neck, shoulder, elbow, wrist, upper back, lower back, hip, knee, and ankle). This questionnaire was filled in for all the workers.

Demolition process

In Iran buildings are usually deconstructed manually using hand tools such as shovel, pick, and hammer. The steel structure of building is cut down by welding apparatuses. Therefore, the most part of working day is spent with hand tools and carrying materials and garbage. In this study, the demolition process is classified into four job tasks: 1) separation of objects (task #1), 2) carrying objects and garbage (task #2), 3) deconstruction of building by hand tools (task #3), and 4) cutting down the steel structure (task #4).

RESULTS

PATH results

This study took place at 8 building demolition sites in Tehran, Iran. Postures, manual materials handling activities, Hand grasps/activities and loads handled were recorded for 45 workers. A total of 920 observations were made on four job tasks.

Trunk postures

Neutral trunk posture was observed frequently (65.8%) in task #2, but in 3 other tasks neutral posture was observed in about 30% of the working time. Totally, moderate flexion was observed 21.8%, severe flexion 28.6%, twisting or lateral flexion 5.7% and simultaneous flexion and twisting 7.6% of the time. The most frequently observed non-neutral trunk posture was severe flexion in task #1 (48%) and task #4 (41.2%). Trunk posture differed significantly among tasks (Chi-square on 12 degree of freedom, $P<0.001$).

Arm postures

Non-neutral arm postures were observed infrequently. Totally one arm at or above shoulder level and both arms above shoulder level were observed 11.5 % and 2.1 %, respectively. The most observed non-neutral arm posture (one arm above shoulder level) was in task #3 (19.9%). Arm postures differed significantly among tasks (Chi-square on 6 degree of freedom, $P<0.001$).

Leg postures

Neutral leg posture was observed 40 percent of the time. The half of the neutral leg posture was observed in task #3 and the remains distributed equally among other three tasks. The number 3 code of leg postures (leg(s) bent) was the most observed (37.8%) non-neutral leg posture. Walking (12.9%), one leg in air (6.8%), sitting on ground (0.5%), and kneeling (0.2%) were the other observed leg postures. Leg postures differed significantly among tasks (Chi-square on 18 degree of freedom, $P<0.001$).

Non-neutral postures of trunk, arm(s), and leg(s)

In order to compare the non-neutral postures of trunk, arm(s), and leg(s) in four studied tasks, all codes of these body parts other than the first code (neutral posture) are regarded as non-neutral posture. Results of this comparison are illustrated in Figure 1. It is clear that trunk and leg (s) are in critical state from awkward postures point of view but arm(s) postures are in a reasonable state and in comparison to trunk and leg(s) are in good condition.

Manual materials handling activities

Manual materials handling (MMH) activities are distributed differently among tasks. Moving was the most observed (35%) and carrying was the less observed (11.8%) MMH activity. In task #1 moving (99%), task #2 pushing/pulling (57.2%), task #3 lowering (37.3%) and task #4 moving (68%) was the most observed MMH activities. MMH activities differed significantly among tasks (Chi-square on 12 degree of freedom, $P<0.001$).

Hand activities

Hand activities were categorized in three groups; gross grasp, pinch grasp, and empty hand. Hand activities were observed in the order of gross grasp (78.5%), empty (16.2%), and pinch (5.3%) in demolition process workers. Gross grasp as a commonly observed hand activity distributed differently among tasks. In task #3 (52.1%), task #4 (23.5%), task #2 (15.8%), and task #1 (8.6%) of working time spend with gross grasp. Hand grasps differed significantly among tasks (Chi-square on 6 degree of freedom, $P<0.001$).

Loads handled

Loads handled were estimated and were grouped into four weight categories (0 kg, 0 kg≤load<5 kg, 5 kg≤load<10 kg, 10≤load). Tools and materials were handled more than 80% of the time for the studied tasks. The most observed weight category was 0 kg≤load<5 kg. The third and fourth categories of weights were observed 4.6% and 9.5%, respectively. The most heavy weights (10≤load) were observed in task #2 and # 4 in 22.4% and 26.8% of the working time, respectively. Loads handled differed significantly among tasks (Chi-square on 9 degree of freedom, $P<0.001$).

Nordic musculoskeletal questionnaire

Nordic musculoskeletal questionnaire was used to collect data on the annual prevalence of musculoskeletal symptoms. The study group was 45 building demolition workers. Mean (SD) of age and duration of employment was 27 (4.7) and 5.2 (2.9) years, respectively. All of the workers have experienced musculoskeletal symptoms during the last year. The prevalence of MSDs symptoms and the status of receiving medical treatment is shown in Table 2. Low back had the highest prevalence of MSDs symptoms (91.1%) and hip had the lowest prevalence of symptoms (6.7%). Among 41 workers who have experienced low back pain, 22 (53.7%) of them have received medical treatment. In other regions of body other than hip, the percentage of received medical treatment ranged from 16 to 34 percent.

DISCUSSION

There is little information about the ergonomic risk assessment of building demolition in the related literature. In this study, PATH method was applied properly in building demolition process. The high prevalence of MSDs in different

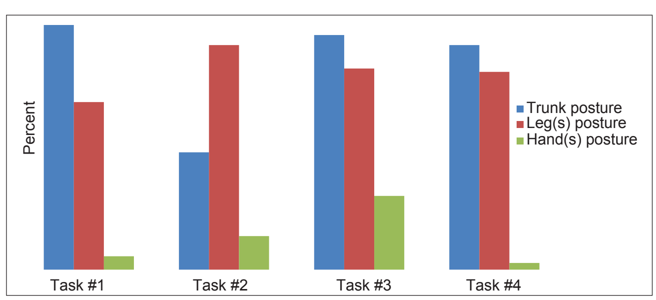

Figure 1: Non neutral postures of trunk, arm(s), and leg(s) among building demolition tasks

Table 2: Prevalence of musculoskeletal disorders in building demolition workers over 12 months

Region of the body	Prevalence of symptoms Number (%)	Status of receiving medical treatment Number (%)	Percent of symptoms received medical treatment
Neck	5 (11)	1 (2.2)	20
Shoulder	25 (55.6)	6 (13.3)	24
Elbow	11 (24.4)	3 (6.7)	27.3
Wrist	38 (84.4)	9 (20)	23.7
Upper back	26 (57.8)	4 (8.9)	15.4
Lower back	41 (91.1)	22 (48.9)	53.7
Hip	3 (6.7)	0	0
Knee	26 (57.8)	9 (20)	34.6
Ankle	24 (53.3)	4 (8.9)	16.7

regions of body revealed that workers in building demolition are at risk of developing MSDs. The frequency of exposure to risk factors for MSDs varied significantly among building demolition tasks. It means that requirements of each task are different from other tasks and different approaches should be considered in ergonomic interventions.

In trunk posture evaluation, forward flexion was recorded as the most observed non-neutral posture. This finding is in agreement with the results of ergonomic analysis of New York apple harvesters. Trunk flexion was the most observed non-neutral posture of apple harvesters.[16] The high occurrence of this posture might result in high prevalence of MSDs symptoms in trunk region. Task # 3 and #4 were the high risk tasks in terms of sever flexion of trunk and need more attention to reduce such an awkward posture. In automobile manufacturing an association between back disorders and non-neutral trunk posture was found by Punnett *et al.*[3] Neutral trunk posture was observed differently among tasks. In cement reinforcement workers, neutral posture was reported 40-80 percent of the working time.[5] The most observed neutral trunk posture in the task #2 is due to the nature of this task. Workers in this task carry the materials in straight trunk posture. Arms had the lowest non-neutral posture among evaluated body parts. In task #3 the highest observed non-neutral posture of hands along with using hand tools can result in higher prevalence of MSDs in the future. Therefore, task #3 is in the high rank of ergonomic interventions for arm postures. Near the half of the leg(s) postures was recorded as non-neutral in tasks other than task #2. Carrying objects and walking related postures are resulted in more non-neutral leg(s) postures in this task. In comparison of non-neutral postures of trunk, arm(s), and leg(s), we found that only arm(s) are in ergonomic good conditions and trunk and leg(s) should be ranked as high priority for ergonomic interventions.

Workers in building demolition have experienced different MMH activities. Moving was the most observed MMH activity. This finding is because of the separation and short replacement of materials and garbage. In case of low weight of moved materials, moving will be a safe MMH activity in building demolition.

Hand grasp is an important item to study in tasks which are accomplished manually. In Iran, buildings are demolished manually in most cases and it is expected that gross grasp would be the most observed hand activity. Our results support this idea and gross grasp is the most coded item for hand activities. Proper design of tools used in building demolition is a vital priority in ergonomic interventions and decrement of MSDs symptoms in upper extremities.

The handled loads in building demolition were in low weight categories. Breaking down the building materials and separation of valuable material for reuse reduces the weight of objects are carried. In tasks #2 and #4, carrying heavy materials by wheelbarrow and carrying steel bars may result in exposure with heavy loads.

In according to NMQ results, wrist and lower back are regions with high prevalence of MSDs symptoms and workers with lower back problems received more medical treatment. The severity of symptom in lower back would be the reason of more rate of clinical treatment. Li *et al.* have reported lower back symptoms in construction workers as the high prevalence symptoms.[7] There is a report of low back pain in 80% of rebar tying workers.[7] In this study the number of participants in NMQ study can be named as a limitation. Therefore, another investigation to study the MSDs symptoms with high number of participants is necessary in building demolition workers.

CONCLUSION

PATH, as a work sampling approach, is an applicable method to dynamic works such as building demolition. Reporting the results in simple mode such as percentage provides easy comparison of tasks. Lower back pain was the severe and most reported symptoms among building demolition workers. Ergonomic intervention is necessary in high prevalence body regions to decrease the symptoms. With respect to the results of PATH method, ergonomic interventions for trunk and leg(s) are necessary in all tasks, but only task #3 is in the priority of arm(s) intervention. Workers education in MMH activities and working postures, reducing the weight of hand tools and proper design of them as general and useful interventions can decrease the prevalence of MSDs in workers population.

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