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Best practices for preventing musculoskeletal disorders in masonry: Stakeholder perspectives

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Abstract

Brick masons and mason tenders report a high prevalence of work-related musculoskeletal disorders (WMSDs), many of which can be prevented with changes in materials, work equipment or work practices. To explore the use of "best practices" in the masonry industry, NIOSH organized a 2-day meeting of masonry stakeholders. Attendees included 30 industry representatives, 5 health and safety researchers, 4 health/safety specialists, 2 ergonomic consultants, and 2 representatives of state workers' compensation programs. Small groups discussed ergonomic interventions currently utilized in the masonry industry, including factors affecting intervention implementation and ways to promote diffusion of interventions. Meeting participants also identified various barriers to intervention implementation, including business considerations, quality concerns, design issues, supply problems, jobsite conditions and management practices that can slow or limit intervention diffusion. To be successful, future diffusion efforts must not only raise awareness of available solutions but also address these practical concerns.
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1. Introduction

There are well-recognized physical risk factors for work-related musculoskeletal disorders (WMSDs) in masonry construction, and research that shows specific changes in materials, work equipment, and work practices can reduce the magnitude of those hazards. At the same time, many masons and mason tenders are working with the same materials and equipment their fathers used. Why have ergonomic improvements not diffused throughout the industry? What characterizes the contractors who use these new methods? What information or action is needed to spread these new methods through the industry? These questions led to a meeting in 2004 to explore improvement in masonry construction with a group of contactors, masons and mason tenders, the findings of which we present here.

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1.1. Scope of the problem

1.1.1. Work-related musculoskeletal disorders (WMSDs)

Construction workers across most trades are at significant risk of musculoskeletal injury. The physically demanding nature of the work, awkward and static postures, vibration, harsh outdoor environment, and related risk factors help explain why strains and sprains are the most common type of work-related injury in construction, accounting for over 37% of all injuries resulting in days away from work (Schneider, 2001; Center to Protect Workers' Rights, 2002).

Masons have 100 back injuries with days away from work per 10,000 full time workers, compared to an average of 70 among all construction workers, and there are 105 injuries due to over-exertion with days away from work per 10,000 full time workers in the masonry industry, compared to 69 among workers in all sectors of construction (BLS 2005). The Construction Safety Association of Ontario (CSAO, 2003) found that 62% of over-exertion injuries among bricklayers are back injuries, with an additional 35% being upper extremity injuries. Fifty percent of all lost time injuries among bricklayers in Ontario were attributable to manual materials handling, compared to 25% for all construction workers. Masons report a high prevalence of back pain and other musculoskeletal pain, with a 12-month prevalence of low back disorder of over 40% (Sturmer et al., 1997; Latza et al., 2002), and as much as a 50% prevalence of shoulder disorders (Stenlund et al., 1992 1993). One study found that over 80% of mason tenders reported symptoms of an MSD in the prior year (Goldsheyder et al., 2002).

1.1.2. Physical hazards of masonry work

Risk factors identified for back injury among masons are the weight of bricks or blocks, the frequency of lifting, the height from which the block is picked up, the height at which the block is placed, the height of the mortar stand, the distance of the block from the worker's body, degree and frequency of twisting involved, and high expected production rates. Shoulder stresses include, in addition, laying brick and block above shoulder height (Van der Molen et al., 1998; Vink and Koningsveld, 1990; Binkhorst, 1989).

Masonry work is physically demanding. Energy use and O_2 consumption exceed recommended levels (Van der Molen et al., 1998; Vink and Koningsveld, 1990; Binkhorst, 1989), and trunk extensor fatigue has been observed in bricklayers performing highly repetitive work (laying 1000–1200 bricks per day) (Jager et al., 1991; Malchaire and Rezk-Kallah, 1991; Jorgensen et al., 1991; Jorgensen, 1997). Bricklayers spend 75% of their work time in 30° or more of back flexion at low wall heights, 20–25% of their time in 30° or more of back flexion at increasing wall heights (Bulthuis et al., 1991; Luttmann et al., 1991) and make an average of 1000 trunk-twist flexions and extensions per day (Jorgensen et al., 1991). In a study of gypsum bricklayers, L5-S1 compressive forces over 2000 N were seen in 11% of observations (Van der Molen et al., 1998); such cumulative spinal loading may result in spinal disease (Seidler et al., 2001).

1.1.3. Ergonomic improvements in masonry construction

Work to improve masonry dates back to 1909, when Frank Gilbreth published a bricklaying system designed to increase productivity and improve working conditions (Gilbreth, 1909). The ergonomic benefits of height-adjustable work platforms are now well-established (Luttmann et al., 1991). Significant ergonomic improvements may be achieved by decreasing brick/block weight (Van der Molen et al., 1998), with a decrease in mean and peak spinal compression. Raising the brick/block supply and mortar supply 30–50 cm off of the ground has been shown to significantly reduce lumbar compression, biomechanical stress, and energetic workload, while increasing bricklayer comfort (Vink and Koningsveld, 1990; Binkhorst, 1989; De Looze et al., 1996; Vink et al., 2002). Other research points to changes in trowel size (Vi et al., 2002) and mechanization in lifting (Van der Molen et al., 1998) as possible strategies for reducing bricklayers' risk of WMSDs. Few studies have examined the effects of these and other ergonomic interventions on total construction time, but there is some evidence suggesting that ergonomic improvements may increase mason productivity (Van der Molen et al., 1998; Luttmann et al., 1991; NCMA, 1989, 1973, 2002; Johnson, 1974).

Mason tenders also move brick and block. In addition, they lift and carry 210 kg bags of cement, shovel sand, and move buckets of water to make mortar, then deliver the mortar to the mason. Some of the interventions described above improve the work of a mason tender, and there are a few specific interventions designed for the mason tender's tasks. De Looze et al. (2001) describe two devices developed to greatly reduce or eliminate manual material handling. A pincer device, used with a crane, loads and transports bricks to the mason's work station on the scaffold. The "opkar" is a variation on a forklift that greatly reduces the frequency of truck torsion and deep bending during movement of bricks, and also eliminates carrying of weights over 40 kg in a wheelbarrow. These devices were used in a participatory ergonomics program, but not evaluated with any quantitative measurements.

1.2. 2004 masonry stakeholders meeting

While the relatively high risk of musculoskeletal disorders among masonry trades is well documented, and preliminary research has identified a number of interventions that may reduce this risk, there is little information on the extent to which ergonomic interventions are being implemented, factors affecting acceptability and use of these controls, and technologies and work practices that need to be developed or refined in the future. To address these issues, the National Institute for Occupational Safety and Health (NIOSH) organized a masonry stakeholder meeting in Cincinnati, Ohio in March 2004. The two-day meeting was co-sponsored by the Center to Protect Workers' Rights (CPWR), the International Council of Employers/Bricklayers and Allied Craftworkers, the International Union of Bricklayers and Allied Craftworkers, the Laborers' Health and Safety Fund of North America, and the Mason Contractors' Association of America. Forty-three stakeholders participated: 15 masonry contractors, 12 masonry tradespeople, 5 occupational health and safety researchers, 4 health and safety specialists, 3 contractor association representatives, 2 ergonomics consultants, and 2 representatives of state workers' compensation programs.

The meeting began with presentations describing the nature and extent of WMSDs in the masonry trades, physical risk factors associated with masonry tasks, and past and present intervention technologies utilized in the US and Europe. These presentations were followed by three break-out sessions designed to explore contractors' and tradespeople's experiences in implementing ergonomic interventions. Contractors and tradespeople were asked to:

(1) review and revise masonry task lists; (2) identify available interventions and describe their effectiveness; (3) discuss job conditions and other factors favoring or disfavoring intervention implementation; and (4) make suggestions to promote acceptability and diffusion of interventions in the future. This paper describes the results of the break-out sessions, presents the interventions used and recommended by the participants, and outlines some future research needs.

2. Methods

NIOSH and meeting co-sponsors sought contractors, masons, and mason tenders who had experience developing and implementing ergonomics programs. Despite efforts to recruit residential contractors, all 15 participating contractors were from the commercial construction sector. Twelve of the 15 contractors were signatory with the International Union of Bricklayers and Allied Craftworkers and/or the Laborers' Health and Safety Fund of North America. Local unions recruited 11 masons and 1 mason tender. Together, the 27 participants represented 12 different states across the United States.

To facilitate discussion of WMSDs physical risk factors, NIOSH and CPWR developed job task lists for the mason and mason tender trades. Mason job activities and tasks were adapted primarily from Everett (1997), who identified eight activities and related tasks performed by southwestern Michigan union bricklayers and allied trades (Table 1). Because tradespeople attending the stakeholders meeting were experienced primarily in brick, block and stone masonry, four tile setting and paving job activities identified by Everett were not included on the list for discussion. Two additional jobs not identified by Everett were added, cutting brick/block and installing reinforcements, based on masonry job task analyses conducted by Davis (2001) and DesMarais and McDonald (1998), respectively. Everett identified two basic job activities for mason tenders, supplying brick/block and mixing/transporting mortar; this was expanded to include additional jobs and job tasks identified by the New York State Laborers' Health and Safety Trust Fund (2001) (Table 2). Demolition and general housekeeping and maintenance activities were not included on either task list, due to time constraints.

In the first session, which involved reviewing the job task lists and generating a list of interventions, masonry contractors were divided into two groups, tradespeople were assigned to a third group, and all other participants were randomly assigned. Contractors and tradespeople were assigned to separate groups in the initial session in order to avoid development of a hierarchy among group members and to encourage full participation. For the following two sessions, in which participants discussed conditions affecting the implementation of interventions and areas for future action, each group included a mix of contractors, tradespeople and others, with contractors and tradespeople assigned to maximize the geographic diversity of each group.

All three sessions were similar in structure to focus groups, having one moderator and one note-taker.

Table 1
Mason jobs and tasks[a]

Jobs	Tasks
Lay brick/block	Formulate work sequence
	Carry materials to work location[g]
	Lay out materials[b]
	Climb scaffolding[b]
	Spread mortar on wall[f,g,h]
	Spread mortar on brick/block[f,g,h]
	Lay brick/block[f,g,h]
	Check level and plumb
	Strike joints[f,h]
	Scrape off excess mortar[b]
	Re-temper mortar[b]
	Inspect work
Cut brick/block[c]	Measure and mark brick/block[c,h]
	Operate saw[c]
Insert insulation[b,e]	
Add reinforcements[d]	Insert rebar[d]
	Lay wire between courses[d]
	Insert wall ties[d]
Grout cells[b]	Mix grout[b,h]
	Transport grout[b,g]
	Pour grout from buckets/control grout hose[b,f,g]
	Handle vibrator[b,g]
Wash down brick/block-work	Formulate work sequence
	Carry materials to work location[g]
	Brush acid on wall
	Spray water on wall with hose
	Inspect work
	Add waterproofing[b]
Restore walls[b]	Grind joints[b,h]
	Brush joints[b,h]
	Clean joints[b,h]
	Remove and replace brick[b]
	Inject epoxy[b,h]
	Add waterproofing[b,h]
Set stones[b,e]	
Install stone panels	Formulate work sequence
	Carry materials to work location[g]
	Measure and mark position of panel edge
	Position panel on wall[g]
	Check for level and fit
	Inspect work
Oversee laborers[b]	Delegate tasks to laborers[b]
	Supervise laborers[b]
Oversee scaffolding safety and maintenance[b,e]	

[a]Unless otherwise described, jobs and tasks are adapted from Everett[(35)].
[b]Added during break out sessions.
[c]Adapted from Davis[(36)].
[d]Adapted from DesMarais and McDonald[(37)].
[e]Break-out groups did not break job into tasks.
[f]Entails risk factor of overhead work.
[g]Entails risk factor of manual material handling.
[h]Entails risk factor of repetitive upper extremity work.

Table 2
Mason tender jobs and tasks

Jobs	Tasks
Mix mortar[a]	Set up mortar mixing station[b]
	Lift and carry bags of mortar mix (unless silo is used)[c,g]
	Empty mortar mix into mixer[c,f,g]
	Shovel sand into mixer (unless silo is used)[c,f,g]
	Dump water into mixer[c,f,g]
	Re-temper mortar[b]
Transport mortar[a]	Empty mortar into container[c,f,g]
	Transport mortar to work location[c,g]
	Move mortar up scaffolding[c,g]
Cut brick/block[b]	Measure and mark brick/block[b,h]
	Operate saw[b]
Transport brick/block[a]	Transport brick/block to work location[c,g]
	Move brick/block up scaffolding[c,g]
	Operate forklift (if used)[b]
Transport stone[b,d,g]	
Transport reinforcements[b,d,g]	
Grout cells[b]	Mix grout[b,h]
	Transport grout[b]
	Pour grout from buckets/control grout hose[b,f,g]
	Handle vibrator[b,h]
Clean up excess mortar[c]	Scrape off excess mortar[c,h]
	Sweep excess mortar[c]
Scaffold erection/take down[c]	Move materials to/from work location[c,g]
	Connect/disconnect pins and stabilizing hardware[c]
	Maintain proper scaffolding height[b]
Oversee scaffolding safety and maintenance[b,d]	

[a]Adapted from Everett[(35)].
[b]Added during break out sessions.
[c]Adapted from New York State Laborers' Health and Safety Trust Fund[(38)].
[d]Break-out groups did not break job into tasks.
[f]Entails risk factor of overhead work.
[g]Entails risk factor of manual material handling.
[h]Entails risk factor of repetitive upper extremity work.

Moderators received background materials and a suggested script to structure the discussions. Researcher attendees were instructed to keep their comments to a minimum, allowing contractors and tradespeople to lead the discussion. Flip charts and notes generated in each session were used to prepare written summaries; all sessions were audio-taped.

Task lists for masons and mason tenders were distributed to attendees prior to the meeting; participants added missing job activities or tasks and identified other necessary revisions through consensus in the first break-out session. Tables 1 and 2 include a notation to risk factors associated with each task. This notation was not discussed in detail at the meeting; the assignment of risk factors was based on the authors' experience and the research cited above. As with much of construction work, the specifics of a task vary between worksites; the notations here are quite general and will not apply each time a task is performed.

After reviewing the task lists, break-out session participants were asked to name tools, materials, equipment and work practices that they had themselves used or seen being used to prevent musculoskeletal injuries among masons or mason tenders. Participants were then asked to provide their opinions regarding the effectiveness and relative importance of the listed interventions, based on their own experiences. Interventions identified by the three independent break-out groups during Session 1 were merged into one comprehensive list for discussion in Session 2.

In Session 2, participants were asked to describe the extent to which ergonomic interventions have been adopted in the industry and to discuss job conditions and other factors that influence their use, including conditions that tend to promote implementation as well as barriers to implementation. Moderators used scripted prompts to ensure that each of the following factors were discussed: cost, productivity concerns, work organization, trade jurisdictions, problems with design or performance of the intervention, building site conditions, materials and design specifications, and resistance to change.

In the third and final break-out session, meeting participants were asked to focus on ways to improve the acceptability and use of ergonomic solutions. Moderators encouraged free-form discussion of interventions in need of evaluation and/or refinement, solutions that need to be developed in the future, and ways to promote widespread intervention diffusion.

3. Results

Contractors and tradespeople added a number of jobs and tasks to both the mason and mason tender task lists (Tables 1 and 2). Most notably, participants in each of the three discussion groups added climbing scaffolding and grouting to the list of activities performed by both masons and mason tenders. Grouting was further divided into the related tasks of mixing grout, controlling the grout hose and handling the vibrator. Jobs added by two of the three discussion groups included oversight of scaffolding safety and wall restoration; the third group decided not to include restoration because it is a specialized job activity representing a relatively small proportion of masonry work. There was occasional disagreement among group participants about which task belonged on which list. For example, several contractors labeled cutting brick and block as a mason tender job, commenting that this time-consuming activity is an inefficient use of masons' time. Several tradespeople, on the other hand, placed this activity squarely on the list of mason jobs, maintaining that laborers lack sufficient training and skill to operate masonry saws.

Discussion on the task lists highlighted fundamental differences between the commercial and residential construction sectors. Participants in all three groups noted that on commercial sites materials handling generally involves operation of a forklift (a mason tender or operator task), with manual materials handling being more common on residential sites. Contractors noted that mortar mixing tasks vary considerably from one site to the next, with use of a mortar silo and pre-blended mix being more common in commercial construction, and manual cement bag handling more common on residential sites. Brainstorming activities and group discussions in the three break-out sessions generated a long list of equipment, tools, materials, administrative controls and work practices perceived to reduce the risk of musculoskeletal disorders among masons and mason tenders. These solutions are categorized according to the hierarchy of controls in Tables 3–5; participants also noted availability of PPE including back belts, work gloves, vibration dampening gloves, and body harnesses & power retracting lanyards.

When asked in Session 1, which interventions they considered to be "most important," multiple contractors and tradespeople in all three discussion groups named adjustable-height scaffolding (Figs. 1a,b) and lightweight block. Participants in both contractor groups also ranked equipment to reduce manual materials handling, such as mortar silos, grout delivery systems and forklifts, among the most important interventions. Other "important" solutions included (in no particular order) proper tool maintenance, small-sized materials pallets, bans on saw

Table 3
Currently available engineering controls identified in break-out sessions

Type of control	Suggested control
Personnel platforms and lifts	Mast climbing work platforms Adjustable tower scaffolding Personnel lifts (for caulkers)
Materials and tool platforms	Split-level scaffolding Mortar pan stands Stock board stands Adjustable-height saw tables
Materials handling equipment	Silo mortar dispensing systems Hydraulic mixers Mixers with hydraulic dumpers Mortar pumps (used in Europe) Grout pumps Grout Hog™ grout dispensing system Wheelbarrows, buggies, handcarts, dollies Power pallet movers Power pallet jacks Forklifts Hoisting equipment Cranes Longer outriggers on scaffolding to run brick and block up separately
Tools	Rebar shakers Dual-handle grinders Power caulking guns Power washers Trowels with angled handles Decreased vibration saws Quick-cut saws Cordless tools Tools with cushion-grip handles
Materials	Lightweight block H-block A-block Knock-out block Large blocks (placed mechanically or by two people) Pre-stressed masonry Self-consolidating grout Pre-blended mortar Reduced-size pallets

Table 4
Administrative controls identified in break-out sessions

Type of control	Suggested control
Jobsite layout and materials staging	Build scaffolding with access from inside building Place Port-a-John on scaffold to reduce climbing Use two-way radio for communication to reduce climbing Pre-stock supplies to avoid delays and schedule changes Stock pre-cut shapes to avoid saw cutting Don't overstock (to avoid traffic problems) Pre-plan materials placement to reduce handling Stage materials close to end use Cover unused materials to keep them dry/light
Work sequencing and scheduling	Hold joint meetings to coordinate activities among subcontractors and trades in order to avoid schedule changes, uncontrolled work and overtime Schedule jobs to utilize equipment optimally Schedule regular rest breaks Schedule rest breaks after particularly strenuous production Rotate workers Avoid overtime Hold less strenuous tasks for overtime
Participatory ergonomics programs	Hold regular labor-management meetings to discuss jobsite ergonomics and possible improvements Get mason and mason tender feedback on new products
Exercise programs	Start each shift with a 10 min stretching session
Training	Provide ergonomics training Strengthen apprentice programs Reinforce apprenticeship training on the job

cutting on scaffolding, good housekeeping and training. There was no general agreement, however, on the relative importance of any one intervention, with some interventions generating significant debate. For example, although multiple participants in all three discussion groups named substituting lightweight block for regular weight block as an especially important intervention, other participants questioned the feasibility of this solution, citing the limited availability of lightweight block in many parts of the country, high shipping costs and quality concerns. Many participants were enthusiastic advocates of silo systems, maintaining that silos reduce manual materials handling, free-up jobsite space, prevent sand from freezing, eliminate waste, and allow for easy clean-up and transportation. Others disfavored silos due to dust problems they had experienced with such systems, high initial purchase cost, and concerns regarding the quality and consistency of the mortar mix.

When asked what conditions or circumstances determine whether new technologies and work methods are adopted on a jobsite, stakeholder participants identified a wide range of factors that can promote or impede intervention implementation. Financial savings, in the form of increased productivity, decreased labor costs, or reduced workers' compensation costs, was the most commonly-cited incentive for adopting new technologies and techniques. Stakeholders also identified concern for workers' health and safety as a chief motivating factor, although business considerations may be at play here as well; several contractors and tradespeople noted that due to labor shortages in the masonry trades, many contractors cannot afford to lose an experienced worker to illness or injury. Other drivers of change included health and safety regulations and the threat of citations, bid requirements associated with best value contracting, and pressure from insurance companies to adopt new ergonomic solutions.

Table 5
Work practice controls identified in break-out sessions

Work activity	Suggested control
Transporting materials	Manually handle materials on scaffolding only Break buckets of mortar/grout into smaller loads Balance loads (carry 2 buckets instead of 1) Use shovels of appropriate size and length
Cutting brick/block	Saw cut brick/block instead of using hammer Saw/cut using table saw, not on scaffolding Select appropriate diamond or matrix for the job Maintain saw blades
Laying brick/block	Use two-person lifting Re-temper mortar to keep it soft Practice economy of motion in mortar technique Use trowel of appropriate size and design
Housekeeping and maintenance	Keep good housekeeping Maintain tools and equipment Maintain proper scaffolding height

Just as business considerations topped the list of reasons for implementing ergonomic solutions, financial concerns dominated the discussion of barriers to widespread intervention diffusion. Break-out session participants described interventions requiring large capital investments as beyond the reach of many contractors. Stakeholders also expressed strong resistance to interventions that may decrease worker productivity, reduce job quality, require frequent and/or costly maintenance, introduce new health or safety hazards, or change the nature of a job so dramatically that it is assumed by another trade or requires added supervision.

Stakeholders also described a number of design issues, supply problems, jobsite conditions and management practices (i.e., site planning and coordination) that render some technologies and work practices impractical on many worksites. For example, participants described architects' and engineers' reliance on rebar and grout as a barrier to widespread diffusion of pre-stressed masonry, which would eliminate the physical stress associated with lifting block over rebar and performing grouting tasks. Examples of problem jobsite conditions and management practices included space limitations, poor ground conditions, poor weather conditions, and disorderly job sequencing resulting in inefficient use of equipment and uncontrolled work.

There was general agreement that architects, engineers and project owners lack awareness and understanding of both WMSD hazards and available solutions, effectively preventing implementation of new technologies and

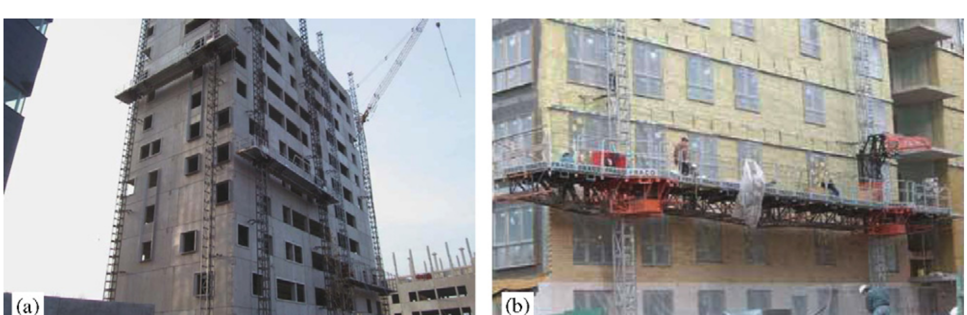

Fig. 1. (a,b) Mast climbing work platforms.

methods on many jobsites. Participants identified lack of training, inexperience, resistance to change, fear of sharing intervention ideas with competitors, and apathy among masonry contractors and tradespeople as significant barriers to change in the industry. Other identified barriers to change included poor labor-management communication on ergonomics issues, personality conflicts among co-workers, inadequate enforcement of regulations, unfair competition, and lack of return-on-investment analysis for individual interventions.

Throughout all three break-out sessions, participants suggested future courses of action to improve the acceptability and implementation of ergonomics interventions in the masonry trades:

3.1. Refinements to existing interventions

Meeting participants suggested refining some available interventions that have been slow to catch on due to high initial cost or performance problems. For example, participants encouraged the development of lightweight block manufactured from locally-available materials (e.g., recycled plastic) in order to eliminate the high shipping costs currently associated with use of this product in many parts of the country. Others suggested stepping up efforts to address the dust problem they associated with silo mortar dispensers and perceived fall risks associated with ladder access to mast climbing work platforms.

3.2. Solutions in short supply

Break-out session discussions also underscored the need to increase the supply and availability of some existing solutions. When several meeting participants reported that small-size materials pallets are easier to handle, place on scaffolding and break down compared to standard-size pallets, other attendees expressed a willingness to use smaller pallets should this solution become available in their areas. Several stakeholders complained of a decline in availability of blocks of different sizes and shapes due to the introduction of just-in-time production models. Expanding the availability of pre-cut sizes and shapes, it was suggested, would eliminate the lion's share of on-site saw cutting and related injuries.

3.3. Interventions for future development

In addition to changes to existing interventions, break-out session participants proposed new solutions for future development, including half-weight cement bags and vacuum lifts for materials transport. Reducing the weight of cement bags by half received serious discussion and widespread support, while the idea of introducing vacuum lifts, an intervention currently utilized in the Netherlands, was met with considerable skepticism. Participants also proposed developing alternatives to split-face block, one of the heaviest concrete masonry units, and finding ways to eliminate the task of laying block in foundation trenches, which involves kneeling, bending and other awkward postures.

3.4. Areas for future research and analysis

When asked directly what researchers and academics can do to promote the use of ergonomic solutions in the masonry trades, meeting participants called for continued documentation of job hazards, related injuries and available solutions, including solutions that have been used successfully in other countries. Others expressed a need for evaluation studies to assess the effectiveness and/or usability of specific interventions, namely, angled trowels, stretching programs, half-weight cement bags and larger blocks. In addition to effectiveness evaluation research, meeting participants reported a need for cost–benefit and return-on-investment analysis to highlight productivity and financial gains that may be achieved by implementing seemingly cost-prohibitive interventions. Finally, support was expressed for development of a "best practices" program based on the above research and analysis, provided that any such program also includes input from industry representatives.

3.5. Dissemination of best practice information

Meeting participants offered a number of suggestions for disseminating ergonomic best practice information throughout the industry. Websites, videos illustrating the physical effects of poor work practices, and "tip sheets" highlighting new or innovative solution ideas were identified as promising diffusion tools. Attendees also supported the development of ergonomics handbooks, complete with best practice information and relevant regulations, for distribution to all newly-licensed masonry contractors, an approach being implemented in Washington State. To reach employers who have no direct contact with the state, stakeholder participants suggested disseminating ergonomics information via equipment and materials suppliers. There seemed to be general agreement that diffusion efforts should specifically target residential and non-union contractors, although it was noted that poor performers can be found in all sectors. Two contractor attendees suggested presenting best practice information at local homebuilders' association meetings, calling on model contractors to become more active in associations generally.

3.6. Training

Frequently, discussions of ways to promote acceptability and use of ergonomic technologies and work practices came back to the subject of training. Stakeholder attendees reported a need for increased training in the specific areas of job site layout, use of ergonomic tools, mortar spreading technique, lifting, and adjustment of mast climbing work platforms and adjustable tower scaffolding. It was repeatedly noted that even where new types of adjustable-height work platforms and scaffolding have been adopted, poorly-trained workers often set the platform so that bricklayers begin work at ankle-level. There was widespread agreement that workers must be taught safe work practices during apprenticeship training and that greater effort must be made to reinforce apprenticeship training on the job. To that end, participants proposed targeting foremen and middle management for training, in addition to tradespeople and contractors.

3.7. Safety in design

To promote the incorporation of ergonomic materials and methods in building specifications, break-out groups repeatedly stressed the importance of efforts to raise ergonomics awareness among architects, engineers and building owners. Members of one discussion group proposed that NIOSH increase its presence at designer association meetings. Others proposed creating more opportunities for designers to interact with masonry tradespeople through programs such as the International Masonry Institute's Masonry Camp, which provides architectural students with hands-on experience in the masonry crafts.

3.8. Regulation and public policy

Although stakeholder participants expressed general resistance to increased regulation in the masonry trades, attendees nevertheless proposed a number of regulatory measures to promote intervention implementation. Regulatory measures proposed by one or more meeting participants included building codes to standardize the use of lightweight block and autoclaved aerated concrete (AAC), standards limiting the weight of cement bags, ergonomic training requirements, two-man lifting requirements, bans on saw cutting on scaffolding, stiffer regulation of ladder access to mast climbing work platforms, and licensure of masons. Additionally, stakeholders called for public policies to give contractors a greater role in setting building codes and standards, the inclusion of "responsible contractor" requirements in public works contracts, and workers' compensation discounts for contractors who implement best practice programs. However, with respect to workers' compensation discounts, it was noted that incentive programs may have the unintended, adverse effect of discouraging injury reporting.

3.9. Regulatory enforcement

Finally, stakeholders attending the meeting repeatedly called for more aggressive and targeted enforcement of existing laws and policies to reduce unfair competition from poor performers. Numerous contractors expressed support for tighter enforcement of OSHA requirements, employment regulations, immigration laws, and responsible contractor provisions in public works contracts. Some meeting participants, including one tradesperson, also endorsed the idea of sanctions for noncompliant workers.

4. Discussion

The stakeholder meeting identified masonry activities that are largely overlooked in the ergonomics literature. Meeting results suggest that grouting, climbing scaffolding, and laying block in foundation trenches are appropriate targets for further hazard assessment and/or solution development. The unexpected emphasis on grouting and climbing scaffolding, both of which were added to the job task lists in Session 1, may reflect recent changes in the masonry industry; the amount of grout being specified on the average masonry project is on the rise (Inglesby and Lang, 2003), and time spent climbing may be increasing as well, with increasing use of mast climbing work platforms and adjustable-height scaffolding. Though climbing may be primarily a fall hazard, addressing the risks of this activity is an appropriate area for ergonomics research because fall risk limits the acceptability of otherwise promising ergonomics solutions. Laying block in foundation trenches, a task noted by meeting participants as an especially stressful activity with no good solution, merits consideration from building designers, contractors and researchers. Other job activities given considerable emphasis in break-out discussions include mortar mixing and saw cutting brick and block; hazard assessment and intervention development should encompass the mortar mixing and saw cutting stations as well as the bricklaying platform.

The stakeholders meeting also identified a wide range of voluntary ergonomic controls currently available and utilized in the masonry trades. While these interventions spanned the hierarchy of controls, industry representatives tended to focus on engineering controls: equipment, tools and materials that eliminate or reduce the intensity of an ergonomic risk factor. Additionally, there was wide support for the use of administrative controls, defined as management-dictated work practices and policies that eliminate or reduce workers' exposure to a risk factor (NIOSH, 1997). Administrative programs to minimize overtime and uncontrolled work, such as through improved coordination of work scheduling and materials staging, were considered especially critical to reducing harmful exposures. Interventions best described as work practice and personal protective equipment (PPE) controls were given the least attention, with PPE receiving only brief mention and limited support. These results suggest that most stakeholder attendees recognized the primary importance of engineering controls, followed by administrative and work practice controls, in eliminating or reducing exposures to WMSD risk factors.

In identifying a long list of available solutions and discussing their effectiveness and implementation, meeting participants tacitly acknowledge the existence of WMSD risk factors in the masonry trades and the desirability of controlling workers' exposure to them. None of the participants expressed serious doubt regarding the presence of WMSD risk factors in masonry or the need for ergonomic solutions, suggesting that, among meeting participants, ignorance of the problem is not a significant barrier to implementation of solutions. This level of awareness was expected, as meeting organizers had purposely invited industry representatives with experience implementing ergonomic solutions.

More surprisingly, there were no serious disagreements regarding the effectiveness of available controls in reducing exposure to WMSD risk factors, with questions only about stretching programs, angled trowels and back belts. When asked to identify areas in need of further research, attendees placed relatively little emphasis on studies of intervention effectiveness, attaching greater importance to economics research and return-on-investment analysis. Meeting participants' apparent agreement on the ergonomic advantages of available controls suggests that rigorous effectiveness evaluation is not always a necessary condition to the trial and adoption of new interventions, a conclusion consistent with findings from a meeting in 2002 exploring the use and development of ergonomic interventions for the mechanical and electrical construction trades (Albers et al., 2005).

With meeting participants having acknowledged the need for and effectiveness of a wide range of available interventions, discussions of ways to promote intervention diffusion centered on the practical feasibility of implementation. Participants discussed a number of practical considerations that may determine whether an intervention is adopted on a given jobsite, including attributes of the intervention itself (e.g., cost, availability, safety, effects on productivity, and impact on trade jurisdiction) and independent factors (e.g., worker knowledge and training, jobsite conditions, building design, materials specifications, and the larger regulatory and enforcement context). Many of these reported considerations are largely outside the control of individual contractors and tradespeople, a key conclusion underscored throughout the break-out sessions. Stakeholder participants expressed particularly strong frustration over their limited ability to influence building design, materials specifications, materials production, and site management systems, underscoring the need to include building designers, engineers, manufacturers and project owners in intervention diffusion efforts

Simply raising awareness of the risk factors for WMSDs and possible interventions among masonry contractors and tradespeople will not, in itself, bring about widespread change in the industry. Instead, diffusion efforts must also address practical barriers to solution implementation, such as business considerations, jobsite conditions, and structural factors limiting contractors' and tradespeople's abilities to effect change on a jobsite. Future research in this area should document not only the effectiveness of individual solutions in reducing exposure to WMSD risk factors, but also the feasibility of implementing solutions under variable conditions and the business value of doing so.

This group of participants may not fully represent the masonry industry in the United States. All the contractors worked in commercial construction, and there would be important differences in tasks and solutions in the residential sector. The express intent of the meeting was to invite participants who had some prior experience with implementation of ergonomic interventions, so we can assume this group had a higher than average awareness of WMSDs in construction. Most of the participants were from the unionized sector of the industry; mason tenders were not well represented. In addition, the results do not cover all tasks, hazards or solutions, but rather the ones raised by the participants. Although we do not see representativeness as a limitation on the results, we caution that the results cannot be generalized to the entire industry. We were looking for suggestions on how to change masonry construction, and intentionally brought in forward thinking contractors and tradespeople. Future work will be needed to explore application of the interventions discussed here in a non-union or residential sector.

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