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# Age, work limitations and physical functioning among construction roofers

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**Abstract**. *Background*: To investigate the intersection of aging with work limitations, chronic medical and musculoskeletal conditions, and physical functioning we undertook a cross-sectional study of U.S. construction roofers who were current union members between the ages of 40 and 59.
*Methods*: Participants were asked about the presence of medical conditions and musculoskeletal disorders (MSDs); the Work Limitations Questionnaire, the SF-12, and other validated assessments of social and economic impact of injury were included.
*Results*: Sixty-nine percent had at least one of these conditions in the previous two years; 31% missed work. Workers with medical and musculoskeletal conditions were older, had the highest prevalence of work activity limitations, and had the lowest SF-12 scores.
*Conclusions*: Older age was associated with the presence of a medical condition, and with reduced physical functioning. Medical and musculoskeletal conditions were strongly associated with work limitation, missed work, and reduced physical functioning. Older workers may be at higher risk of disability retirement compared to younger workers with similar medical conditions and work limitations.

Keywords: Occupation, construction, roofer, musculoskeletal disorders, injury

## 1. Introduction

Construction, one of the largest industries in the US, is also one of the most dangerous. Despite continuing efforts to reduce the number of occupational injuries and illnesses, the construction industry continues to record a high rate of injuries. In 2005 , there were 193 injury and illness cases with days away from work per 10,000 full time equivalent workers [4]. Cross-sectional studies reveal a high prevalence of chronic musculoskeletal complaints (pain, ache, and discomfort) among construction workers [13,14,18,23, 31]. The physically demanding nature of the work, manual materials handling, 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 a high percentage of all injuries resulting in days away from work [3,28] as well as a high prevalence of musculoskeletal disorders (MSDs) [11]. Roofers in particular have a high rate of injury, at 216 per 10,000 workers [4] and a high prevalence of MSDs [9,16].

At the same time, the average worker, including the average construction worker, is getting older. The US Bureau of Labor Statistics projected that between 1995 and 2005 the number of workers over age 55 would increase at an annual rate of 2.5%, a rate faster than

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other age strata [25]. Construction workers are typically younger than the national labor force; however they are also aging. From 1980 to 2000, the proportion of construction workers aged 40 to 49 years increased from 17 to 28%, while the proportion of construction workers in the 20-to-29-year age group decreased from 32 to 21% [3]. As we learn more about the characteristics of older workers, and their ability to maintain health and productivity on the job, the evidence suggests that work demands need to be changed in order to accommodate the work limitations found in an older workforce [15].

This cross-sectional study investigated the prevalence of medical and musculoskeletal conditions among working roofers, and examined the association between these conditions and age, physical functioning, and work limitations. The project was reviewed and approved by the institutional review boards of the Center to Protect Workers' Rights and George Washington University.

## 2. Methods

### *2.1. Selection of study population*

Our goal was to enroll 1000 currently employed roofers. The Roofers International Union provided us with names, home addresses and dates of birth for all union members as of March 2004, and we randomly sampled just over 3000 subjects, by age and union membership status; based on pilot data we sampled more than our target population of 1000 to allow for loss to follow-up . Roofers on the union membership roster were eligible to be selected for the target population if they: 1) were between the ages of 40 and 59; 2) were current union members; and 3) had maintained continuous union membership during the previous two years. Roughly equal numbers of subjects were selected from the age sub-groups 40–44, 45–49, 50–54 and 55–59 years. Workers aged 40 to 59 were targeted for selection based on pilot study data that showed this age range to account for the majority of all reported health conditions.

At the time of the interview we found that 59 of the subjects in the target population were included erroneously; 51 were no longer union members and 8 were deceased. Of the remaining individuals, 1200 could not be contacted by phone, for a lost-to-follow-up proportion of 40%; 1808 target subjects were successfully contacted by phone. Members of the target population were eligible for participation in the study if they were working as a roofer or roofing supervisor (either full- or part-time) or expected to be so employed in the next 3 months; this information was determined in the interview, and 239 did not meet this criterion. Among the 1569 subjects who did meet this final criterion, 979 (62%) completed an interview. There was no significant difference in participation rates between age groups.

### *2.2. Data collection methods*

A letter describing, in English and Spanish, the nature and purpose of the study was sent to members with known phone numbers in the month before the first interview attempt. Both directory assistance and a commercial vendor were used to find telephone numbers, and at least six interview attempts were made for each subject for whom a phone number was found. Informed consent was obtained from each subject over the phone prior to initiation of the interview. Interviews were conducted in both English and Spanish using a computer-assisted telephone interview.

### *2.3. Measures*

The baseline interview included questions on: (1) medical and musculoskeletal (MSD) conditions experienced by the respondent in the past two years, (2) missed work and job accommodations related to these conditions, (3) frequency and duration of MSD symptoms, (4) the respondent's functional status, (5) economic status, and (6) basic demographics. The medical condition portion of the interview included questions on the following specific diseases and conditions, termed "target medical or MSD conditions": cancer/leukemia; heart attack/disease; stroke; liver problems; stomach/intestinal problems for which the respondent took medication or regularly saw a doctor; kidney/bladder problems; diabetes-related health problems; lung/breathing problems; neurological problems; loss of vision; serious burns that required medical attention; and psychiatric/emotional problems or drug/alcohol problems for which the respondent saw a doctor or other health professional. These initial questions were modeled on questions from the National Health Interview Survey, with the addition of specific questions about the impact of each condition on work ability and time off work over the prior two years. Additionally, each subject was asked whether he or she had taken medication or regularly seen a doctor

for problems with his or her neck/upper back, shoulder, elbow/forearm, finger/thumb, hand/wrist, lower back/sciatica, hip, knee, or ankle/foot.

We identified the most serious medical or MSD condition for each respondent. For respondents who reported missing work for only one condition, that condition was classified as the most serious. Respondents with multiple conditions who did not miss work, or who missed work for more than one condition, were asked to specify the most serious condition.

To assess the impact of health problems on respondents' functional status and work performance we used previously validated instruments: the Short Form 12 (SF-12) [33,34], eight items from the Work Limitations Questionnaire (WLQ) [21], and a series of questions developed and validated by Pransky [25,26] to assess social or economic changes in the past 12 months.

The SF-12 has been used in many studies; more details on development of the instrument, the specific questions, and validity of the scales can be found on the Quality Metrics website.[1] The WLQ has been validated in a range of different employee populations and for a variety of different health conditions [2,20, 24]. We included the WLQ questions that asked if the respondent (1) was able to do all of the work he/she needed to do without stopping to take breaks or rest; (2) was able to lift, carry, or move the objects he/she needed at work; (3) was able to walk or move around to different locations at work he/she needed to; (4) was able to bend, twist, or reach as much as he/she needed to; (5) was able to concentrate on his/her work; (6) was able to see and hear well enough to do all his/her tasks; (7) if he/she used hand held tools, pens, or computer equipment, was he/she able to use the handheld tools, pens, or computer equipment he/she needed to; and (8) if he/she needed to make the same movements repeatedly, how often was he/she able to do this as much as needed. The respondent was asked to answer each question using the categories of: none of the time, some of the time, about $1/2$ the time, most of the time, or always. We classified each participant as having none, one or two, or three or more limitations among these eight questions. Participants who answered fewer than four of the eight questions were excluded from analyses using the WLQ.

To assess the social impact of the MSD and medical conditions we asked the respondent to use the options of "almost always, often, sometimes,rarely, or never" and tell us: (1) how often have you felt like you can't take care of your family like you used to? (2) how often have you been afraid that in the future you will be unable to earn a living? (3) how often have you worried that your health will get worse if you continue to work? (4) how often have you felt like you couldn't cope with stressful problems – like financial difficulties, conflicts with your spouse or partner – as well as you used to? A 5th question asked: if you had to spend the rest of your life with your health as it is right now, would you feel very dissatisfied, somewhat dissatisfied, neither dissatisfied or satisfied, somewhat satisfied, or very satisfied?

[1] http://www.qualitymetric.com/products/comparesfsurveys.aspx.

### 2.4. Statistical analysis

Descriptive statistics were used to summarize the results of the survey. Dichotomous variables were compared using the Chi-Square test of general association. Ordinal data were compared using the Cochran-Armitage test for trends or the Cochran-Mantel-Haenszel test for s x r tables. The analysis of variance (ANOVA) method was used for continuous variables when comparing means of more than two groups. Of the twelve items in the SF-12 measure of health status, five items were used to create four subscales. The Physical Functioning (PF) health concept was estimated using two items which included health limitations due to moderate activities and problems such as climbing several flights of stairs. Bodily Pain (BP) consisted of one item about pain interference with normal work. General Health (GH) was comprised of one item about general health. Vitality (VT) was comprised of one item about energy. The SF-12 v2 manual provided formulas to transform each raw score to a 0–100 scale, as well as formulas to standardize the scores to a Norm-Based Score (NBS) system [33]. The NBS is a linear transformation of the scores to achieve a mean of 50 and a SD of 10 in the general U.S. population, and this system makes interpretations and comparisons more meaningful across scales. Lower SF scores indicate less favorable health status.

All statistical analysis was performed with SAS for Windows Version 9.1 [27].

## 3. Results

Sixty-nine percent (69%) of respondents had experienced at least one target medical or musculoskeletal condition in the previous two years. Fifty-four per-

Table 1
Proportion of 979 respondents reporting target musculoskeletal conditions

| Condition | N | (%) |
|---|---|---|
| Lower back/sciatica | 281 | (28.7) |
| Knee | 147 | (15.0) |
| Neck/upper back | 138 | (14.1) |
| Shoulder | 105 | (10.7) |
| Elbow/forearm | 95 | (9.7) |
| Ankle | 87 | (8.9) |
| Hand/wrist | 81 | (8.3) |
| Finger/thumb | 60 | (6.1) |
| Hip | 38 | (3.9) |

Table 2
Proportion of 979 respondents reporting target medical conditions

| Condition | N | (%)* |
|---|---|---|
| Lung/breathing | 142 | (14.8) |
| Stomach/intestinal | 104 | (10.9) |
| Vision | 72 | (7.5) |
| Burns | 40 | (4.2) |
| Neurological | 36 | (3.8) |
| Heart | 38 | (4.0) |
| Kidney/bladder | 37 | (3.9) |
| Psychiatric/emotional | 34 | (3.6) |
| Liver | 22 | (2.3) |
| Cancer/leukemia | 22 | (2.3) |
| Drug/alcohol | 16 | (1.7) |
| Diabetes+ | 9 | (0.9) |
| Stroke | 4 | (0.4) |

*Because we were most interested in the impacts of respondents' most serious health problems and cancer was presumed to be more serious than other target medical conditions, 22 respondents with cancer were not asked about other medical conditions. Consequently, the total number of respondents was 979 for cancer/leukemia and 957 for all other medical conditions, and prevalence of medical conditions may be slightly underestimated compared to that of musculoskeletal problems.
+Numbers represent respondents who reported diabetes-related health problems, not simply a diabetes diagnosis.

cent (54%) of subjects reported at least one MSD, and 42% reported at least one medical condition. The total number of conditions reported by any one person ranged from one to nine, with 42% of subjects reporting multiple conditions and 28% reporting multiple MSDs. Lower back/sciatica problems were the single most commonly reported health problem, affecting over a quarter of all respondents; lung disease led the list of medical conditions (Tables 1 and 2). An MSD was the most serious condition for 65% of subjects; of the 530 subjects with at least one MSD, 58% reported that their symptom episodes in the prior year were either frequent or of long duration. Of those with an MSD as their most serious condition, 79% of these roofers reported that their MSD was work-related.

Among subjects whose most serious condition was a medical condition, 15% reported that the problem had started more than ten years prior, and another 15% reported onset occurring five to ten years previously; almost half of subjects with medical problems were estimated to be younger than age 45 when the problem began. The pattern was similar among subjects whose most serious condition was an MSD condition; more than 50% of subjects with a serious MSD were estimated to be younger than age 45 when the problem began.

Ten percent of our participants were Hispanic, and 11% were members of a racial minority. There was no association between ethnicity or race and either age or prevalence of health conditions. Only three of our participants were women; they were included in all analyses and not presented separately. Table 3 shows that the prevalence of medical conditions increased with age ($p < 0.01$), while the proportion of subjects with MSDs was roughly equal across all age groups. Increased age was also significantly associated with decreased physical functioning, but not with bodily pain, general health, vitality, missed work, or work limitations. (Table 3 includes several different statistical measures, since the SF-12 scores are continuous, which the other variables are ordinal; see methods).

Nearly one-third (31%) of all respondents reported missing time from work in the two years prior to interview due to a target medical condition or MSD, and the likelihood of missing work increased significantly as the number of reported conditions increased ($p < 0.001$) (data not shown). Sixty-four percent (64%) of those with three or more conditions reported missing work due to their health in the previous two years, compared to 33% of subjects with one or two target conditions. Forty-one percent (41%) of subjects with at least one musculoskeletal problem and 31% of subjects with at least one medical condition reported that an MSD had caused them to miss work. Of all target conditions, cancer/leukemia was most likely to result in time away from work (55% of cases), followed by heart problems (53%), diabetes (33%), burns (38%), and lower back/sciatica problems (35%).

Table 4 shows the proportion of participants reporting work limitations in five areas, and Table 5 shows the association of work limitations with health conditions. Fourteen percent (14%) of workers with a medical condition indicated a limitation in three or more work activities, compared to only 4% of respondents with no condition. Workers with both medical and musculoskeletal conditions had the highest prevalence (18%) of limitation in three or more work activities. The presence of one or two work limitations varied from

Table 3
Relationship between age and SF-12 subscales, missed work, medical and/or MSD conditions, economic impact score and work limitations

| | Age Group | | | | |
|---|---|---|---|---|---|
| | 40–44 $N = 243$ | 45–49 $N = 276$ | 50–54 $N = 254$ | 55+ $N = 206$ | p-value |
| Physical Functioning | $51.6 \pm 7.8$ | $50.7 \pm 8.3$ | $49.2 \pm 9.6$ | $48.5 \pm 9.6$ | 0.003* |
| Bodily Pain | $48.5 \pm 10.3$ | $47.0 \pm 11.9$ | $47.9 \pm 11.5$ | $47.5 \pm 11.4$ | 0.46* |
| General Health | $49.2 \pm 9.8$ | $48.4 \pm 10.0$ | $47.4 \pm 10.5$ | $47.9 \pm 9.4$ | 0.22* |
| Vitality | $53.7 \pm 9.6$ | $54.3 \pm 9.8$ | $54.7 \pm 8.3$ | $55.0 \pm 7.9$ | 0.46* |
| Any Missed Work (vs. No Missed Work) | 31% | 33% | 31% | 26% | 0.27** |
| No Medical or MSD Condition (vs. any) | 36% | 30% | 30% | 27% | 0.05** |
| Health Condition (vs. none) | | | | | |
| MSD Condition Only | 29% | 30% | 25% | 25% | 0.77** |
| Medical Condition Only | 11% | 12% | 19% | 20% | $< 0.01$** |
| Both MSD and Medical Conditions | 41% | 49% | 46% | 52% | 0.13** |
| Work Limitations | | | | | 0.95*** |
| None | 52% | 51% | 52% | 49% | |
| 1–2 | 39% | 37% | 39% | 39% | |
| 3+ | 9% | 12% | 10% | 12% | |

Data presented as Mean $\pm$ Std or %.
Some responses do not sum to 100% due to rounding.
*Analysis of Variance (ANOVA).
**Cochran-Armitage test for trend.
***Chi-square test.

Table 4
Association between medical conditions and participants' self-assessment of health, pain, and ability to care for family

| | Type of Condition | | | | |
|---|---|---|---|---|---|
| | None $N = 302$ | MSD Only $N = 265$ | Medical Only $N = 146$ | Both Medical and MSD $N = 260$ | p-value |
| Reported health as "poor" or "fair" (vs. "good", "very good", or "excellent") | 4.6% | 8.3% | 19.7% | 24.6% | $< 0.01$ |
| Accomplished less than you would like because of physical health (vs. not accomplished less) | 8.3% | 17.7% | 25.3% | 39.4% | $< 0.01$ |
| Pain interfered with work inside and outside the home "quite a bit" or "extremely" (vs. "not at all", "a little bit", or "moderately") | 2.3% | 11.6% | 19.3% | 10.5% | $< 0.01$ |
| Pain interfered with work inside and outside the home "quite a bit" or "extremely" (vs. "not at all", "a little bit", or "moderately") | 1.7% | 5.3% | 7.5% | 13.6% | $< 0.01$ |
| Felt "often" or "almost always" that you could not take care of your family "like you used to" (vs. "sometimes", "rarely", or "never") | 2.3% | 4.9% | 6.1% | 16.3% | $< 0.01$ |

Numbers presented as %. All Comparisons are done using the Chi-Square test.

Table 5
Proportion of respondents reporting work limitations, by type of condition

| | Type of Condition+ | | | | |
|---|---|---|---|---|---|
| Total Number of Responses Indicating a Work Limitation (Out of 8 Possible) | None $n = 302$ | MSD Only $n = 265$ | Medical Only $n = 146$ | Both Medical and MSD $n = 260$ | All Respondents $n = 973$ |
| 0 | 63% | 54% | 45% | 38% | 51% |
| 1 to 2 | 33% | 37% | 41% | 44% | 38% |
| 3 or more | 4% | 9% | 14% | 18% | 11% |

*Six subjects who were non-responsive to 4 or more of the work limitations questions were excluded from the analysis.
+p value $< 0.001$ for difference in distribution of work limitation responses using Cochran-Mantel-Haenszel test.

33% among participants without medical or MSD conditions reported some work limitations, to 44% among participants with both medical and MSD conditions. MSD and medical conditions were also strongly associated with the participants' self-assessment of health, pain, and their ability to accomplish things and care

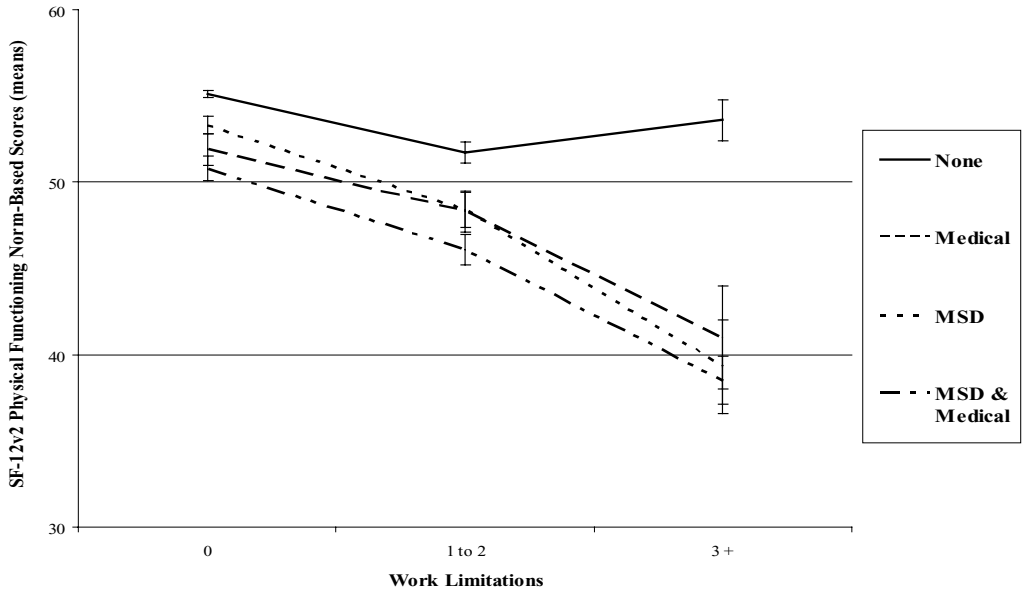


Fig. 1. Association between Work Limitations and SF-12v2 Physical Functioning Norm-Based Scores, by Type of Condition.

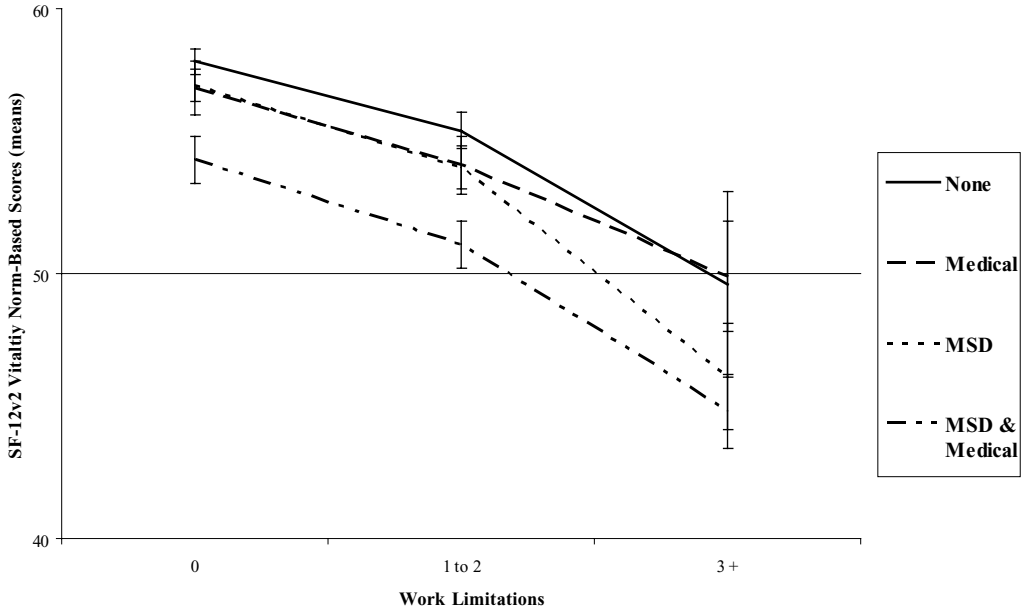


Fig. 2. Association between Work Limitations and SF-12v2 Vitality Norm-Based Scores, by Type of Condition.

for their families. Only 2.3% of the workers with no conditions felt often, almost always or always that they could not take care of their families like they used to; this proportion increased to 16.3% among workers with both an MSD and medical condition.

Figures 1 and 2 display the relationship between work limitations and the SF-12 norm-based subscales for physical functioning (PF) and vitality (VT) The data are presented for those participants with no medical conditions, MSD conditions only, medical conditions only, and both MSD and medical conditions. For individuals with health conditions the figures show that as work limitations increase, the SF-12 sub score decreases. The figures also show that the participants without reported work limitations, MSDs, or medical conditions had functioning substantially above the popula-

tion average score of 50, with average normed scores of 58 for vitality and 55 for physical functioning.

## 4. Discussion

In this study we found that (1) there was a significant burden of MSDs and medical conditions among construction roofers ages 40–59 who were actively employed; (2) many construction workers continue to work with pain and work limitations; (3) construction workers with medical and MSD conditions had more work limitations than the rest of the study group (4) construction workers without MSDs or medical conditions described higher than expected vitality and few work limitations and (5) increasing age was associated with reduced physical functioning independent of the presence of a medical condition or MSD.

In our study 69% of respondents had experienced at least one target medical or musculoskeletal condition in the previous two years. This is somewhat higher than prevalence found using a definition similar to ours in a Finnish study of a large working population; 45% of the men aged 45–54 had a long term illness diagnosed by a physician, increasing to 50% in ages 55–64 [15]. Our participants specifically had a high prevalence of low back pain, consistent with several prior cross-sectional studies among construction workers, although rates vary and the definitions of low back pain across the studies are not strictly comparable [5, 14,23,31]. In the Finnish study the reported prevalence of any MSD was 64.3%, and of back pain was 28%, with prevalence increasing with age somewhat [15].

Physical functioning was significantly lower in the 55+ age group compared to younger workers. Mean scores on the physical component of the SF-12 are available for the US population, and this score does decrease with age, from a mean of 53.8 in 20–29 year olds to a mean of 45.6 in 60–69 year olds. Nationally men 40–49 had a mean score of 50.9, and those 50–59 a mean score of 48.6. The mean value for our group of roofers falls within the 95% confidence intervals for this national data. These national means do include the entire civilian non-institutionalized population, and since 40% of the entire US population is not employed, our respondents are not drawn from the same sample and so these data are not strictly comparable.

The presence of a health condition, physical functioning, missed work and work limitations were intertwined. Having a medical condition in combination with an MSD was associated with work limitation, missed work, and lower SF-12 scores among these roofers. Lower SF-12 scores were associated with more work limitations. Some work limitation was reported by 49% of our participants; a similar prevalence of work limitation has been reported in two retrospective surveys of workers with MSDs [17,26].

In this analysis, older age is associated with decreased physical functioning, and older workers were more likely to have medical conditions. Medical and musculoskeletal conditions – which are quite prevalent – are strongly associated with work limitation, missed work, or reduced physical functioning, and the prevalence of medical conditions increases with age. However in looking at all the relationships between work limitations, SF-12 scores, age, and condition, we find that our older workers may be at higher risk of early retirement even when these other factors are accounted for in an analysis. It may be that disease among older workers has a greater impact on physical functioning than it does in younger workers, or that older workers describe limitations in physical functioning even without a specific medical diagnosis [8,15,29]. Older persons generally have poorer outcomes from treatment of back pain [10,12,22], and are more likely to miss work [32]. A longitudinal study in Finland found that the proportion of workers who perceived their health to be good or rather good decreased with age, from 80% in the ages 30–44 down to 48.7% of men over 55 [15] .

We believe these roofers are reasonably representative of our target population of union roofers in age, ethnicity and race. As noted above, there was no significant difference in participation by age group. Although the Roofers International Union does not keep data on race and ethnicity for its members, we estimate that 16% of union roofers are Hispanic based on the following information:. Thirteen percent (13%) of union and 21% of non-union construction workers are Hispanic, with an overall rate of 19% [3]. Since twenty three percent of all roofers in the US are Hispanic, a reasonable estimate is that 16% of all union roofers are Hispanic. The proportion of all construction workers who are Hispanic varies significantly by age [3], with Hispanic workers making up 17% of the 30–35 years olds, 13% of the 45–49 year olds, 7% of the 50–54 year olds, 6% of the 50–55 year olds and 3% of the 55–59 year olds; we do not have similar estimates for roofers in particular. Given the age distribution of our study group, 40–59, the 10% proportion of Hispanics enrolled is reasonable close to national estimates for union roofers. Finally nationwide 12% of roofers are from a racial minority, again quite comparable to the 11% among our participants.

Like older working populations, this study population has surely been subject to selection, since it includes the workers with MSDs who managed to return to work and thus be eligible for entering this study [6, 7]. A healthy survivor effect is suggested by the fact that a majority of the conditions reported among our participants began before age 45. Siebert et al. examined the impact of medical conditions on job change in a cohort of German construction workers, and found that the presence of a back or spine disorder increased the likelihood of changing jobs, with a RR of 1.17; the peak age for job mobility was between ages 45 and 49 [30]. In the Netherlands, the risk for disability among construction workers increased with age until age 54; workers 55 and older had a risk of disability retirement comparable to the workers aged 30–34. The number of cases in the group over 55 was much smaller than in other age groups as well, suggesting that the workers over 55 were healthy survivors [1]. Assuming that some workers with medical conditions and MSDs change occupations or leave the workforce shortly after condition onset, no cross-sectional group of workers is representative of all workers ever-employed in construction.

Given the high prevalence of medical and musculoskeletal conditions, the moderate rate of missed work and work limitations, in combination with a decrease in physical function with aging, this group of roofers is at risk for substantial disability from work. It is likely that a large proportion of the burden of MSDs and associated functional impairment is work-related; these roofers reported that almost 80% of the MSDs classified as the most serious condition were caused by work, and much other research supports the very significant contribution of physical factors to MSDs among construction workers [14,18,19,23,28]. Any effort to prolong the working career of construction roofers will need to be multi-faceted, and should include reduction in the physical load of work, specific job accommodations after injury, and special attention to functional limitations in older workers at a minimum. Without concerted attention to these issues, the US will face a worsening shortage of skilled construction workers.

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## References

[1] A. Burdorf, M.H. Frings-Dresen, C. van Duivenbooden and L.A. Elders, Development of a decision model to identify workers at risk of long-term disability in the construction industry, *Scand J Work Environ Health* **31** (2005), 31–36.

[2] W.N. Burton, C.Y. Chen, D.J. Conti, A.B. Schultz, G. Pransky and D.W. Edington, The association of health risks with on-the-job productivity, *J Occup Environ Med* **47** (2005), 769–777.

[3] Center to Protect Workers' Rights, *The Construction Chart Book: The US Construction Industry and Its Workers*, D1-02, 1–120. 2002. Silver Spring, MD, CPWR.

[4] Center to Protect Workers' Rights, *The Construction Chart Book: The US Construction Industry and Its Workers*, 1–120. 2007. Silver Spring, MD, CPWR.

[5] T.M. Cook and C. Zimmerman, *A Symptom and Job Factor Survey of Unionized Construction Workers*, Taylor & Francis: Philadelphia, 1992.

[6] B.C. de Zwart, J.P. Broersen, M.H. Frings-Dresen and F.J. van Dijk, Repeated survey on changes in musculoskeletal complaints relative to age and work demands, *Occup Environ Med* **54** (1997), 793–799.

[7] B.C. de Zwart, J.P. Broersen, A.J. van der Beek, M.H. Frings-Dresen and F.J. van Dijk, Selection related to musculoskeletal complaints among employees, *Occup Environ Med* **54** (1997), 800–806.

[8] B.C. de Zwart, M.H. Frings-Dresen and F.J. van Dijk, Physical workload and the aging worker: a review of the literature, *Int Arch Occup Environ Health* **68** (1995), 1–12.

[9] J.M. Dement and H. Lipscomb, Workers' compensation experience of North Carolina residential construction workers, 1986–1994, *Appl Occup Environ Hyg* **14** (1999), 97–106.

[10] P.G. Dempsey, A. Burdorf and B.S. Webster, The influence of personal variables on work-related low-back disorders and implications for future research, *J Occup Environ Med* **39** (1997), 748–759.

[11] G. Engholm and E. Holmstrom, Dose-response associations between musculoskeletal disorders and physical and psychosocial factors among construction workers, *Scand J Work Environ Health* **31** (2005), 57–67.

[12] G.M. Franklin, J. Haug, N.J. Heyer, S.P. McKeefrey and J.F. Picciano, Outcome of lumbar fusion in Washington State workers' compensation, *Spine* **19** (1994), 1897–1903.

[13] D. Goldsheyder, M. Nordin, S.S. Weiner and R. Hiebert, Musculoskeletal symptom survey among mason tenders, *Am J Ind Med* **42** (2002), 384–396.

[14] E. Holmstrom and G. Engholm, Musculoskeletal disorders in relation to age and occupation in Swedish construction workers, *Am J Ind Med* **44** (2003), 377–384.

[15] J. Ilmarinen, Towards a longer and better working life: a challenge of work force ageing, *Med L* **97** (2006), 143–147.

[16] L.L. Jackson, Non-fatal occupational injuries and illnesses treated in hospital emergency departments in the United States, *Injury Prevention* **7** (2001), i21–i26.

[17] J.P. Keogh, I. Nuwayhid, J.L. Gordon and P.W. Gucer, The impact of occupational injury on injured worker and family: outcomes of upper extremity cumulative trauma disorders in Maryland workers, *Am J Ind Med* **38** (2000), 498–506.

[18] U. Latza, W. Karmaus, T. Sturmer, M. Steiner, A. Neth and U. Rehder, Cohort study of occupational risk factors of low back pain in construction workers, *Occup Environ Med* **57** (2000), 28–34.

[19] U. Latza, A. Pfahlberg and O. Gefeller, Impact of repetitive manual materials handling and psychosocial work factors on the future prevalence of chronic low-back pain among construction workers, *Scand J Work Environ Health* **28** (2002), 314–323.
[20] D. Lerner, B.C. Amick, III, J.C. Lee, T. Rooney, W.H. Rogers, H. Chang and E.R. Berndt, Relationship of employee-reported work limitations to work productivity, *Med Care* **41** (2003), 649–659.
[21] D. Lerner, B.C. Amick, III, W.H. Rogers, S. Malspeis, K. Bungay and D. Cynn, The Work Limitations Questionnaire, *Med Care* **39** (2001), 72–85.
[22] T. Mayer, R.J. Gatchel and T. Evans, Effect of age on outcomes of tertiary rehabilitation for chronic disabling spinal disorders, *Spine* **26** (2001), 1378–1384.
[23] L.A. Merlino, J.C. Rosecrance, D. Anton and T.M. Cook, Symptoms of musculoskeletal disorders among apprentice construction workers, *Appl Occup Environ Hyg* **18** (2003), 57–64.
[24] R.J. Ozminkowski, R.Z. Goetzel, S. Chang and S. Long, The application of two health and productivity instruments at a large employer, *J Occup Environ Med* **46** (2004), 635–648.
[25] G. Pransky, K. Benjamin, C. Hill-Fotouhi, J. Himmelstein, K. Fletcher, J.N. Katz and W.G. Johnson, Outcomes in Work-Related Upper Extremity and Low Back Injuries: Results of a Retrospective Study, *Am J Ind Med* **37** (2005), 400–409.
[26] G. Pransky, K. Benjamin, C. Hill-Fotouhi, J. Himmelstein, K.E. Fletcher, J.N. Katz and W.G. Johnson, Outcomes in work-related upper extremity and low back injuries: results of a retrospective study, *Am J Ind Med* **37** (2000), 400–409.
[27] SAS Institute Inc., *SAS for Windows*, Release 9.1, SAS Institute Inc.: Cary, N.C., 2003.
[28] S.P. Schneider, Musculoskeletal injuries in construction: a review of the literature, *Appl Occup Environ Hyg* **16** (2001), 1056–1064.
[29] R.J. Shephard, Age and physical work capacity, *Exp Aging Res* **25** (1999), 331–343.
[30] U. Siebert, D. Rothenbacher, U. Daniel and H. Brenner, Demonstration of the healthy worker survivor effect in a cohort of workers in the construction industry, *Occup Environ Med* **58** (2001), 774–779.
[31] T. Sturmer, S. Luessenhoop, A. Neth, M. Soyka, W. Karmaus, R. Toussaint, T.R. Liebs and U. Rehder, Construction work and low back disorder. Preliminary findings of the Hamburg Construction Worker Study, *Spine* **22** (1997), 2558–2563.
[32] J.A. Turner, G. Franklin and D.C. Turk, Predictors of chronic disability in injured workers: a systematic literature synthesis, *Am J Ind Med* **38** (2000), 707–722.
[33] J.E. Ware, M. Kosinski, D.M. Turner-Bowker and B. Gandek, *How to Score Version 2 of the SF-12 Health Survey* (*with a Supplement Documenting Version 1*), QualityMetric Incorporated: Lincoln, RI, 2002.
[34] J.E. Ware, M. Jr. Kosinski and S.D. Keller, *SF-12: How to Score the SF-12 Physical and Mental Health Summary Scales*, second edition, 1995, Boston, Health Institute, New England Medical Center.