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Validity of a self-completed questionnaire measuring the physical demands of work

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Objective. This study determined the accuracy of workers in quantifying occupational physical demands on a self-administered questionnaire.

Methods. First, a self-administered questionnaire on work postures, manual materials-handling, and repetitive upper-limb movements was validated using direct simultaneous observations for 123 randomly selected employees from 6 occupational settings. Second, weight estimation accuracy was assessed on visual analogue scales for 6 manual materials-handling activities using 20 randomly selected employees from 1 occupational setting.

Results. At a dichotomous level (ever-never), the accuracy of most of the self-reported physical demands was good (sensitivity 60-100%; specificity 56-100%). A more-detailed analysis of the dimensions studied (frequency, duration and amplitude) also showed that the accuracy of the self-reported estimates was satisfactory. Full agreement between the estimated and observed frequency was >60% for most of the manual materials-handling activities. In addition the average difference between the estimated and observed duration of the physical demands was found to be small. Finally the average difference between the self-reported and actual weights of various loads was found to be modest.

Conclusions. The self-reported questionnaire used in this study would provide a useful instrument for estimating occupational physical demands and the frequency, duration, and amplitude of these demands in future epidemiologic studies associated with musculoskeletal pain.

Key terms. epidemiology, ergonomics, musculoskeletal, observation, physical work load.
therefore important to evaluate the performance of a questionnaire in obtaining valid information about physical demands before an epidemiologic study based on self-reports on a questionnaire is conducted (16, 18). Despite this situation, there have been relatively few studies published concerning the validity of quantitative data collected by self-administered questionnaires (19).

This study determines how accurately workers quantify the physical demands of their work in a self-administered questionnaire and validates the questionnaire across a variety of occupational groups carrying out a diverse range of manual tasks. It is the first phase of an epidemiologic survey investigating how the physical demands of work are associated with shoulder pain.

Subjects and methods

Design and subjects

The study comprised two investigations, both cross-sectional in design.

Subjects

Part 1. Employees from 6 workplaces in south Manchester formed the population from which the subjects were selected for part 1 of the study. The subjects comprised 140 full-time employees randomly selected to represent between 5% and 10% of each occupational setting. The occupational groups included cashiers and shop assistants (department store, N=20), production-line workers (packaging factory, N=20), mail sorters (post office, N=20), nurses (hospital, N=20), security staff and baggage handlers (airport, N=20).

The subjects were randomly assigned 1 hour of their workshift for which observations were made of the physical work being carried out. After the period of observation, the subjects completed a self-administered questionnaire concerning the same hour of physical work.

Part 2. An additional 10% random sample of cashiers and shop assistants was selected from 1 occupational setting (department store, N=20) to form the subjects for part 2 of this investigation.

The subjects estimated the weights of 5 items of known weight involved in 6 manual materials-handling operations.

Self-administered questionnaire (part 1)

A questionnaire was developed that included 8 items on manual materials-handling, 4 items of work postures, and 2 items on repetitive movements of the upper limbs. (See the appendix). The items were selected because they had previously been identified as risk factors for shoulder pain. For each of the manual materials-handling operations, the subjects were asked to estimate the frequency (on a 4-point scale — after a preliminary analysis revealed that employees had difficulty estimating frequency as an absolute value), weight (on a visual analogue scale — not analyzed in the current study), and duration (recorded in minutes). For the work postures and repetitive movements, the subjects were asked to report only frequency and duration. The reference period for the questionnaire was 1 specified recent workhour.

Observations

The observations were carried out by 2 researchers, an ergonomist and a physiotherapist, who discussed and agreed upon the definitions of the observations being made (eg, "work above shoulder level" was defined as "a task being carried out with arm(s) raised above a 90° angle). The researchers then practiced the observation method at the research institution by observing volunteers carrying out each physical demand.

Each subject was observed for 1 hour by 1 of the 2 researchers. The observations were carried out using a time-sampling approach. At 30-second intervals the researchers recorded which physical demands were being carried out on an observation schedule after being prompted by an auditory cue.

The definition of standing and sitting for periods of more than 30 minutes required positive observations of these postures to have been made consecutively on at least 60 of the 30-second time intervals.

Crude estimates of frequency were calculated for the manual materials-handling activities as a summation of positive observations made at the 30-second intervals (a maximum of 120 representing the hour of observation). For the analysis, frequency was categorized into 4 groups reflecting the ordinal scale in the self-administered questionnaire and compared with categories of self-reported frequency. Estimates of duration for the occupational physical demands were based on the total number of positive observations made at 30-second intervals divided by 2 (a maximum of 60 minutes).

A pilot study of the observation method using 2 researchers was carried out to determine interobserver agreement in the assessment of the duration of physical demands. Six manual workers from a flour mill in south Manchester were observed simultaneously by the 2 researchers for 1 hour. The interobserver repeatability was very good for the duration of work postures and manual materials-handling activities (table 1). There was less agreement for the repetitive use of the wrists and arms, the 95% limits of agreement ranging from -4.8 to 6.8 minutes and from -5.2 to 3.6 minutes, respectively. The imprecise definition used by necessity to describe repetitive upper-limb movements (defined as "an observed
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Table 1. Interobserver repeatability of the observation method.
(95% CI = 95% confidence interval)

| Physical demands          | Mean duration (min) | Difference in means | 95% CI |
|---------------------------|---------------------|---------------------|--------|
| Work postures             |                     |                     |        |
| Standing                  | 38.3                | 38.8                | -0.5   | -1.8—0.8 |
| Sitting                   | 7.7                 | 7.5                 | 0.2    | -1.1—1.5 |
| Kneeling                  | 1.0                 | 1.2                 | -0.2   | -1.6—1.2 |
| Work above shoulder level | 4.4                 | 4.5                 | -0.1   | -0.5—0.3 |
| Manual materials-handling |                     |                     |        |
| Lifting with both hands   | 1.5                 | 1.5                 | 0.0    | -1.1—1.1 |
| Lifting with one hand     | 1.4                 | 1.1                 | 0.3    | -0.5—1.1 |
| Carrying with both hands  | 1.5                 | 1.8                 | -0.3   | -1.5—0.9 |
| Carrying with one hand    | 1.8                 | 1.6                 | 0.2    | -0.8—1.2 |
| Carrying on one shoulder  | 0.1                 | 0.2                 | -0.1   | -0.5—0.3 |
| Lifting above shoulder level| 0.4                | 0.5                 | -0.1   | -0.5—0.3 |
| Picking                   | 1.4                 | 1.0                 | 0.4    | -1.5—1.7 |
| Pulling                   | 1.7                 | 1.3                 | 0.4    | -0.6—1.4 |
| Repetitive upper-limb movements |       |                     |        |
| Use of wrists             | 6.7                 | 5.7                 | 1.0    | -4.8—6.8 |
| Use of arms               | 10.0                | 10.6                | -0.8   | -5.2—5.6 |

* 95% confidence interval of the difference between observers.

activity requiring multiple wrist or arm movements*) might have resulted in this greater discrepancy.

*Estimation of handled weight*

Various items were selected from the warehouse of the department store and weighed using electronic scales. Five different items were used in 6 manual materials-handling operations (4 tasks involving lifting and carrying and 2 tasks involving pushing and pulling — total of 30 items). The tasks and items were presented in random order to the subjects, who were asked to complete a visual analogue scale (VAS) for each estimate of weight before proceeding to the next.

*Statistical analysis*

The accuracy of self-reported occupational physical demands was calculated using a sensitivity and specificity analysis based on the premise that the observations represented the standard. Sensitivity and specificity were calculated as the proportion of workers correctly reporting positive exposure (sensitivity) and the proportion of workers correctly reporting negative exposure (specificity). The analysis was carried out as a dichotomous exposure (ie, whether or not the physical demand was carried out).

Estimated frequency (recorded on a 4-point ordinal scale: 1—10 times/hour, 11—30 times/hour, 31—50 times/hour, ≥51 times/hour) was compared to observed frequency (using the same categories), the percentage of full agreement being calculated as the proportion of workers’ estimates of frequency in the same category as the observed frequency. Disagreement was described as mild, moderate, and severe if the workers’ estimates of frequency were 1, 2, or 3 categories away from the recorded frequency, respectively. In addition, weighted kappa statistics were calculated for the comparisons where there were more than 10 employees answering the frequency questions.

For both duration (part 1) and estimated weight (part 2) the differences between reported (estimated) and observed (weighed) were calculated on a continuous scale, and the median and interquartile range were reported.

*Results*

Of the 140 employees observed, 123 (88%) completed and returned the questionnaires on the day of observation, the majority having completed the questionnaire immediately after the reference hour, 76 of whom were women (92%) and 47 were men (82%). The mean age of the employees who completed the physical demands questionnaire was 36 years. The respondents did not differ from the 17 employees who did not complete the questionnaire in terms of age (P=0.58), gender (P=0.81), or physical demands recorded by the researchers (P>0.20 for all comparisons). It is likely, therefore, that nonresponse was related primarily to general disinterest in the study, an impression confirmed by researchers visiting the participating companies.

All of the physical demands detailed in the questionnaire were observed to take place (table 2, column 2). For the work postures, approximately 10% of the employees were observed to be standing or seated for periods of ≥30 minutes, whereas approximately half the employees were observed to kneel or carry out work at shoulder level. The majority of the manual materials-handling was observed to be carried out by most of the subjects, with as many as two-thirds of the employees lifting or carrying weights. However only 4 persons were observed to carry weights on a shoulder during the observation hour. Two-thirds of the employees were observed to carry out repetitive movements of the wrists or arms for periods of ≥10 minutes.

Questions referring to activities involving “lifting” and “carrying” were combined after 5 of the 6 companies had been visited, when it was established that employees did not distinguish between the 2 activities.

*Agreement for the recording of physical activities*

The accuracy of self-reported estimates of occupational physical demands at a dichotomous level (ever; never) was greatest for the work postures (table 2). For all the posture variables the sensitivity and specificity of the self-reports were at least 70%.

For the majority of the manual materials-handling the accuracy of the self-reports was good. The sensitivity values for the self-reports were at least 60% for all
except 2 of the manual materials-handling activities ("carrying weights with one hand" — 43% and "lifting weights above shoulder level" — 40%). Only the activity "lifting weights with both hands" had a low specificity value, all the other activities receiving a specificity of at least 70%.

Activities involving repetitive movement of the wrists and arms showed good sensitivity (above 80% for both activities); however, the specificity was below 60% for repetitive arm movements.

Agreement for the frequency and duration dimensions of exposure

The employees' ability to discriminate between levels of frequency (according to the 4-point scale) was satisfactory (table 3). Full agreement was above 60% for the majority of the manual materials-handling activities, with kappa statistics of moderate concordance (kappa 0.2—0.6). The poor kappa statistics observed for "carrying with both hands" and "pulling weights" reflects the high proportion of employees reporting a frequency of

Table 2. Comparison of self-reports of physical demands with observations (observation time = 60 minutes). (E = exposure reported, N = no exposure reported)

| Physical demands | Positive to items | 2 x 2 table of concordance | Accuracy |
|------------------|-------------------|---------------------------|----------|
|                  | Self-report | Observation | Observer E | Observer N | Observer E | Observer N | Sensitivity (%) | Specificity (%) |
| Work postures    |            |             |             |             |             |             |             |             |
| Standing >30 minutes | 30 | 11 | 8 | 3 | 22 | 90 | 73 | 80 |
| Sitting >30 minutes | 17 | 9 | 9 | - | 8 | 106 | 100 | 93 |
| Kneeling         | 58 | 53 | 48 | 5 | 10 | 60 | 91 | 86 |
| Work above shoulder level | 65 | 68 | 48 | 20 | 15 | 40 | 71 | 73 |
| Manual materials-handling | | | | | | | | |
| Lifting weights with both hands | 76 | 62 | 54 | 8 | 12 | 11 | 87 | 48 |
| Lifting weights with one hand | 44 | 62 | 39 | 14 | 11 | 20 | 74 | 65 |
| Carrying weights with both hands | 28 | 30 | 13 | 17 | 15 | 40 | 43 | 73 |
| Carrying weights with one hand | 28 | 30 | 13 | 17 | 15 | 40 | 43 | 73 |
| Lifting or carrying weights with both hands | 24 | 32 | 26 | 6 | - | 6 | 81 | 100 |
| Lifting or carrying weights with one hand | 24 | 32 | 26 | 6 | - | 6 | 81 | 100 |
| Carrying weights on one shoulder | 6 | 4 | 3 | 1 | 3 | 116 | 75 | 97 |
| Lifting weights above shoulder level | 19 | 30 | 12 | 18 | 7 | 96 | 40 | 92 |
| Pushing weights | 66 | 73 | 54 | 19 | 12 | 38 | 74 | 76 |
| Pulling weights | 49 | 55 | 33 | 22 | 16 | 52 | 60 | 76 |
| Repetitive movements | | | | | | | | |
| Repetitive use of wrists, ≥10 minutes | 86 | 94 | 76 | 18 | 10 | 10 | 81 | 66 |
| Repetitive use of arms, ≥10 minutes | 87 | 87 | 72 | 17 | 15 | 19 | 81 | 56 |

Table 3. Comparison of self-reported frequency of manual materials-handling for 4 categories (1—10, 11—30, 31—50 and ≥51 times/hour) with similar categories in the observations.

| Manual handling of weights | Agreement | Mild disagreement of 1 category | Moderate disagreement of 2 categories | Severe disagreement of 3 categories | Weighted kappa |
|----------------------------|------------|---------------------------------|--------------------------------------|-------------------------------------|----------------|
|                            | N %        | N %                             | N %                                  | N %                                 |                |
| Lifting with both hands    | 14 70      | 6 30                            | - 0                                  | - 0                                 | 0.39           |
| Lifting with one hand      | 9 60       | 4 27                            | 1 7                                  | 1 7                                 | 0.36           |
| Carrying with both hands   | 18 78      | 5 22                            | - 0                                  | - 0                                 | 0.12           |
| Carrying with one hand     | 4 57       | 1 14                            | 2 29                                 | - 0                                 |                |
| Lifting or carrying with both hands | 14 54 | 10 33                           | 2 8                                  | - 0                                 | 0.58           |
| Lifting or carrying with one hand | 9 39 | 9 39                            | 3 13                                 | 2 9                                 | 0.25           |
| Carrying on one shoulder   | 2 67       | 1 33                            | - 0                                  | - 0                                 |                |
| Lifting above shoulder level | 4 57 | 3 43                            | - 0                                  | - 0                                 |                |
| Pushing                    | 35 81      | 7 18                            | 2 5                                  | - 0                                 | 0.39           |
| Pulling                    | 19 79      | 4 17                            | 1 4                                  | - 0                                 | 0.11           |

a Number of subjects classified as exposed and not exposed by the subjects (self-reports) and by the researchers (observations).
b The sensitivity and specificity have been predicted on the assumption that the researchers' observations are the standard for the self-report.
c Data only available for the first 5 companies (N=85).
d Data only available for the last company (N=38).

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| Pulling                    | 19 79      | 4 17                            | 1 4                                  | - 0                                 | 0.11           |

a Frequency information obtained in a closed question (categories 1—10, 11—30, 31—50, ≥51 times/hour) for the last 3 companies (N=73).
b The lifting and carrying variables were combined after the analysis of the data from the first 5 companies. For this reason, frequency information in a categorized form was only available for these variables separately for 2 companies (N=35) and for these variables combined for 1 company (N=38).
One limitation of the time-sampling approach adopted in this study is the likelihood that the frequency of manual materials-handling would be underestimated. The observers might have missed activities being repeated between the 30-second time intervals. In this respect, the observation method cannot be considered as a standard, and our analysis of these data is restricted to a comparison of self-reports with a crude measure based on the observations. Although the agreement between the self-reported and observed frequencies was high for the majority of the manual materials-handling activities, the high level of agreement is likely to reflect a clustering of responses in the lowest frequency categories. It is therefore
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lightest item — heaviest item
(actual weight minus estimated weight)

Figure 1. Box-and-whisker plots of the accuracy of estimating weights on the visual analogue scale (actual weight minus estimated weight).

difficult to draw any definitive conclusions regarding the accuracy of the frequency of manual materials-handling in this study. However, studies which have used reference measures to validate the self-reported frequency of manual materials-handling have observed good agreement, although they have tended to concentrate on the frequency of lifting specified weights (19, 20). For example, Wiktorin et al (19) used an ordinal scale similar to that used in the current study to represent frequency and found good agreement between the estimated and observed frequency of weights of >1—5 kg (kappa = 0.65—0.66).

The greatest variation in the estimation of self-reported duration was for repetitive movements of the wrists and arms. This finding is likely to have been a reflection of the natural difficulty in understanding what represents
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a "repetitive movement". Rather than impose an artificial definition which is necessarily complicated, it was decided to leave assessment of what represented a repetitive activity to the participants themselves. On the average, the misclassification in terms of overestimated duration was still small for these movements.

It is difficult to compare our analysis of the self-reported duration of physical demands with that of other studies given the different styles of question used to represent duration; other studies have tended to inquire about duration as a closed question. For example, Wiktorin et al (19) used a 6-point ordinal scale with a categorization of weights. This method requires employees to be familiar with the weights of items they have handled, and it appears that employees find it easier to remember handling heavier loads (6-15 kg) than lighter loads (1-5 kg) (19). Given that the employees accurately estimated the weight of a variety of both light and heavy loads on the VAS, the use of a VAS (together with the illustrated conversion card) might be a more appropriate measure with which to estimate the self-reported weight of handled items in a questionnaire than more direct questions are.

Methodological issues

Although the observation method was found to have good interobserver reliability (table 1), it is unlikely that the observations were entirely accurate measures of the physical demands carried out by employees. Ideally, the use of a direct measure (eg, video taping) would have provided a more accurate reference for the self-reports. However, the use of such methods was not practical for the present study. It is possible that, using the time-sampling approach, the observers missed activities carried out between the 30-second time intervals. If so, it would have resulted in an underestimate of the specificity. However, despite possible flaws in the observation method, the accuracy of the majority of self-reported exposures was still found to be good.

As mentioned previously, the time-sampling approach used in the study is likely to have led to an underestimation of the frequency of manual materials-handling. The occupational groups chosen for study tended to report a low frequency of manual materials-handling, and this result may explain the high proportion of agreement between the self-reports and observations. For occupational groups with a greater frequency of manual materials-handling, the time-sampling approach would not have been appropriate for assessing frequency accurately. In such situations, when observations are made, accurate measures of frequency can only be obtained by recording in real time.

One factor that might have influenced the estimates of validity in this study is the observation procedure. It is possible that the presence of an observer may have influenced the way in which the workers carried out their work or may have prompted them to remember activities carried out during the recall period. It is unlikely that the workers would have changed their normal work activities due to the observations, given the demands of the work involved in the occupational settings. However it is unclear whether the observers could have indirectly influenced recall; employees, aware of the observation procedure, may have estimated physical exposures in greater detail than if the observations had not taken place (20).
The reference period of 1 hour was appropriate for the occupational settings forming the sampling frame for the current study. Occupational activities could be well defined in a relatively short reference period because the tasks did not vary substantially across the shifts. Clearly, for occupations with much greater variability of occupational tasks, the reference period may result in a less accurate quantification of physical demands.

Concluding remarks

General conclusions from previous studies of the validity of self-reported physical demands have been that, while recall is satisfactory at a dichotomous level (ever; never), quantifying the magnitude of the physical demands is more problematic. In this study we demonstrated that workers can estimate both general physical demands and the dimensions of these demands with satisfactory accuracy. The questionnaire in this study was used in a variety of occupational settings, and it differed in several ways from those used in previous studies. This result may have contributed to the improved accuracy observed in the recall of the workers, for example, the use of a VAS to estimate weight instead of questions with specified levels of weight.

Although the questionnaire on occupational physical demands in our study was designed to assess potential physical factors associated with shoulder symptoms, it covered a wide spectrum of exposures also relevant to other musculoskeletal conditions, for example, low-back symptoms, neck symptoms, and lower-limb symptoms. The questionnaire on occupational physical demands is therefore recommended as an instrument for estimating physical factors associated with musculoskeletal pain in appropriate occupational settings in future epidemiologic studies.

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Appendix

Self-administered questionnaire on occupational physical demands

Manual materials handling

Example: in the specified hour

1) Did you lift weights with one hand?

   YES  
   NO  

If you answered YES, please answer the questions below.
If you answered NO, please go to question 2.

(a) Please put an X on the line below to estimate the average weight you lifted with one hand.

\[ 0 \quad 5 \quad 10 \quad 15 \quad 20 \quad 25 \quad 30 \quad 35 \quad 40 \quad 45 \quad 50 \]

Weight in kilograms

(b) Please put an X on the line below to estimate the heaviest weight you lifted with one hand.

\[ 0 \quad 5 \quad 10 \quad 15 \quad 20 \quad 25 \quad 30 \quad 35 \quad 40 \quad 45 \quad 50 \]

Weight in kilograms

(c) How many times do you think you lifted weights with one hand?
   (please tick the correct box)
   1—10 times per hour
   11—30 times per hour
   31—50 times per hour
   More than 50 times per hour

(d) How many minutes or seconds did you spend, in total, lifting weights with one hand?

\[ \ ] \quad \text{minutes}

OR

\[ \ ] \quad \text{seconds}

2) Did you lift weights with both hands?
3) Did you carry weights with one hand?
4) Did you carry weights with both hands?
5) Did you carry weights on one shoulder?
6) Did you lift weights above shoulder level?
7) Did you push weights?
8) Did you pull weights?
Work postures

example: in the specified hour -

9) Were you standing in one position for 30 minutes or more?

| YES | NO |
|-----|----|

If you answered YES, please answer the questions below.

If you answered NO, please go to question 10.

How many minutes did you spend, in total, standing in one position?

| minutes |

10) Were you seated in one position for 30 minutes or more?

11) Did you kneel down?

12) Did you work at or above shoulder level?

Repetitive movements of the upper limbs

example: in the specified hour -

13) Did you carry out tasks involving repetitive movements of the wrists for periods of 10 minutes or more?

| YES | NO |
|-----|----|

If you answered YES, please answer the questions below.

If you answered NO, please go to question 14.

(a) What tasks were you doing at the time?

(b) How many minutes did you spend, in total, carrying out repetitive movements of your wrists?

| minutes |

14) Did you carry out tasks involving repetitive movements of the arms for periods of 10 minutes or more?