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The accuracy of self-report and trained observer methods for obtaining estimates of peak load information during industrial work

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Abstract

The purpose of this study was to determine how well self-report (questionnaire = QR) and trained observer (checklist = OBS) data recording methods compared with more expensive video analysis (VID) for estimating various peak physical loading exposure variables on the low backs of 99 employees during work in an automobile assembly plant. The variables studied were L4/L5 spine compression and shear forces, L4/L5 moment, trunk angle, and hand load. Peak low back loads associated with the working postures of, and the applied loads on, each worker were estimated using a 2D biomechanical model that could accommodate inertial forces acting in various directions on the hands independently. Correlations between the VID and OBS methods were greater for each variable than between VID and QR methods, with ranges in coefficients from 0.6 to 0.8, and 0.1 to 0.4, respectively, giving a discouraging impression of the QR, and the OBS method to a lesser degree, for peak low back exposure assessment. Despite the better performance of OBS method for individuals, it was still only able to account for between 36% and 64% of the variance relative to the VID method. When all workers were considered as a single group, compression and shear forces, moment and hand load estimates were the same regardless of method used to collect the data. Self-reported trunk flexion was significantly greater than that reported by trained observers or on video ($p < 0.0001$).

Relevance to industry

Considerable time and expense could be saved in large scale studies if it were possible to rely on worker's reports or observation of the physical demands of their jobs instead of traditional video and biomechanical analyses. Assessments of peak exposure of individuals using the self-report and observation methods were discouraging. Analysis of a single group proved more promising, but other groups need to be studied. Interview assisted self-reports may help to improve assessments of individuals and also need to be investigated in the future.

Keywords: Self-report questionnaire; Trained observer checklist; Video; Physical demands; Low back exposure

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1. Introduction

The data acquisition and reduction costs of many biomechanical methods such as computerized video (e.g. Punnett et al., 1991), electro-goniometers (e.g. Marras et al., 1993), and EMG assisted biomechanical models (e.g. McGill and Norman, 1986; Marras and Sommerich, 1991) are usually prohibitive for practically obtaining biomechanical exposure measures in industry on numbers of individuals suitable for an epidemiological investigation. Considerable time and expense could be saved if it were possible to rely on workers' reports (via questionnaires) or trained observation (via checklists) of the physical demands of their jobs including posture (Kumar, 1993). Burdorf (1995) suggests that self-reports using questionnaires are only valid and reliable for assessing gross postural activities such as the duration of sitting and standing, while observational techniques need to be used if low back load resulting from trunk posture is of interest. Questionnaires in general have not compared well against objective estimates of physical exposure in field settings (Baty et al., 1986; Burdorf and Laan, 1991; Winkel et al., 1991; Wiktorin et al., 1993). However, recent work by Andrews et al. (1995), which required participants to select their own posture from a series of trunk and arm posture diagrams on a questionnaire, suggested that peak low back compressive loading resulting from fairly simple lifting tasks in a laboratory setting compared well with spine compression load estimates from digitized slides and video. Testing this encouraging method of self-reporting on a larger scale in a field setting, and for a greater number of peak loading variables, is an important next step.

Like questionnaires, the use of trained observer checklists for recording workplace postural loading on a large scale is attractive, since they typically require little time and technology to complete, and minimal training of the observers is necessary in most cases (Karhu et al., 1977). Numerous examples of checklists exist, including OWAS (Karhu et al., 1977), posture targeting (Corlett et al., 1979), and an ergonomic risk factor checklist developed by Keyserling et al. (1992) which can be used to identify awkward postures of the trunk, legs and neck. However, there seems to be a trade-off between the time required to complete an analysis using observer checklist methods, and the detail, and type of physical demands information produced (Keyserling, 1986). De Looze et al. (1994) concluded that trained observation of body posture during dynamic manual material handling tasks was not valid, and that methods involving video recording and computer analysis are required for accurate assessments of dynamic working postures.

Epidemiological studies have shown that low back injury is associated with extreme trunk postures (Punnett et al., 1991) and high moments of force (Marras et al., 1993). Biomechanical considerations have identified numerous other exposure variables, including lumbar spine compression forces (Jäger et al., 1991; Genaidy et al., 1993), shear forces (Kumar, 1990; Potvin et al., 1991; Krypton et al., 1995), and hand load (Kumar, 1990; Marras et al., 1993), suspected to be related to low back injury risk in industrial workers. Cost effective quantification of the magnitudes of physical exposure variables such as these is important if the potential for injury as a result of unnecessarily physically demanding workplace activities is to be reduced.

The purpose of this study was to determine how well self-report (questionnaire) and trained observer (checklist) data recording methods compared with more expensive video analysis for estimating various peak physical loading exposure variables on the low back during work in an automobile assembly plant. The peak exposure variables studied were L4/L5 spine compression and shear forces, L4/L5 moment, trunk angle, and hand load.

2. Participants and methods

2.1. Participants

Data from 99 workers in a large automobile assembly plant were used in this study. Participants were a mixture of production operators, utility relief, maintenance, and support personnel. Production operator jobs typically consisted of several short cycle, repetitive assembly line tasks (e.g. running screws, bolting parts together, installing parts), whereas the jobs of the utility relief, maintenance and support personnel were more varied and had longer cycle times (e.g. equipment repair, stock handling). Personal information about the workers as a group is summarized in Table 1.

2.2. Data collection team membership and training

At any time there was a complement of approximately 6 staff members collecting and reducing the data for the large epidemiological study of which this is a sub-study. All staff members had extensive backgrounds in Occupational Biomechanics, Physical Ergonomics, and Kinesiology. Three of the staff complement were trained as observers to work on two separate on-site data collection teams. Observer training was extensive, consisting of instruction and practice in using the checklist (see description below) for a variety of tasks in the workplace. An observer was considered to be adequately trained when their answers were repeatedly consistent with those of a senior team leader. The video analyzers, who extracted coordinate data from the video images collected in the field, were usually team members, other than the trained observer, that were present when the video was being collected. Video analyzers were trained by repeatedly digitizing test postures which were randomly presented to them, until they could complete five analyses consecutively within criterion ranges of spine compression and reaction shear forces of 170 N and 50 N, respectively. Criterion values were established by consensus of three experts in spine biomechanics and ergonomics.

2.3. Determining heaviest instant of each job

The magnitudes of each of the variables reported in this study were estimated at the heaviest instant of each worker's job using each of the three methods, questionnaire, observer checklist and video. The job of each worker typically comprised several different tasks. The heaviest instant of each identified task was chosen independently by the worker, by the observer at the worksite and by the video analyzer during subsequent analysis. The choice of heaviest instant by the observer and the video analyzer was based on the presence of risk factors such as the degree of trunk inclination, magnitude of the applied load, horizontal reach distance, and subjectively estimated moment of force. The task with the highest measured loading was chosen to represent the peak loading of that worker's job. The questionnaire was completed without assistance by each worker at home prior to on-site data collection. The heaviest instant selected by the worker may therefore have been different than those selected by the trained observer and the video analyzer.

2.4. Video (VID) methods

Each participant was videotaped from the right side (as much as possible in the sagittal plane) while executing their work. Coordinates of the metatarsal, ankle, knee, hip, shoulder, elbow, wrist, hand, and L4/L5 vertebral joint, the C7 vertebral body and the ear canal were determined at the heaviest instant using one of two methods: digitization or manikin. In cases where the view of all the above joints were unobstructed on the video image the coordinates were obtained by digitization. However, in some instances body landmarks were obstructed by workplace limitations, machinery, or by the participant working partially inside an automobile. In these cases, a computerized, manipulable manikin representing a 50th percentile human by height was positioned according to what was visible on the video. The digitization and manikin methods resulted in x- and y-coordinates which were subsequently input

Table 1
Personal information for all workers ($n = 99$)

Gender	Number	Mean age (years)	Mean height (m)	Mean mass (kg)	Mean years worked
Male	93	42.3 (8.0)	1.8 (0.1)	83.8 (14.9)	6.3 (7.5)
Female	6	47.0 (7.2)	1.7 (0.1)	72.1 (9.6)	10.8 (12.5)
total	99				

Participants included production operators, utility relief, support and maintenance personnel. Mean years worked refers only to the present job. Standard deviations are included in parentheses.

into a 2D biomechanical model that output estimates of L4/L5 spine compression and shear forces, L4/L5 moments, and trunk angle. The video-based measures were considered to be the most accurate or 'criterion' estimates of peak exposure that could be obtained in this study. The same measures determined from self-reports (questionnaire) (Wells et al., 1993) and trained observer (checklist) methods were compared with these criterion values for each participant.

The biomechanical model that was used comprises 15 segments (2 feet, lower legs, thighs, hands, lower and upper arms, and a pelvis, torso, head/neck). Anthropometric proportions for segment masses and locations of mass centers for the men and women in this study were taken from Plagenhoef (1971) and Zatsiorsky and Seluyanov (1983). Each participant's height, mass and gender were input into the model and were then used to estimate the location of segment and body centers of mass according to the proportions reported in the sources referenced. Magnitudes and directions of dynamic forces or static load masses acting on the hands separately were also input. If dynamic hand forces are input, their effects are reflected in the output of the model although the body segment inertial forces are not. Therefore, the term 'quasi-dynamic' has been used to describe the model (McGill and Norman, 1985). The model calculates forces and moments at each joint starting at the wrist of each arm and proceeding to the elbow, shoulder, 7th cervical vertebra and down to L4/L5. Compression and shear forces are estimated at L4/L5 from knowledge of the moment of force and reaction forces at this motion unit. A 6.0 cm moment arm length is used to represent the geometry of a single equivalent torso extensor 'muscle'. Selection of this moment arm was based on many sagittal plane, dynamic load handling experiments that were analyzed using an anatomically complex, EMG assisted, multiple muscle model which included the effects of antagonist co-contraction and passive tissue support of the moment (McGill and Norman, 1986), but is too complex for industrial use.

2.5. Self-report method (questionnaire = QR)

Workers were asked to select the trunk, arm and forearm postures from diagrams given in a questionnaire which they felt represented the position of their segments at the heaviest instant of their hardest task. The same questions asked of the participants on the questionnaire about their perceived peak loading are included in Appendix A. Responses to these questions were subsequently entered into a software program which computed relative x- and y-coordinates of the selected postures by estimating body segment lengths as a proportion of the participant's height (Dreyfuss, 1960), and adjusting them according to 5th, 50th and 95th percentile ranges for height for men and women (Canadian Test of Fitness Operations Manual, 1986). The computed coordinates, together with reported information about the load handled (maximum value of the ranges given in question 24 in Appendix A) and the direction of force in the hands, were then input into the biomechanical model such that lower back loads, and trunk angles could be determined. These measures corresponded to the worker-reported postures and were compared to the same measures estimated from the criterion postures captured on video.

2.6. Trained observation method (checklist = OBS)

Concurrently with the video collection, a trained observer on the data collection team documented the postures, measured the magnitude of the loads or forces on the hands, the direction of any applied forces, and various other components at the heaviest instant of each task, using the observer checklist (OBS). The task with the highest loading was chosen to represent the peak loading of that worker's job. The posture choices on the checklist were identical to those supplied on the questionnaire (see Appendix A). The postures and load information were input into the same software package as the self-reports, and the resultant coordinates were input into the biomechanical model such that estimates of each of the measures could be obtained from the trained observer reports.

2.7. Statistical analysis

A correlation matrix was generated to provide some estimate of differences between and within methods for individuals. Means for each exposure variable were also determined for all participants

Table 2
Between method correlation coefficients for variables determined from video (VID) versus trained observation (OBS) and from self-report (QR)

Methods comparison	Compression	Moment	Reaction shear	Trunk angle	Hand load
VID versus OBS	*0.7*	*0.7*	0.6	*0.8*	[a]
VID versus QR	0.2	0.1	0.1	0.4	0.3

Data are from all 99 participants.

[a] The same load mass or sizes and directions of forces on the hands were used in the VID and OBS methods. Refer to Section 4 and to Table 3 for more information.

($n = 99$) as a single group, regardless of tasks performed. A repeated measures ANOVA (for method), was used to test for significant differences between means for each of the five exposure variables.

3. Results

3.1. Individual comparisons

Correlation coefficients between the VID and OBS methods were greater for each variable than between VID and QR methods (Table 2). Specifically, the correlations for VID versus OBS were all greater than or equal to 0.7 (accounting for approximately 50% of the variance), except for reaction shear ($r = 0.6$), whereas the largest coefficient in the VID versus QR comparisons was only 0.4 for trunk angle. Despite the better performance of OBS relative to the QR method for individuals, OBS was still only able to account for between 36% and 64% of the variance (ie. between $r = 0.6$ and $r = 0.8$) relative to the criterion VID method.

Within method correlations of hand load and trunk angle versus the other variables estimated using each method are listed in Table 3. In most cases the same mass or hand force was used as input into the VID and OBS methods. Despite this, correlations between hand load and compression ($r = 0.5$; $r = 0.8$) and hand load and moment ($r = 0.4$; $r = 0.6$) were not the same for the VID and OBS methods, respectively. This shows that both the posture of the head, arms and trunk, and the hand load contribute to low back spine compression and moment, and that the spinal loading estimates are not dominated by either the hand load or trunk angle alone.

Correlation coefficients of L4/L5 spine compression data from the experiments reported by Andrews et al. (1995) for simple laboratory tasks using similar video and self-report methodology, are included in

Table 3
Within method correlation coefficients for hand load and trunk angle versus all other variables determined from each of the methods (video (VID); trained observation (OBS); and questionnaire (QR))

Method		Compression	Moment	Reaction shear	Trunk angle
VID	hand load (kg) [a]	0.5	0.4	0.3	−0.3
OBS	hand load (kg) [a]	*0.8*	0.6	0.3	−0.3
QR	hand load (kg)	0.4	0.3	0.2	−0.1
VID	trunk angle (deg)	0.1	0.1	0.3	1.0
OBS	trunk angle (deg)	0.1	0.1	0.2	1.0
QR	trunk angle (deg)	0.1	0.0	0.1	1.0

Data are from all 99 participants. Coefficients ≥ 0.7 are shown in italics.

[a] The same load mass or sizes and directions of forces on the hands were used in the VID and OBS methods. Despite this, correlations between hand load and compression and hand load and moment are not the same for the two methods. This shows that more than just hand load contributes to low back loading, including trunk angle, and that the VID and OBS methods are not driven by hand load or trunk angle entirely. Hand load and trunk angle alone seem to be poor correlates of low back spine moment, and spine compression and shear forces.

Table 4
Correlation coefficients for L4/L5 spine compression estimated using a biomechanical model from joint position data determined from the participants' actual working posture (digitized slides and video = VID) and from the participants' reported working posture (questionnaire = QR)

Methods comparison	Task 1	Task 2	Task 3	Task 4
Experiment 1				
Slides versus QR	*0.8*	*0.9*	−0.1	*0.7*
Experiment 2				
VID versus QR (S1)	*1.0*	*0.8*	0.6	
VID versus QR (S2)	*0.8*	*0.8*	*0.7*	
QR (S1 versus S2)	*0.8*	*0.9*	*0.7*	
VID (S1 versus S2)	*1.0*	*0.9*	*0.9*	

The questionnaire was the same as in the present study. Data are for 12 and 15 participants for experiment 1 and experiment 2, respectively. The tasks were simple, sagittal plane lifts executed in the laboratory and are not the same for the two experiments. Experiment 2 tasks were executed in two sessions (S1 and S2) separated by 1 week (for more details see Andrews et al., 1995).

Table 4 for comparison. The tasks involved lifting, holding, lowering and moving various hand held loads (boxes, metal pans) ranging in mass from 1.0 kg to 9.3 kg. In almost all cases these correlations are much higher than those determined from the QR data reported in the current field study.

3.2. Group comparison between methods

The group averaged (±SD) L4/L5 moment, compression force, shear force and hand load estimates were the same statistically regardless of method (Fig. 1). The mean trunk angle estimated from the QR responses was significantly greater than from both the VID and OBS methods ($p < 0.0001$). The mean worker-reported hand load was much less variable than from the VID and OBS methods, likely due to the restricted ranges of hand load options available to workers on the questionnaire (question 24 in the Appendix A).

4. Discussion

The correlational analysis for individuals gave a somewhat discouraging picture of the QR and OBS methods relative to the criterion VID method for assessing peak low back exposure. The group averaged L4/L5 compression and shear forces, L4/L5

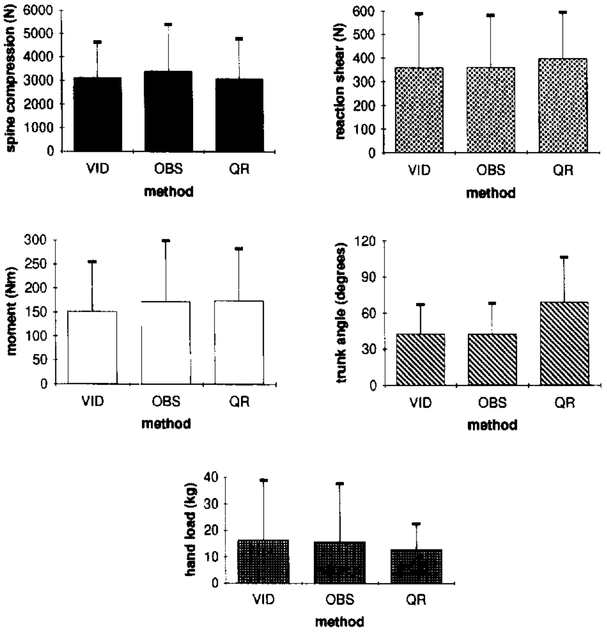

Fig. 1. Mean (±1 SD) L4/L5 moments, spine compression and shear forces, trunk angles and loads handled for all participants. VID = video methods (either digitized video or manikin); OBS = checklist method (trained observation); QR = questionnaire method (self-reports). The group averaged trunk angle estimated from the QR was significantly different from those estimated from the VID and OBS methods ($p < 0.0001$). Mean differences for all other variables were not statistically significant.

moment and hand load estimates were found to be the same regardless of method. Only the mean trunk angle estimated from the self-reports (QR) was significantly greater than that from both the video (VID) and trained observer (OBS) methods.

Several of the possible sources of variability that may have lead to the outcomes of this study include: differences in static and dynamic hand loads between methods; possible differences in the visual perspectives of the video images, trained observers and recollection of the participant; differences in selection of the heaviest instant between methods; the use of the same hand load or applied force in the VID and OBS methods; the use of categorical load and posture data for QR and OBS but continuous measures for VID; and difficulties experienced by workers filling out the questionnaire. It has been shown that low back moments during lifting can be dramatically affected if the biomechanical model used does not attempt to account for the inertial components of the load and the body segments (McGill and Norman, 1985). This is a potential source of variability in the absolute magnitudes of the low back loads estimated in this study. However, a quasi-dynamic model was used to attempt to account for accelerated loads in the hands when applicable, although most movements were performed quite slowly. This approach provides a reasonable alternative to a completely dynamic model (McGill and Norman, 1985). In addition, the same model was used for each method and therefore any variability due to its quasi-dynamic nature would have been the same in each case. It was the relative comparison of the methods which was the primary interest in this investigation.

Each of the workers was videotaped and observed from the right side, in the sagittal plane as much as possible. Worker-reports of trunk posture not in the sagittal plane or not analyzable using the biomechanical model (i.e. back postures 7 to 9, 13 and 14 in Appendix A), were not included in this analysis. Although some of the peak instant working postures of the workers on the job did involve some deviation from pure sagittal motion, it has been shown by Bone et al. (1990) that L4/L5 compression forces and moments output from the 2D and 3D versions of the model differed by less than 10% when a participant who handled loads from, or close to the floor, was filmed out of the sagittal plane by as much as 30° and 40°, respectively. Although the Bone et al. (1990) study cannot be generalized to all asymmetric, dynamic tasks, particularly those where large axial torsions of the spine are involved (e.g. pure twists or one handed lifts), it does show that there is some justification for the use of a 2D model in apparently 3D or one handed lifting tasks, even those appreciably out of the sagittal plane. If large axial twists are present, then the absolute spinal compression will be underestimated because of failure to account for large trunk muscle co-contractions observed in twists. However, it must also be re-emphasized that the same 2D model was used to estimate the lumbar loading variables corresponding to the joint coordinates input from each of the different methods. Any errors associated with the model because of its 2D nature would have been the same for each method. Therefore, the estimates of low back exposure determined from video were considered to be the 'criterion' estimates in this study.

A potentially greater source of variability in the estimates of each variable between methods was that the heaviest instants determined by the trained observers, the video analyzer, and the worker may not have been exactly the same. The determination of the heaviest instant of a worker's job was left up to the individual worker, observer, and video analyzer. Differences in the magnitudes of the exposure measures as a result of this were expected since the methods depend on the user's own perception. Although differences could have resulted from the heaviest instant determination, and from errors in recording the postures and external loads, the relative contributions of each were not separated out in this study. This would also be the case if any of the methods were used independently, as they normally would be in industry. However, data that were previously collected but not reported in the first set of laboratory experiments (Andrews et al., 1995) using similar methodology, seems to suggest that little difference due to the identification of the heaviest instant of a particular task by workers may be expected, at least for simple tasks. Accurate assessments of the exact instant chosen by the observer, video analyzer and worker needs to be done in the future if the error associated with heaviest instant determination is to be separated out from other potential sources. This requires a more controlled experiment than was possible under the constraints of the larger epidemiological study.

In most cases the same load mass or force on the hands was used as input into the VID and OBS methods. One might expect this to force similarity in these two methods. Despite this, correlations for the VID and OBS methods between hand load and compression ($r = 0.5$ and $r = 0.8$, respectively) and hand load and moment ($r = 0.4$ and $r = 0.6$, respectively) were modest at best and not the same. Spine compression and moment are related measures which vary depending on the magnitude of variables such as trunk and arm posture, hand load, body height, and the mass of the body located above the L4/L5 joint. It must be understood as well that recording the same load mass or hand forces by the observer and the video operator is inevitable in the field if either method was used alone, since in practice the observer or video analyzer would record the magnitude of the handled load or exerted force after physically measuring it on their own using a scale or force gauge.

The authors recognize that differences between the QR and OBS methods, and the VID method (see Table 2), may also be a result of comparing 'continuous' postures captured on video to the 'categorical' postures collected using the QR and OBS methods. One might expect the magnitude of the correlations to be lowered as a result of categorization because of category misclassification. Regardless, this does not alter the conclusions reported here since it must be recognized that the same categorical variables from both the OBS and QR methods were correlated with the continuous variables from VID. As a result, any error that is associated with comparing the categorical to the continuous estimates of low back exposure, will be the same in each case. The absolute error associated with using categorical posture data in this manner is currently being determined.

There is evidence that, under certain conditions, individual workers can describe their postures reasonably well. Kumar (1993) had participants sketch the trunk postures they felt they held during work. Compared to postures determined from photographs, reported stoops and twists were accurately and reliably estimated but side bending, pushing and pulling were not. An advantage of choosing postures rather than drawing them may be that the choices are standardized for each participant and angles associated with each posture are known, allowing for quick input into a biomechanical model to estimate the magnitude of low back exposure variables such as the ones reported in this study. In agreement with Burdorf (1995), trunk angles estimated using trained observation, rather than worker self-reports, correlated better with those estimated from video records. Despite this better 'performance', the OBS method was still only able to account for between 36% and 64% of the variance relative to video. This supports the conclusion made by De Looze et al. (1994) that body postures during workplace activities were more accurately estimated using video recording than using trained observation. Wiktorin et al. (1993) suggested that self-reports of exposure to posture and to handled loads greater than 5 kg may be sufficiently accurate, compared to direct measurements or observation, for use in large epidemiologic studies, but that self-reported exposure may be too crude for use in smaller studies where more accurate information is required. The difficulties some workers had in this study with distinguishing between the many working trunk, arm and forearm postures included in the questionnaire, lends support to this notion. Even if a questionnaire was designed to allow for more detailed estimates of exposure from self-reported posture and hand load information, a tradeoff does exist with the amount of additional information that can actually be extracted from such a method.

The group analysis results of this study are similar to those reported by Andrews et al. (1995), with the following notable exceptions. In order to get 99 questionnaires with peak loading information that was useable for this study, approximately 184 questionnaires were reviewed. Many workers did not fill out the questions in the peak loading section and many that did respond, chose twisted trunk postures from the available diagrams. These problems as well as any questions that the workers had when filling out the questionnaire could have been dealt with if it had been filled out in the presence of one of the investigators, as was the case in the previous laboratory study. Using an interview to obtain the worker-reported postures may reduce the differences between the QR and VID methods for individual workers, and is currently being investigated. Interviewer assisted questionnaires, of course, increase administration costs. Costs prohibited an interviewer assisted approach in the larger study of more than 300 workers. Moreover, pilot studies on the questionnaire suggested that interviewer assistance was not critical. This observation is now in doubt.

The correlational analysis indicates that the less costly QR and OBS methods may have limited usefulness for assessing low back exposure for individual workers. Regardless of the purpose of the group assessment, we have shown that the two types of analyses can result in different conclusions regarding method accuracy. The results of a group may have fewer obvious applications for industrial practitioners than do individual results, but in this study the group results, among other things, have proven valuable as comparative data for our previous work in the laboratory. In fact, the analysis of individuals was included to show that the group analysis was a limiting one, although encouraging, and that an incomplete impression of the accuracy of the less costly methods could be obtained if the analysis of individuals is omitted.

5. Summary and conclusions

A self-report (QR) and an observation (OBS) method were presented and how well peak low back exposure variables compared with the same variables estimated from a criterion method (VID), was assessed for a group of 99 workers. Comparisons of individual's estimates of peak low back loads between methods provided a discouraging impression of the usefulness of the QR, and to a lesser degree the OBS method, for peak low back exposure assessment. This suggests that the type of analysis being performed using the less costly methods outlined in this study, should be considered a priori. Group averaged compression and shear forces, moment and hand load estimates were the same regardless of method. The mean trunk angle estimated from the QR responses was significantly greater than those from both VID and OBS methods. Problems that some workers had using the QR method included difficulty interpreting the arm postures, and including more than just the single task they perceived to be the heaviest when asked to select one. Problems like these could have been addressed by having the questionnaire filled out with one of the investigators present, but the need for an interviewer increases costs. Future work needs to address the usefulness of interviewer assisted self-reports before the questionnaire methodology is completely ruled out as a viable approach.

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Appendix A

The questions and diagrams included below are the same as those in the questionnaire given to each participant. Previous to these questions participants are asked: about personal information (height, weight, etc.); about their activity level outside work; about general risk factors for low back injury (e.g. twisting, leaning far forward etc.); to describe each task comprising their job. Participants are also asked to rate the 'heaviness' of each task on their low backs. Questions following these asked participants more about general risk factors in their current and past jobs (e.g. vibration, jolting, etc.), and questions about their work history and potential for injury in their current job. Using the checklist (not shown here), the trained observers recorded their best estimates of the peak loading information using the same questions and posture diagrams as included here.

22. a) Which task is **heaviest** on your back? (*CIRCLE ONE*)
    1 Task #1
    2 Task #2
    3 Task #3
    4 Task #4
    5 Task #5
    6 Task #6
    b) Please describe the physical components of this task:
    ....

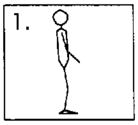
Imagine you are doing the task which you identified as heaviest on your back in question 22. The following questions all apply to the heaviest **instant** of that task (try to imagine a single photo or freeze-frame of the moment in the task which is **most stressful** on your back).

23. a) **Refer to the pictures on the next page (marked 'BACK') for this question.** Which of these pictures best describes your back posture at the **heaviest instant** of the task chosen in **Q22**. (The heaviest instant in the task is the single point where you feel the most force/load on your body.)

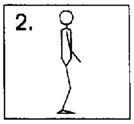
    At the heaviest instant of this task my back position is: .... (*PICK A NUMBER FROM THE 'BACK' PICTURES ON THE NEXT PAGE*)

    Pick ONE (1) picture which BEST MATCHES your posture during the most stressful instant for your back.

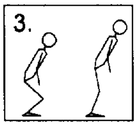
BACK [For questions 21(b) and 23(a) identify the picture which BEST describes the position of your back] (Ignore the positions of your arms and legs)



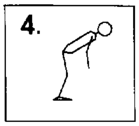
Leaning back slightly

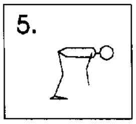


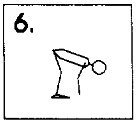
Back straight



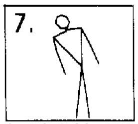
Leaning forward slightly



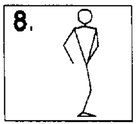




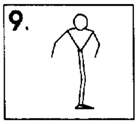
Fully bent over



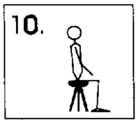
Leaning sideways



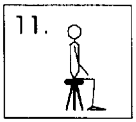
Twisted



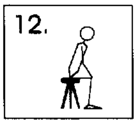
Twisted and bent



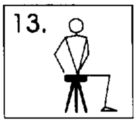
Sitting, leaning back



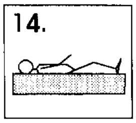
Sitting



Sitting, leaning forward



Sitting twisted

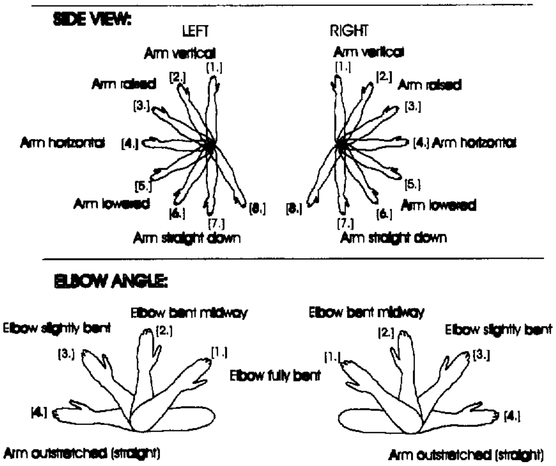


Lying down

23 b) At this instant of the task, where do you hold your arms? (*FOR EACH ARM: SELECT THE POSITION THAT MOST CLOSELY APPLIES AND CIRCLE THE APPROPRIATE NUMBER.*)

Describe the arm positions that BEST MATCHES the back posture you identified in the last question.

Please select ONE EACH for left and right arms.



24. How heavy is the load that you handle when you are in this posture? (*CIRCLE ONE NUMBER*)
    1 No load → **(GO TO Q27)**
    2 Light (0–11 lbs or 0–5 kg)
    3 Medium (11–25 lbs or 5–11 kg)
    4 Moderately heavy (25–40 lbs or 11–18 kg)
    5 Heavy (40–50 lbs or 18–23 kg)
    6 Extremely heavy (over 50 lbs or over 23 kg)

25. With which hand do you handle the load at the heaviest instant of this task? (*CIRCLE ONE NUMBER*)
    1 Right hand only
    2 Mostly right hand
    3 Both hands equally
    4 Mostly left hand
    5 Left hand only

26. At this instant in this task which of the following BEST describes the direction in which you are exerting force? (*CIRCLE ONE NUMBER*)
    1 Lift/lower/pushing up/pulling up

2 Pushing down/pulling down
3 Pushing forward
4 Pulling back

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