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Research Report TM/92/08
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Graveling RA, Johnstone J, Symes AM

World Health Organisation Collaborating Centre For Occupational Health

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DEVELOPMENT OF A SCREENING METHOD FOR MANUAL HANDLING

by

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SUMMARY

More than a quarter of the accidents reported each year to the enforcing authorities in the UK are associated with the manual handling of loads. Many more injuries occur gradually, with progressive wear and tear damaging the back, until incapacity results. As a result of European and UK National Legislation, employers are to be required to assess manual handling operations for risks to safety and health and to take steps to reduce such risks. In the Coal and Steel Communities of the CEC, guidance has been produced to aid employers to identify ways and means of achieving that risk reduction. This document has been produced as an aid to employers in identifying where such risk reduction is required. It draws together the results from scientific attempts worldwide to quantify the strains arising from manual handling to produce a simple screening method.

The method is based upon the application of a checklist - inevitably fairly lengthy given the complexity of factors influencing safe manual handling. After completion, the checklist entries are used to identify a series of multipliers, which are in turn used to derive a safe load for a given handling task. This can be used to compare against the actual task load in order to establish whether or not the load is acceptable.

Although ad-hoc preliminary applications had suggested that the checklist was relatively straightforward, formal trials with British Coal staff who received a minimal amount of training indicated problems with its use. Poor inter- and intra-individual repeatability produced inconsistent results and it remains to be seen whether this difficulty can be rectified with training. A more fundamental problem was that, even when applied by experts in its use (those responsible for its production and testing) it did not reliably indicate potential risk. Compared against the objective measurement of intra-abdominal pressure (IAP) it generally over-estimated the risk of injury. Although it is recognised that the IAP technique for quantifying truncal strain does have its detractors previous attempts to quantify risk mathematically (notably the equation produced by NIOSH) have similarly tended to result in an overestimation of that risk. Care should be taken in applying numerical limits without recognising their limitations and potential inaccuracies.

1. INTRODUCTION

In the United Kingdom, about a quarter of the accidents leading to more than three days off work and reported each year to the Health and Safety Executive are associated with lifting, lowering, carrying, pushing or pulling loads (Health and Safety Commission, 1991). According to David (1985) 'Handling goods' accounted for between 25% and 30% of all accidents reported for the five years from 1976 to 1980, a proportion encountered in a variety of industrial sectors including manufacturing industry, offices, shops and railway premises and the construction industry. In British coal mines, which use a different accident classification system, approximately 20% of accidents occur 'whilst handling supplies .....' a lower but still unacceptable figure. Although precise comparisons are difficult, there is little doubt from published reviews that a similar picture is encountered throughout Europe (e.g. Hettinger, 1985 - West Germany; Metzler, 1985 - Luxembourg; Biering-Sorensen, 1985 - Denmark). Indeed, it is apparent that the problem occurs throughout the Western world. Troup and Edwards, (1985) report statistics from Australia, Canada and the United States which show a similar picture.

Against this background, the EC have produced a Council Directive laying down the 'minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers' (CEC, 1990). In response, the United Kingdom Health and Safety Commission issued a consultative document proposing 'Regulations and Guidance for Handling Loads at Work' (Health and Safety Commission, 1991). Under these Regulations, employers would be required to make 'an assessment of the handling operations .....[at work]'.

Clearly, employers are going to require guidance in evaluating the risks of handling injury to which their workforce are exposed. In the past, assessment of safe manual handling has concentrated, rather simplistically, on safe lifting of loads. Previous regulations such as those relating to the Agricultural and Woollen and Worsted industries (which will be revoked under the new regulations), have referred to maximum permissible weights - frequently appearing to reflect custom and practice at the time the legislation was enacted rather than having any scientific basis (Graveling, 1985). It is now recognised that adherence to such limits in isolation is likely to be misleading. Scientific research has shown that the factors known to influence the safe handling of loads are complex. They include features of the task and the load as well as characteristics of the individuals carrying out the handling tasks.

This scientific research has resulted in a vast array of papers and reports. The proceedings of a conference on Industrial Back Pain in Europe (Davis, 1985) resulted in nearly 700 references. Employers cannot hope to assimilate all this information and must look towards some form of distillation of these papers in order to formulate some realistic assessment. Several different approaches to determining acceptable limits have been devised, both in Europe and in the USA. These include measurement of intra-abdominal pressure (IAP) (e.g. MHRU, 1980) and the psychophysical approach where individuals are asked how much they are willing to lift in a given set of circumstances (e.g. Snook, 1978). The HSC Draft Guidelines recommended that they should only be used by professionally competent persons, yet to date, few of these have been presented in a form which would be easily applicable by a non-specialist user. One attempt to make this research more accessible was published by the American National Institute for Occupational Safety and Health (NIOSH, 1981). Their 'Work Practices Guide for Manual

Lifting' was produced by a committee of research workers who combined elements of a selection of research findings to produce an algebraic equation for an 'Action Limit'. However, the limits produced were deemed to apply only to smooth, two-handed asymmetric lifting in the sagittal plane of moderate width objects (no greater than 75cm). Such lifting tasks are comparatively rare since most will involve lateral movement, rotation or some other asymmetrical requirement.

The purpose of this project therefore was to produce a simple screening method for assessment of manual handling tasks. The intention was to devise an approach which could be applied by non-experts to fulfil the proposed requirement for an assessment of manual handling at work. It was to be widely applicable and not to be constrained to artificial tasks which were seldom encountered in practice.

2. FORMAT OF THE ASSESSMENT

There is a tendency, especially where scientific knowledge is incomplete or the issue is complex, for guidance and assessments to be couched in very general terms. These may be effective in directing attention to the factors involved but do not provide the means whereby any definitive assessment can be made. For example, an Annex to the European Council Directive (CEC, 1990) states that a task may present a risk of back injury if it requires 'excessive lifting, lowering or carrying distances' but gives no indication of what constitutes 'excessive'. The Annex lists over twenty factors with a footnote: 'With a view to making a multi-factor analysis, reference may be made simultaneously to the various factors listed.....' which gives some indication of the complexity of the problem. This complexity must somehow be reconciled with the fact that those responsible for assessing tasks in industry will want numbers. They will want to be able to say 'Is this object too heavy when lifted like this?' and, if the answer is yes, 'How heavy can it be?' or 'How can it be lifted safely?' It was decided therefore that the scientific literature would be surveyed to provide a database of numerical guidance. This database would then be used to derive a series of 'multipliers', reflecting the risk of back injury associated with that factor. These multipliers could then be applied to a standard maximum load to derive a safe handling load for the circumstances described. The relative size of the various multipliers would also serve to indicate which avenues for ameliorative action would be most likely to yield an acceptable load. Finally, despite the increasing availability of personal computers, it was decided not to produce a computer-based aid as intrinsically-safe computers are not yet widely available in the coalmining industry.

3. SCIENTIFIC DEVELOPMENT OF THE ASSESSMENT AID

This section describes the derivation of the various correction factors from the scientific literature. No particular significance is attributed to the order in which they are addressed. There is usually a wide variation between guidance values produced using different criteria. Several papers have been published on this issue including Garg and Ayoub, (1980) comparing biomechanical, psychophysical and metabolic criteria; Freivalds, (1987) comparing the NIOSH and MHRU guidelines; and Garg, (1987) who contrasted the NIOSH guidelines with psychophysical, metabolic and biomechanical criteria. The discrepancies identified in the latter paper indicate the difficulties to be encountered, as the NIOSH guidelines were composite values based on the same criteria. The values described below were generated by a combination of consensus and compromise, with a certain element of pragmatism included where the scientific evidence was incomplete. Occasionally, individual values were also adjusted slightly in order to remove or minimise anomalies produced when multipliers were used together in practical examples.

It is difficult to make numerical provision for some risk factors (for example, unstable or unwieldy loads). Most research has been carried out on moderately sized, symmetrical, stable, regularly shaped objects, although some, less tangible, factors have been studied, for example the work by Drury, (1985) on the effects of hand positioning. In most cases, no provision has been made for assessing such factors. The one notable exception, because of its considerable relevance to coalmining, is unstable flooring.

3.1 Maximum Load

It was decided that the starting point for the assessment would be the maximum load acceptable for a single, two-handed lift under ideal circumstances. The NIOSH guide (NIOSH, 1981) adopts a maximum load of 40Kg to which its own series of multipliers is applied. This load is deemed to be acceptable to over 99% of men and over 75% of women at work. Although age is acknowledged to be a potential risk factor, no specific provision is made for age adjustment and the guide is intended to embrace all normal working age groups. In contrast, the guidelines based on intra-abdominal pressure (IAP) (MHRU, 1980) do take age into account, reducing the safe working load in age decades above the age of 40. The greatest load provided for (code H, pages 10/11) primarily relates to work above shoulder height. Although this may induce lower IAP responses, work above shoulder height is a known risk factor. The maximum load at chest height, close to the body is 40Kg ($\leqslant$40 years) or 37Kg (41-50 years). These figures relate to male industrial workers. The exact range of workers accommodated is not entirely clear. The introduction indicated that the values represent a worker whose height and weight coincided with the fifth percentile limits of the British population - but then stated that 'any male worker should be able to apply [these forces] without undue risk of injury'. This issue has been discussed in more detail by Graveling *et al.* (1986) and will not be expanded upon here.

Snook (1978) published tables of acceptable (to the worker) weights of lift, lower etc. The heaviest lifting load for the majority of the male population (90%) was 33Kg. Age was not found to be a significant variable and was not therefore considered separately.

A much higher maximum (50Kg) was incorporated into a 'compendium' produced by the Directorate of the Danish Labour Inspection Service (1986). Unfortunately, the origins of this limit are not documented.

Of these limits, the most relevant to the British mining industry would seem to be that based on IAP measurement. However, research on British coalminers (Graveling *et al.* 1986) showed these limits to considerably over-estimate the truncal strain. The strain recorded amongst a group of mineworkers was an average of 33% lower than predicted by the IAP contours across a variety of weights. Graveling *et al.* (1986) recommended that IAP contour values be adjusted by some 25-30% as a conservative correction. A 30% correction would yield maximum levels of 52 and 48Kg for the two age groups. Although these values are higher than are recommended by NIOSH, it can be argued that the mining population is arguably a self-selected population in comparison with the general industrial population targeted by NIOSH and, as a result, the 99% cover promoted by NIOSH is unnecessarily restrictive. British Coal are currently investigating the introduction of strength testing for new recruits which would ensure that those coming into the industry are at least as strong as those already employed, thus ensuring that the future mining population is not 'diluted' by changes in employment practice.

It was therefore decided that a maximum load of 50Kg under ideal conditions was appropriate for the British coalmining industry and that the present study should adopt this level as its standard.

3.2 Horizontal Location of Load (distance away from body)

The distance of the load away from the body is the parameter most widely studied and reported in the scientific literature. Some authors adopt an anatomical reference frame such as 'half arms length' (e.g. Jäger and Luttmann, 1989). Others, including the NIOSH guidelines (NIOSH, 1981) incorporate a distance measurement. However, care must be taken in interpreting these, as the reference point varies between sources. For example, the NIOSH guidelines define the distance as 'forward of midpoint between ankles' whereas Snook (1978) referred to the 'width of the object away from the body'. This may cause even further confusion as the distances given are the width of the object, the hands being located at the mid-point. Garg (1987) suggested that the NIOSH guidelines yielded different values to other criteria because, it was alleged, a different horizontal distance definition was used in developing the guidelines than was given for their application. However, no data were presented to support this claim. There is, however, a more fundamental difference. The NIOSH guidelines show horizontal location to have a curvilinear relationship with permissible weight while others, such as the MHRU data indicate a more linear relationship (depending upon limb angle).

The multipliers selected from the appraisal of the literature were:

Horizontal location of load (distance away from body)

Location		*Multiplier*
Close to or against body	(<20 cm)	1
Elbow length	(35 cm)	0.8
Wrist length (ie arms slightly bent)		0.5
Hand length	(70 cm)	0.3
Reaching out beyond head when stooping		0.2

Thus, holding a load close to the body would permit a load of (50 x 1) - 50Kg whilst, at wrist length, the load would be (50 x 0.5) - 25Kg.

It was decided to provide anatomical references as well as distances as some individuals may find actual distances difficult to estimate. It should be noted that, according to these multipliers, the variation in strain with horizontal distance is not linear.

3.3 Vertical Location at Start of Lift (height from ground)

In the NIOSH guidelines, the acceptable load decreases linearly above or below knuckle height. To reach loads below knuckle height it is clearly necessary to bend the knees or the back. As the posture adopted clearly influences the load factor, it was decided to separate the posture adopted from the vertical location factor - particularly as many papers do not describe the posture employed beyond the term 'freestyle lifting posture'. Thus, 'vertical location' was to cover the range from knuckle height to above head height. However, inclusion of a posture factor (see below) extended the range to floor level.

Lifting above head height is often cited as a high risk activity. Surprisingly, the load factors cited in the literature do not always reflect this concern. For example, the MHRU data, based on IAP measurements, do not show any significant reduction in load until the hands are above head height. Between shoulder and head height, the data indicate an initial increase in permissible loading. Mital (1984) reported a comparison between three different studies each of which had used a psychophysical methodology. The vertical height range 'shoulder to reach height' showed the least agreement between the studies with changes from 'knuckle to shoulder' values ranging from approximately 8% (Mital, 1984) to 21% (Ayoub *et al.* 1978). It appears however that these values may represent some form of average across all other variables. For example, Mital gave a value from Snook (1978) of about 19% whereas values in Snook actually ranged from 5-8% for single lifts up to 30% for some frequent lifting rates. In deriving correction factors for vertical location it was therefore necessary to try to remove the influence of other factors as much as possible. At the same time, care had to be taken to ensure that, when combined with the multipliers for those factors, values reasonably consistent with the literature were obtained.

One further problem was that not all authors differentiated between 'knuckle to waist' and 'waist to shoulder'. Taking all these factors into account, the following set of multipliers was derived from the literature.

Vertical location at start of lift (height from ground)

Location	Multiplier
Below knuckle height	1
Knuckle to waist (70-100 cm)	1
Waist to shoulder (100-135 cm)	0.85
Above shoulder height (135+ cm)	0.75

3.4 Maximum Vertical Distance of Lift (or lower)

Few authors have reported any experimental investigation of this factor. Yet it clearly is important, particularly when any load has to be lifted over an obstruction. The NIOSH guidelines incorporate a lift distance factor ranging from 1.0 to 0.7. The influence of the factor reduces with existing lift height in an exponential fashion. The work of Snook and his colleagues, reported by Snook (1978) also showed shorter distances to have a proportionately greater effect. Reported over a wide range of lifting frequencies, increasing the lifting height from 25 to 51 cm showed a typical decrease in acceptable load of some 15%, whilst increasing it from 51 to 76 cm resulted in a typical effect of less than 10% and, in a large number of cases, no difference was obtained. Studies reported by Sims *et al.* (1986) also support this progression, although not enough different heights were studied to confirm the precise nature of the relationship.

It was considered inappropriate to expect field observations by relatively untrained observers to differentiate between small changes in the relatively short lifting distances over which most of the effect occurs. Therefore, the linear progression described below was devised to represent the effect of vertical lifting distance.

Maximum vertical distance of lift (or lower)

Distance	Multiplier
Up to 30 cm	1
30-50 cm	0.9
Over 50 cm	0.8

3.5 Asymmetric Handling

Until recently, there had been very few reported studies of asymmetric lifting. Most of the emphasis had been on symmetrical lifting in the sagittal plane. However, a number of papers on this issue have now been published and, because of the practical importance of this topic, it seems appropriate to discuss these in a little more detail than some other topics.

One of the few earlier studies was that of Kumar (1980) using intra-abdominal pressure measurement. It incorporated both of the two main elements studied in subsequent papers: lifting when twisted and twisting when lifting. However, it was unusual in that the twisting when lifting involved a movement from 45° leftwards rotation to 45° rightwards rotation - therefore actually combining both elements. Subsequent papers involving twisting when lifting have described tasks either starting or finishing in the sagittal plane.

The magnitude of any correction factors has been shown to vary according to how the impact of the asymmetric handling was measured. Kumar, in two series of experiments reported in 1984 and 1988, showed that the plane of lifting activity had no significant effect on energy cost. In contrast, Garg and Banaang (1988) reported significant increases in heart rates and perceived exertion with increased body rotation - despite the fact that the weight lifted was reduced. The authors suggested different correction factors depending upon the measurement parameter employed - although no corrections were derived from these particular parameters. For example, at 90° rotation (lifting when twisted) a correction factor of 0.58 was recommended based on static strength whilst a psychophysical 'maximum acceptable weight' criterion resulted in a correction factor of 0.79. It is interesting to note the implication that subjects will apparently tolerate a greater proportion of their lifting strength when lifting asymmetrically.

The authors suggested that there was no significant effect on asymmetric lifting of either lifting frequency or lifting height, although this is not in agreement with data reported by Kumar (1980), who showed that a 90° lift produced a considerably greater IAP response in proportion to the appropriate sagittal plane lift for lifting from ground to knee level compared to hip or shoulder level. It may be significant that all of these papers have reported studies of actual lifts - albeit in controlled laboratory environments - and therefore include some influence of lifting style or range of movement during the lift. Ridd (1985) reported the results of measurements of IAP responses to the application of force in essentially static postures. These showed generally smaller changes than did most of the other papers.

The various authors who have published the results of work in this area have either adopted a 0°, 30°, 60°, 90° sequence or a 0°, 45°, 90° sequence - or a reduced set from either of these. An exception was Marras and Mirke (1989) who examined 15° and 30° lifts. However, this study was methodologically different from all others in that the subjects were strapped into position. For the production of the present assessment aid it was decided that, although a 45°/90° sequence might be easier to estimate, it was possibly too coarse and a 30°, 60°, 90° sequence was selected instead.

There were not sufficient data on which to base different correction factors for lifting in a twisted position or twisting when lifting. The following multipliers were derived from the range of values given in the literature.

Twisting Body

Rotation of trunk	*Multiplier*
No rotation	1
30° 'one-o'clock' (or eleven)	0.9
60° 'two-o'clock' (or ten)	0.85
90° 'three-o'clock' (or nine)	0.8

3.6 Lifting Posture

'Squatting', not stooping, to lift is at the core of much lifting training although some authors (e.g. Graveling *et al.* 1985) have questioned the dogmatic adherence to this in the light of conflicting scientific evidence. For example, Andersson *et al.* (1976) reported on a comparison between squatting and stooping to lift using direct measurement of intra-discal pressure and two indirect measures of spinal load electromyography and IAP. Contrary to what might be expected, the differences between the three measures were generally small. However, Troup *et* *al.* (1983) made comparisons between squat and stoop lifting using predictions of disc compressive force and measurements of IAP. They showed that stoop lifting produced significantly lower predicted peak lumbosacral compression values and lower intra-abdominal pressures than did squat lifting.

Interpretation of the published research results is difficult because of a general lack of precision in defining the lifting posture adopted. Back or stoop lift is reasonably understood and seldom open to variation although the horizontal distance of the load away from the body is not always cited. However, the term 'squat lift' gives no indication of whether, for example, the foot position is asymmetric and/or the load is small enough to pass between the knees. Chaffin (1975) used biomechanical calculations to show how a 15.5Kg load stoop-lifted generated considerably less compressive force on the spine than the same load squat-lifted where the load was lifted <u>beyond the knees</u>. With the load close to the stooping body, the force ratio for such a weight could be as high as 1:1.4 in favour of stoop lifting. Similar ratios have been shown by authors, such as Kumar (1984), who have studied the relative energy costs of the two techniques. In contrast, Ridd (1985) showed that, according to IAP measurements, the loads which could safely be lifted when stooping or bending were only approximately 40% of those previously suggested for standing or squatting postures (MHRU, 1980).

Andersson and Chaffin (1986) reported the results of biomechanical studies which compared stooping with squat lifts involving parallel or 'straddle stances'. In most cases, straddling the load produced the lowest levels of disc compression whilst parallel stances were not only worse than straddle stances but were, in most cases, worse than stooping.

In deriving a correction factor, the influence of the horizontal distance of the load away from the body had been allowed for separately. A correction factor needed to be derived which, when used in conjunction with the distance factor, would reconcile these apparent conflicts by assuming that loads squat-lifted <u>beyond</u> the knees would exert more force on the spine and therefore create more risk of spinal damage than stoop-lifting the same load close to the body. A slight forward lean was considered to be reasonably acceptable - and it was unrealistic to expect observers readily to differentiate between small changes in back angle. Furthermore, there is little evidence to indicate the relative influence of different leaning angles (most authors having concentrated on gross lifting postures) although this comparison could be made using biomechanical predictions. It was therefore decided to restrict the assessment to whether a worker was essentially upright, stooping or squatting. The following corrections were therefore derived for these general body postures. As stated, when the knees are bent in a squat lift, the vertical height reference points are shifted (so that, for example, knuckle height may become zero centimetres) and the influence of starting height should be evaluated with the criteria adjusted accordingly.

Stooping

Posture	*Multiplier*
Slight lean (<20°)	1
Curved back	0.65
Straight back, bent knees lifting*	1

* Bending the knees alters the absolute position of the knuckles, waist and shoulder heights. In this case the 'new' heights should be applied to assess the vertical location.

3.7 Frequency of Lifting

Frequency of lifting has been widely studied and reported. In some cases, such as the work reported by Ciriello and Snook (1983) it has been addressed as one of the main variables being examined. In others, it almost appears to be incidental to the main purpose of the research (e.g. Garg and Banaag, 1988). Snook (1978) reported acceptable (psychophysical) loads for frequencies ranging from once a shift (8 hours) to once every five seconds (12 min^{-1}) and this seems to represent the widest range of frequencies reported by any author. This work of Snook is unusual in that the results are reported as how often a lift occurs (e.g. 14 second intervals) rather than a frequency (14 seconds $\equiv$ 4.3 lifts min^{-1}). It will be noticed from this conversion that some of the time intervals (9 seconds, 14 seconds) seem a little arbitrary. Few authors other than Snook report lifting frequencies slower than 1 min^{-1} with most reports concentrating on a band from 1 min^{-1} to 8 min^{-1} although there is a further cluster at 12 min^{-1}.

Over most of the range there is a remarkable degree of consistency between studies in comparison with other variables. This is possibly due to the fact that the majority of studies involving varying frequencies of lift seem to have used psychophysical criteria. However, this apparent consistency appears to break down at the higher handling frequencies.

The NIOSH (1981) guidelines are notable for the conservative nature of their values in comparison with the general trend. Depending upon the circumstances of the lift, NIOSH multiplication factors at 12 min^{-1} range from 0.33 down to zero (no lifting allowed). In contrast, authors such as Mital (1987) indicate a correction of 0.7 for the same frequency.

The correction factors shown below represent a distillation of the values in the published literature. Reasonably broad frequency bands have been selected to simplify the assessment. It will be noted that the final multiplier is for frequencies greater than 12 min^{-1} with no further reduction. At frequencies above this level, the load itself is unlikely to cause a problem. However, experience has shown that, to work at such speeds, workers often have to maintain a particular posture. Particular attention must therefore be paid to the design of the workplace. High handling rates may also provoke upper limb disorders – again depending upon the working posture.

Frequency of Lifting

Frequency	*Multiplier*
Infrequent (<1 in 30 minutes)	1
Occasional (1 in 5-30 minutes)	0.8
1 in 5 mins to 1 min^{-1}	0.7
1-4 min^{-1}	0.6
5-8 min^{-1}	0.5
9-12 min^{-1}	0.4
>12 min^{-1}	0.2

3.8 One-handed Lifting

Possibly because, almost by definition, lifting with one hand involves lighter weights, few such studies have been reported. Of these, even fewer studies have made any form of comparison between one- and two-handed lifting in comparable conditions, which would allow the calculation of a correction factor. Most authors, such as Mital (1985) have concentrated specifically on one-handed lifting.

It could be argued on the basis of biomechanical calculations that the forces generated in the spine are essentially the same whether they are transmitted via one arm or two, although the asymmetric loading could be expected to produce additional compensating forces. Strength-based criteria where arm lifting is involved would presumably indicate approximately a 2:1 relationship under these circumstances.

One set of criteria which does address both one- and two-handed lifting is that based on IAP measures reported by the University of Surrey (MHRU, 1981). One apparent anomaly in these guidelines is that, at full arm's length, more weight can be lifted in one hand than in two. This is possibly explained as due to the effect of the weight of the arms themselves, although the authors offer no comment. However, if this explanation is the case then the effect disappears remarkably rapidly as the situation is reversed at wrist length and continues in this sequence at any closer arm position. Apart from this isolated anomaly, the ratio of one- to two-handed loading is approximately 0.6 - 0.7:1.

One-handed Lifting

One hand multiplier	0.65

3.9 Team Lifting

Rushworth *et al.* (1985) reviewed what little published information was readily available at the time on team lifting. It was concluded that, allowing for typical mining conditions, two people could lift 1.5 times the limit for one person and that three people could lift twice the one person limit. Since then, several other papers have been published which have suggested that higher values might be appropriate. Karwowski and Mital (1986) reported studies which showed relationships as high as 94% the sum of individual capabilities. However, these studies were strength tests rather than actual lifting tests. As this would have reduced the influence of factors such as coordination and control, higher forces would perhaps be expected. Support for this can be found in the report for isokinetic tests involving movement, which indicated combined values that were not only lower than the isometric test values but were also lower than those recommended by Rushworth *et al* (1985) (e.g. 68 kg vs 75Kg for a 50Kg single person load). The practical relevance of this work may be further questioned due to the decision to provide shorter subjects with platforms to stand on to eliminate differences in stature.

Karwowski and Ayoub (1988) reported a study of actual lifting tasks using the psychophysical approach. The authors reported a lower fifth percentile limit of 83.4Kg for occasional lifting by two males - based on student subjects. It must be seriously questioned whether the psychophysical approach is an appropriate technique for group lifting. The complex pressures within the group could create anomalous results. Taking this new information into account it was concluded that the recommendations made by Rushworth *et al* (1985) were still appropriate.

<u>Team Lifting</u>

Number	*Multiplier*
1 person	1
2 people	1.5
3 people	2.0

3.10 Lifting with Unstable Floor Conditions

Because of the difficulties which would be encountered in quantifying the degree of instability it is not surprising that no papers reporting studies of the effects of this factor have been found. It is an assumption of all studies (whether or not explicitly stated) that any lifting which is being assessed or studied will be taking place with 'good underfoot conditions'. However given the nature of mining, it is clearly useful to give some guidance which can be applied in poor conditions. A pragmatic solution was considered of adopting the limits for one-handed lifting - thus notionally leaving one hand free to provide additional support and stability.

One potential outcome of such conditions would be for the lifter to slip, possibly resulting in a sudden, jarring, loading. Marras *et al* (1987) reported the results from a study of sudden loading which showed that, in general, sudden unexpected loading resulted in a trunk muscle response comparable to approximately twice that to the load when it was lifted normally. This was considered to provide partial endorsement for the pragmatic approach proposed and the following text was prepared for the screening method.

<u>Unstable Floor</u>

It is very difficult to quantify the effects of an unstable floor on lifting and carrying. The additional strain of maintaining balance can be considerable. In addition, the increased risk of slipping or falling brings further hazards. It would also be hard to determine any 'unit of instability' against which to establish lifting values, (i.e. if a floor is greater than 2.0 'slipunits' then lifting load should be reduced by........). The primary objective must be one of stabilising the floor. However, as a temporary expedient in very poor conditions it is recommended that the one-handed multiplier (0.65) should be used for lifting or carrying, notionally leaving one hand 'free'.

3.11 Vertical Location at Start of Lowering

Lowering has seldom been studied in isolation. In most cases, it is included as an integral part of the lifting cycle (e.g. Kumar, 1988). The situation is complicated by the fact that, in many industrial tasks, lowering can be regarded as little more than a controlled drop. The forces involved will however vary with the amount of care involved.

Studies of handling mining supplies, carried out by the IOM (Sims *et al*, 1986) have shown that the IAP response to lowering is generally smaller than lifting the same load under the same circumstances. However, none of the tasks studied involved lowering from above about waist height. Snook (1978) reported both lifting and lowering loads determined using the psychophysical technique. These showed that as the height was increased, the relationship between lowering from or lifting to that height changed. Thus, between floor and knuckle height, heavier loads could be lowered than could be lifted; between knuckle and shoulder height the loads were comparable; and above shoulder height more could be lifted than could be lowered. Multipliers were derived based on these data, although, drawing from our own studies, the changeover level was altered to waist height rather than knuckle height.

Lowering	*Multiplier*
From above shoulder height	0.85
From above waist height but below shoulder height	1
From waist level or below	1.15

3.12 Holding and Carrying

Many papers have been published relating to the physiological loads arising from carrying tasks - few have addressed the question of holding. Of these papers, some have studied the effects of differing methods of carriage such as the use of back packs (Pandolf *et al* 1977) or have compared the effects of different methods of load carriage (e.g. Legg and Mahanty, 1985). Despite the fact that carrying by hand is the most energy inefficient method (Legg, 1985) this technique is most commonly used in industry and is the technique assumed here. Most industrial carrying tasks are performed over comparatively short distances and practical constraints largely militate against the use of carrying aids on a regular basis.

Many studies of carrying are concerned with physiological fatigue rather than the risk of injury. For example, Haisman (1988), in reviewing factors affecting load carrying ability, concluded that a load eliciting 33% of VO_2 max for a working day would be appropriate. Although some authors have reported extensive studies of the effects on load carriage of different factors such as frequency and distance, these have not often been 'translated' into carrying limits.

Carter (1969) referred to a Soviet standard which permitted an individual to carry additional weight (80Kg vs 50Kg) if the load was lifted onto his back! However, in general it seems to be a reasonable principle that most carrying starts with a lift and it is therefore inappropriate to expect individuals to carry more than they can lift.

Evans *et al* (1983) reported a comparison of responses to carrying and holding tasks. This work showed that subjects could consistently hold a load for longer than they could carry it (or hold a heavier load than could be carried for a given length of time). This difference was not statistically significant with lighter loads and, at heavier loads, although differences were statistically significant, they were of little practical importance (0.3 seconds difference with a 40Kg load). Most of the holding tasks encountered in mining are likely to involve heavy loads (e.g. supporting an arch girder in place). It was therefore decided, in the absence of useable data on holding, to use carrying criteria to derive holding tasks.

The most comprehensive database on carrying limits is that published by Snook (1978). Examination of the carrying frequency data indicated reasonable comparability with those for lifting.

Consequently it was decided for simplicity to use the same correction factors. Snook (1978) reported the data in terms of acceptable weight for a given carrying distance at a range of frequencies. These values were used to derive the carrying distance multipliers given below. However, as carrying speed was not specified, holding time could not be obtained directly from these data. Elsewhere in the report, Snook (1978) referred to walking speeds of 4.7 and 4.8 km hr^{-1} (approximately 1.3 ms^{-1}). For simplicity a walking speed of 1.0 ms^{-1} was assumed which yielded the holding time correction factors given below. These may be compared to reports from Rodahl (1990) that a force representing about 50% of maximum voluntary capacity (MVC) can be maintained for about 1 minute, whilst, as general guidance, static forces (e.g. holding) exceeding 15% MVC should be avoided.

Carrying distance

Distance	*Multiplier*
< 1 m	1
1-2 m	1
2-4 m	0.9
4-8 m	0.85
> 8 m	0.6

Holding time

Time	*Multiplier*
1 sec	1
2 sec	1
4 sec	0.9
8 sec	0.85
> 8 sec	0.6

3.13 Pushing and Pulling

3.13.1 'Standard' value

As with lifting, the first requirement was to determine maximum 'best-case' push or pull forces. Many of the studies published in this area have been concerned more with achievable force rather than safe force. For example, Kroemer (1974) suggested maxima of 500 Newtons (51 Kgf) pushing or pulling with both hands or with one shoulder and the back. In contrast, limits derived from IAP measurements (MHRU, 1980) were much lower and, unlike those of Kroemer, showed a variation between pushing and pulling. Maximum push force was 27Kg and maximum pull force was 50Kg, both values being obtained by subjects adopting an erect, straight backed stance. However, less upright postures, studied by Ridd (1985), resulted in higher values and also markedly reduced the difference between pushing and pulling (see section 3.13.5). Lee *et al* (1987) reported the results of studies which included predicted spinal disc compressive forces. These studies again showed pushing to be safer than pulling, although the results were expressed as a compressive force for a given load and were not used to derive limiting values. The pushing task reported in this latter paper involved pushing a 'dynamic pushing and pulling device' a distance of six metres. However, it is not apparent whether the data apply to any initial peak inertial force or to that required to maintain momentum.

On the basis of these and similar studies, a base or standard value for an occasional single push <u>or</u> pull, over a short distance, with good footing (braced) was set at 50Kg. It was decided that additional multipliers would be required for selection of influential factors. Those selected were underfoot conditions, frequency of pushing, distance pushed, and the vertical location of the point of contact.

3.13.2 Underfoot conditions

Kroemer (1974) reported the results of studies of the effects of variations in the coefficient of friction between the floor and the footwear on push and pull forces. Clearly, in a mining context, it is impracticable to derive a detailed assessment of a formal coefficient. In many cases, miners pushing or pulling a load have ready access to a firm foothold such as a railway sleeper or a rocky protrusion. In most other cases, rough floor conditions will allow a reasonable level of bracing. The following multipliers were therefore selected:

<u>Underfoot conditions</u>

Conditions	*Multiplier*
Sleeper or other bracing structure	1
Rubble etc. providing reasonable purchase	0.6
Wet or smooth slippery surface	0.4

3.13.3 Frequency of pushing

Because of the emphasis in many papers on achievable rather than desirable push and pull forces, most attention has been paid to single applications of force rather than repeated pushing or pulling. The notable exception is Snook (1978) who reported push forces over a similar range of frequencies to these studied for lifting, lowering etc. Multipliers based on these data were derived and are shown below.

Frequency	*Multiplier*
Infrequent (1 in 30 mins)	1
Occasional (1 in 5-30 mins)	0.85
1 in 5 mins to 1 min^{-1}	0.75
1-5 min^{-1}	0.65
6-10 min^{-1}	0.55

3.13.4 Pushing distance

As stated above most authors, in concentrating on maximum force application, have only considered single applications of force. Normally, these have been applied to an immovable handle or other surface. However, in many tasks, objects are not just pushed against but are pushed to move them to a different location. It therefore becomes necessary to take that movement into account. In doing so, it is important not to forget wider safety issues. For example, Kroemer (1974) reported that a higher level of force application could be produced by workers putting their back against the object to be moved, bracing their feet and pushing with their legs. For an object which may move once the initial inertial forces are overcome - or perhaps when a small obstacle is surmounted - this action is potentially dangerous and consideration of acceptable forces should not legitimise such activities.

Snook (1978) is again the principal author to have reported data relating to pushing distance and the multipliers given below are based on these data.

Distance	*Multipliers*
0 - 2m	1
> 2m - 15m	0.8
> 15m	0.6

3.13.5 Vertical height of point of force application

The posture, which workers adopt to apply a pushing or pulling force, either voluntarily or because of the constraints of the working environment, has a marked effect on the force which can be exerted. Ridd (1985) showed, using IAP measurement, how moving from an upright to a leaning stance could increase the safe working load by as much as 240% although the upright stance involved was rather artificial and unlikely to be adopted in practice. Pheasant *et al* (1982) showed how the force which could be exerted (not necessarily a safe force) varied with partial changes brought about by changing the handle height and the amount of headroom available over it. Snook (1978) reported acceptable force values (acceptable to the individual applying the force) for three hand heights, roughly representing shoulder height, wrist height and calf height.

The multipliers given below were selected to reflect the variations indicated by these data sources.

Vertical Location	*Multiplier*
Hands above knee, below shoulder	1
Hands below knees	0.5
Hand above shoulder	0.6

4. EVALUATION OF THE ASSESSMENT AID

4.1 Introduction

The assessment criteria for the aid, produced as described in the previous chapter were collated as assessment multipliers. To facilitate their administration, the multiplier categories were used to devise recording sheets which could be completed by the assessor observing the task. The record and multiplier sheets, together with an explanatory text, are given in Appendix 1 which also shows a worked example. The next stage of the project was to evaluate the assessment aid.

An evaluation study was devised to seek answers to four questions:

1. How consistent are different individuals in applying the aid (test – retest)?
2. How do these individuals' assessments compare with each other?
3. How do the assessments of these individuals compare with the correct (expert) assessment?
4. Is it possible to provide any objective corroboration of the assessments obtained?

In order to answer these questions, it was decided to produce video recordings of manual handling tasks which could be assessed using the aid. The use of 'live' observations was considered but it was decided that space constraints underground were such that it was impracticable to have a reasonable number of observers under such conditions. In addition, it would of course be necessary to use video recordings for the retest element. To provide for some form of objective corroboration, intra-abdominal pressure (IAP) measurements were to be obtained during the filming of the handling activities. IAP has previously been used to study mining handling tasks (Sims *et al.* 1986) and, despite its shortcomings, probably provides the most practicable form of measurement of truncal loading.

4.2 Video Recording of Manual Handling Activities

Four full-time Mines Rescue brigadesmen acted as subjects. They attended a British Coal Training Centre where they each swallowed pressure sensitive radio pills for IAP measurement (see Sims *et al.* 1986). They then carried out a series of unloading, moving and loading tasks, handling a variety of mining materials as described in Table 4.1. The handling activities were all video recorded for subsequent application of the assessment aid. These video recordings were then edited to provide a sample of activities to which the assessment aid could be applied. Table 4.2 lists the activities chosen. Appendix 2 contains the instructions given to the subjects regarding the film.

The IAP records were analysed for peaks of pressure to provide an objective comparison.

4.3 Evaluation Trials

It was originally intended, following guidance from British Coal staff, that the evaluation trials would be carried out by coalmining deputies attending refresher courses at a British Coal training centre. However, the pressures of their course schedule meant that this was not possible. The aid was therefore applied by two groups of mining trainees. The first group of five men were adult (over 18 years) trainees. The second (six men) were trainee mechanical and electrical engineers (under 18 years of age).

After the general purpose of the aid was explained to them, the different elements of the aid were described and questions answered regarding any terms or phrases used which were not fully understood. The trainees then observed the selected video recorded activities and made their assessment using the record sheets provided (see Appendix 2).

Table 4.1 Approximate weights of materials handled

3 Corrugated iron lagging sheets ('tins')	16.5 Kg (5.5 Kg/tin)
Stonedust bags	25 Kg
Arch Sections	70 Kg
Pipes	30 Kg

They were not asked to apply the appropriate multipliers to the records made to calculate the safe load for the task in question. On the following day, the exercise was repeated to provide data for test-retest comparisons. No feedback was given from the initial exercise.

A team of three ergonomists also viewed the tapes and collectively agreed the correct entries on the record sheets to provide an expert assessment.

4.4 Results

Twelve tasks or elements of tasks were evaluated by eleven trainees. Their recorded entries were used to calculate the safe weights by an ergonomist applying the relevant multipliers.

Table 4.3 gives the assessment scores derived in this manner for each trainee, for the first test. Table 4.4 gives the equivalent values for the retest.

Table 4.2 Tasks selected for assessment

1. Pushing or pulling arch sections along roadway
2. Lifting arch sections from a roadside stack
3a. Carrying pipes across roadway
3b. Lowering pipes onto stack
4. Lifting pipes from stack
5. Carrying lagging sheets (tins) along roadway
6. Lifting tins from a roadside stack
7. Lowering tins onto stack on vehicle
8a. Carrying stonedust bags
8b. Lowering stonedust bags onto roadside stack
9. Lifting stonedust bags from full tub
10. Lifting stonedust bags from roadside stack

Table 4.3 Assessment scores (Kg), first test.

Subjects are in decreasing order of average estimated safe load. Tasks are in decreasing order of average score across the subjects.

TASK	SUBJECT	K	C	B	I	J	F	D	G	A	E	H
Lift Arch	2	29	25	47	38	36	42	45	47	40	29	36
Lower Pipes	3b	28	20	30	28	39	27	22	22	30	10	34
Lower Bags	8b	25	25	21	23	22	32	25	20	17	14	14
Push Arch	1	26	26	19	18	16	18	19	18	26	37	16
Carry Pipes	3a	24	8	28	22	40	15	18	19	22	10	16
Carry Bags	8a	19	21	19	14	19	24	15	25	14	11	12
Lower Tins	7	12	27	25	21	8	17	17	23	11	18	6
Lift Bags	9	10	21	18	15	17	15	17	11	18	14	14
Lift Pipes	4	19	5	20	18	26	14	24	22	9	11	4
Carry Tins	5	20	27	22	7	45	20	30	13	9	8	7
Lift Tins	6	22	24	16	25	16	8	14	14	18	9	8
Lift Bags	10	5	13	10	16	4	10	3	11	4	7	2

Table 4.4 Assessment scores (Kg) - retest

TASK	SUBJECT	K	C	B	I	J	F	D	G	A	E	H
Lift Arch	2	42	42	26	54	42	34	45	54	27	34	29
Lower Pipes	3b	30	28	25	28	25	22	25	15	20	11	16
Lower Bags	8b	25	26	21	21	23	28	29	24	20	17	14
Push Arch	1	30	30	19	20	9	18	19	20	26	32	16
Carry Pipes	3a	18	24	20	22	31	22	20	11	16	9	11
Carry Bags	8a	23	27	19	17	17	22	13	20	25	17	10
Lower Tins	7	23	36	17	23	25	40	21	11	20	10	6
Lift Bags	9	27	17	16	15	23	23	16	20	23	15	12
Lift Pipes	4	21	31	20	22	21	19	22	14	10	11	8
Carry Tins	5	18	15	12	14	12	7	14	8	16	8	6
Lift Tins	6	11	10	12	15	11	13	25	8	10	11	6
Lift Bags	10	21	8	16	18	9	10	6	7	4	5	2

As a result of the wide variation in weights of the materials lifted it was considered more appropriate to examine different parameters in terms of the ratios of differences rather than absolute values. Because of this, together with the derivation of the scores by multiplying various factors, it was decided to use a log transformation to analyse the data. Such analyses were found to explain more of the variance and to provide more readily interpretable results.

The data were analysed using analysis of variance (ANOVA) procedures. An initial analysis indicated no significant difference in the data from the two groups of trainees. As a result of this the two sets of results were pooled in subsequent analyses. Of the twelve tasks, one (Task 10 – lifting stonedust bags from a roadside stack) gave scores which were markedly lower than the others. It was therefore analysed as a separate factor. The remaining eleven tasks could be classified in two ways: the material being used in the task (e.g. pipes) and the type of task being executed (e.g. lifting). These factors, together with any differences between subjects, any test-retest differences, and a series of possible interactions, constituted the factors which were investigated in the analysis of variance. The ANOVA table from this analysis is given in Table 4.5. Of the twelve tasks, task number 10 had scores which were significantly lower than the others. The analysis also showed significant differences in scores between the different materials handled and significant differences between the different handling tasks. There was also a significant difference between subjects. However, there was no significant material/task interaction. This would indicate that an estimate could be made of an unobserved combination of material and task such as carrying arches provided that there was some information on the material and task from other combinations. Back transforming the fitted values from the log scores yielded a series of estimated mean safe weights, shown in Table 4.6. These show the markedly lower score for task 10 than for any other task.

Table 4.5 Analysis of variance, data from trainees

Change	d.f.	s.s.	m.s.	variance ratio
+ TASK 10	1	18.27	18.27	170.4 ***
+ MATERIAL	3	11.88	3.96	36.9 ***
+ TASK	3	7.36	2.45	22.9 ***
+ MATERIAL. TASK	4	0.28	0.07	0.6 NS
+ SUBJECT	10	12.19	1.22	11.4 ***
+ TASK 10. SUBJECT	10	4.68	0.47	4.4 ***
+ MATERIAL. SUBJECT	30	6.13	0.20	1.9 **
+ TEST-RETEST	1	0.01	0.01	0.1 NS
Residual	201	21.56	0.11	
Total	263	82.36	0.31	

*** p = .001; ** p = .01
Percentage variance accounted for = 65.8%

Table 4.6 Geometric mean of trainees assessments of safe weights, tabulated according to material and task type.

	MATERIAL				
	Arch	Pipe	Tin	Bag (NOT 10)	Bag (TASK 10)
TASK					
Push	21				
Lift	37	15	13	17	7
Carry		18	13	18	
Lower		23	17	22	

As well as the strong evidence for differences between subjects there was a strong interaction between subjects and task 10 and subjects and type of material: that is, the differences between subjects depended on the material and also on whether or not task 10 was being considered. Looking at the differences in greater detail, subjects E and H gave low scores for pipes, tins, bags and for task 10, but not for arches. The other subjects did not differ significantly for tasks 1–9. For task 10, subjects A, D and J also gave low scores. There were no systematic differences between test and retest scores: neither overall nor by subject, nor by task. However, comparison of Tables 4.3 and 4.4 shows large random differences. The worst example is task 4, subject C, with a first score of 5, and a retest score of 31.

Table 4.7 gives the "correct" safe weights as determined by the experts, again categorised by type of task and material handled to facilitate comparisons with the data from the trainees shown in Table 4.6.

Table 4.7 Safe weights as assessed by the experts, tabulated according to material and task type.

	MATERIAL				
	Arch	Pipe	Tin	Bag (not 10)	Bag (task 10)
TASK					
Push	15.6				
Lift	36.0	12.7	17.6	12.2	6.7
Carry		17.55	16.25	17.0	
Lower		22.4	34.5	16.6	

The data were again analysed on the log scale, with the response variate as: log (trainee score/expert score) = log (trainee score) − log (expert score), known as log ratio. Thus a log ratio of 0 indicates no difference between trainee and expert scores. A positive log ratio would indicate that the trainees gave a higher score than the experts. Table 4.8 gives the ANOVA table for an analysis similar to that conducted for the trainees. It can be seen from this that the effects of task type and task 10 have been reduced substantially. The most important effect is the large effect attributable to the type of material being handled. This indicates a systematic difference between the trainees' and the experts' scores. Examination of the ratios of trainee scores to experts' scores, transformed from the logarithms, given in Table 4.9 shows that the trainees tended to give lower scores for tin handling tasks than the experts but higher scores for handling other materials.

Table 4.8 Analysis of variance of log ratio scores.

Change	d.f.	s.s.	m.s.	v.r.
+ TASK 10	1	0.10	0.10	0.9 n.s.
+ MATERIAL	3	15.29	5.10	47.5 ***
+ JOB	3	1.97	0.66	6.1 ***
+ MATERIAL.JOB	4	3.15	0.79	7.3 ***
+ SUBJECT	10	12.19	1.22	11.4 ***
+ TASK 10.SUBJECT	10	4.68	0.47	4.4 ***
+ MATERIAL.SUBJECT	30	6.13	0.20	1.9 **
+ TEST-RETEST	1	0.01	0.01	0.1 n.s.
Residual	201	21.56	0.11	
Total	263	65.07	0.25	

*** p=.001; **p=.01
percentage variance accounted for = 56.4%

Examination of the assessed weights for trainees and experts (Tables 4.6 and 4.7) shows that the mean values of the trainees were generally (75%) within 5Kg of those determined by the experts. However, this masked a wide degree of individual variation - as indicated by the significant subject main effect in the ANOVA.

Table 4.9 Ratios of trainee scores to experts scores

	MATERIAL				
	Arch	Pipe	Tin	Bag (not 10)	Bag (task 10)
TASK					
Push	1.34				
Lift	1.04	1.18	0.74	1.37	1.07
Carry		1.02	0.82	1.04	
Lower		1.04	0.49	1.30	

Any ratio above 1.142, or below 0.876 is significantly different from 1.

Stubbs (1981) reported that the magnitude of the initial peak pressure associated with a lift gives an indication of the maximal truncal stress. Consequently, peak IAP pressures were determined for each of the lifting tasks from the records obtained during the video-recording session. Table 4.10 details the means and standard deviations of these data for the five lifting tasks studied (2, 4, 6, 9 and 10). The table also includes the number of individual peaks recorded. For each task, the probability was determined of an IAP peak greater than 90mm Hg occurring other than due to chance. This was calculated by examining the means and standard deviations for each task and assessing, from tables of the normal distribution, what proportion of the peak pressures associated with that activity would exceed the criterion level of 90mm Hg. Graveling *et al.* (1986) have previously discussed the various descriptions of the treatment of data in previous studies which appear to imply a normal distribution.

Table 4.10 Intra-abdominal pressures : means and standard deviations for each lifting task and number of peaks recorded.

ACTIVITY	INTRA-ABDOMINAL PRESSURES Mean	s.d	n
2 Lifting arches from roadway to vehicle	77.9*	14.3	16
4 Lifting pipes from roadway to vehicle	36.5	11.0	40
6 Lifting tins from the roadway to a second stack	38.6	19.8	77
9 Lifting stonedust bags from the vehicle to the roadway	44.8	16.3	181
10 Lifting stonedust bags from the roadway into the vehicle	35.6	14.1	154

* 1 in 5 probability of peak pressure greater than 90mm Hg indicating an unsafe task. All other values indicate a probability of a peak pressure greater than 90mm Hg of less than 1 in 100.

4.5 Discussion

The first questions presented at the start of the evaluation exercise (Section 4.1) were: 'How consistent are different individuals in applying the aid?' and 'How do these individuals compare with each other?' Inspection of the data presented reveals a complex pattern of variability between trainees and between tasks for both applications of the aid (test-retest). However, a reasonable overview answer to the first question is that individuals recorded large differences in repeat applications of the method. There was no clear systematic pattern to this inconsistency; i.e. the differences were not related to task or material. With regard to differences between individuals, these were appreciable although smaller than the differences between tasks and materials. The subjects comprised two groups, one a group of engineering trainees (under 18) the second a group of older mining trainees. Both groups were relatively young although the differences between individuals appeared unrelated to these groups.

An examination of the clustering of scores showed that two trainees (E and H) tended to determine lower scores for pipe, tin and bag handling tasks (but not for arches) than the other subjects who showed a greater degree of consistency. Bag lifting from the roadway (task 10) was fairly regularly assessed as the least safe task there only being three trainees who, on the initial assessment, did not score it as the lowest (or, on one occasion, equal lowest). It is also noteworthy that the two other tasks which also involved lifting from or near the roadway level (Tasks 4 and 6) also generally featured towards the lower scores - although with less consistency. However, the derived scores did differentiate between the type of material being handled and the type of handling task. It is a little surprising that the analysis did not reveal any task/material interaction, as one might expect there to be a difference in the way in which different materials are handled for a given task.

Some better understanding of the reasons behind these inconsistencies can perhaps best be obtained from considering the different components which are combined to derive the overall assessment. The number of components associated with each task depends upon the nature of the task. Some, such as the frequency of an action, will be recorded for each task. Others, such as the presence of a bracing surface, will only apply to specific types of task (in this case pushing). Frequency was notably one of the elements which the subjects were inconsistent in assessing. Despite the instructions that they could use a watch and actually time the action if they wished, few trainees were observed to do this. For nine of the twelve tasks, fewer than half of the subjects recorded the same frequency in both the test and the retest.

Some of the inconsistency may have resulted from carelessness rather than actual inability to assess. For example, for some tasks some subjects had difficulty in deciding whether the lifter had used one or two hands and, somewhat surprisingly, some were inconsistent in recording whether one or two people had carried out the manoeuvre! The estimation of angles required to decide whether or not the body of a lifter was twisted caused some difficulties. To a certain extent, similar problems were encountered in differentiating between a slightly leaning or a stooping back. Graveling *et al.* (1980) reported on the difficulties some individuals experience in assessing angles. It was hoped that the relatively coarse resolution required in the assessment aid would minimise these problems. However, this coarse scale could have contributed to some of the large discrepancies. For example, an error of 30^{o} in judging body rotation will not produce an error greater than 10%, and probably less, whilst misjudging a straight or a curved back will introduce a much larger error, because of the different multipliers of 1 or 0.65 respectively.

It is perhaps not surprising, given such inconsistencies, that there was also a poor level of agreement between the test subjects and the experts, the topic of the third question presented. There was an average difference between the test scores and the experts of 21.3% - a worse degree of agreement than between the test subjects. However, this again masks a considerable degree of variability. Some trainees were encouragingly close to the experts' assessment on most occasions - several being within 5Kg on eight out of twelve tasks. Considering the low level of instruction provided this represents quite good agreement. Considerable variability was also observed between trainees on individual tasks, although on one task (task 7) all of the trainees arrived at a lower safe assessed load than that derived by the experts. This trend was also observed on the other two tasks (5 and 6) involving tin handling.

It must be noted, however, that the test subjects were not being asked to make a value judgement as to the riskiness of a handling activity - rather they were required to make a series of numerical estimates of physical parameters. Within the UK, there has been some criticism of the draft guidance published by the Government's Health and Safety Commission because of its lack of numerical examples. This attempt to provide a means of providing numerical guidance has demonstrated how difficult such an exercise can be. One alternative approach would be to encourage an assessing official to make direct measurements of the physical parameters described in formulating this guidance - in a comparable exercise to that required in applying the guidance/assessment provided by NIOSH (1981). However, in an applied working situation it would frequently be impracticable to obtain such measurements. Possibly, a training package would be effective in improving the reliability of the technique although this has yet to be proved.

The final question posed at the start of this chapter was whether or not it was possible to obtain any objective corroboration of the assessments provided. An attempt to provide such corroboration was made by recording the IAP responses of the subjects carrying out the handling tasks. Most of the literature on IAP has concentrated on its applicability to lifting tasks. Consequently, although IAP was registered continuously during the tasks, the analysis was restricted to the pressure peaks associated with the onset of each lift – as described by Davis (1981).

An examination of the IAP results presented in Table 4.10 indicates that there is a strong probability, in the arch-lifting task; of peak pressures greater than 90mm Hg occurring. Indeed, out of the 16 lifts studied, 3 actually resulted in peaks exceeding this value. According to the means and standard deviations none of the other tasks had more than a slight chance (less than 1 in a 100) of a peak value greater than 90mm Hg occurring. Nevertheless, such peaks did occur during two further tasks (6 – lifting tins from floor level; 9 – lifting stonedust bags from a vehicle). The studies described by Graveling *et al.* (1986) on which the assumptions of a normal distribution were based all largely involved laboratory based force applications. It seems probable that, in the present case, the lifting actions and consequent forces were more heterogenous. Certainly, the coefficients of variation for these two tasks are higher than the 30.5% typical value quoted by Davis (1981). The scope for variation in load was certainly considerable, particularly in the tin handling task where it is possible that, although the subjects normally lifted three tins, they may on occasion have lifted a fourth.

Examining the loads involved, (Table 4.1) and the safe loads, calculated by the experts using the assessment aid, given in Table 4.7, indicates that although three tins would be no heavier than the load calculated by the experts (and only a few kilos greater than the mean value calculated by the trainees (Table 4.6), four tins would weigh more than either value, indicating an element of risk. All methods of assessing risk agree that lifting the steel arches presents a risk of back injury. The weight of the arches is greater than the safe load calculated by the experts or the miners, the distribution analysis indicates a 1 in 5 probability of IAP peaks exceeding 90mm Hg and 3 out of 16 peaks (18%) actually exceeded that figure. For the other tasks however there is less agreement. In the pipe lifting, the weight of the pipes far exceeds the calculated safe load and yet the peak IAP values were low, with a low probability of high peaks occurring – and none were actually registered. The tin lifting task calculations indicate that, provided no more than three tins are lifted at any one time, the task is within safe limits, and these calculations are generally supported by the IAP recordings. However, handling stonedust bags fails to produce any agreement. The calculations indicate a high degree of risk, – calculations not generally supported by the IAP data – and the task which produced the lowest calculated safe load also tended to produce the lower IAP peak values. One aspect of handling which the assessment aid makes no attempt to quantify – and for which there is very little guidance in the literature – is the 'awkwardness' or other characteristics of the load. Sheets of corrugated iron for example are more likely to present a risk of injury than a compact, symmetrically-shaped box of a similar weight. Although the manner in which the load is handled will reflect this difference to a certain extent it would not adequately account for factors such as the size and possible flexibility of the sheets – or other possible factors such as the presence of sharp edges.

In its present form therefore, the assessment aid would not appear to be an effective means of assessing risk of back injury. As well as being difficult for different individuals using it to obtain agreement, even the values derived by the experts appear to over-estimate the associated risk in most cases.

It is worth contrasting this lack of agreement with comparisons of lifting guidelines published in the literature. Frievalds (1987) compared the Force Limits derived from intra-abdominal pressure (MHRU, 1980) with the Action Limit provided for in the NIOSH Lifting Guidelines (NIOSH, 1981). The comparison identified a complex non-linear relationship, complicated by the fact that both sets of guidance attempted to allow for different factors. Thus, the one parameter singled out for particular attention by the MHRU guidelines (age) was not addressed at all by the NIOSH guidance, which provided a far more sophisticated correction for frequency of lifting. Frievalds reported that the MHRU Force Limits yielded average loads 1.8 (range 0.78 - 2.7) times those calculated from the NIOSH document. Garg (1987) also examined the NIOSH guidance, this time examining psychophysical data on maximum acceptable weights, criteria based on energy expenditure, and biomechanical calculations of disc compressive forces. One set of comparisons showed psychophysical limits approximately 20Kg higher than the NIOSH Action Limit - a 200% increase. A further comparison showed limits derived from biomechanical calculations some 30-45 Kg greater. Valaues derived from energy expenditure criteria were 40 Kg higher at low lifting frequencies, but were much closer at high frequencies ($\approx$ 4Kg at 12 lifts min^{-1}). This is less surprising as energy cost is an inappropriate criterion for infrequent or single lifts.

The use of the physiological criterion of metabolic cost was questioned by Mital *et al.* (1987). The authors addressed in particular comparisons between handling tasks of various frequencies. At low frequencies, two sets of criteria differed, with one study yielding permissible loads at least 11 Kg greater. In contrast, as the frequency of lifting increased, the relationship between the two was reversed until, at 12 lifts min^{-1}, the recommended values, using the technique originally yielding higher values, had reduced to zero whilst the second approach indicated loads over 10 Kg.

In deriving the guidance in the present study, an attempt had been made to reconcile some of these differences. The assessment aid incorporates influencing factors which had not been taken into account in deriving some sets of guidance. It also reduces the influence of those approaches which appear to be out of line with the majority by adopting general consensus values.

This is not the first time that studies by the Institute using direct measurement of IAP on mineworkers have indicated that published guidelines appear to over-estimate the risk. Graveling *et al.* (1986) reported comparisons between direct IAP measurements and the guidance based on IAP (MHRU, 1980). As stated in section 3.1 of this report, these indicated an inherent underestimation by the MHRU data of 25-30%. An attempt was made to compensate for this by adopting 50Kg rather than 40Kg as the upper limit for calculating safe loads to lift. This assumption of a linear relationship now appears to be over-simplistic.

Finally, all the calculations and discussion presented above are based upon the assumption that intra-abdominal pressure is a reliable indicator of truncal strain. Despite its previous promotion by one research group (e.g. Davis, 1981) who have cited previous studies suggesting a good correlation with intra-discal pressures, other authors have been more sceptical. For example, Ortengren *et al.* (1981) reported that, although significant linear relationships could be established between disc pressure and IAP the relationship altered markedly when comparing symmetric and asymmetric lifting postures. Frievalds (1987) refers to the relationship between disc compressive force and IAP as being highly complex and non-linear – although the force in this case was derived from biomechanical calculations which are themselves open to question.

5. CONCLUSIONS

1. An aid for assessing the risk of injury from manual handling has been derived from the published literature.

2. It takes into account a wide range of factors influencing safe handling including horizontal distance of the load from the body, the starting position for the load, the gross body posture (bending, twisting etc.) and the frequency of lifting.

3. An evaluation of the aid showed that a considerable level of inconsistency was demonstrated by British Coal staff in employing the aid, both within themselves and in comparison to its use by a team of ergonomists. This may, in part, have been due to their relative youth and inexperience of mining.

4. Attempts to assess its effectiveness against a more objective measure indicated a general over-estimation of the risk - a feature it shares with other published assessment procedures.

5. It would appear that, in being derived from published data which are themselves inconsistent, much of this inconsistency has been perpetuated.

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REFERENCES

Anderson CK, Chaffin DB. (1985). A biomechanical evaluation of five lifting techniques. Applied Ergonomics; 17: 2-8.

Andersson GBJ, Ortengren R, Nachemson A. (1976). Quantitative studies of backloads in lifting. Spine; 1: 178-185.

Ayoub MM, Dryden RD, McDaniel JW, Knipfer RE, Aghazadeh F. (1978). Modelling of lifting capacity as a function of operator and task variables. In: Drury CG, ed. Safety in manual materials handling. Washington: National Institute for Occupational Safety and Health: US Government Printing Office 120-130. (DHEW(NIOSH) Publication No. 78-185).

Biering-Sørensen F. (1985). Risk of back trouble in individual occupations in Denmark. Ergonomics; 28: 51-60.

Carter PJ. (1969). Manual lifting and carrying. Work Study and Management Services; June, 362-365.

Chaffin DB. (1975). Biomechanics of manual materials handling and low back pain. In: Zenz C, ed. Occupational medicine: principles and practical applications. Chicago: Year Book Medical Publications.

Ciriello VM, Snook SH. (1983). A study of size, distance, height and frequency effects on manual handling tasks. Human Factors; 25: 473-483.

Commission of the European Communities (1990). Council Directive of 29 May 1990 on the minimum health and safety requirements for the manual handling of loads where there is a risk, particularly of back injury to workers. Official Journal of the European Communities. No. L156, 21.6 1990, 9-13.

David GC. (1985). UK national statistics on handling accidents and lumbar injuries at work. Ergonomics; 28: 9-16.

Davis PR. (1981). The use of intra-abdominal pressure in evaluating stresses on the lumbar spine. Spine; 6: 90-92.

Davis PR (ed). (1985). Special Issue; Industrial Back Pain in Europe. Ergonomics; 28 (1).

Directorate of the Danish Labour Inspection Service (1986). Heavy lifts "backaches" compendium. Copenhagen: Danish Labour Inspection Service.

Drury CG. (1985). The role of the hand in manual materials handling. Ergonomics; 28: 213-227.

Evans OM, Zerbib Y, Faria MH, Monod H. (1983). Physiological responses to load holding and load carriage. Ergonomics; 26: 161-171.

Freivalds A. (1987). Comparison of United States (NIOSH lifting guidelines) and European (ECSC force limits) recommendations for manual work limits. American Industrial Hygiene Association Journal; 48: 698-702.

Garg A. (1987). A psychophysical, physiological and biomechanical evaluation of NIOSH guidelines for manual handling. In: Asfour SS, (ed). Trends in ergonomics/human factors IV. Amsterdam: North Holland: 925-931.

Garg A, Ayoub MM. (1980). What criteria exist for determining how much load can be lifted safely? Human Factors; 22: 475-486.

Garg A, Banaang J. (1988). Maximum acceptable weights, heart rates and RPEs for one hour's repetitive asymmetric lifting. Ergonomics; 31: 77-96.

Graveling RA, Simpson GC, Mabey MH, Flux RB, Hodge CJ, Leamon TB. (1980). An investigation of stress on coalface workers and the temporal variation of such stress. Final report on CEC Contract 6245-11/8/50. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/80/07).

Graveling RA, Simpson GC, Sims MT. (1985). Lift with your legs, not with your back: a realistic directive? In: Brown ID, Goldsmith R, Coombes K, Sinclair MA, (eds). Ergonomics international 85. London: Taylor and Francis. 910-912.

Graveling RA, Sims MT, Graves RJ. (1986). Intra-abdominal pressure response of mineworkers to standard loads. Applied Ergonomics; 17: 105-109.

Haisman MF. (1988). Determinants of load carrying ability. Applied Ergonomics; 19: 111-121.

Health and Safety Commission. (1991). Manual handling of loads. Proposals for Regulations and Guidance. London: Health and Safety Executive.

Hettinger Th. (1985). Statistics on diseases in the Federal Republic of Germany with particular reference to diseases of the skeletal system. Ergonomics; 28: 17-20.

Jäger M, Luttmann A. (1989). Biomechanical analysis and assessment of lumbar stress during load lifting using a dynamic 19-segment human model. Ergonomics; 32: 93-112.

Karwowski W, Mital A. (1986). Isometric and isokinetic testing of lifting strength of males in teamwork. Ergonomics; 29: 869-878.

Kroemer KHE. (1974). Horizontal push and pull forces exertable when standing in working positions on various surfaces. Applied Ergonomics; 5: 94-102.

Kumar S. (1980). Physiological responses to weight lifting in different planes. Ergonomics; 23: 987-993.

Kumar S. (1984). The physiological cost of three different methods of lifting in sagittal and lateral planes. Ergonomics; 27: 425-433.

Kumar S. (1988). The effects of the reach and level of lifting/lowering tasks on metabolic cost in symmetric and asymmetric planes. International Journal of Industrial Ergonomics; 2: 273-284.

Lee K, Waikar A, Aghazadeh F. (1987). Lower back loading in dynamic pushing and pulling. In: Asfour SS, (ed). Trends in ergonomics/human factors IV. Amsterdam: North Holland: 949-956.

Legg SJ. (1985). Comparison of different methods of load carriage. Ergonomics; 28: 197-212.

Legg SJ, Mahanty A. (1985). Comparison of five modes of carrying a load close to the trunk. Ergonomics; 28: 1653-1660.

Manual Handling Research Unit. (1980). Force limits in manual work. Luxembourg: Community Ergonomics Action.

Marras WS, Mirka GA. (1989). Trunk strength as a function of trunk asymmetry and trunk velocity during concentric and eccentric exertions. In: Mital A, (ed). Advances in industrial ergonomics and safety I. London: Taylor and Francis: 159-166.

Metzler F. (1985). Epidemiology and statistics in Luxembourg. Ergonomics; 28: 21-24.

Mital A. (1984). Comprehensive maximum acceptable weight of lift database for regular 8-hour work shifts. Ergonomics; 27: 1127-1138.

Mital A. (1985). Preliminary guidelines for designing one-handed material handling tasks. Journal of Occupational Accidents; 7: 33-40.

Mital A. (1987). Patterns of differences between the maximum weights of lift acceptable to experienced and inexperienced materials handlers. Ergonomics; 30: 1137-1147.

Mital A, Fard HF, Khaledi H, Channaveeraiah C. (1987). Are manual lifting weight limits based on the physiological approach realistic and practical. Asfour SS, (ed). Trends in ergonomics/human factors IV. Amsterdam: North Holland: 973-977.

National Institute for Occupational Safety and Health. (1981). Work practices guide for manual lifting. Washington: US Government Printing Office. (DHHS [NIOSH] Publication No. 81-122).

Ortengren R, Andersson GBJ, Nachemson AL. (1981). Studies of relationships between lumbar disc pressure, myoelectric back muscle activity, and intra-abdominal (intragastric) pressure. Spine; 6: 98-103.

Pandolf KB, Givoni B, Goldman RF (1977). Predicting energy expenditure with loads while standing or walking very slowly. Journal of Applied Physiology: Respiratory, Environmental and Exercise Physiology; 43: 577-581.

Pheasant SJ, Grieve DW, Rubin T, Thompson SJ. (1982). Vector representations of human strength in whole body exertion. Applied Ergonomics; 13: 139-144.

Ridd JE. (1985). Spatial restraints and intra-abdominal pressure. Ergonomics; 28: 149-166.

Rodahl K. (1989). The physiology of work. London: Taylor and Francis.

Rushworth AM, Mabey MH, Graves RJ, Collier SG, Nicholl AGMcK, Simpson GC. (1985). A study of powered hand tools. Final report on CEC Contract 7247/12/009. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/85/09).

Sims MT, Graveling RA, Graves RJ, Mabey MH, Morris LA, Simpson GC. (1986). An ergonomics evaluation of the haulage and transportation of mining supplies. Final report on CEC Contract No. 7247/12/014. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/86/03).

Snook SH. (1978). The design of manual handling tasks. Ergonomics; 21: 963-985.

Stubbs DA. (1981). Trunk stresses in construction and other industrial workers. Spine; 6: 83-89.

Troup JDG, Edwards FC (1985). Manual handling and lifting. An information and literature review with special reference to the back. London: HMSO.

Troup JDG, Leskinen TPJ, Stalhammar HR, Kuorinka IAA. (1983). A comparison of intra-abdominal pressure increases, hip torque, and lumbar vertebral compression in different lifting techniques. Human Factors; 25: 517-525.

APPENDIX 1

Manual Handling Assessment Sheets

MANUAL HANDLING ASSESSMENT

In ideal conditions it is currently believed that most mineworkers can safely lift 50 Kg. Many can lift more, but this assessment is not just for them. Unfortunately, ideal conditions rarely occur. Many factors reduce what can safely be lifted below this ideal. This document details the main ones of these as 'multipliers' - factors by which the starting load of 50 Kg should be multiplied to account for any aspect which is less than ideal. A record sheet is provided for use in making this assessment.

Separate recording and assessment sheets are provided for lifting, holding or carrying, lowering and pushing and pulling. Lowering normally results in the same or higher limits than the equivalent lifting action and can often therefore be ignored. However, where the load position relative to the body alters markedly then lowering can become the critical element. For example, if a load is moved away from the body - perhaps to stack it on a pile - or if the lifter twists before lowering, then the lowering action will also require assessment. Similarly, short-term holding (up to two seconds) or carrying (up to two metres) can usually be ignored unless the load is held in a less advantageous position than in the initial lift. As you become more familiar with the various multipliers you will find it easier to recognise the critical aspects of the task and carry out the assessment much more quickly.

To make an assessment, watch someone carrying out the job in question. As the job progresses you will notice how the lifting varies. Much of this will be obvious - for example it is easier to unload bags from the top of a tub than to get the last few layers out. Any chance of getting the stockyard just to load the top half? As you become experienced in making assessments you will learn to spot the critical factors, which will make your job a lot easier. Once you have decided which is the most difficult part of the job then this is the part which you should assess. You are interested in forming a general impression of the way in which that job is done - not completing a separate form for every bag of stonedust unloaded. Complete the record sheet by ticking one box on each row. Choose which entry best represents what you have observed. These are all factors which affect how much can safely be lifted. Once you have completed the record sheet then read the multipliers from the appropriate chart.

Consider, for example, reaching into the bottom of a mine car to remove stone dust bags. The relevant multipliers should be applied to the starting load of 50 Kg.

(i) the sides of the tub force the miner to adopt a stooping posture to reach in

$50 \times 0.65 = 32.5$

(ii) depending on the thickness of the slides, he may not be able to get the bags closer to the body than elbow height

$32.5 \times 0.8 = 26$

(iii) He will then need to lift the bags to clear the sides of the tub – more than 50 cm

$26 \times 0.8 = 20.8$

(iv) finally, there is the frequency of lifting which will depend upon where the bags are being carried to. At about 15 seconds per lift and a 4m carry the multipliers would be 0.6 and 0.9

$20.8 \times 0.6 \times 0.9 = 11.23$

So, the safe working load for lifting out of the bottom of a tub would be just over 11 Kg (25 lb) – good justification for not carrying 20 Kg of stone dust in tubs.

In contrast, as a palletised load on a flat tram, the bags could be lifted without undue stooping and could be brought close to the body before lifting. The equivalent multipliers would therefore be 1, 1, 0.8, 0.6 and 0.9, yielding a safe lifting load of 21.6 Kg.

LIFTING MULTIPLIERS page 1

Horizontal location of load (distance away from body)

Location	*Multiplier*
Close to or against body (<20 cm)	1
Elbow length (35 cm)	0.8
Wrist length (i.e. arms slightly bent) (60 cm)	0.5
Hand length (70 cm)	0.3
Reaching out beyond head when stooping	0.2

Vertical location at start of lift (height from ground)

Location	*Multiplier*
Below knuckle height	1
Knuckle to waist (70-100 cm)	1
Waist to shoulder (100-135 cm)	0.8
Above shoulder height (135+ cm)	0.7

Maximum vertical distance of lift

Distance	*Multiplier*
Up to 30 cm	1
30-50 cm	0.9
Over 50 cm	0.8

Twisting Body

Rotation of trunk	*Multiplier*
Little or no rotation	1
30^{o} 'one-o'clock' (or eleven)	0.9
60^{o} 'two-o'clock'	0.85
90^{o} 'three-o'clock'	0.8

Stooping

Posture	*Multiplier*
Slight lean (<20^{o})	1
Curved back	0.65
Straight back, bent knees lifting*	1

* Bending the knees alters the absolute position of the knuckles, waist and shoulder heights. In this case the 'new' heights should be applied to assess the vertical location.

LIFTING MULTIPLIERS page 2

Frequency of Lifting

Frequency	*Multiplier*
Infrequent (<1 in 30 minutes)	1
Occasional (1 in 5-30 minutes)	0.8
1 in 5 mins to 1 min^{-1}	0.7
1-4 min^{-1}	0.6
5-8 min^{-1}	0.5
9-12 min^{-1}	0.4
>12 min^{-1}	0.2

One-handed Lifting

One hand multiplier	0.65

Team Lifting

Number	*Multiplier*
1 person	1
2 people	1.5
3 people	2.0

Unstable Floor

It is very difficult to quantify the effects of an unstaqble floor on lifting and carrying. The additional strain of maintaining balance can be considerable. In addition, the increased risk of slipping or falling brings further hazards. It would also be hard to determine any 'unit of instability' against which to establish lifting values. (i.e. if a floor is greater than 2.0 'slipunits' then lifting load should be reduced by ...). The primary objective must be one of stabilising the floor. However, as a temporary expedient in very poor conditions it is recommended that the one-handed multiplier (0.65) should be used for lifting, notionally leaving one hand 'free'.

LOWERING MULTIPLIERS page 1

Starting position

Position	*Multiplier*
From above waist height	1
From waist level or below	1.15

Horizontal location of load (distance away from body)

Location	*Multiplier*
Close to or against body (<20 cm)	1
Elbow length (35 cm)	0.8
Wrist length (i.e. arms slightly bent) (60 cm)	0.5
Hand length (70 cm)	0.3
Reaching out beyond head when stooping	0.2

Twisting Body

Rotation of trunk	*Multiplier*
Little or no rotation	1
30^{o} 'one-o'clock' (or eleven)	0.9
60^{o} 'two-o'clock'	0.85
90^{o} 'three-o'clock'	0.8

Frequency of Lowering

Frequency	*Multiplier*
Infrequent (<1 in 30 minutes)	1
Occasional (1 in 5-30 minutes)	0.8
1 in 5 mins to 1 min^{-1}	0.7
1-4 min^{-1}	0.6
5-8 min^{-1}	0.5
9-12 min^{-1}	0.4
>12 min^{-1}	0.2

One-handed Lowering

One hand multiplier	0.65

LOWERING MULTIPLIERS page 2

Team Lowering

Number	*Multiplier*
1 person	1
2 people	1.5
3 people	2.0

Unstable Floor

As with lifting, in very poor conditions it is recommended that the one-handed multiplier (0.65) should be used.

PUSHING OR PULLING MULTIPLIERS

Single push or pull, short distance (<2m), well braced (e.g. against rail or sleeper).

Acceptable force = 50 Kg

Poorly braced - Multiplier = 0.6

Frequency	*Multiplier*
Infrequent (< 1 in 30 mins)	1
Occasional (1 in 5-30 mins)	0.85
1 in 5 mins to 1 min^{-1}	0.75
1-5 min^{-1}	0.65
6-10 min^{-1}	0.55

Distance	*Multiplier*
0 - 2m	1
>2m - 15m	0.8
>15m	0.6

Vertical Location	*Multiplier*
Hands above knee, below shoulder	1
Use of body or shoulder	1
Hands below knees	0.5
Hands above shoulder	0.6

HOLDING OR CARRYING MULTIPLIERS page 1

Horizontal location of load (distance away from body)

Location	*Multiplier*
Close to or against body (<20 cm)	1
Elbow length (35cm)	0.8
Wrist length (i.e. arms slightly bent) (60cm)	0.5
Hand length (70cm)	0.3
Reching out beyond head when stooping	0.2

Vertical location of load (height from ground)

Location	*Multiplier*
Below knuckle height	1
Knuckle to waist (70-100 cm)	1
Waist to shoulder (100-135 cm)	0.8
Above shoulder height (135+ cm)	0.7

Twisting Body

Rotation of trunk	*Multiplier*
Little or no rotation	1
30^{o} 'one-o'clock' (or eleven)	0.9
60^{o} 'two-o'clock'	0.85
90^{o} 'three-o'clock'	0.8

Stooping

Posture	*Multiplier*
Slight lean (<20^{o})	1
Curved back	0.65

Frequency of Carrying or Holding

Frequency	*Multiplier*
Infrequent (<1 in 30 minutes)	1
Occasional (1 in 5-30 minutes)	0.8
1 in 5 mins to 1 min^{-1}	0.7
1-4 min^{-1}	0.6
5-8 min^{-1}	0.5
9-12 min^{-1}	0.4
>12 min^{-1}	0.2

HOLDING OR CARRYING MULTIPLIERS page 2

One-handed Carrying or Holding

One hand multiplier	0.65

Team Carrying or Holding

Number	*Multiplier*
1 person	1
2 people	1.5
3 people	2.0

Unstable Floor

Floor condition	*Multiplier*
Reasonable	1
Poor	0.65

Holding time

Time	*Multiplier*
1 sec	1
2 sec	1
4 sec	0.9
8 sec	0.85
> 8 sec	0.6

Carrying distance

Distance	*Multiplier*
1 m	1
1-2 m	1
2-4 m	0.9
4-8 m	0.85
> 8 m	0.6

APPENDIX 2

Video Trials of Manual Handling Assessment Procedure

Task 1

This shows two men unloading arch sections and stacking them at the side of the roadway. You should assess the lifting carried out by the man nearest the camera.

Please make an assessment of one part of this task:

1. Sliding the arches along the roadway – assess the load involved in pushing or pulling the arch along the roadway to the stacking position.

Task 2

Two men are reloading the arches. Again, please assess the man nearest the camera for one part of this task:

2. Lifting from the stack.

Task 3

Two men are unloading pipes from a vehicle, carrying them across the roadway and stacking them at the side.

Please make an assessment of two parts of this task:- just the man nearest the camera:

3a Carry

3b Lower onto stack.

Task 4

Re-loading the pipes. In this case, please just assess the initial lift from the stack.

Task 5

Unloading tins from a flat tram.

The man half lifts – half drags the tins across the pile before lifting the whole weight. He than carries them a short distance down the roadway before stacking them. Please assess one part of this task:

5. The carry

Task 6

Moving the tins.

The tins are moved from one stack to another. Please just assess the lift from the pile, (when the whole tin is lifted - not the initial lift of one side).

Task 7

Reloading the tins.

In this case, the lift and carry are essentially the same as you have already seen. Please assess the lowering onto the vehicle.

Task 8

Unloading stone-dust bags.

Do not assess the lift from the tub - that will be covered in the next task. Please assess:

8a The carry.

8b Lowering onto the stack.

Task 9

Unloading stone-dust bags.

Please assess one part of this task.

9. Lifting from the top of the tub.

Task 10

Re-loading stone-dust bags.

The task changes as the stack gets lower. Please assess the earlier lifts from the stack, down to the last few layers when he starts regularly to stand on the remains of the pile, getting the bags closer before lifting them.

Lifting Record Sheet

Observer: Date:

Colliery: Location:

Task:

Please tick one box for each aspect of the lifting task

Horizontal location of load (distance of hands away from body)

[ ]	[ ]	[ ]	[ ]	[ ]
Close to body (<20cm)	Elbow length (35cm)	Wrist length (60cm)	Hand length (70cm)	Reach beyond head when stooping.

Vertical location at start of lift (height of hands from ground)

[ ]	[ ]	[ ]	[ ]
Below knuckle height	Knuckle to waist (70–100cm)	Waist to shoulder (100–135cm)	Above shoulder height (135+cm)

Maximum vertical distance of lift

[ ]	[ ]	[ ]
up to 30cm	30–50cm	over 50cm

Twisting body

[ ]	[ ]	[ ]	[ ]
little or no rotation	30^0 rotation (one–o'clock)	60^0 rotation (two–o'clock)	90^0 rotation (three–o'clock)

Stooping

[ ]	[ ]	[ ]
Slight lean (<20^0) back 'straight'	Curved back	Straight back bent knees lifting

Frequency of Lifting

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Infrequent <1 in 30 mins	1 in 30– 1 in 5 mins	1 in 5 to 1 min^{-1}	1–4 min^{-1}	5–8 min^{-1}	9–12 min^{-1}	>12 min^{-1}

<u>One-handed Lifting</u>

[ ] One hand [ ] Two hand

<u>Team Lifting</u>

[ ] 1 person	[ ] 2 people	[ ] 3 people

<u>Floor Conditions</u>

[ ] Reasonable [ ] Poor

<u>Rating Assessment:</u> kg

<u>Actual Load:</u> kg

Holding or Carrying Record Sheet

Observer: Date:

Colliery: Location:

Task:

Please tick one box for each aspect of the holding or carrying task

Horizontal location of load (distance of hands away from body)

[ ]	[ ]	[ ]	[ ]	[ ]
Close to body (<20cm)	Elbow length (35cm)	Wrist length (60cm)	Hand length (70cm)	Reach beyond head when stooping.

Vertical height of load (height of hands from ground)

[ ]	[ ]	[ ]	[ ]
Below knuckle height	Knuckle to waist (70–100cm)	Waist to shoulder (100–135cm)	Above shoulder height (135+cm)

Twisting body

[ ]	[ ]	[ ]	[ ]
little or no rotation	30^0 rotation (one-o'clock)	60^0 rotation (two-o'clock)	90^0 rotation (three-o'clock)

Stooping

[ ]	[ ]	[ ]
Slight lean (<20^0) back 'straight'	Curved back	Straight back bent knees lifting

Frequency of Carrying or Holding

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Infrequent <1 in 30 mins	1 in 30– 1 in 5 mins	1 in 5 to 1 min^{-1}	1–4 min^{-1}	5–8 min^{-1}	9–12 min^{-1}	>12 min^{-1}

One-handed Carrying or Holding

[ ] One hand [ ] Two hand

Team Carrying or Holding

[ ]	[ ]	[ ]
1 person	2 people	3 people

Floor Conditions

[ ] Reasonable [ ] Poor

Holding Time

[ ]	[ ]	[ ]	[ ]	[ ]
1 sec	2 sec	4 sec	8 sec	>8 sec

Carrying Distance

[ ]	[ ]	[ ]	[ ]	[ ]
<1 metres	1–2 metres	2–4 metres	4–8 metres	>8 metres

Rating Assessment: kg

Actual Load: kg

Lowering Record Sheet

Observer: Date:

Colliery: Location:

Task:

Please tick one box for each aspect of the lowering task

Starting position for Lowering

[ ] From above waist height	[ ] From waist height or below

Horizontal location of load (distance of hands away from body)

[ ] Close to body (<20cm)	[ ] Elbow length (35cm)	[ ] Wrist length (60cm)	[ ] Hand length (70cm)	[ ] Reach beyond head when stooping.

Vertical location at start of lower (height of hands from ground)

[ ] Below knuckle height	[ ] Knuckle to waist (70–100cm)	[ ] Waist to shoulder (100–135cm)	[ ] Above shoulder height (135+cm)

Twisting body

[ ] little or no rotation	[ ] 30^0 rotation (one–o'clock)	[ ] 60^0 rotation (two–o'clock)	[ ] 90^0 rotation (three–o'clock)

Frequency of Lowering

[ ] Infrequent <1 in 30 mins	[ ] 1 in 30– 1 in 5 mins	[ ] 1 in 5 to 1 min^{-1}	[ ] 1–4 min^{-1}	[ ] 5–8 min^{-1}	[ ] 9–12 min^{-1}	[ ] >12 min^{-1}

One–handed Lowering

[ ] One hand [ ] Two hand

Team Lowering

[ ]	[ ]	[ ]
1 person	2 people	3 people

Floor Conditions

[ ] Reasonable   [ ] Poor

Rating Assessment: kg

Actual Load: kg

Pushing and Pulling Record Sheet

Observer: Date:

Colliery: Location:

Task:

Please tick one box for each aspect of the pushing or pulling task

Bracing

[ ] Sleeper or other rigid surface to brace against	[ ] No bracing surface

Frequency

[ ] Infrequent <1 in 30 mins	[ ] Occasional 1 in 30 to 1 in 5 mins	[ ] 1 in 5 to 1 min^{-1}	[ ] 1 - 5 min^{-1}	[ ] 6 - 10 min^{-1}

Distance

[ ] 0 - 2m	[ ] >2m - 15m	[ ] >15m

Vertical Location

[ ] Hands above knee, below shoulder or use of body or shoulder	[ ] Hands below knees	[ ] Hands above shoulder

Rating Assessment: kg

Actual Load: kg

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