AN EVALUATION OF KINETIC HANDLING METHODS
AND TRAINING

Ian David Mason

Submitted for the degree of Doctor of Philosophy

October 1982

Dept of Occup Health
& Safety
Univ. of Aston in
Birmingham

AN EVALUATION OF KINETIC HANDLING METHODS AND TRAINING.

Ian David Mason

Submitted for the degree of Doctor of Philosophy.

SUMMARY

This thesis examines Human Kinetics. It assesses the validity of the concepts upon which kinetics is based and investigates the potential contribution of training in general and Human Kinetics in particular to the prevention of Handling injuries in industry.

Human Kinetics concepts are discussed within the framework of a literature review. Their application in training courses is assessed using analyses of video recordings and questionnaires. The nature of Handling accidents is explored using retrospective analyses of official and other statistics and a literature review.

The applicability of Human Kinetic techniques to shop floor settings is explored using trained observers to record the interacting variables via a specially devised evaluation package. Subsidiary studies address the suitability of other lifting training techniques which are currently seen as potential solutions to handling problems.

The concepts which form the backbone of Human Kinetics were found to be valid. Training courses achieved considerable success at altering the movement patterns of trainees in the desired directions and turning them into potential instructors.

The results identified a number of problems which are likely to constrain the industrial application of Human Kinetics. These concern;

(a) The layout and design of many industrial workstations or tasks.

(b) The prevalence of a number of misconceptions regarding the nature of industrial handling accidents, the role of Human Kinetic and other training techniques in prevention, and the content and communication of good movement patterns. These misconceptions are identified and their implications discussed.

HUMAN KINETICS

HANDLING ACCIDENTS

LIFTING

BACK INJURY

TRAINING

Scrire quid valeant humeri, quid ferre recusent - Persius.

With gratitude to ARH, DP, TMA and HG for the final fillip.

TO DTM.

CONTENTS

Page

THE REFERENCES FOLLOW PAGE 247.

LIST OF TABLES, FIGURES AND OTHER ILLUSTRATIONS

CHAPTER 1: INTRODUCTION

1.1 RESEARCH BACKGROUND

In 1974 the Department of Occupational Health and Safety* of the University of Aston was approached by the training manager of the Acocks Green Training Centre of the Royal Society for the Prevention of Accidents (ROSPA) who was concerned about the validity and reliability of the courses in Human Kinetics run by the centre. From this contact arose an MSc. project (Clarke: 1975) which took an initial look at the problem. Using questionnaire techniques Clarke found that Human Kinetics was 'reasonably well received by industry' and in a comparison study of kinetic methods of lifting with other methods he found the kinetic method resulted in a lower physiological cost. In short he was optimistic about the potential of kinetic teaching, and suggested that the method warranted further study. Clarke's major recommendation was for a 'thorough study of the teaching of Human Kinetics to workers' and as supporting evidence for this need he cited Brown's (Brown: 1972) observation that 'few workers in the industrial situation use the prescribed method of lifting'.

ROSPA offered the facilities of its training courses and the assistance of its training instructor in the project. ROSPA's objective was to gain more systematic justification for its teaching and an evaluation of and improvements to the effectiveness of its courses.

A number of industrial organisations who were carrying out training in kinetic or other approaches to handling agreed to

* Then called the Department of Safety and Hygiene.

provide support and information for the study. The major industrial sponsors were a heavy metal manufacturer in the West Midlands, a pharmaceutical company in the North of England and a major service industry.

At the same period the Health and Safety Executive (HSE) were starting a major review of the legislation relating to lifting and handling accidents (Handling accidents are defined on page 29) against a background of parliamentary questions and pressure from MPs such as Bob Cryer to introduce legislation on maximum permissible weight limits for objects lifted or handled in industry. In view of this interest HSE agreed to finance the study.

It was against this background that the research reported in this thesis was conducted.

1.2 OBJECTIVES OF THE RESEARCH

A preliminary review of the literature was undertaken, retrieved from a survey using the keywords, 'Human Kinetics', 'handling accidents', 'industrial accidents', 'handling', 'back injury', 'musculo-skeletal injuries' and 'training' (coupled with handling; lifting; movement; industrial safety). This and a series of visits to the industrial sites of the sponsoring companies and to the ROSPA training centre soon revealed that, although a large amount of information was available about specific aspects of both the practice of kinetics and the problem of handling injuries, there were large and surprising gaps. In particular there was a lack of any overall framework into which the pieces of the jigsaw could be fitted. It became apparent that, before any detailed experimental assessment of kinetic training could take place, it was necessary to look at the framework in which it was set and examine some of the apparently violently conflicting views expressed in the literature about the whole subject.

The overall objectives of the research therefore became:

(i) To examine the potential contribution of training in general and Human Kinetics in particular to the problems of handling injuries in industry.

(ii) To assess the validity of the concepts upon which Human Kinetics training is based.

(iii) To examine the success of the ROSPA courses in teaching Human Kinetics and to assess the obstacles to teaching.

(iv) To assess the applicability of the Human Kinetics taught on the courses to the problems encountered by the instructors in their companies.*

1.3 STRUCTURE OF THE THESIS

The main argument of the thesis is as follows:

CHAPTER 2: Preliminary discussions with the project's industrial sponsors and the training staff at ROSPA indicated the existence of a group of beliefs regarding the nature of handling injuries, handling accidents, and the most appropriate solutions for them. Put simply these beliefs were that manual handling was largely concerned with lifting, which if performed 'wrongly' would result in back injury. This chapter contains a review of literature covering

* All of the courses studied at ROSPA were of one weeks duration and were aimed at training instructors in Human Kinetics who would then return to their own companies and teach others.

academic publications, the trade and technical safety press, visual media and institutional publications indicating a formidable propaganda supporting the dissemination of such views. The widespread nature of these beliefs has strong implications for training.

CHAPTER 3: contains an historical analysis of the emergence and sources of the beliefs described in Chapter 2 based on a survey of official Government policy and an examination of 74 years Chief Inspector of Factories (HMFI) reports. This shows how the strong links fostered and found between manual handling, lifting and back injury have developed throughout this century and led to the emergence of training as a preferred solution to the problem. The current position of training in schools and colleges is also described.

CHAPTER 4: Official sources of statistics and several surveys of industrial statistics were analysed to determine if the distribution of type of injury or cause of accident within the category of manual handling accidents supported or refuted the beliefs described in Chapters 2 and 3. In the light of the findings those beliefs were found wanting.

CHAPTER 5: turns to the technique of Human Kinetics. Its historical development is described. The basis of kinetic theory is explained and the framework which Chapter 6 uses to examine Human Kinetic concepts is developed.

CHAPTER 6: reviews findings from the literature which are relevant to kinetic concepts under seven broad headings. These relate to; Acute and chronic musculo-skeletal disorders; musculo-skeletal disorders and working posture(s); characteristic postures and connective tissue; flexibility and connective tissue; physiology of connective tissue; Human Kinetics and static muscular work; and Human Kinetics and muscular types. All the findings are reviewed in a chapter summary.

CHAPTERS 7-10: Before turning to the assessment of Human Kinetic training courses (Chapters 11 and 12) the thesis looks at the confusions in language and concepts related to handling (and particularly to lifting) which form the background against which any attempt to train people in Human Kinetics must be assessed. In Chapter 7 the language employed in simple training courses and techniques is studied and sources of misconception or confusion are identified. In particular, one simple training technique introduced is the 'six point drill' for lifting training, and Chapter 8 demonstrates that Human Kinetics has been widely confused with this technique. Chapter 9, continues the theme by looking at the confusion engendered by illustrations used in training literature. It discusses the possibility that a broad group of techniques which are often confused with Human Kinetic methods are in fact impossible to perform for any anthropometrically normal human. Chapter 10 rounds off this section of the thesis with a report of a simple but objective evaluation of a training booklet which exemplifies the problems discussed. The evaluation introduces some of the techniques employed in Chapters 11 and 12.

CHAPTER 11: describes the derivation and use of a questionnaire to explore the extent to which ROSPA trainees hold certain misconceptions or attitudes pre training and to judge the success of one week's training in Human Kinetics in altering these beliefs.

CHAPTER 12: turns to the assessment of the success achieved by kinetics training in altering the movement patterns of trainees. Slow motion analysis of movements performed before and after training was carried out using a set of kinetic criteria developed for this purpose. Parallel studies of training techniques discussed in Chapters 7-9 were also performed using similar measures.

CHAPTER 13: examines the final link in the training process. ROSPA having trained a group of Human Kinetics instructors sends them back to their own places of work to pass on the methods learnt to others. A vital question was the applicability of these methods in a shop floor setting. This chapter looks at factors likely to constrain the applicability of kinetics training through a study using a trained group of observers to look at the interaction of kinetic and design criteria at a sample of workstations and jobs. They employed a special evaluation package to collect the data and the derivation of the package is also described.

CHAPTER 14: reports conclusions, and indications for further work. In the latter section a number of studies are reported which fall under the heading of pilot studies for future work.

CHAPTER 2: HANDLING ACCIDENTS: THE NATURE OF THE PROBLEM

2.2 INTRODUCTION

One of the conclusions of this thesis is that there are a number of misconceptions about the nature of handling injuries, that these misconceptions are widespread and that they have given rise to inappropriate solutions.

The importance of these beliefs prevalent in society became apparent from the very start during preliminary discussions with the project's industrial sponsors and a training instructor from ROSPA.

The ROSPA instructor stated that his job of teaching trainees Human Kinetics was made all the more difficult by the fact that many of his trainees arrived for a week's course expecting to be taught how to lift and little else. Further that the majority of them were already familiar with the 'six point drill' (see page 97) method of lifting in one or another of its forms, and believed that its application would prevent back injury. He said that before kinetics teaching could commence he had to spend a disproportionate amount of time getting the trainees to 'unlearn' the 'six point drill' thinking because the technique contradicted the teachings of Human Kinetics on a number of important points (see page 99.)

Interview with a range of safety advisers in the early stages of the project showed that similar views appeared to be quite common; i.e. that there was a'correct'way to lift (called here six point drill but essentially comprising keeping the back straight and bending the knees) and that its raison d'etre was the prevention of back injuries.

It seemed important to explore the prevalence of such beliefs and their source because the answer to such questions would reveal the basis on which training had to be built and so could have widespread implications for its success.

Even the most superficial review of available literature points to a strong link being drawn between handling accidents, back injury and lifting; consider for example the choice of symbol for certain categories of accident reported in four years reports of the then Chief Inspector of Factories.

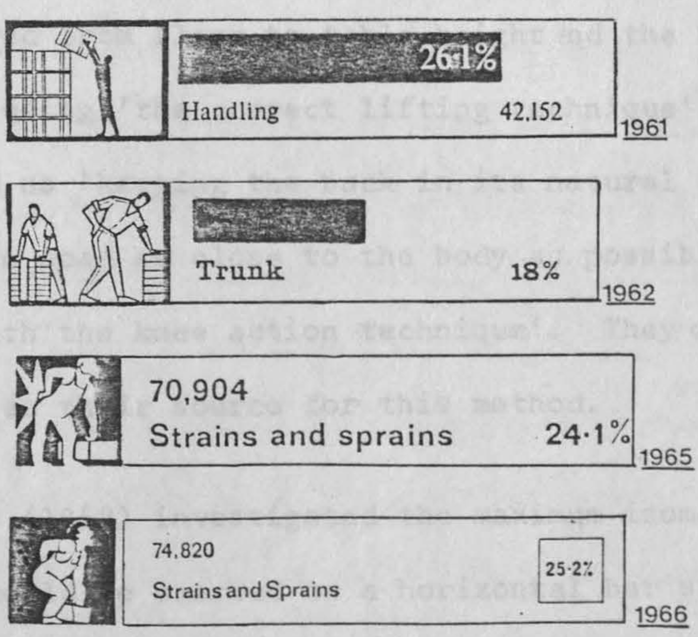


Figure 1. Symbols from HMFI statistical reports.

2.3 REVIEW OF THE LITERATURE

In the section which follows evidence will be cited to show that this stereotype and the concept of a 'correct drill' of lifting are present in (i) Academic publications (ii) The trade and technical safety press (iii) All forms of visual media, and (iv) institutions such as the courts, parliament and government publications. The review of available literature threw up many examples to support the existence of these stereotypes and there were very few statements which contradicted them. Although the evidence presented falls short of proof it is never-the-less very indicative.

2.3.1 ACADEMIC PUBLICATIONS

a) Jorgensen and Poulsen (1974) in a much quoted paper examined physiological problems in repetitive lifting and were concerned with measuring the maximum weight which could be lifted from floor to table height and the maximum oxygen uptake using 'the correct lifting technique'. This they defined as 'keeping the back in its natural curved form with the load as close to the body as possible lifting the load with the knee action technique'. They cite Whitney (1958) as their source for this method.

Whitney (1958) investigated the maximum isometric force which could be exerted on a horizontal bar situated in the frontal plane under different lifting conditions. The introduction to his paper draws attention to 'the link between weight lifting and back injury' and he examines two types of lifting action which are stated to be extremely different and labelled the 'derrick action' and the 'knee action'. The derrick action is defined as lifting by 'bending over the trunk with the knees kept straight.' The knee action is defined as involving 'flexed knees with an upright trunk.' Whitney cites the following as sources for the advocacy of this latter method. Anderson (1951); Cyriax (1954); Hereford (1954); Wayne (1954); Floyd and Silver (1955).

Upon further investigation Hereford, Cyriax and Wayne are found to be short letters in three successive issues of the British Medical Journal, all of which begin by stressing the link between 'bad lifting' and back injury. Hereford merely remarks that advice on 'proper lifting' should be given but does not mention knees or an upright trunk, and neither does Wayne. Cyriax advocates 'maintaining lordosis' during different types of work and a poster is reproduced with his letter. The poster reads 'Your back is not a derrick - legs are designed for lifting' and has an illustration showing a classic drill. (as described on page 97 of this thesis). Floyd and Silver investigated the function of the erectores spinae muscle in certain movements and postures and state that their electromyograms indicate that heavy weights 'should be lifted with the knees and hips flexed and the trunk as upright as possible.'

Whatever the merits of this latter recommendation it is a big leap for anything so vague to be labelled 'correct' in another (Jorgensen's) publication.

b) In an unrelated study Kassab and Drury (1976) describing an ergonomic investigation speak of the 'Use of "correct techniques" of lifting with the back straight and the knees bent'.

c) Sometimes the handling/lifting link is subtle: for example Konz and Bhasin (1974) open their paper (which examines foot positions during lifting) with a first paragraph which states that 25 per cent of compensable industrial injuries are due to incorrect handling of materials. The next sentence poses the question 'What are the characteristics of a safe lifting situation?' Sometimes the link is more direct, e.g. Noro (1967) states that lifting is the most important cause of acute accidents and lower back trouble. He does not however furnish any evidence.

d) Final example is a letter in the British Medical Journal contributing to a debate in those columns on traumatic conditions of the vertebral column, which draw attention to the amount of backache in the community 'stemming from faulty lifting techniques" (Cropper 1977).

2.3 THE TRADE AND TECHNICAL SAFETY PRESS

a) Himbury publishing under the auspices of the International Labour Office (Himbury 1967) states that 'manual load handling is at the origin of a considerable number of injuries in all countries and in almost every branch of economic activity. The great majority of these injuries affect the spinal column and adjacent muscles and are particularly prone to occur during the process of load lifting.'

b) A similar statement is made by Kerr (1979) 'Lifting weights incorrectly is one of the major causes of back trouble'.

c) Glover and Davies (1961) open their article with the observation that the largest percentage of industrial injuries occur during material handling. They quote a figure of 25% of injuries observed in a medium sized engineering factory for the year 1959. These figures - they say- 'confirmed the necessity of introducing a training programme for manual handling and lifting.' They listed their first priorities as back cases and altering attitudes towards lifting.

d) In a New Zealand safety publication Maunsell (1972) states that lifting appears to be the most common cause of back ache problems, and that methods of safe lifting are widely publicised but it seems that people do not bother to follow the suggested techniques.

e) The British Safety Council in support if its Human Kinetic training stated (British Safety Council-undated) that 27% of all accidents in industry result from incorrect lifting techniques.

f) Haynes (1979) in a training paper entitled 'Pass on the lifting message' states that.. 'the problem associated with the manual handling of materials in industry and hospitals are as great today as they have ever been. This is in spite of the increasing mountain of literature on back problems, and the specialist organisations created to combat back pain!

g) Many other papers in the safety literature follow a standard format, opening with comments on the large number of handling accidents, the predominence of back injuries due to incorrect lifting practices and the need for training, eg anon (1962), Pitts Fenby (1962).

h) Reports of the activities of the Back Pain Association also draw similar links eg Timbs (1978). In bold type the article opens with 'Although almost twice as many working days are lost in Britain through back pain than through strikes, relatively little attention has been paid to prevention. Olivia Timbs reports on the latest campaign to alert workers to the correct ways of lifting and handling materials and thus avoid back pain.'

2.3.3 VISUAL MEDIA

a) The illustration shown below is taken from a publicity booklet for the film 'Make Light of Lifting' by Millbank Films Ltd.

Figure 2: A publicity still for the film "Make Light of Lifting."

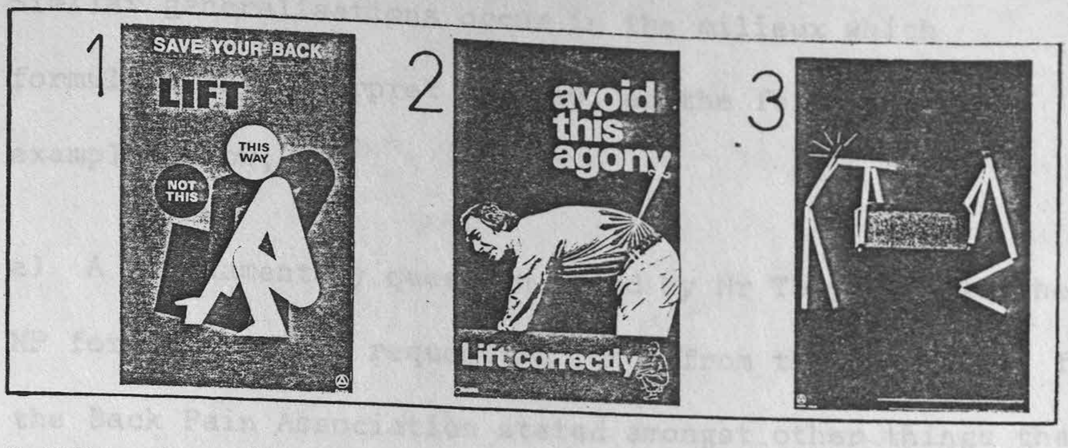
b) ROSPA produces over twenty training posters devoted to the aim of reducing handling and lifting accidents.

I was granted access to the sales record for these posters for a twenty seven month period during the years 1978; 1979 and 1980.

The 23 posters cover a broad range of problems associated with manual handling; they illustrate the handling of a broad range of objects and types of movement, protective clothing and environmental considerations.

The full range of posters, their sales figures and supplementary notes about the derivation and validity of these figures are shown in appendix 1 (page 211).

The 'top selling' posters are shown below:



RoSPA's top three selling posters. Out of a total range of 23 posters covering manual handling safety these three account for 42% of total sales in that category.

These three posters account for nearly 42% of the sales for all 23 posters in the manual handling category. There must be considerable confidence among the designers of these posters, and the safety officers who buy them that the 'six point drill' method is widely appreciated. For example the third poster contains no text at all.

In the context of the complete sales catalogue poster number 1 is very successful. Altogether ROSPA produces some 630 posters with an average sale of 50 per month. Sales of this poster average 138 per month.

c) Such generalizations also filter out into society via radio and television. For example in 'Medicine Today' transmitted 7th November 1967) about Back Pain an 'expert' stated that 'The patient is usually a young or middle-aged adult male who gives a clear history of acute disabling pain following an episode of bending or lifting.

2.3.4. INSTITUTIONS

Similar generalisations occur in the milieux which formulate and interpret the law, as the following examples show;

a) A parliamentary question posed by Mr Toby Jessel (then MP for Twickenham) requesting funds from the government for the Back Pain Association stated amongst other things that

> 'There is a need for education in preventing back pain. This is primarily a matter of education in the lifting of weights - in the need to squat instead of stoop when lifting weights.' Hansard (1980)

> In his reply the Under Secretary of State for Health and Social Security (Sir George Young) remarked that 'All ministers will take the advice of my hon. friend when they pick up their (despatch) boxes, namely, to squat and not to stoop!'

It is not just among parliamentarians that over-strong links between handling accidents - lifting - and back injury have been drawn. Len Murray (TUC Secretary) addressed the 'World Safe 76' conference in the following manner, during a special speech highlighting the £300 million per annum problem of back trouble, 'To the melancholy catalogue of industrial disease and accidents we have to add the hazards that are not so easily defined - manual handling for example. No one can measure the pain, suffering and just plain discomfort the lifting and carrying of heavy or awkward loads has caused to the backs of those who have literally borne the burdens of society.

c) A headline appeared in the Birmingham Evening Mail on

Saturday 10th February 1979, it read 'Lifting paving slabs needs training - Judge.' and the story reported that a post office engineer had been awarded £3,000 in the High Court because the Post Office had never taught him how to lift a paving stone. Deputy High Court Judge Jowitt ruled that the post office were to blame for the plaintiff's back injury because they had not given him proper instructions in how to lift the slabs. The writ and judgement in this case encompass some of the stereotypes that I have been discussing. The writ claimed that the employers were negligent because they caused the plaintiff to carry out the lifting task knowing that he had no training, and knowing that such work carried with it the risk of injury, in particular of a strained back if not carried out using proper techniques. The expert witnesses cited were a consultant orthopaedic surgeon who confirmed that the plaintiff was suffering from a prolapsed intervertebral disc, and a firm of consulting engineers who ventured an opinion about what training should have been given. The engineers' report stated that the plaintiff's action should succeed 'because lifting can produce very high strains in the back unless a special technique is used... the technique is not entirely straight forward and is something about which men need instruction.... the back should be kept straight and the trunk almost upright'. The engineers cited the Ministry of Labour (Department of Environment) publication "Lifting and Carrying" (Great Britain 1958) as supporting 'the fact that the trunk should be kept straight and as vertical as possible'. This is despite the fact that this publication was withdrawn in September 1976 (Seth 1980)

d) A major contibutor to the dissemination of the notion that handling accidents are predominantly a matter of incorrect lifting must be this official government publication which is No 1 in the Health and Safety at Work series (Great Britain: 1958). The Health and Safety Executive withdrew this publication on the 26th November 1976. However enquiries with HMSO (Seth 1980) revealed that, since its introduction in 1958, the booklet had been re printed ten times and a total of 123,500 copies had been distributed.

Headed 'Lifting and Carrying - The Rights and Wrongs', the opening to the booklet states that every year 'over 40,000 accidents are caused in the handling and carrying of goods' 'In many instances insufficient understanding of the 'know-how' of lifting and lack of proper training are the causes of accidents.'

The book advocates lifting using the leg and thigh muscles and keeping the back erect and the arms straight.

The illustration reproduced in figure 3 is used to demonstrate the principles visually.

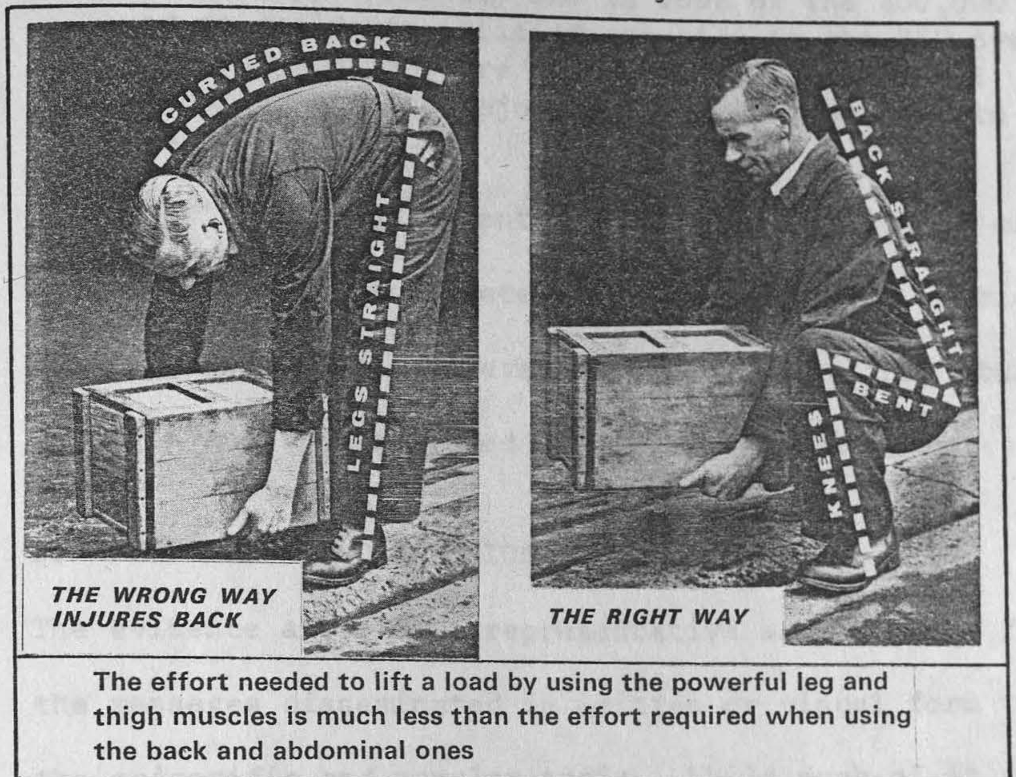


Figure 3: Illustrations and text are taken from the pamphlet "Lifting and Carrying" (Great Britain:1958)

e) The most recent official publication on Manual Handling of loads is the Health and Safety Commission Consultative Document 'Proposals for Health and Safety (Manual Handling of Loads) Regulations and Guidance (Great Britain 1982).

In the introduction to this document it is stated that;

> 'The principal benefit expected to arise from the enactment of the proposed regulations and the observance of the associated guidance is a reduction in the number of manual handling accidents. DHSS data of the number of days of certified incapacity due to back injuries suggests that, even without making any allowance for the cost of absences of less than four days duration, manual handling accidents result in as much as £50 million per annum of lost output alone (at current prices).'

Elsewhere the same consultative document states that;

> Manual Handling can be dangerous, DHSS statistics of claims for industrial injury benefits indicate that

> back injuries have been responsible for the loss of about 2 million working days each year since 1975. Approximately one in four of the 300,000 or so accidents notified annually to the HSE over the same period were associated with the manual handling and the majority of these gave rise to back injuries.

In support of the statement regarding the incidence of back injuries the document quotes 'a recent analysis of manual handling accidents ' however no reference to this study is given and it has proved impossible to trace.

2.4 SUMMARY AND DISCUSSIONS

The evidence above is a representative sample drawn from the messages disseminated in written or visual form through the scientific and popular media. While much of it is anecdotal in nature the volume of material builds up to a formidable propaganda putting over the message that manual handling is largely concerned with lifting and if done 'wrongly' results in back injuries.

The following evidence from ROSPA trainees indicates the extent to which the message is taken in.

As part of work reported elsewhere in this thesis (page 121) a total of 138 trainees on nine Human Kinetics training courses were given a general questionnaire prior to any contact with their trainer. As part of a general battery of questions to determine why they thought they were there the open ended question 'Why was it felt Kinetics would be useful' was posed. It elicited the following responses;

Reduces back injuries	24%
Reduce accidents	20%
Reduce lifting accidents	18%
For training employees	20%
Reduce injuries	8%
Reduce strains	4%
Reduce muscular strains	4%
No reply	2%

Thus a sizeable proportion of the trainees hold the misconceptions under discussion and since most come from large companies these beliefs would appear to be very widespread. (A look at the companies which sent them to be trained revealed that 76% of their companies are listed in The Times Top 1000 UK companies, and 63% are in the top 500.)

CHAPTER 3: HANDLING PROBLEMS AND TRAINING - A historical review

3.1 INTRODUCTION

The data above (2.3) demonstrate the strong links fostered and found between manual handling, lifting and back injury. This section examines the prevalence of the link with a further concept, that of training as a solution to the problem. The following evidence indicates that training has a strong historical tradition of being linked in this way in the scientific and official literature.

3.2 THE REVIEW

a) Mess (1926) notes that evidence submitted to the Home Secretary for compiling the Factories Bill of 1924 included statements from Cadbury's at Bourneville which said

> 'It is notorious that many men suffer from ruptures and strains and it is clear from the practice of the best employers that the suffering is unnecessary. Where the lifting of heavy weights is necessary, it could be allowed subject to conditions to minimise the risk. Thus at Bourneville when it was found that certain male workers who had to lift weights became liable to hernia, arrangements were made for their careful selection and for their training in the gymnasium, with a view to weight lifting by proper methods.'

b) <u>Historical Review of HMFI Reports</u>

The identification of early recommendations such as the one above led to a systematic survey of every annual Chief Inspector of Factories Report (HMFI) for the years 1900 - 1974. The aims were to trace the development of official findings, observations and attitudes to the problems of lifting and handling.

Every published mention of information relevant to handling accidents and contained within these 74 years reports is contained in a separate document (Mason: 1977). There follows a selection of truncated extracts from this document. The extracts trace the development of the notion that correct lifting must be taught and also of the wider misconceptions relating to the whole problem of handling accidents. The format of the extracts is to show the year of the relevant HMFI report, and page, together with the author of the observation (if available). The most relevant parts of each extract are underlined.

Early reports contained speculation about the nature of harmful lifts or postures and vague recommendations about improvements

1911 (p.16) Mr Garvie (Wolverhampton)

'Heavy weights appear to cause injury, such as rupture, from <u>some jerking lift</u> rather than solely from the excessive weight lifted, but excessive weights are painfully frequent, and are not all due to <u>excess of zeal</u>.'

1913 (p.26) Mr Crabtree (Burnley)

'Sprains due to weight lifting in the weaving shed are more numerous than is apparent. Many do not figure in accident reports, as the persons concerned either continue at work or resume work within seven days. But sprains are incidents of daily occurrence, more especially among women and girls who lift beam weights of 36 to 52 lbs. These are located near the floor, and <u>necessitate a stooping posture.</u>'

1913 (p.27) Mr Williams (N. Division) looking at the fish curing industry '... the 'farlanes' or troughs containing the fish are commonly on or near the level of the ground, so that the women, while employed in gutting are compelled to almost continuously <u>bend their backs</u> in a <u>most uncomfortable fashion</u>, the upper portion of the body forming nearly a right angle with the legs. Enquiries among the workers left no doubt as to their feelings on the subject - many of them complained that the position was back breaking.

Mr Neely (Inverness) 'on first acquaintance with herring curing I was much struck with what appeared to me to be absolutely unnecessary fatigue which the women had to undergo in <u>bending or stooping</u> to gut the herring by reason of the farlanes being so low.'

In the year 1918 the first real mention of training occurred;

1918 (p.31) Mr Taylor OBE

> ...'The subject of labour and fatigue saving appliances is intimately associated on one hand with that of movement study', a subject which is now receiving increased attention from progressive manufacturers in this country. Simple appliances for holding the workers' tools and parts of machines for assembling, etc., are essential for the successful application of movement study methods, and great stress is laid upon the importance of the initial training of workers so that they can carry out their work with such movements as involve the minimum amount of fatigue to themselves. In connection with this subject Miss A.M. Anderson (Principal Lady Inspector) draws attention to the necessity for systematic training in weight lifting. Miss Pearson mentions a case where by application of a proper method two persons were able to lift with ease heavy sacks of chestnut meal on to a high barrel.'

With no real mention in the reports for the intervening years it is however apparent that by 1930 the provision of training was underway.

1930 (p.64) Reporting on a discussion of weight lifting held at a conference it was noted that;

> '.... Models to demonstrate methods of weight lifting and carriage with illustrations of factors in the causation of accidents from weight lifting are being considered for the Industrial Museum.'

1949 (p.73)

> 'In view of the large number of strains, ruptures and fractures which were sustained in manual handling accidents, there appears to be room for education and training in methods of moving materials, estimating weights and loads, and the use of mechanical handling.'

1956 (p.85)

> 'The accident reports show that far too many men do not know the correct way to lift heaving weights, as just over 19% of the total of 412 accidents resulted in strained backs.'

1957 (p.82)

> 'Many accidents in factories are caused by workers using the incorrect methods of handling and lifting heavy loads.'

By the year 1960 most elements in the stereotyped picture of manual handling accident aetiology, lifting and training were enshrined in HMFI observations. The report for that year stated the following under the section dealing with handling accidents;

> 'Many of the 31% of handling accidents which damage the trunk are due to incorrect methods of lifting and carrying weights. That many workers do not understand the safe method of lifting is due in part to a lack of proper training by firms. A worker will soon appreciate, when shown, that his leg and thigh muscles are stronger than those of the back and abdomen and will tend to form the habit of using the former in lifting, keeping his back erect and his arms straight.'

Throughout the late fifties and sixties the HMFI reports drew attention to the HMSO booklet 'Lifting and Carrying' (see above page.18.) stating that the application of the principles outlined in the booklet would prevent strains and sprains in handling accidents.

There has always been a strong emphasis on training new entrants to industry, the 1967 HMFI report (p.91) said that new entrants should be taught, amongst other things;

> 'The importance of personal cleanliness, and the correct methods of handling heavy objects to avoid the occurrence of strained or twisted muscles.'

In fact the Inspectorate has, via its annual reports often lobbied for training to be done at a much earlier stage in schools.

3.3 LIFTING AND HANDLING TRAINING IN SCHOOLS AND COLLEGES

The HMFI report for 1958 contained the following report; (p.48)

'Many accidents in factories are caused by workers using the incorrect methods of lifting and handling heavy loads. In all 27% of the total number of accidents reported to the Factory Inspectors in 1957 came under the category of handling goods. It is now considered that more can be done to interest physical education teachers in this aspect of safety training. Lessons learned in the physical education classes at a comparatively early age could help considerably towards the avoidance of this type of accident. At a technical college in SE England, a lecturer in physical education and hygiene is now giving instructions on safe methods of lifting and carrying the loads which many students will have to handle when they enter industry.'

The Health and Safety Executive Library were contacted to find out if any trace of this instruction programme could be found, or of the records of its results. Sadly I was notified that the files had been destroyed. (Smales: 1980) However there is evidence that systematic training is carried out in many schools.

The Department of Education and Science safety series has recommendations regarding lifting and handling. No 4 of the series 'Safety in Physical Education' (Great Britain: 1973) refers to children lifting or carrying equipment in the gymnasium;

'The use of the strong muscles of the leg, straightness of the back in the vertical position to avoid strain, body balance and control of weight are all points to be stressed.'

The guide continues:

'Some teaching of the appropriate techniques of lifting and carrying heavy and awkwardly shaped objects, such as might be encountered in domestic or industrial situations is a proper part of physical education .'

Should any pupils have slipped through the net in their adolescent years number 5 in the same safety series 'Safety in Further Education' re-inforces the need for this sort of instruction and readers are referred to the 'useful advice' given in 'Lifting and Carrying' Booklet No 1 in the Health and Safety at Work Series (Great Britain 1958) (see page 19).
Some education authorities supplement this information with more specific guidelines. In one authority surveyed (Gloucestershire County Council), the chief education officer confirmed that 'The principles of Lifting' a short document reproduced below was distributed to all schools. The document was intended for use by kitchen staff, and teaching staff and was kept on a central file so that all staff had access to it at any time. (Clark 1980).
The drill was taught in metalwork classes in some schools and in most cases the document was the only instruction staff would receive.

PRINCIPLES OF LIFTING

1. Make sure your feet are close to the load to be lifted, about 12 inches apart, with one foot slightly behind the other.

2. Go down by bending, and keeping your back as straight as possible.

3. Get a good grip of the load using the whole of the arms and forearms.

4. Keep your arms close to your body with the elbows well into the sides.

5. Tuck your chin in and keep it tucked in.

6. Keeping your back straight, straighten your legs and stand up, making the weight part of your body.

7. Never twist your body whilst lifting.

8. Lead the lifting movement with your head, this will automatically help to straighten your back.

9. Ensure that once lifted, the load does not obscure your view. Make sure that there is a clear space in which to put your load down.

There are thus strong reasons for suspecting that substantial numbers of children will leave school or college having had exposure to some sort of simplistic lifting training.

CHAPTER 4: STATISTICS OF HANDLING ACCIDENTS

4.1 INTRODUCTION

The stereotyped approach to handling accidents described in the previous section has at its root the notion that statistics show the majority of handling accidents to be caused by lifting and to result in a back injury. In the section which follows a description of handling accidents is given and a number of sources of data are examined to see if this notion could be refuted or supported.

4.2 OFFICIAL SOURCES OF STATISTICS

Handling has been a sub-classification of official statistics of all reportable accidents since 1924, when the 3 day reporting standard was fully established.

By definition, official records classify as a 'handling accident' those injuries which occur when raw materials, articles in process, finished projects or plant and machinery are being handled. Injuries due to the dropping of articles etc. whilst goods are being handled are also included in the definition. The criterion is that the article must be capable of being carried by hand by one or more persons; the definition therefore includes the carrying, moving and setting down of the article and not only its lifting. Accidents which occur when hand trucks, barrows and lifting machinery are used are not regarded as handling accidents. The figures for the years since 1924 are set out in table 1 as numbers and percentages of total reported accidents, in factories only.

Year	Handling Injuries No.	% of total	Year	Handling Injuries No.	% of total	Year	Handling Injuries No.	% of total
1924	29,613	19.0	1943	77,096	26.2	1962	40,128	25.5
1925	15,093	9.5	1944	71,255	26.7	1963	38,522	25.8
1926	22,063	17.1	1945	62,632	27.7	1964	58,842	27.0
1927	28,799	19.8	1946	60,399	29.1	1965	62,460	29.2
1928	30,740	21.5	1947	54,082	29.2	1966	64,585	26.8
1929	32,292	21.7	1948	54,370	29.7	1967	61,234	27.8
1930	29,831	22.4	1949	49,577	28.8	1968	68,997	27.1
1931	22,692	22.0	1950	48,064	28.2	1969	72,436	27.1
1932	21,862	22.4	1951	45,368	28.1	1970	70.417	27.5
1933	23,546	22.5	1952	43,185	27.8	1971	62,779	27.6
1934	30,068	23.8	1953	43,861	27.7	1972	60,046	27.7
1935	33,532	24.4	1954	43,451	26.9	1973	65,134	28.2
1936	39,865	24.6	1955	46,613	28.5	1974	62,073	28.3
1937	44,487	25.2	1956	44,313	27.7	1975	58,480	28.6
1938	39,626	24.7	1957	41,109	27.3	1976	59,419	29.4
1939	43,410	25.4	1958	38,469	26.9	1977	61,429	29.6
1940	53,030	25.2	1959	38,878	26.2	1978	53,266	28.7
1941	64,291	25.7	1960	42,067	26.1	1979	56,380	33.6
1942	76,419	25.8	1961	42,152	26.1	1980	41,738	31.5

Figure 4: Table, Handling Injuries 1924-1980 - Source H.M. Chief Inspector of Factories Reports

The proportion that handling injuries form of total injuries in factory processes has stayed at just above a quarter over the last half century. The category is, however, one of activity during which the injury occurred, rather than of cause of injury. The only years to give a breakdown of primary cause of injury by injury type were 1961 and 1964; these breakdowns are shown in figures 5 and 6

Taking the two years together some 35% of handling injuries are to the trunk or spinal column. However the change in classification which occured in the years separating these tables confuses the picture. Clearly a large number of injuries which fell under the category 'trunk' in 1961 came under the category 'spinal column and adjacent muscles' in 1964.

However it appears that some 90% of the handling injuries to the trunk and spinal column were strains. Fig. 7 also shows that these handling injuries to the muscles of the back form only 65% of all injuries to the muscles of the back. The

Site of injury	No of Handling Injuries 1961 No.	1961 %	1964 %	1964 No.	Site of Injury
1. Head & Neck (excluding 2)	595	1.2	0.3	220	Scalp
			1.0	723	Other head
2. Eye & Socket	849	1.7	1.6	1,162	Eye & Socket
3. Spinal Column	707	1.5	27.8	19,689	Spinal Column & Adj. muscles
4. Trunk	15,365	31.5	9.1	6,464	Trunk
5. Upper Limb (excluding 6)	2,468	5.1	8.3	5,890	Upper Limb (excluding hand)
6. Hand & Wrist	16,603	34.1	28.6	20,249	Hand
7. Lower Limb (excluding 8)	2,211	4.5	4.2	2,997	Lower leg & ankle
			1.9	1,368	Other & multiple lower limb
8. Foot & Ankle	9,714	19.9	8.5	6,043	Toes
			8.2	5,797	Foot (excluding toes)
9. Other injuries	230	0.5	0.4	278	Other
Total	48,742	100	100	70,880	Total

Figure 5. Handling Injuries by Site of Injury 1961 & 1964 - from H.M.Chief Inspector of Factory Reports

	Site of Injury	1961 Handling	1961 All accidents	1964 Handling	1964 All accidents	Site of injury	
Spinal Column	Fracture	12	196	197	756	Fracture & Dislocation	Spinal Column & Adj. muscles
	Strain of Joints	185	411	18,970	28,407	Strains of muscles	
	Not otherwise specified incl. displacement of intervertebral disc	510	855	522	5,478	Other	
	Total	707	1,462	19,689	34,641	Total	
Trunk	Fracture	141	1,919	191	2,498	Fracture & Dislocation	Trunk
	Strains of Joints	13,184	20,454	5,159	8,607	Strains including hernia	
	Internal injury (not hernia)	36	257	43	194	Internal injury	
	Open wound laceration	23	241	876	9,383	Open wound & surface injury	
	Surface injury	656	8,328				
	Foreign body in orifice	1	14	1	6	Foreign body in orifice	
	Burns	30	220	54	439	Burns	
	Other	1,294	2,497	140	781	Other	
	Total	15,365	33,930	6,464	21,908	Total	

Figure 6: Detailed breakdown of trunk and spinal column injuries 1961, 1964.

remaining 35% happen mainly on falls or the use of hand tools. Table 7 from the same source shows that approximately a further 7% of handling accidents are dislocations, sprains or strains to other muscles or joints in the body.

Site of injury		1961 Handling	1961 All accidents	1964 Handling	1964 All accidents	Site of Injury	
Upper Limb (excluding hand/wrist)	Fracture	90	2,011	392	5,313	Fracture & Dislocation	Upper Limb
	Dislocation	37	463				
	Sprain/strain	1,258	2,756	2,910	6,728	Sprain/strain	
Hand/ wrist	Fracture	1,573	8,285	1,944	8,694	Fracture	Hand
	Dislocation	59	294				
	Sprain/strain	1,318	3,540	906	2,552	Sprain/strain	
Lower Limb (excluding ankle/foot)	Fracture	111	1,729	294	4,314	Fracture Dislocation	Lower leg ankle
	Dislocation	20	179				
	Sprain/strain	646	3,935	1,345	14,342	Sprain/strain	Lower limb (incl. multiple
Ankle/Foot	Fracture	2,965	10,331	3,588	11,093	Fracture Dislocation	Foot & Toes
	Dislocation	18	155				
	Sprain/strain	263	7,296	174	2,134	Sprain/strain	
Multiple	Fracture	3	253	1	166	Fracture Dislocation	Multiple
	Dislocation	-	4				
	Sprain/strain	26	119	-		-	
Total all sites of injury		48,742	192,517	70,880	268,648	Total all sites of injury	

Figure 7: Table, Dislocations, sprains etc. from Handling Accidents

These tables sub divide site of injury, but what of causation? It is clear from the definition given on page 29 that handling cannot be considered a mutually exclusive category of accident causation.

Attempts have been made by HMFI to give breakdowns but they have been sporadic and are well hidden in official records.

A survey of all official HMFI statistics for the years 1900 - 1974 (Mason 1977) which extracted every instance of a complete or partial analysis including lifting as a separate category revealed the following:

- An analysis of 1,238 accidents reported in the Bristol District during 1901 revealed that 3 per cent were 'cases of over exertion due to lifting' resulting in strains, ruptures, or spinal injuries.
- An industry-specific breakdown indicated that 'strains from overlifting' were the cause of 3% of accidents in 1909, 5% in 1910, 4% in 1911 and 5% in 1913, in docks, wharves and quays.
- A more detailed analysis of Dock Accidents occurring in the Port of London and reported during 1922 reveals that lifting resulting in strain, sprain, or rupture was responsible for 2% of the 1588 accidents reported.
- A breakdown of the accidents reported from engineering works in the HMFI statistics for 1931 has separate categories for 'handling materials' and 'carrying or lifting'. When all figures are examined the former category forms 11% and the latter 3.3% of total accidents.
- An analysis completed in 1946 and reported in the Chief Inspector of Factories report for that year summarised the scrutiny and sub classification of 2,000 handling accidents.

The results showed that 24% of these accidents fell into the category of objects lifted; the complete breakdown is shown below. Handling accidents were 29.1% of total reported accidents in 1946.

Figure 8: Breakdown of 2000 handling accidents by cause.	No.	as % handling	as % Total accidents
Object dropped or allowed to slip from hands	534	27	8
Objects lifted	483	24	7
Trapped between objects	328	16	5
In connection with trucks, barrows, bogies etc.	257	13	4
Objects falling during handling on load or pile	87	4	1
Bad Housekeeping	81	4	1
Damaged objects, splinters, protruding nails etc..........	58	3	1
Miscellaneous	172	9	2
Totals	2,000	100	29%

However in the report it was also acknowledged that 'objects lifted' could be further subdivided because it noted that 'Many accidents caused in lifting were due to standing in awkward positions and constricted spaces, or lack of secure foothold on stacks piles and vehicles'.

In summary official statistics indicate that approximately 25% of reported accidents are 'handling accidents' and that between 35 and 40 per cent of handling injuries are musculo-skeletal injuries.

The best estimate provided by official figures is that approximately one quarter of handling accidents are lifting accidents, ie lifting accidents represent about 6% of total accidents.

The tables demonstrate that both causation and site of injury can be further sub-divided.

In order to explore further the information available from a more exhaustive breakdown investigative surveys were conducted in some of the industries supporting the study.

4.3 INDUSTRY DATA

4.3.1 HEAVY METAL COMPANY

Excellent data were available at one site, a heavy metal company in the west Midlands. Accident records had been kept in the same format and recorded by the same staff for a period of 23 years from 1954 to 1976. The data covered a workforce of approximately 2,000 people. All accidents had been recorded using edge-punched record cards (multiple indexed). Both the notch system and the considerable space afforded for narrative description ensured the following were recorded;

(i) The site of the accident

(ii) The nature of the movement performed

(iii) The dimensions and weight of the object handled

(iv) Any unusual work practices operating at the time of the accident.

The records were comprehensively cross indexed (although surprisingly no analysis had been attempted prior to my survey). For the 23 years there were 3,947 3 day lost time accidents and of these 705 (18%) were attributed to manual handling.

It was assumed, since these accidents were recorded by experienced staff and were also transcribed onto F43 forms for submission to HM Factory Inspectorate for national statistics, that the definition of handling accidents did not differ substantially from that given on page 29 of this thesis.

Lifting was categorised by the safety officer who filled in the accident report and as well as straightforward raising or lowering of objects from floor to bench more complex movements had been included. For example supporting heavy pieces in a static posture or tipping out a box of finished parts. This will be commented on in the analysis.

4.3.1.1 METHOD

All 3,947 accident record cards were sorted and the 705 for manual handling selected. According to the definitions given above the accidents were sorted into three categories

(i) Lifting causing strained back or other back injury

(ii) Lifting causing other injuries

(iii) Handling causing other injuries

Finally the original 3,947 records were re scrutinised and all instances of back injury in categories other than handling selected.

4.3.1.2 RESULTS AND DISCUSSION

The results of this analysis are shown in figure 9. Examining this data it is clear that the maximum potential for reduction of back injury by the successful application of a simple lifting technique (such as the six point drill) is 25 per cent of the handling accidents or approximately five per cent of their total three day lost time accidents. (The number of accidents in category (i) above.)

YEAR	Total+ 3 day lost time accidents	Total* handling	%(+)	Lifting causing 'strained back' or other back injury	% (*)	Lifting causing other injuries	% (*)	Handling causing other injuries	% (*)	Other back inuries	% (+)
1954	505	93	18.4	22	23.6	7	7.5	64	68.8	16	3.2
55	499	94	18.8	17	18.1	7	7.5	70	74.5	16	3.2
56	295	39	13.2	14	35.9	4	10	21	53.9	16	5.4
57	269	36	13.4	13	36	1	2.8	22	61	5	1.9
58	140	18	12.9	1	5.6	1	5.6	16	88.9	3	2.1
59	124	15	12.1	5	33.3	–	0	10	60	7	5.7
1960	160	13	8.1	6	46.6	–	0	7	53.9	4	2.5
61	149	17	11.4	6	35.3	–	0	11	64.7	2	1.3
62	90	19	21.1	5	26.3	–	0	14	73.7	1	1.1
63	109	26	23.9	4	19.2	2	7.7	20	77	5	4.6
64	136	20	14.7	7	35	–	0	13	65	6	4.6
65	163	31	19	5	16.13	–	0	26	83.9	7	4.3
66	126	17	13.5	5	29.14	–	0	12	70.6	5	4
67	130	41	29.3	13	31.7	2	4.9	26	63.4	4	3.1
68	154	28	18.2	5	17.9	–	–	23	82	2	1.3
69	147	27	18.4	10	37	2	7.4	15	55.6	4	2.7
1970	137	36	26.3	3	8.3	2	7.7	31	86	1	0.7
71	116	19	16.4	8	42	–	0	11	57.9	2	1.7
72	120	24	20	7	29.2	2	8.3	15	62.5	4	3.3
73	112	26	23.2	5	19.2	2	7.7	19	73.1	1	0.9
74	99	17	17.2	5	29.4	2	11.8	10	58.8	4	4
75	102	26	25.5	6	23.1	–	0	20	77	4	3.9
76	92	23	25	10	43.5	3	13	10	43.5	5	5.4
Total	3,947	705		182		37		486		124	
$\bar{X}$			18.3		25.3		7.8		67.7		3.1

Figure 9: Table of results for thesis section 4.3.1.2. Showing the statistics of handling accidents and back injury from 23 years records for a West Midlands heavy metal industry.

This figure is an over estimate because it reduces considerably when the following question is asked

- In how many of these cases was the subject lifting a compact load in free space? (ie there were no obstacles to movement or other elements likely to impede or alter the character of the movement)

Analysis showed this to be the case in only 34 of the category (i) accidents. This would modify the totals amenable to lifting drill (eg. six point drill) training to five per cent of the handling accidents or less than one per cent of the total three day lost time accidents. In only six of these 34 cases was the object handled box like (the commonly illustrated example) and comprised a box, tin, crate or carton. In the other accidents the object handled was Coil or wheel (6); Scrap metal (3); Piping (2); Small dustbin (2); Saddle (1); Acetylene cylinder (1); Insulator (1); Anode (1); Vice (1); Roof baton (1); Gate end (1); Press tool (1); Radiator (1); Floor plate (1); Jig (1); Flame trap (1); Clay (1); Pads of felt (1); grinding wheel (1).

The 'lifting causing strained back' accidents involving more complex movements included

. Combination of a lift and a pull while freeing a stuck part
. Lifting and sliding a heavy piece on a table
. Lifting from stack; out of trucks; out of stillages; off machines or into vices
. Supporting heavy pieces in a static posture
. A combination of a lift and a turn on the subjects trunk axis manipulating a hand truck
. Tipping out boxes of work into a skip.

The question was then posed;

> Is the movement described and the nature of the object lifted covered by instruction on a ROSPA human kinetics course?

It was found that there was a 'kinetic way' taught for doing the actions described in a further 73 (40 per cent) of the category (i) cases (making a total of 107 or 58.7% which could be 'solved' by kinetics). In 22 (12 per cent) of the category (i) cases it was assessed that any training in movement techniques was wholly inappropriate because extremely cramped workplaces, oily floors or an unpredictable third party were involved. A further 53 (29.2 per cent) were the result of poor planning of the lift, temporary obstruction, or slipping during the lift. It should be stressed that these retrospective assessments can at best only be estimates. However in the case of the questions concerning the application of Human Kinetics the records were rescrutinised by a ROSPA instructor and his estimate was within five per cent of my own. (It was felt necessary to take this step because these were early days of the project and I felt there were gaps in my knowledge of Human Kinetics.)

4.3.2 BAGGAGE HANDLING

Shortly after the survey in the metal industry was completed I was fortunate to have access to the accident records for baggage handling staff at a major international airport. The safety officer was planning to implement six point drill training using a small pamphlet.

There were 350 porters who in the year 1976 had sustained 53 (3 day lost time) accidents of which 15 were classified as handling. The records contained a separate coding for strain or sprain during lifting and by cross referencing this with records for site of injury it was possible to construct a table using the same categories examined in the heavy metal industry.

The results for both industries are summarised below;

	Total reportable	No.	%reportable	Lift causing back injury			Lifting causing other injury		
				No.	% of reptble	% of handling	No.	% of reptble	% of handling
Metal Co 1954-1976	3,947	705	18.3	182	4.6	25.3	37	0.9	7.8
Baggage Handling 1976	53	15	28.3	4	7.6	26.7	2	3.8	13.3

	Other handling causing other injuries			Other Back Injuries	
	No.	% of reportable	% of handling	No.	% of reportable
Metal Co	486	12.3	67.7	124	3.1
Baggage handling	9	16.9	70.0	6	11.0

Figure 10: Table, Handling and back injuries for 2 companies.

4.3.2.1 RESULTS AND DISCUSSION

Although the numbers studied in the baggage handling were small, the results are comparable with the Metal Company data, as fig 10 shows. The work done by the porters obviously involved more 'handling' and this is reflected in a higher percentage for this category of accident. However the percentage of lifting accidents causing a back injury remained remarkably constant across the two groups.

4.3.3 OTHER SOURCES

a) A survey in the motor industry (Manning and Shannon 1979) studied a total of 225 lost time accidents sustained by a workforce of 2,000 men in the year 1974. Their data shows that there were 54 lumbosacral injuries resulting in lost time accident reports and of these 17 were attributed to a sudden onset of pain whilst lifting, straining or stooping.

Thus the proportion of lost time accidents resulting in back injury which would be prevented by successful six point drill lifting training would be 7½ per cent in this instance. Manning and Shannon show that the major cause of lumbosacral injuries in the factory studied is slipping accidents, which caused 37 per cent of back injuries. They speculate that the number of lumbosacral injuries due to slipping is probably underestimated in most records because accident classifications like 'handling' are not sub divided into component causes.

b) Daniel et al (1980) did a study of low back pain in a large steelworks. Of the industrial back injuries they studied 14 per cent were attributed to lifting.

c) Jackson (1968) completed an analysis of industrial injuries to dockworkers in the Port of London. Examination of his figures showed that back injuries arising during manual handling accounted for 31 per cent of back injuries and 8 per cent of the total three day lost time accidents. From a detailed examination of the back injuries arising during manual handling Jackson concluded that a large number of these fell into the category of direct trauma - being struck on the back or by slipping and falling onto the back etc. - Jackson points out that the back is a large target area for direct trauma and there is no protective clothing to safeguard it as at other anatomical sites.

d) In another study the then Assistant Chief safety officer in one of the major service industries (Hooper 1975) showed that, in his industry as a whole, injuries to the back represented about one fifth of injuries arising from all causes and the proportion of handling accidents which resulted in back injury was almost 44 per cent. However his report also showed that only a quarter of handling accidents occurred when objects were actually being lifted or set down.

4.4 CONCLUSIONS

Taking all the sources of data together it is apparent that: The best estimate of lost time accidents caused by lifting and resulting in a back injury is 25 per cent of handling accidents or five per cent of total three day lost time accidents but the last figure could be as low as one per cent or rise as high as ten per cent.

The scope of the application of six point drill techniques is limited to approximately 20 per cent of lifting accidents causing back injury and the scope for Human Kinetics to 60 per cent of lifting accidents causing back injury. The relationship of Handling accidents, lifting accidents and back injury is summarised in fig 11 (shown below).

This diagram should be interpreted with care because the scope for kinetics training which covers a much broader repetoire of movement skills than just lifting will be more extensive than the diagram suggests. Also design criteria will constrain movements other than lifting. These two latter problems are explored in greater detail in Chapter 13 (see page 180)

There is a question mark which hangs constantly over the accuracy of figures on musculoskeletal injuries because of the difficulty of testing whether injury has really occurred, and of diagnosing its cause. This has led the Health & Social Executive to consign Sprains, strains, hernia and other back injuries to Group 2 of their classification because ' there is legitimate doubt (for a proportion) whether they were caused by a truly accidental happening at work'.

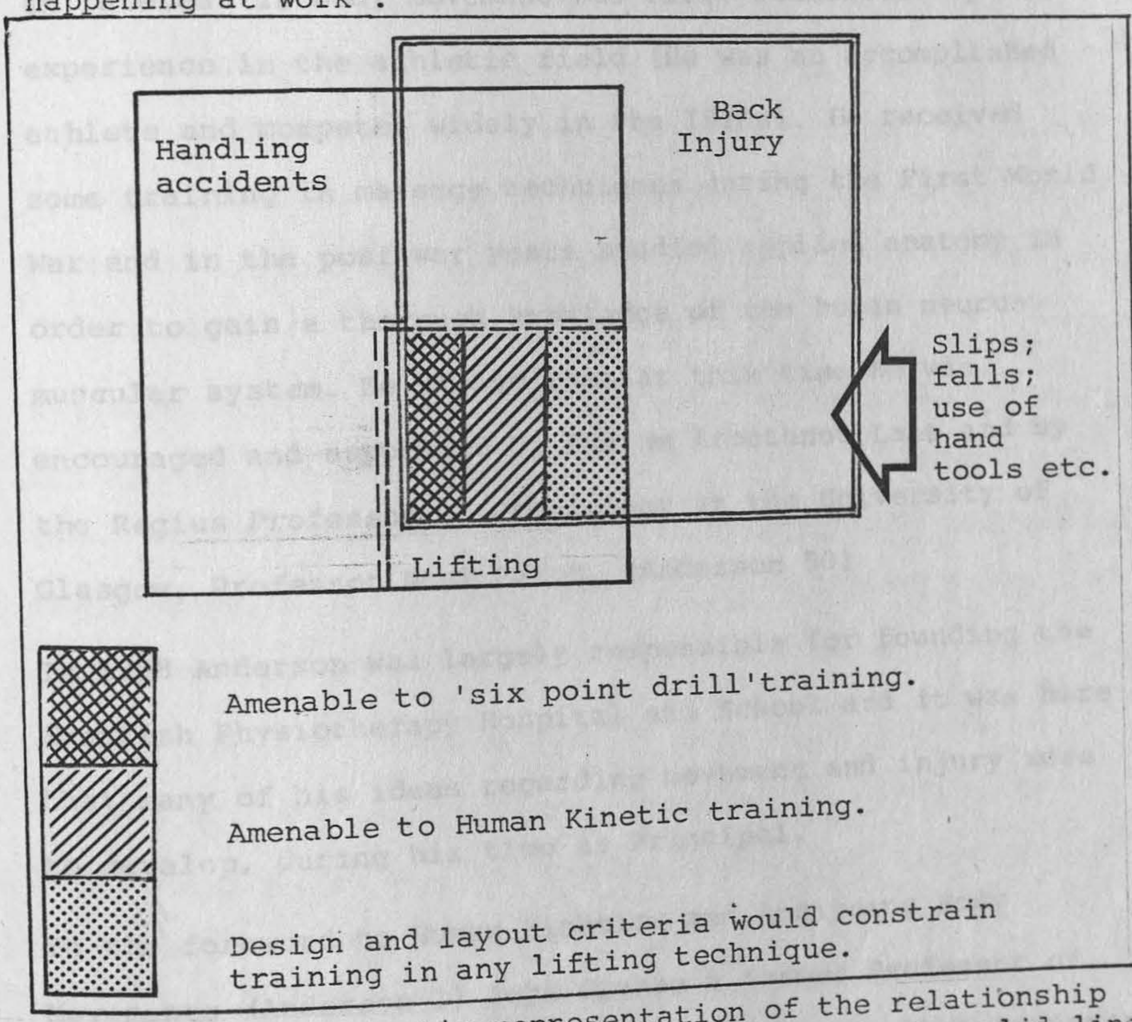


Figure 11: A diagrammatic representation of the relationship between Handling accidents (Square bounded by single solid line) Back injuries (square bounded by double solid line) Lifting accidents (a subset of handling - indicated by dotted lines) and forms of training (shaded and labelled.) The contribution of each element to the total problem is approximately indicated by area.

CHAPTER 5: CRITICAL EXAMINATION OF HUMAN KINETICS

5.1 HISTORY OF HUMAN KINETICS

Human Kinetics is the term used by Tom McClurg Anderson to describe a body of knowledge he developed from observations which began during the First World War and continued until his death in February 1981.

He defines the subject as:

'The study of mechanical, nervous and psychological factors which influence the functions and structures of the body, as a means of producing cumulative strain.' (Anderson 45)

In the introduction to his book (Anderson 1) he stated that an interest in body movement was first stimulated by his experience in the athletic field (He was an accomplished athlete and competed widely in the 1920s). He received some training in massage techniques during the First World War and in the post war years studied applied anatomy in order to gain a thorough knowledge of the human neuro-muscular system. He stated that at this time he was encouraged and supported by Sir Wm Arbuthnot Lane and by the Regius Professor of Physiology at the University of Glasgow, Professor Noel Paton. (Anderson 50)

In 1928 Anderson was largely responsible for founding the Scottish Physiotherapy Hospital and School and it was here that many of his ideas regarding movement and injury were to develop, during his time as Principal.

In the foreword to Human Kinetics and Analysing Body Movements (Anderson 1) John Graham a former Professor of Anatomy at the University of Glasgow, remarks that Anderson had abundant material and an unrivalled opportunity to study occupational stresses and strains at the Scottish Physiotherapy Hospital because up to 45,000 treatments were carried out annually.

Anderson himself was making observations and analyses to develop his theory that the physical development of muscular and other tissues had a definite relationship to the normal habits of the individual, and was investigating a number of systems for trying to assess the normal physical habits of the individual by the condition of their tissues.

Anderson's major contact with industrial safety training began in 1948 when he studied the problems of fatigue and injury at the ICI Ardeer Factory in Scotland. Following a pilot study he was invited to examine work throughout the entire factory and develop a training programme for employees. This work was widely reported and led to invitations from the American Society of Mechanical Engineers to make an address on the Industrial Application of Human Kinetics. (Anderson 22)

Requests for further information and instructional material led Anderson to form the Institute of Human Kinetics in 1950. This body developed close links with ROSPA following their adoption of Human Kinetics as the basis of Industrial Safety Week in 1959. (Anderson 6)

This relationship matured over the years and Anderson trained all ROSPA instructors including the current one Douglas Payne, as well as writing much of their instructional material. (Anderson 45, 56, 47, 48, 49)

5.2 INTRODUCTION OF THE EXAMINATION OF KINETICS

Many of the notions which underpin Human Kinetics teaching are beliefs and theories which although plausible and persuasive attempts to explain the aetiology of musculo-skeletal disorders, remain unproven. Although Anderson produced over fifty papers and publications and claimed that they were based on appropriate observations, none of his papers contained references to substantiate his views. In a similar fashion although he may have completed many thousand observations the fact that he did not set out his exact methodology for physical examination linked to appropriate recordings of occupational movements means that his evidence remains at best anecdotal and does not exclude alternative explanations.

This has caused a number of problems for ROSPA and other institutions teaching Human Kinetics. There is a general concern that the theories developed by Anderson for the most part half a century ago may not withstand critical analysis in the light of more recent findings.

This section of the thesis will set out Anderson's work as a basis of a discussion of its validity. The analysis is necessarily incomplete because a review of over 1,000 papers, drawn from key words selected to elicit information which might confirm or refute key kinetic notions, showed that there is a real paucity of information regarding the links (if any) between muscular habits and deleterious musculo-skeletal changes.

Also Anderson claimed that almost every review of his work either misrepresented his basic ideas or simplified them to the extent of encouraging misconceptions (Anderson 37 and 45).

In order to show where and how the 'skeleton' of kinetic thinking distilled for critical analysis in the next section fits into the framework of his teaching, one of Anderson's more concise reviews of kinetic movement (Anderson 5) is included in this thesis as appendix 2 page 214)

5.3 BASIS OF HUMAN KINETICS

Human Kinetics is based on observations which draw links between habitual forms of muscle usage and fatigue, strain or injury. Underpinning all of Human Kinetics teaching is the notion of cumulative strain. To ROSPA trainees it is defined as progressive stiffening of the body tissues due to habitual excessive contractions. (Anderson 45) In Anderson's 1951 book (Anderson 1) the term used was 'accumulative strain' and it was defined as 'structural changes produced in tissues as a result of repeatedly performing the same type of work'.

Harmful movements - says Anderson - are those where muscles are subject to excessive tensions and the result is a reduction in their natural elasticity and sensitivity. Elsewhere he states that: 'The structure of healthy tissues is influenced by regular functional demands. Fibrous tissue in muscles which habitually perform static work tends to increase at the expense of contractile muscular tissue'. Thus muscles which rhythmically contract and relax become more vascular while the muscle fibres become full and more sensitive: 'muscles, connective tissue and skin which are never stretched lose their elasticity'. (Anderson 1)

Human Kinetics courses explain the role of muscle connective tissue in producing cumulative strain in the following fashion - (Anderson 45).

'The muscle fibres are supported in a connective tissue framework and the muscle as a whole is enclosed in a connective tissue sheath. This connective tissue, by means of which the muscles are attached to the bones they operate, should have certain elastic properties which allow for the expansion of the muscle fibres when they contract. Its main function is to maintain a certain degree of tension between the parts it supports. If the normal tension is consistently reduced it will shorten to re-establish the tension, but if the tension is excessive consistently it will stretch. If the muscles are not stretched and expanded consistently the connective tissue will lose its capacity for stretching, so that it will then resist both elongation and expansion of the muscle fibres.

When the muscle fibres are constantly in a state of excessive contraction the connective tissue will shorten to relieve the muscle fibres of the load they carry.

Any shortening of the connective tissue reduces the circulation in the muscle, makes the muscle more easily tired and increases the risk of injury.'

5.4 MOVEMENTS AND CUMULATIVE STRAIN

Anderson believes that all movements performed in the upright position can be divided into two groups; they are either 'top-heavy' or 'base' movements. Top heavy movements are defined as those beginning by the bending of the head, upper trunk, and upper limbs, so that the lower limbs and back stiffen to prevent the body falling over. They lead to staccato movements which concentrate stresses in the shoulders, neck and lower back. (Anderson 5)

In contrast to this initial stiffening of the lower limbs a base movement begins by relaxation of the lower limbs so that one foot can move reflexly to safeguard balance. (Anderson 5)

Andersons' explanation for the development of top heavy movements begins with the neonate and states that -

'When a baby touches an object with its hands the gripping muscles contract and it automatically brings its hands towards the mouth. In a short time this pattern of action becomes associated with vision so that looking at an object also results in the tendency to contract flexor muscles all over the body. What a child sees it wants to touch and what it touches it wants to taste so that looking and gripping become associated with the contraction of flexor muscles in different parts of the body.'

The theory continues that -

'When a child begins to walk, this tendency to double up still operates and conflicts with the instinctive desire to maintain the upright position. Because kinaesthetic sense is not yet developed, a child has to regulate the placing of its feet during early efforts at walking by watching them. (Thus starting a top heavy movement.)

When looking down the flexor muscles contract so that the child becomes unbalanced and tends to fall forward. This gives rise to excessive pressure on the toes, so that the bending muscles of the feet and calves contract automatically and suddenly increased pressure on the toes causes the child to fall backwards. The child thus reinforces the earlier links between vision and flexor muscle activity with a linking of balance and flexor muscle activity.' (Anderson 29)

Whatever the truth of the development of top heavy movement patterns there can be little doubt of their prevalence. Later sections of the thesis (see 12.6) examine this problem more methodically but for now figure 12 is included to illustrate what is meant by 'top heavy' and to demonstrate that such patterns exist. The illustration was made by accurately tracing the outlines of subjects on a video monitor with the frame stopped. The drawings were then photo reduced and combined. They show 18 subjects from one of the ROSPA course assessments about to lift a box. The replay was frozen in each case just as they entered camera shot and they are all at least four paces away from the box. However in the majority of them their head and hands are already moving down towards the box. They are top heavy. Such movement patterns, says Anderson, are one source of excess static muscular work, arising from the need to keep the top heavy posture established. There is evidence to support this link. Carlsoo (1961) used an electro myographic study to show that even the slightest forward inclination of the head and trunk produces high static activity in the neck, sacrospinalis and ischio-crural muscles.

Apart from transforming movement patterns from top heavy to base there are other techniques used in Human Kinetics to minimise needless static muscular work and thus cumulative strain. They are concerned with the efficient stablisation of limbs for transmitting forces, the diffusion of movements over a number of joints, and the use of the appropriate muscles for performing movements or doing work that is essentially postural. Appendix 3 gives the answers to a

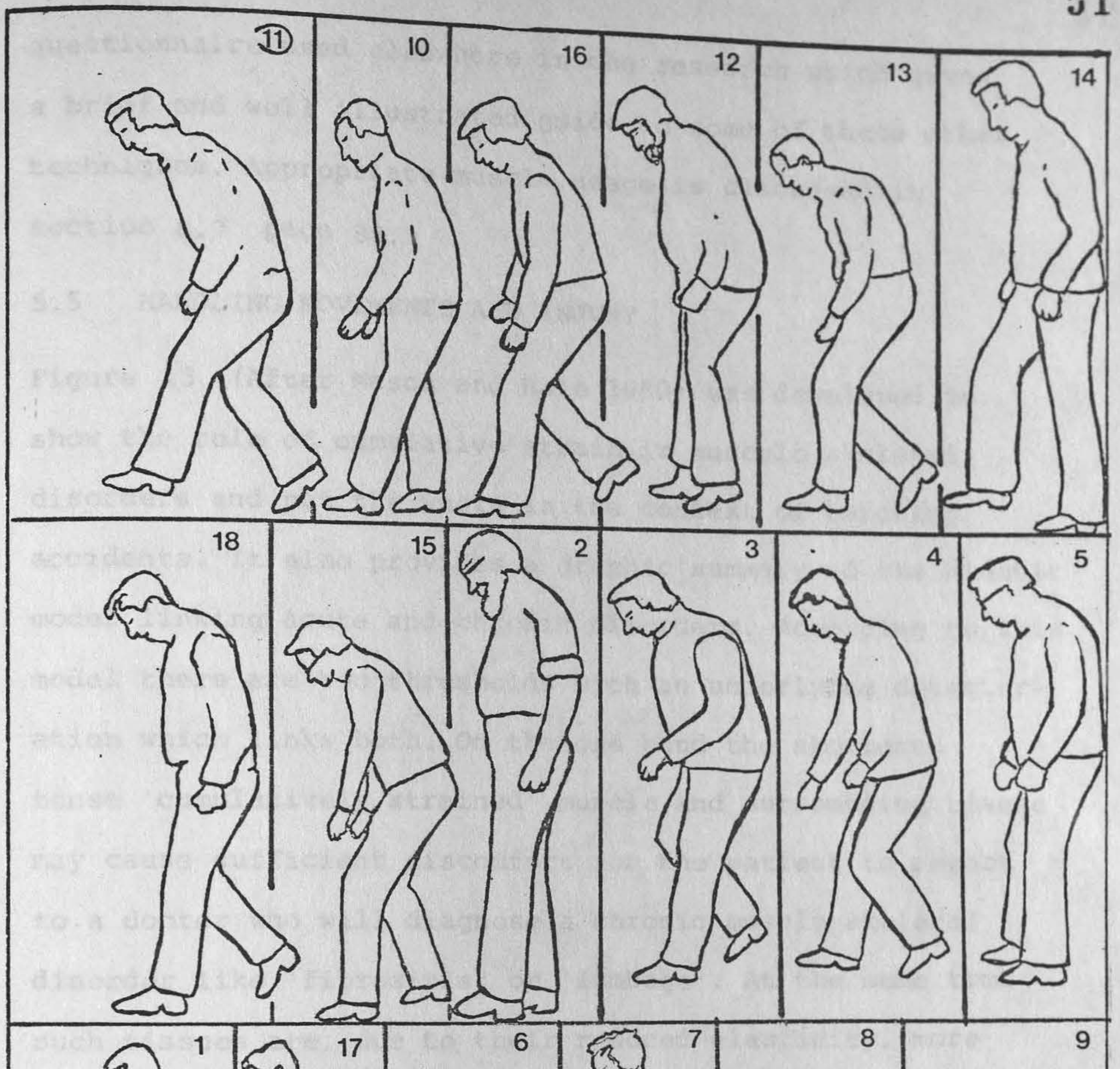


Figure 12: Eighteen subjects from one RoSPA course showing 'top heavy' movement as they move into camera shot. (The number in the top right of each frame is merely a subject identification number.)

questionnaire used elsewhere in the research which gives a brief and well illustrated guide to some of these other techniques. Appropriate muscle usage is discussed in section 6.7 page 83.

5.5 HANDLING MOVEMENTS AND INJURY

Figure 13 (After Mason and Hale 1980) was developed to show the role of cumulative strain in musculo skeletal disorders and put the whole in the context of handling accidents. It also provides a graphic summary of the kinetic model linking acute and chronic disorders. According to this model there are two thresholds with an underlying deterioration which links both. On the one hand the shortened tense 'cumulatively strained' muscle and surrounding tissue may cause sufficient discomfort for the patient to report to a doctor who will diagnose a chronic musclo skeletal disorder like 'fibrositis' or 'lumbago'. At the same time such tissues are, due to their reduced elasticity, more likely to suffer an acute tear, sprain, or strain.
Anderson's kinetic model maintains that the effects of cumulative strain are reversible, up to a point. Elasticity can be returned. The treatments advocated by Anderson to do this are not controversial and embrace many techniques currently employed by physiotherapists. They include gentle massage to reduce 'musculo fibrous spasticity', specific gentle stretching exercises and instruction to counteract faulty movement patterns or postures. (Anderson 2) They will not be the subject of any further discussion, as this thesis concentrates on the causes and prevention of cumulative strain, not its treatment.

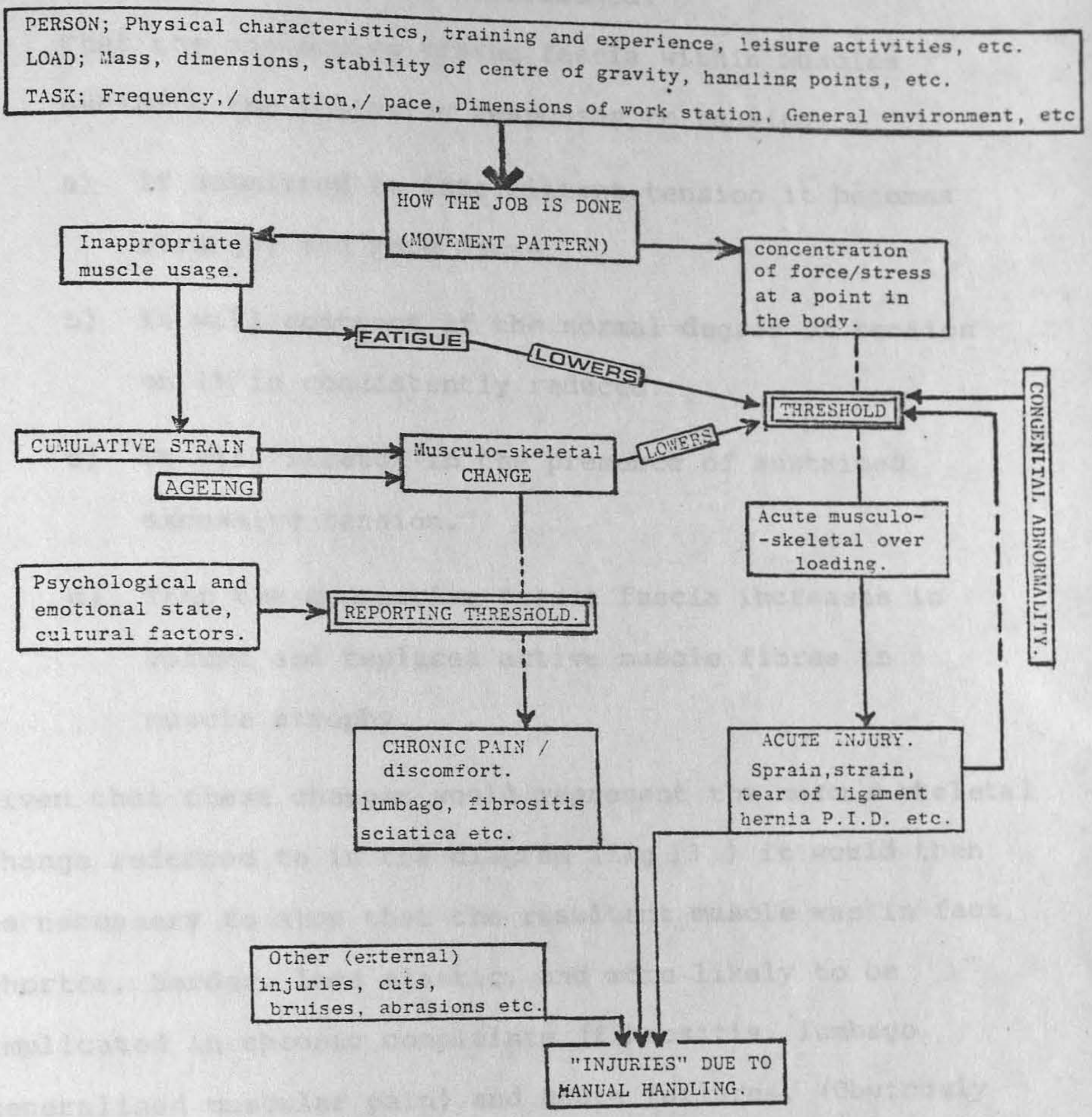


Figure 13: Diagrammatic representation - A model which links handling tasks to injuries (acute and chronic) via the 'mechanism' of cumulative strain.

In order to prove the notion of cumulative strain the following would have to be established:

That the connective tissue fascia within muscles exhibits the following responses to tension;

a) If submitted to intermittent tension it becomes stronger and more dense.

b) It will contract if the normal degree of tension on it is consistently reduced.

c) It will stretch in the presence of sustained excessive tension.

d) That the connective tissue fascia increases in volume and replaces active muscle fibres in muscle atrophy.

Given that these changes would represent the musculo skeletal change referred to in the diagram (fig 13) it would then be necessary to show that the resultant muscle was in fact, shorter, harder, less elastic, and more likely to be implicated in chronic complaints (fibrositis, lumbago, generalised muscular pain) and acute failures. (Obviously other fibrous connective tissue in tendons, ligaments, cartilage and even scar tissue would also be involved in the latter group.)

In the sections which follow the results of a literature review to examine the extent to which current knowledge supports or refutes the notion of cumulative strain is reported.

It should be stated in advance that although in many cases the evidence falls short of a complete justification for cumulative strain I could not find any papers supporting a counter argument. In other words there was no evidence that:

(i) Occupational movements involving excessive or sustained static muscular work are beneficial

(ii) Muscle function and connective tissue morphology are unrelated.

(iii) Literature supporting the inverse argument of propositions a - d (above) exists.

The links referred to in statements (a), (b) and (c) are difficult to verify directly from the available literature. In vivo studies, or in vitro studies of connective tissues are rare.

However findings which shed light on some of the crucial stages in the model of cumulative strain and its role in the aetiology of musculo skeletal pathology were identified in the literature.

5.6 HEADINGS FOR REVIEW OF FINDINGS

The findings are reviewed under the following broad headings

(i) Acute and chronic musculo skeletal disorders.

(ii) Musculo skeletal disorders and working posture(s)

(iii) Characteristic postures and connective tissue.

(iv) Flexibility and connective tissue.

(v) Human Kinetics and static muscular work.

(vii) Human Kinetics and muscle 'types'.

(viii) Review of sections (i) - (vii).

CHAPTER 6: CRITICAL EXAMINATION OF HUMAN KINETICS - THE LITERATURE

6.1 ACUTE AND CHRONIC MUSCULO-SKELETAL DISORDERS

The view that musculo-skeletal pathology can be divided into acute and chronic complaints is commonplace. Noro (1967) divided the health effects of muscular work into acute and chronic influences. The former including common sprains to muscles and joints and the latter included 'stress diseases'- deformities in vertebrae or in other bones as well as myalgias or myosites. He also included degenerative changes in tissues which are often rather far advanced by the age of 45 or 50. He classed pains in the lower back, ischialgias and lumbago in this category. Jackson (1968) examined musculo-skeletal injury in dockers. His model of injury suggests two groups of pathological conditions (i) those in which long-term effects of load handling are super imposed upon other factors and contribute to, or are associated with the degenerative conditions of the musculo skeletal system and (ii) those in which the forces of insult are greater and produce immediate effects of acute trauma and industrial injury.

He quotes case histories from an orthopaedic surgeon to support this view. However it is not clear from the model, or case histories, whether the degenerative changes are 'normal' ones associated with ageing or are from some other cause.

Similar observations have been made by sports medicine workers. Kottke, Professor of physical medicine at the University of Minnesota Medical School (Kottke 1961) stated that injury to the low back may be due either to a sudden extreme force which exceeds the compressive strength of bone or the tensile strength of ligaments and connective tissue, or to a prolonged stress which stretches ligaments and connective tissue and causes pain.

However, reviews that support a link between chronic deterioration and acute trauma are rare. Vorobiev, the USSR team physician, reviewed musculo-skeletal injuries in his athletes and concluded that not only acute but also chronic injuries must be considered. 'The causes of acute injuries are chronic ones which pave the way for injury.' (Vorobiev 1977)

Van Wely (1970) came up with a continuum of musculo-skeletal disorders, similar in many respects to Anderson's, when he completed a factory based study which aimed to examine any links between poor working postures and musculo-skeletal disorders. He also pointed to some of the methodological problems inherent in examination of such links.

The main problem in Van Wely's view is how experiments or studies can be set up to get more information on the connections between the design of work and the health of workers. He rules out prospective experimentation on the grounds that it would be difficult to commit workers and production processes to remain unchanged for the probable time span of observation (up to 10 years). He also draws attention to the ethical problems of letting a worker carry on using a system of work which may be suspected of producing deleterious health effects.

His study examined musculo-skeletal problems in over 8,000 employees of a major electrical manufacturer. Drawing on the current knowledge regarding functional anatomy and muscle physiology he made a list of postures which either (i) involved a static load on the musculature (ii) overloaded muscles or tendons (iii) loaded joints in an uneven or unbalanced manner. He added to this list probable sites of pain, stiffness or other symtoms; this list is shown below as Fig 14.

Table: 'Bad postures' versus probable sites of symptoms

Bad postures	Probable site of pain or other symptoms
Standing (and particularly a pigeonfooted stance)	Feet, lumbar region
Sitting without lumbar support	Lumbar region
Sitting without support for the back	Erector spinae muscles
Sitting without good foot-rests of the correct height	Knee, legs and lumbar region
Sitting with elbows rested on a working surface that is too high	Trapezius, rhomboideus; and levator scapulae muscles
Upper arm hanging un-supported out of vertical	Shoulders, upper arms
Arms reaching upwards	Shoulders, upper arms
Head bent back	Cervical region
Trunk bent forward; stooping position	Lumbar region Erector spinae muscles
Lifting heavy weights with back bent forward	Lumbar region Erector spinae muscles
Any cramped position	The muscles involved
Maintenance of any joint in its extreme position	The joint involved

The working postures of any patients presenting to the works physiotherapy department with any of these symptoms were recorded. He then assessed the degree of correspondence between hypothesised links between posture and symptoms and what actually occurred in the factory.

Out of 50 patients studied he states that the hypothesised links were confirmed in 89% of the cases, on the basis of discovered connections between the posture adopted by a worker and the symptoms causing him to see a doctor. Van Wely went on to study a larger group of 300 patients, to see if it was possible to be more sophisticated about the nature of the links between postures and physical symptoms.

On the basis of this later study he divides the symptoms of musculo-skeletal distress following poor working posture into three groups (i) Minor short term effects; (ii) Major long term effects; (iii) Major short term effects. He states that there is a gradual transition from healthy people who develop superficial symptoms and lose them quickly after stopping the bad posture (group i) via patients who get syndromes after a long time of strain in a bad posture; (group ii) to patients in group (iii) who Van Wely classifies as having a 'decreased tolerance' to certain postures, mostly due to congenital or other pre-existing defects of the musculo-skeletal system.

On the basis of his study he draws up a list of ergonomic design criteria which includes the recommendation that muscles should be used for movement not fixation and static muscular work should be reduced.

Models of injury causation linking chronic and acute damage have caused considerable controversy in the United States. Hershenson (1979) discusses the legal implications of a

Californian compensation claim for chronic low back problems. This case set something of a precedent and formed the basis for many other claims collectively called Cumulative injury claims. The court stated that 'We think the proposition irrefutable that while a succession of slight injuries in the course of employment may not in themselves be disabling, their cumulative effect in work efforts may become a destructive force. The fact that a single but slight work strain may not be disabling does not destroy its causative effect, if in combination with other strains it produces a subsequent disability. The single strand when entwined with others make up the rope of causation.'

The insurers had naturally been keen to prove that cumulative injury is not particular to any employment or degenerative disease but is part of the normal ageing or 'wear and tear processes of daily life.'

6.2 MUSCULO-SKELETAL DISORDERS AND WORKING POSTURES

Evidence which demonstrates links between injury and movement patterns or working posture(s) is sparse.

Hadler (1977) stated that for generations medicine has assumed that many of the musculo-skeletal diseases encountered in industry are use-related but that the literature supporting these assumptions is almost entirely anecdotal.

Karhu et al (1974) agreed that the problem of identifying and classifying poor working postures is complicated, stating that scientific literature on ill effects of working postures is scant; well controlled epidemiological studies are few and present knowledge is mainly based on case reports and common sense. However a number of the theories advanced by Anderson can be wholly or partly corroborated by other workers. Anderson refers repeatedly to the role of muscle tension in producing problems. Tension has been implicated by many authors, indeed the current edition of the Penguin Medical Encyclopedia defines fibrositis as 'a vague but convenient term for ill defined pain in and around muscles' and says that faulty posture is an important factor in bringing on an attack as is sitting 'tensely' in any position.

Barlow (1955) examined more than 500 students and members of the armed forces, looking for postural defects. He does not define his criteria for inclusion in this category but he reports the results of a number of cases where selected subjects were successfully given postural re-education. He links faulty posture very closely with 'maldistributed tension' for example he shows a series of people who suffer from lateral curvature of the spine and using electromyography demonstrates that even when these people are sitting at rest one side of their erector spinae group is considerably more active than the other and is habitually tense. The patient is unaware of this fact. He reports a number of other cases where habitually tensed neck muscles led to postural deformity. He does not however advance any explanations regarding the cause of this excessive tension.

Le Bato (1971) addressed the question of whether school-children would benefit from being taught to recognise and control excess muscular tensions. He stated that

'A certain level of tension is required for efficient movement, but rigid contracture in the muscles may become habitual and can often lead to awkward, inaccurate movements. The performance of the movement patterns would entail a greater amount of energy than would normally be required, allowing fatigue to set in more quickly.

Kraus and Raab (1961) in their book 'Hypokinetic disease' develop ideas similar in many respects to Anderson. They discuss muscle tension and state that the ability of a muscle to relax and give up tension is missing in many patients they have treated and that this constant tension can lead to contracture of the muscle. 'This constant tension shortens muscles and deprives them of elasticity. Once this muscle tightness has reached a sufficiently high level, and lack of physical activity had weakened tense muscles, an acute muscle injury may be precipitated by a relatively minor stress.'

Their theories are based on observations made as Professors of Medicine, active in Physical Medicine and rehabilitation. They quote Tiegel (1956) as having shown that 'repeated tensing of a muscle results in loss of length in what he calls "Verkuerzungskontraktur' (contracture). Kraus and Raab's preferred term is 'adaptive shortening' and they report that it often leads to physical discomfort. 'Shortened, contracted muscle groups are predisposed to minor or major strains causing painful muscle spasm. Chronic tension results in tigethening and hardening of muscle groups'. The chronic conditions, they say, may often be diagnosed as fibrositis, myofibrositis or myofascitis. Many of their suggested treatments, like Anderon's, involve relaxation training, gentle stretching exercises, and reformed movement patterns designed to re-balance antagonistic muscle groups.

Kraus, completed a further study (Kraus 1964) which involved an evaluation of all the patients presenting to the Columbia Presbyterian Hospital with back pain. Each patient was evaluated by a team of specialists including an orthopaedic surgeon, neurosurgeons, and specialists in physical medicine, rehabilitation, rheumatology and psychiatry. Over 9,000 patients were examined. Kraus and his team concluded that in over 80% of the cases no organic or mechanical cause could be found to explain the patients difficulties. The most obvious findings on examination of these patients were muscle deficiencies, namely weakness and stiffness of key postural muscles, general muscular tension and soft part tenderness, with muscle spasm in acute episodes. Many of these patients - says Kraus-showed a history of poor working posture, although it is not said how postures were deficient or how the information was collected.

Logan and Dunkelberg (1964) referred to the shortening of muscle tissue and connective tissue separately. Muscle tissue, they said, will adapt in length to habitually shortened positions if enough time is allowed for it to do so and they cite poliomyelitis as an example explaining that when the agonist has lost its innervation, the antagonist - because of its ability to shorten by active contraction - will eventually adapt to its shortest length if proper therapeutic exercise is not employed to maintain an adequate range of motion.

Referring to connective tissue they submit that if imbalances or poor postural habits are allowed to persist they may encourage adaptive shortening of connective tissues and once such shortening has occurred correcting the fault becomes more difficult. Stretching will be required before strength and endurance activities can become effective for the resumption of good alignment.

Thus Logan and Dunkelberg hold that body segments need to be constantly taken through their full range of motion. If movements requiring a limited range of movement are used habitually, some of the muscles surrounding a joint will shorten and a muscular imbalance develop.

The authors cite case histories of characteristic poor postures to illustrate their argument.

The theoretical standpoint that muscle tissue, and the connective tissue within it, may both be implicated in adaptive shortening via differing mechanisms has been postulated by other authors;

Hollingshead (1960) refers to neurogenic and fibrotic contracture

> 'An important factor in muscular imbalance is the fact that muscle fibers tend to so adjust their lengths (under the control of the nervous system) that they are exactly long enough, but no longer than is necessary, to bring about the range of movement ordinarily required of them. In order to retain their original lengths, they need to be stretched and made to contract over the total distance that they normally do.'

> 'Thus if a part is so bent that the muscle or muscles crossing it need to contract over half the distance that they ordinarily would have to, these muscles contract enough to take up the slack. The longer the part is kept in such a position, the more 'set' the muscle fibers become in this short, partially contracted condition, and the more difficult it will be

> later to stretch them back to their original lengths. Such shortening of muscle fibres which can become permanent, is known as neurogenic (because controlled by the nervous system) contracture.'

As an example of neurogenic contracture he cites the case of a finger which is splinted in pronounced flexion (in order to avoid tension on a tendon that has been cut and sutured).

The other type of contracture, fibrotic,

> 'occurs when muscles degenerate (as a result of being deprived of their blood supply or nerve supply). As the muscle fibres disappear they are replaced by inelastic fibrous connective tissue and as this grows older it shortens, producing, if it is not sufficiently resisted by normal muscles or braces, a contracture that is reversible only by surgical removal of the fibrotic tissue.
>
> '.........A paralysis, therefore, can result either in a neurogenic contracture of opposing muscles or in a fibrotic one of the paralyzed muscles.'

If this division into 'neurogenic' and 'fibrotic' is an accurate description of what happens it is probable that the contractures observed by some authors are a mixture of both. For instance Hajek et al (1947) drew on a range of examples to demonstrate that excessive and prolonged shortening of skeletal muscle is associated with changes in its properties whereby the muscle becomes set at a new length and fails to return to its original length during relaxation. They stated that this could occur during immobilisation in a shortened state by means of casts or other mechanical restraint, loss of normal stretching force due to paralysis of antagonist muscles or conditions such as tenotomy. They reported the results of an experiment to support their observations. This produced prolonged states of shortening in rat gastrocnemius muscle produced initially by tenotomy or by local injection of tetanus toxin.

The effect of movement patterns and habits on connective and muscular tissues is further complicated when the effects of ageing are considered. The elasticity of muscular tissue declines with age. Measurements based on determination of Young's modules for muscle removed from fresh corpses shows that the difference between a one year old and a seventy four year old is in the order of 80%. Muscle has also been shown to have a greater resistance to breakage in youth than in old age. 63% greater at one year than at 30 years and 53% greater at 30 years than at 74 years. Cureton (1941) uses these figures to support his argument that older persons are particularly susceptible to ruptured muscle fibres when exposed to sudden jerks, shocks, or when full range exercises are taken too forcibly. The question of how such a decline in elasticity may be modified by movement patterns remains unanswered in these measurements.

Billig and Loewendahl (1949) dealt with this problem by making separate reference to the contractile and elastic properties of connective tissue.

Billig a physical educationalist, and Loewendahl a physician who concentrated on industrial rehabilitation, produced a book which examined the role of connective tissue in determining the range of movement of body joints.

Their argument, supported by many hundreds of published case histories, is that the fascial ligamentous bands and their attachments play a principal role in the mobility of the human body. These structures have a tendency to shorten with advancing age and to become less flexible. Contractual shortening may be exacerbated by chronic bad posture, or poor postures commonly adopted at work. When excessive shortening occurs stiffness or immobility results. The reduction in mobility can be measured using a battery of tests the authors developed. The treatments used included a range of passive and active mobilisations. The main argument, at a mechanistic level, of these authors is that fascia has the quality of contractility as well as elasticity. The contractility persists throughout life but the elasticity decreases with age. Thus contractility will occur wherever the body lets it but elasticity has to be cultivated by regular conditioning and physical training.

In more recent investigations ergonomic studies have attempted to draw more direct links between work posture and musculo-skeletal disorders. The conclusions of several of these studies tend to support the Human Kinetic model of cumulative strain.

In Finland concern that repetitive movement in industry could be at the root of 35% of their compensated occupational disease led them to convene a special symposium. The aim was to collect papers which linked occupational movements to cervicobrachial syndromes (chronic musculo-skeletal disorders of the neck, shoulder and upper limb).

(Waris 1980; Kurpa et al 1979; Waris et al 1979; Kuorinka 1979; Luopajarvi et al 1979 and Videman et al 1979) The overall conclusions were vague, notably that there was a paucity of research linking work load in repetitive tasks and musculo-skeletal disorders. However, Waris (1980) notes that various cervicobrachial syndromes notably fibrositis, fibromyositis, myofascial syndrome, muscular rheumatism and tension myalgia have become so prevalent among office and factory workers whose work involves repetitive or static loading of the muscles involved that the syndrome (cervicobrachial myalgia) has been labelled an occupational cramp. He cites Ferguson (1971) and Maeda (1975) as evidence.

A special study in Japan by the 'Committee on Cervicobrachial disorder' stated that the disease is a functional and organic disorder due to muscular and mental fatigue in static and/or repetitive arm and hand work (Maeda 1977). The class of evidence that they considered is not clear and Waris (1980) concludes that the cause is speculative but that the most commonly proposed theory for the pathogenic mechanism involved focuses on localised muscle fatigue due to static sustained contraction. Interestingly Simons (1975) who reviewed pathological findings in cases of tension myalgia states that one of the cardinal features in many cases is a palpable hardening of the affected muscle group.

Anderson, whose work was based on observation of habitual posture and palpation of the muscles involved regarded palpable hardening as a symptom of the onset of chronic pathology.

Grandjean (1977) examined the premise that bad sitting and standing postures are sometimes accompanied by pains in muscles and connective tissues of tendons, joint capsules and ligaments which can become the symptoms of chronic diseases attributed to rheumatic disorders. He says that static muscular work will impair blood supply to the muscle and in a strong contraction the accumulation of waste products will cause acute pain. If the static load is repeated frequently and for long periods of time, chronic pains and troubles may result due to pathological changes in the muscles. To support this line of argument he cites earlier studies of his own (eg Grandjean 1968) which linked somatic troubles in shop girls to considerable static work load and Grandjean and Burandt (1962) which was a systematic study of sitting postures and somatic troubles.

Tichauer (1976) in producing his 'biomechanical profiles' made linked recordings of posture, movement, electromyography and subjective discomfort. He was able to show in some movements, notably on manipulative tasks involving the hands and arms that continued muscle tension in the muscles stablising the arms was a cause of great discomfort and fatigue. He was primarily concerned with finding the optimum ergonomic chair height for an operator doing this work. The excess stablising work and concomitant discomfort and fatigue increased as the angle between the upper arm and torso (determined by chair height) moved away from the optimum.

Onishi et al (1973) took the link between fatigue and discomfort a stage further (albeit in a very loose manner) when they reported a study of fatigue in operators of computer terminals. Using questionnaire techniques and body mapping to collect location and intensity of subjective discomfort they demonstrated that a great many operators of the terminals studied suffered from local fatigue in the upper limb regions occasioned by consistent static loading of the affected muscles and further that in many cases the local fatigue developed into chronic disorders of the neck, shoulder and arm regions. However no figures were given to support the development of local fatigue into chronic disorders.

6.3 CHARACTERISTIC POSTURES AND CONNECTIVE TISSUE

In the last section (section ii) Barlow (1955) was quoted as linking habitually tensed neck muscles to a concomitant postural deformity. Findings like this suggest that any literature on characteristic postures may clarify the adaptability of connective tissue. Anderson stated that the 'tendency of the body to economise in energy expenditure by shortening and strengthening fibrous tissue to take the place of muscle fibres little used for movements can be demonstrated in many characteristic postures.' (Anderson 1)

Anderson also suggests that mechanisation in industry has resulted in less florid manifestations of such links. However when industrial conditions were more severe, at the turn of the century, Factory Inspectors commonly made similar observations;

Mr Seymour the Inspector for Preston reported in 1908 on children who carried cuts of cloth on one shoulder that;

'I enquired from the medical superintendent of schools in Preston as to whether any evil results ensue, and found that girls particularly were in many instances showing a tendancy to distortion to one side.'

Another Inspector Miss Pearson, in 1911 reported that;

'Workers continually employed on hand presses in tin box works tend, especially if the operator is above or below the normal height, to become crooked and that the effect is not noticeable when the operator is able to operate

the press alternately with the right and left hand'.
-both examples in (Mason 1977).

Examples such as these are legion in early reports. At a crude level they supply further anecdotal evidence to support the kinetic argument, but they do not constitute proof. It is always possible that people with deformities found a job which suited their anomaly.

However a shortening of muscular tissue has been demonstrated in many more contemporary examples of characteristic postures.

Scott (1963) notes that in women who wear high heels constantly the muscles of the ankle adjust themselves to this extended position of the foot; but the state of tonus may be the same as in another person accustomed to low heels. The difference is the development of a different resting length of the gastrocnemius and soleus: and with the shortening of the latter this process of change produces tension or stretching of the anterior ankle muscles.

Bourne (1960) noticed the same process. He said that the wearing of high heels even in men's shoes will allow the calf muscles to become permanently shortened with the result that full dorsiflexion of the foot can no longer be obtained.

Harrison Clarke (1975) reported a number of faulty postures involving hollow back or lumbar lordosis in which the curve of the lumbar spine is exaggerated, the pelvis tips down in front and the abdominal muscles, basic fixators of the trunk anteriorly become stretched, the abdomen protrudes, and the back muscles and posterior ligaments in the lumbar region are shortened and become tight.

Lowman (1948) in attempting to improve the posture of round shouldered patients attributed their problem to a faulty relationship between opponent muscle groups noting that they all had short tight pectorals as against weakened and overstretched rhomboids.

Goldthwait et al (1971) compared the shape of the thorax in a sample of patients with various postures and styles of using the respiratory muscles. They noted that people who habitually relaxed or failed to use the accessory muscles of respiration end up with a slumped chest 'which becomes fixed in that position.'

Floyd and Ward (1966) studied repetitive machine based tasks using photography and activity sampling techniques to record behaviour, anthropometric measures of the workers and machine dimensions. They note characteristic postures of workers which conform to their habitual working posture determined by the workstation dimensions. They speculate that in three cases, where the workers had been at the work station for 9½, 15½ and 16 years that working at these particular machines had been the major cause of the workers stooped postures; although they do make it clear that it is impossible to verify the link.

There is wide spread agreement that poor postures overstretch some muscles and ligaments and relax others allowing the shortened ones to contract and so further increasing the bad effect (eg Becket 1959) This 'vicious circle of causation' was also described by Kendall (1952) 'Muscles that are tight tend to pull the body segments to which they are attached out of line. Muscles that are weak allow deviation of the body segments by their lack of support.'

'...Just as initial weakness or tightness of muscles may cause faulty alignment, so faulty alignment may give rise to adaptive weakening or tightness. The appearance of the fault is the same in either case making it impossible to distinguish cause and effect in this regard to established postural faults.'

The ability of connective tissue to be modified in both directions (to contract or be lengthened) is evinced by the above review of characteristic postures. Many of the findings described relate to shortening of the tissues. A separate review was made of papers reporting changes in the positive direction, e.g. improvement in the range of joint flexibility via stretching and other exercises. This is reported in section (iv) below.

6.4 FLEXIBILITY AND CONNECTIVE TISSUE

Since connective tissue in the form of ligaments, tendons, and collagenous structures within muscles regulates and controls the extent of movement around a joint (Bourne 1960), one source of evidence regarding the ability of connective tissue to adapt to functional demands is to be found in sports medicine publications, and specifically in those concerned with flexibility (the normal ranges of movement to be found at various body articulations.).

That flexibility can be improved by a wide variety of static and ballistic stretching and exercise training techniques was demonstrated by de Vries (1962) in an experimental comparison of various yoga and ballistic techniques. He also cited six further studies by other authors to support the notion of modifiability of flexibility.

The philosophy underpinning the need for flexibility exercises was stated by Cureton (1941) as follows:

'It is common practice to give considerable flexibility work in body building and corrective classes. The assumption underlying this is that certain of the muscle groups become unduly shortened by being exercised in short static positions and with the opposing muscle groups poorly conditioned, the result is an imbalance of the muscular tensions for best posture. One method is to shorten up the weak antagonists, and this is usually done. The other approach is to stretch the shortened groups. The result should be better balance of the muscle tensions and better posture.'

Leighton (1956) attempted to establish some baseline data on the flexibility characteristics of males aged ten to eighteen years of age. He used a specially designed range of instruments to measure the ranges of flexion and extension for ten joints. He found that groups up to the age of sixteen were more or less homogeneous as far as the measured variables were concerned but that great variations occured after this age. He postulated that the diversity in the older group reflected different patterns of body movement because of varied occupations.

The notion that extensive and prolonged participation in physical activities which use characteristic repertoires of physical movement will result in the development of unique patterns of joint flexibility was examined by Harrison Clarke (1975).

He found that the results of eight experimental studies covering five sporting activities supported this contention. Each of the sports produced a specific pattern of joint flexibility which was homogenous for the participants, and contrasted with control groups. The dependent variables were joint flexibility patterns (ranges of movement) for thirty joint measurements.

These and similar findings have been used to link flexibility to acute injury in sporting activity.

Davis, Logan and McKinney (In Harrison-Clarke: Op.Cit.) postulate that there is an ideal or optimum range of flexibility for the prevention of injury. They suggest that extreme flexibility may predispose to injury of joints whereas restricted flexibility may result in the tearing of connective tissues.

Brown (1975) is critical of extreme flexibility and states that the range of motion which ballet and other dancers develop in some joints is above normal physiological limits and is acquired and maintained at high cost in over extended ligaments, which are weakened and repeatedly damaged.

In athletic circles it is now generally accepted that flexibility training via either static or ballistic stretching of muscle groups, has come to be appreciated as an aid to overall performance and as a protection againt muscle soreness and injury. (Schultz 1979) The team physician of a US university has the impression - albeit undocumented that athletes who stretch regularly have fewer muscle pulls and less soreness than those who do not. (Cooper 1977).

The ability of connective tissue to adapt to functional demands is shown clearly by this review of sports medicine publications which link joint flexibility to habitual patterns of movement involving stretching.

This concludes the sections which look at the relationship between connective tissue adaptability and movements or postures. The next section examines the literature available to form some mechanistic explanation for the behaviour of connective tissue.

6.5 PHYSIOLOGY OF CONNECTIVE TISSUE

The Human Kinetic model of cumulative strain is underpinned by the notion that connective (fibrous) tissue is adaptable to functional demands and that, in muscles which habitually perform static work, it will increase at the expense of contractile muscular tissue. A review of current knowledge of the physiology of connective tissues tends to substantiate this view, but falls short of proof.

Firstly connective tissue is not randomly distributed in muscles. The amount of connective tissue relative to muscle fibres is much greater in some muscles than in others a fact which largely explains why some cuts of meat are tougher than others. (Bourne 1960).

Second, that connective tissue can increase at the expense of muscular tissue has been known for a long time.

GRAYS ANATOMY OF 1913 stated that

'It often happens that when muscle fibres waste away their place is taken by fibrous and fatty tissue to such an extent that the affected muscles increase in volume, and actually appear to hypertrophy.

"Ossification" of muscular tissue as a result of repeated strain or injury is not infrequent.' .

In 1932 Capretta sent a questionnaire to 45 physiologists to canvass their views on the cause of a 'muscle bound' condition. He summarised their views as follows:

> 'The outstanding opinion seems to be that the condition of muscle bound is associated with hypertrophy, and is a condition of over growth or excessive development of the muscles. It is seen commonly when training is associated with severe muscular strain. The excessive development results in a condition of fibrosis resulting in a preponderance of fibrous linen in muscle bundles due to the amount of stress and strain to which the muscle is subject.' (Capretta 1932)

Given that increases in connective tissue may occur it remains to establish evidence regarding the conditions likely to precipitate an increase.

Suominen et al (1977) examined the role of connective tissue in the adaption of skeletal muscle to physical training. Using animal experiments they showed that biosynthesis of muscle collagen can be activated by experimental hypertrophy.

The authors took this finding a stage further and demonstrated an increased turnover in collagen in a group of old people exposed to a vigorous exercise programme. These findings showed the adaptability of muscle connective tissue even in old persons.

However these experiments were all concerned with muscle hypertrophy and the authors noted that little is known regarding the metabolism of collagen during skeletal muscle atrophy.

The same is true of Booth and Gould (1975) who reviewed the effect of training and disuse on connective tissue, quoting a series of experiments which showed that training can increase the breaking strength of both ligaments and tendons. Other experiments in their view demonstrate that the rates of synthesis and degradation of collagen can be altered by changes in the level of physical activity. Regarding the connective tissue present within muscle they report experiments which show an increase in collagen during hypertrophy. The only paper reporting on the role of collagen in disuse or atrophy was by Cooper (1972) who examined collagen synthesis during skeletal muscle atrophy and demonstrated that connective tissue will replace degenerating muscle fibres.

The nearest approximation to an explanatory mechanism which could explain connective tissue increase in muscles habitually performing static work comes from Pickup (1978) who made a review of the adaptive mechanisms of connective tissue to tensional stimuli which may result in pathogenic effects. His hypothesis is that habitual (Isometric) muscular tension provides a long term tensile stimulus for collagenous deposition in muscle. He further states that such a mechanism would be physiologically inconvenient because of restriction and replacement of functionally active tissue mass. It could also result in atrophy or deterioration of organic functioning at some distance from the site of collagenous deposition by occlusion of blood and lymph vessels and impedance of neural transmission. Pickup states that such a mechanism would also explain the loss of muscle fibres in aging resulting from invasion by connective tissue (as shown by Edginton and Harkness: 1974).

He cites a list of experimental findings to support his hypothesis; notably that:

a) an adaptive response of connective tissue to mechanical stress has been repeatedly demonstrated in tissue cultures both in vitro and in vivo;

b) tension has been shown to have a direct effect upon the behaviour of fibroblasts, which multiply more rapidly and orientate themselves in parallel lines in the direction of the strain;

c) an increase in the rate of deposition of collagen is accompanied by orientation along the lines of stress in tissue;

d) increases in collagen density within muscle has been shown to be greater in muscles which are primarily postural and depending on the muscle group between 46 and 59% of the variation in collagen content is not associated with age.

These findings go a long way towards an explanatory basis for the Human Kinetic model of cumulative strain. The notion that tension directly affects the behaviour of fibroblasts is an interesting one and the nearest approach I have seen for explaining some of the properties of connective tissue. However the problem remains of extrapolating from an in vitro finding to a more perfectly formed theory which can look at the actions performed and the mode of use of a muscle and link these to a fully explained intra muscular pathology.

The final two sections of the this chapter (vi and vii: below) look at the justification for Human Kinetics from a separate but compatible view point which concentrates on the type of muscular action rather than on pathology.

6.6 HUMAN KINETICS AND STATIC MUSCULAR WORK

Anderson refers to static muscular work as the most 'expensive' form of muscle work. (Anderson 5)

Even if the concept of cumulative strain proved fruitless, or impossible to demonstrate, it seems likely that Human Kinetic teaching could be justified on the grounds that kinetic movements reduce needless static muscle work and that this alone would reduce fatigue and possibly injury. The link between static (isometric) muscle work and fatigue has been amply demonstrated.

Gaskell (1877) was the first to describe the relationship between muscular activity and the blood flow to the active fibres. He described the mechanical constriction of the blood vessels by the compression of the contracting fibres and thus supplied the information necessary to show why static effort fatigues more readily than rhythmic exercise. In 1919 Lindhard claimed that occlusion of blood flow through muscles involved in static work was a crucial factor in fatigue, due to accumulation of waste products.

Atzler et al (1925) suggested that the static component is an important determinant of fatigue in moderately heavy dynamic work, and today it is generally accepted that a continuous static contraction (such as when holding an object or maintaining a particular posture) impedes blood flow, thus generally inducing muscle fatigue earlier than dynamic contractions. (Chaffin 1969)

Experimental evidence to support this view has come from many sources

Rohmert (1966) in a paper which examines relaxation time in industrial operations states that static muscular work and one sided muscular work of small muscle groups are important determinants of fatigue and supplies measures of pulse rate as evidence. Armstrong et al (1980) also demonstrated that circulatory responses associated with static work are more stressful than those encountered in dynamic work.

Comparing static and dynamic contractions Simonson (1978) made the point that while isolated static performance is possible, isolated dynamic work performance is not. Maintenance of posture and stabilisation of parts of the body by muscle groups not directly involved in movements is necessary; consequently there is no dynamic work without some static component. (Simonson 1978)

Given that the static component of a dynamic action, or the magnitude of an isolated static contraction is variable, there have been measurements made of the static tension necessary to totally occlude peripheral intramuscular circulation.

Barnes (1980) reported an experimental study designed to quantify the relationship between maximum isometric strength and intramuscular circulatory occlusion.

He concluded that at static tensions corresponding to approximately 35kg, intramuscular occlusion occurs in all individuals regardless of maximum strength. He postulates that this finding may have important implications for the design of manual tasks requiring sustained isometric contractions.

Given the nature of the links between static muscular work and fatigue there have been attempts to draw conclusions about the effects of working postures involving excess static muscular contractions.

A revised edition of the then Ministry of Labour and National Service Safety Pamphlet No 16 published in 1943 recommends that static muscular effort should as far as possible be eliminated. The reasons stated for this are that it is a costly and fatiguing form of work. It cites positions of the body where the centre of gravity falls outside the base of support as generating excess static muscular effort. It quotes studies by the Industrial Fatigue Research Board (Report 29) as the experimental basis of these views. The positions of the body cited as costly and fatiguing are exactly those labelled 'top-heavy' in kinetics nomenclature.

Chaffin (1973) examined localised muscle fatigue in a series of experiments and reviews conducted to provide base line data for ergonomic work station design. He showed via EMG studies of increased muscle tremor and collection of subjective measures of discomfort that prolonged static muscular work stabilising the arms and hands for precision operations led to considerable local discomfort.

Other researchers have taken similar techniques of measurement out into the factory. Ortengren et al (1975) studied localised muscle fatigue on a car assembly line. They were able to isolate a number of tasks involving 'strenuous postures'. These were ones in which certain muscle groups were under constant static load for up to a minute at a time. The authors were able to link worker-assessed feelings of subjective heaviness of work with electromyographic measures for fatigue for the affected muscles.

The circulatory responses associated with static muscular work have led it to be implicated in chronic complaints other than musculo-skeletal ones.

Jackson et al (1973) concluded from a literature review of other experimental work that angina pectoris would occur at lower work intensities for combined static and dynamic work than those for pure dynamic work; they suggested that static work associated with carrying a suitcase is a major factor in so called 'airport angina'.

However the fact remains that some static muscular work is necessary in most movements. The axes of movement of limbs and the attachments of muscles must all be stabilised. A skilful action will, according to kinetic criteria, keep such work to the absolute minimum. One of the means employed to do this is via kinetic movements which use muscle groups to perform the type of work for which they are best adapted. This is discussed below.

6.7 HUMAN KINETICS AND MUSCLE TYPES

Innappropriate muscle usage can arise in a number of ways. In Anderson's 1951 book (Anderson 1) he introduces Kinetics with a first chapter on muscle tissue.

In this he states that

> 'some muscles fibres are red in colour and others white. The red fibres contract more slowly and are capable of a more sustained contraction than the white fibres. The red fibres contain greater quantities of the muscle haemoglobin (myoglobin) which stores oxygen and so facilitates sustained contraction.' 'Most skeletal muscles contain both red and white fibres, but in some red fibres predominate, while white fibres predominate in others.' 'It has been the habit of the writer (Anderson) to consider red muscles as "postural" muscles and white muscles as "active", the former being deeper and essentially concerned with the stabilization of joints and the latter left free for performing actions.'

On the basis of the above distinction Human Kinetics seeks to use surface and deeper muscles appropriately, postulating that long periods of stabilizing static work from large muscle groups would constitute inappropriate usage and lead to cumulative strain.

The observations which were the foundations for these suggestions were prevalent, long before Anderson published. Ranvier (1873) reported experimental work showing that 'red' and 'white' muscles contracted at different speeds, and the edition of Gray's Anatomy in circulation when Anderson was writing his book stated that in man and other vertebrates both pale and red fibres are predominant in all the voluntary muscles, but in varying proportions. Gray's estimated that in some muscles e.g. the gastrocnemius, the pale fibres predominate, while in others e.g. the soleus the red fibres are in the majority, and suggested that the former are mainly concerned with the initiation and performance of movements, while the latter are mainly concerned with posture. (Gray's Anatomy 1949)

Another respected text book of anatomy of that period agreed with this view, adding that the deeper heads of muscle have more of the slow fibres but it expressed the view that 'there is no such thing as a purely postural muscle in man' (Cunninghams textbook of Anatomy 1951).

More recent editions of Gray's are more definite, but add very little to the earlier editions. The 1972 edition again described the two types of fibre, repeating the observations about the gastrocnemius and soleus and stating that white fibres have a higher metabolic rate and are capable of more rapid contraction, while red fibres are capable of more sustained activity and are mainly concerned with the maintenance of posture. The same edition also notes with interest the observation that in the quadriceps extensor group of the thigh the vastus lateralis has been shown to possess a relatively high content of red fibres although the vastus medialis is composed mainly of pale fibres, suggesting that a high proportion of red fibres in one constituent muscle of a group is sufficient to cover the requirements of postural movements and maintenance.

Current nomenclature holds that the two main types of muscle fibres known to exist in human skeletal are slow twitch muscle fibres (ST) also called Type I fibres, and fast twitch muscle fibres (FT) also called Type II fibres. This nomenclature is almost identical to the old one which was related to the terms 'red' and 'white' muscles respectively. (Karlsson and Sjodin 1977)

The same authors suggest that the fast twitch muscle fibre population contains three sub groups FTa, FTb, FTc, which can be histologically differentiated by staining myofibrillar ATP ase.

In agreement with earlier experiments they demonstrated that the FT fibre population has a greater capacity for energy metabolism per unit of time than the ST fibre population. On the other hand, the oxidative processes are more efficient users of the chemically stored energy of the carbonhydrate metabolites and ST fibres are therefore more suitable for prolonged exertion. Moreover they note that there are differences in the capillary network surrounding the two main fibre types in human skeletal muscle, more capillaries being found around ST fibres than around FT fibres.

Despite this agreement on the existence of different muscle types, a taxonomy of which muscles are predominantly 'active' and which 'postural' has never been developed and could be troublesome given that composition may change with habitual activity.

Barnard et al (1970) showed that white fibres can be transformed into red fibres as a direct result of physical activity. Their study involved guinea pigs, and specific muscle groups were trained in treadmill running tasks. The gastrocnemius became a 'redder' muscle after 18 weeks of training.

Fugl Meyer (1977) did a muscle biopsy study, on human corpses in order to try and find out whether asymmetrical muscle fibre composition can occur in the adult male. He found that muscles with stereotyped and often repeated postural demands are relatively rich in ATP -ase- high fibres. Furthermore, side to side differences in fibre composition may occur if the postural demands are asymmetrical.

Although it is not clear on what basis he assessed postural demands his general observation has been confirmed by other workers, especially in the sphere of sports medicine.

Gollnick et al (1980) reviewed the effects of various types of athletic training on muscle fibre populations and noted that fibres are to a degree interconvertible. Fast twitch a fibres can change into fast twitch b fibres with endurance training, cessation of training reversing the process.

Similar observations which show that world-class athletes appear to have percentages of muscle fibre types favourable to their events (McCafferty et al 1977) have sparked something of a nature vs nurture controversy in the sports medicine literature.

Taking all of these morphological studies together it seems likely that some muscles are more suited to postural work than others by nature of their fibre composition but that nobody has yet produced a map of average fibre types for human musculature, and that the composition of a given muscle may change over time.

6.8 SUMMARY AND CONCLUSIONS

The role of static muscular work in a model of muscle pathology which links it to chronic and acute failures via the mechanism of cumulative strain (fig 13) was found to be well supported in the literature. This may fall short of proof in the absence of a cause (movement patterns: muscle usage) and effect (changes in tissues at a molecular or cellular level) mechanism.

The evaluation of such links is hampered by imperfectly formed explanations at many levels. The terms used by the medical profession to label chronic musculo-skeletal disorders are almost meaningless (fibrositis: lumbago etc) and as other sections of this thesis show the terms used by ergonomists and physiologists to label types of movement are also vague.

However the broad range of observations covering degenerative conditions of the musculo-skeletal system; muscle atrophy and hypertrophy; characteristic postures and the role of tension and contracture or lengthening of connective tissue support the statements (a) - (d) made in the introduction.

The connective tissue fascia in muscles will become stronger and more dense if submitted to intermittent tension; will contract if the normal degree of tension on it is reduced; will stretch in the presence of sustained excessive tension and will increase in volume and replace active muscle fibres in muscle atrophy.

A possible addition to the theory of cumulative strain which was identified in the literature is the notion that shortening of muscle groups may involve 'neurogenic' as well as 'fibrotic' contracture. That is the shortening may also result from a central rather than peripheral effect and the nervous system will adjust a muscle to a new and shortened resting length.

In summary Anderson's theory stands up well to the critical examination presented here.

CHAPTER 7: THE LANGUAGE AND CONCEPTS OF TRAINING IN MOVEMENT

7.1 INTRODUCTION

In the year 1974 there was a debate within British Rail regarding the suitability of Kinetics training for employees. I was fortunate to be given copies of all correspondence relating to this debate.

In one letter from the then (December 1973) Group Medical Officer for the BR Board he is broadly critical of Anderson's need to provide definitions for many of the concepts and movements used in kinetics teaching. 'How much better' he says 'to use simple, uncompromising language such as 'STAND FIRMLY', 'KEEP YOUR BACK STRAIGHT', 'BEND THE KNEES'.

This theme is returned to in a later letter from the BR London Midland Regional Accident Prevention Officer to ROSPA (April 1974) where he says:

'In order to teach relatively uneducated manual workers, at whom the BR Lifting drill card is aimed, it is necessary to stick to simple words which do not need special definition.'

In the section which follows there is a review of some of the language, terms, and possible sources of confusion which have been identified in training literature.

The possible misinterpretations of some of these terms will be examined further in Sections 10.3 and 11.5.1.

7.2 REVIEW OF LANGUAGE, TERMS AND POSSIBLE SOURCES OF CONFUSION

Current wisdom holds that:

> 'there appear to be two basis positions adopted for lifting objects from a low level, the stooping position in which the legs are relatively straight and the trunk horizontal, and the flexed knee position in which the legs are bent at the knee and the trunk is held in a more vertical position.' (Jackson 1968)

It is normally assumed that the stooping position is the way that a worker will attempt to lift unless converted to a 'flexed knee position'.

Glover and Davies (1961) demonstrate the stoop position as an example of bad lifting saying 'this is generally accepted as the normal method of picking up an object from the floor'; a better method of lifting the box is what they call the 'sit down' position.

I assume that the 'sit down' of Glover and Davies is the same lift as the 'flexed knee' of Jackson.

As the following review demonstrates I found the stoop referred to as; bent back; stooping; cantilever lift; derrick lift; and a number 7 lift.

Synonyms for flexed knee lifting included: straight back; squatting; jacking action; with the 'spinal jib' vertical; the pelvic tilt position; knee action; Number 4 position and finally lifting with the back 'in its normal curved position'.

It was clear from talking to people on the shop floor that one source of their confusion was the conflict between the current wisdom of today and the myths which are prevalent in factories largely based upon yesteryears 'simple advice'.

Wisdom, current in the twenties, held that a narrow stance was vital to prevent rupture.

The Engineering and Allied Employers National Federation published a series of booklets in the twenties called 'Safety Instructions for Fitters, Assemblers and Mill-wrights'. In booklet No 6, instructions are given for lifting.

> 'If you have to lift a heavy weight from the floor, do so with your legs together and obtain leverage from your knees. By this means you will reduce the risk of a rupture or strained back.'

The need for a narrow stance was still being stressed twenty years later. Tugman (1943) advised;

> 'Lifting a package from the floor should be done by placing the feet flat on the ground, heels fairly close together, bending the knees, keeping the back straight and then taking a firm grip with the hands. Keeping the back straight, the knees are straightened and the lift accomplished. A wide stance is dangerous, and wherever possible the arms should be outside the knees..'

In the same year the then Ministry of Labour and National Insurance published a guide to lifting (Great Britain 1943).

Readers were directed to note that desirability of the 'narrow, firm stance' in the following illustration.

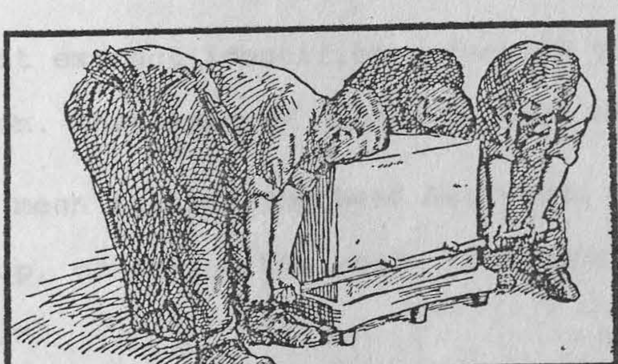


Figure 15: An illustration of "desirable" lifting postures circa 1943.

Although more contemporary examples of simple lifting advice may stress bending the knees, for some the older notion of a 'firm narrow stance' seems hard to dispel.

On a television programme called 'Mr Smith's Rock Garden' (Transmitted on Wednesday 12th March 1980 at 19.15 hrs) the narrator stated 'Bend your knees and keep your feet close together and you won't do any harm lifting rocks for your rockery'. (Despite this he lifted every rock with straight legs, feet apart and stooped from the waist.)

Other more recent advice tends not to mention the positioning of the feet, but concentrates on the knees and back; eg the following from New Scientist:

> 'If you want to lift a heavy object you should hold it as close to you as possible and bend your knees, rather than your back before taking the strain'. (Eagle 1979)

It is commonly recommended that the back should be kept vertical as shown by McFarland (1969):

> 'Leg lift with back vertical and knees bent affords a stronger vertical pull than back lift and entails much less risk of injury.'

Osman (1976) writing in the Sunday Times advocated 'lifting a load with the spine vertical and the head back'.

This last extract identifies a further potential area of confusion. What exactly does 'the head back' mean?

Does it mean tilting the head backwards with your chin moving up, or moving the whole head back keeping the chin tucked in?

The two following descriptions by Kerr (1979) and Poulsen and Jorgensen (1971) respectively, show further scope for misconceptions;

(i) 'To lift a load in the correct manner, the back and arms should be held straight to avoid strain. The knees should be bent to ensure that the strain of lifting is taken up by the thigh and leg muscles. Feet should be held apart and facing the direction of travel. Lifting loads in this manner will avoid straining the weak areas of the body. This technique is known as straight back lifting.'

(ii) 'Lifting a load from floor level to table height should be carried out by the so-called 'knee action technique' holding the burden as near to the body as possible while keeping the back in its normal curved position and performing the actual lifting by an extension of the legs.'

How do you 'hold' the back and arms straight? How straight should they be? How much should the knee be bent? How far are feet 'held apart'? and what is the 'direction of travel', is it the direction you approach the load or the direction you intend to go?; in fact which part of a foot 'faces' in any direction?

In the second case 'normal curved' is open to a number of interpretations; does it mean do nothing special?; or curve your back the way you would 'normally curve it'?

Problems like these have led some authors to resort to simple comparisons;

The Institute of Municipal Safety Officers Booklet 'Manual Lifting and Handling (1979) says Manual lifting is best achieved by bending the legs going down to the load and straightening them when taking the weight of the load in the form of a jacking action.'

Jackson (1968) opts for a similar ploy

'A dockworker who lifts a heavy load with the so called "cantilever" lift risks injury ... the dockworker should use his spinal jib as vertically as possible and adopt a different lifting action using his legs like a jack to lift his loaded body.'

Does this also mean opening the legs wide so that this form resembles a jack?

Simpson (1970) advocates emulating trained weight lifters who...

> 'use the powerful muscles of the legs and buttock. They rise from a squatting position, holding the upper part of the body erect and tense.'

The following example while ingenious was not accompanied by any form of illustration to clarify the postures;

> 'Poor lifting position is called the "7" position - because bending at the hips with the knees extended resembles the number seven. The weight should be lifted with the knee extensors rather than the back extensors and the starting position is called the "4" position because it resembles the number four. Many potential injuries can be avoided through proper lifting mechanics.' (Logan and Dunkelberg 1964)

King (1979) gets into trouble when he tries to clarify foot positions:

> 'To pick an object off the floor the knees should be bent not the back .... Lifting a large or fairly heavy object should be done by placing one foot on either side of it and slightly behind it (one foot slightly in front of the other) bending the knees and hip joint, not the back, and grasping the object with both hands. The object is lifted by straightening the knees and hip joint, still without bending the back.'

<u>The possibilities for misinterpretations increase as authors try to clarify particular concepts, as the following extracts show</u>;

> a) '- Always bend your knees...
> use your stomach muscles to keep the back straight and in the pelvic tilt position'. (Imrie: undated)
>
> b) For workers doing lifting we have two pieces of advice
>
> 1. When lifting or lowering straight ahead, align the feet. When turning, have the foot on the side opposite to the turn ahead
> 2. Don't be a jerk.' (Konz and Bhasin 1974)

> c) 'The knees should be flexed just beyond a right angle with the long axis of the vertebral column titled forward by 20 degrees.' (Perrott 1961)
>
> d) 'During the lifting operation the position of the head is important. As the object is being raised the chin should be brought down into a normal walking position.' (British Safety Council)

Sometimes the message is extremely simplified Miller (1977) developed a training programme for his industry which was based on the simple message

> 'Every time you bend over - bend your knees.'

However even these eight words tend to suggest - a stooping lift by using the words 'bend over'.

The reader may well feel he understands the nature of a stooping lift. In which case I challenge him to follow the recommendation in this extract taken from a Guardian Newspaper 'Special Report' on back trouble. The author John Beard quotes 'a leading surgeon' as saying

> 'It is a matter of balance. If you are lucky enough to have the correct strength in all your muscles, use them effectively and stoop rather than bend; you may then avoid back trouble.' (Beard 1976)

"One thing you have to admit about Simkins. He really *reads* those safety posters."

Figure 16: Cartoon - Source unknown. Draws attention vividly to the possible misunderstanding of the sort of language used in much training literature.

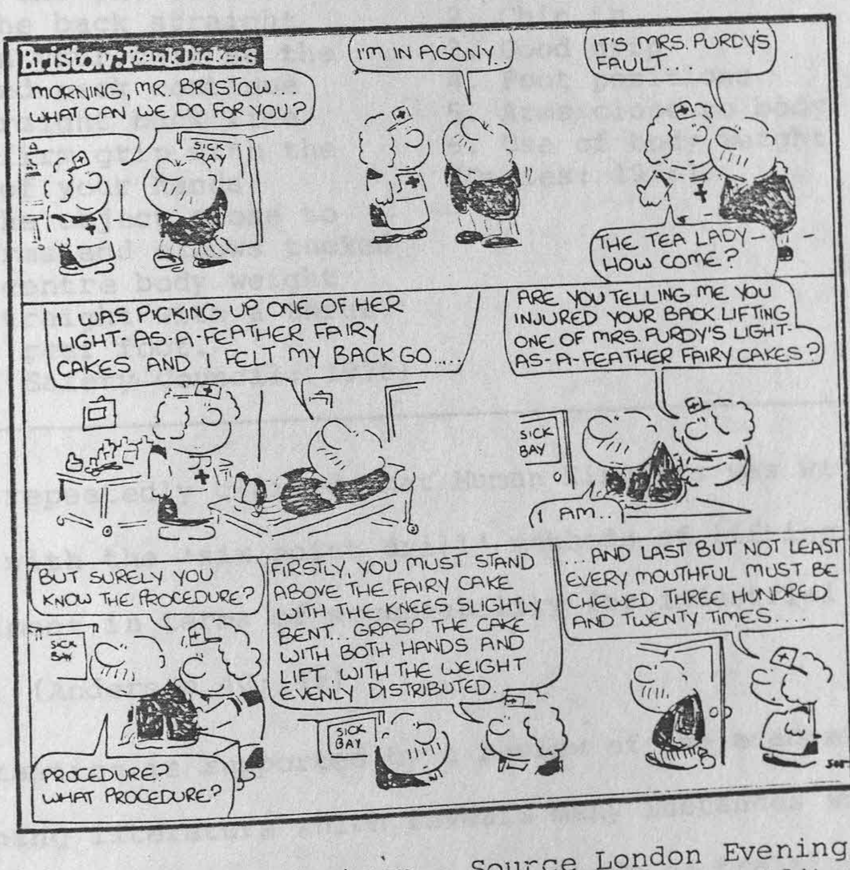


Figure 17: Cartoon - Source London Evening Standard. Draws attention to the 'rigidity' of much lifting training.

CHAPTER 8: HUMAN KINETICS AND THE 'SIX-POINT DRILL'

8.1 EXAMPLES OF THE DRILL

The kinetic method of lifting is described in detail on page 147. At other places I have referred to a simplified form of lift called the 'six point drill'. The reduction of lifting to a six point drill or 'the six key factors' is widespread in safety training literature. The six key points of the title are variously described as;

1. Correct position of feet
2. Straight back
3. Arms close to body
4. Correct Hold
5. Chin In
6. Use of body weight

(British Safety Council: Undated)

1. Proper Hold
2. Straight back
3. Chin in
4. Proper foot positions
5. Arms into body
6. Use of body weight

(Maxwell: 1957)
(also Peres: 1960)
(also Himbury: 1967)

1. Put one foot alongside the object and one behind
2. Keep the back straight
3. Tuck in your chin so the head and neck continue the straight back line
4. Get a firm grip with the palms of your hands
5. Draw the object close to you, arms and elbows tucked in to centre body weight
6. Lift straight with a thrust of the rear foot.

(National Safety Council: 1976)

1. Back Straight
2. Chin in
3. Good grip
4. Foot positions
5. Arms close to body
6. Use of body weight

(Davies: 1976)

Anderson repeatedly claimed that Human Kinetics was widely confused with the 'six point drill' methods of lifting to its detriment in terms of acceptability for industrial training. (Anderson 40; 45)

This contention is supported by a review of the academic and training literature which reveals many instances where six point drill or other simplistic methods of training have been wrongly labelled as Human Kinetics and attributed to Anderson.

The British Safety Council (Undated) state that the

> 'The kinetic method of lifting can be applied if strict attention is paid to a special proce-dure. This proce-dure can be divided into six parts.' They then reproduce the 'drill' shown above.

Peres (1960) produced a drill (also shown above) and said it represented the 'scientific lifting in the system of Human Kinetics initiated by Anderson'. The same labelling of drill factors as kinetic principles occurred in Himbury (1967); Brown (1972); Jones (1972). The Ceramics, Glass and Mineral Products Industry Training Board (Anon 1974) and the Home Office (Great Britain 1977). The six point drill lift and the Human Kinetic lift both lay emphasis on using a straight back for lifting.

8.2 JUSTIFICATION FOR USING A STRAIGHT BACK

Anderson's rationale for keeping the back straight at the moment a load is lifted is that the load-carrying efficiency of the back muscles is reduced by the flexibility of the spinal level upon which they operate. When the spinal column is flexed and has to be extended against strong resistance, the back muscles are more likely to suffer injury because they are simultaneously fulfilling two conflicting functions, first moving the spinal bones upon each other and second, trying to stabilise the spine so that it may act as an effective lever. Further he stated that in the flexed position the stresses imposed on the spine are transmitted through the inter vertaebral discs. Lifting with a straight back means that the extensor muscles of the back are essentially concerned in stabilising the spine and that stresses are transmitted more directly from bone to bone. (Anderson 1)

Kottke (1961) produces a similar argument and states that bending from the waist with the knees straight increases the stress on the lumbar spine, because the centre of gravity of the load and body combined falls well forward of the lumbosacral joint. In common with other authors he states that flexing at the hips with the knees straight and the arms hanging from the shoulders will produce a torque of over 600 inch pounds even though no additional weight is lifted.

Chaffin and Park (1973) also demonstrate how the torque at the lumbo sacral joint increases as the distance of the load from that joint increases.

The importance of this as stated by Perrot (1961) is that if the trunk is bent too far forwards or the knees not flexed sufficiently the resultant lifting position will increase the distance of the load from the lumbo sacral joint and the sacrospinalis muscles will act at considerable mechanical disadvantage.

8.3 THE DIFFERENCE BETWEEN A KINETIC AND A 'SIX POINT DRILL' STRAIGHT BACK

A factor common to six point drill lifts is the emphasis put on keeping a straight back which results in the instruction to adopt it at an early stage in the movement, and to maintain it throughout the movement.

As section 9.2 shows this means that considerable hyper flexion of the knees is required to reach under a load at floor level and very unstable postures can result.

In contrast, the kinetic method of lifting ensures that although the back is straight at the moment the load is taken up, it is allowed to flex in the stages of the lift immediately preceeding this, allowing the hands to reach under low loads in a posture which is both balanced and more comfortable for the knees. It would appear that this crucial difference arises from a problem which is well documented in the literature on part versus whole training when learning motor skills. Holding (1954) states that

> 'In most physical skills the dissection into parts must be approached with even greater caution, the risk being that one has the learner practice a part action which is qualitatively different from its counterpart in the whole activity'.

The 'six point drill' is clearly divided into discrete 'parts'.

The 'setting' of the back straight in the drill and keeping it that way throughout the entire lift is certainly qualitatively different to the straight back of the kinetic lift which is introduced only at the moment immediately preceeding the load being taken. In the kinetic action the back is straightened using a movement called the 'headlock' (described in detail on page 149). This subtle movement introduced at the appropriate stage in the movement has been translated in almost every example of the drill to the simple and misleading instruction to keep the 'chin in', often again throughout the entire lifting action. In other words the crucial sequential and interlinked actions of kinetics become in the drill discrete and overlapping units.

The problems arising from the considerable hyper flexion of the knees demanded by six point drill techniques are discussed below;

CHAPTER 9: PROBLEMS WITH ILLUSTRATIONS IN TRAINING LITERATURE

9.1 INTRODUCTION

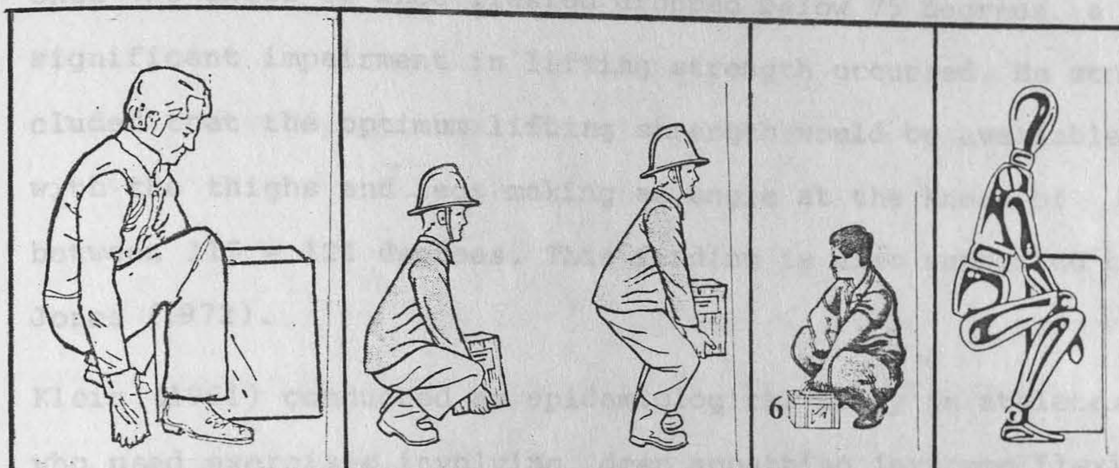
Whitney (1958) used the term 'derrick action' to describe a stooping lift. He remarked that although this type of lift was possible over a large range of grasp heights and foot placements a lift involving squatting is only possible for a particular subject over a quite restricted range of heights and placements. He states that in many cases of attempted knee actions the trunk cannot be kept erect, but must be inclined forwards. He also showed that when the trunk is bent forward in a stooping action the strain perceived in the hamstring tendons leads to a tendency for the subject to flex the knees slightly and relieve this strain. In practice therefore Whitney believed that actions which are intermediate between stooping and squatting are to be expected.

Despite these anatomical considerations which seem to preclude the back being kept erect and straight during lifting many training pamphlets and other articles giving instructions in 'correct' lifting ask the worker to do the impossible - namely to keep the back straight and vertical (erect), as the following review shows.

9.2 REVIEW OF EXAMPLES

In the illustrations shown below (fig 18) the following points are worth noting;

Fig (i) Note the degree of knee hyperflexion required for the hand to be able to reach floor level. The back is erect but a brief personal experiment will suffice to show the instability of this posture.



(i) Hayne (1974) | (ii) Great Britain (1977.b.) | (iii) Osman (1976) | (iv) Anon (1979)

Figure 18: Four illustrations of lifting action taken from the lifting literature.

Fig (ii) Again the posture shows knee hyperflexion and marked instability. The box is already shown slightly off the floor and one must seriously question whether the fireman could have reached under it using the method shown

Fig (iii) Taken from a colour transparency and showing that even with the knees at maximum flexion the lifter can only just reach the conveniently placed handle on the box.

Fig (v) Despite the considerable knee flexion the anthropometric model can only reach half way down the object handled.

These observations support Whitneys argument regarding the need to incline the trunk forward. This is necessary so that the hands can reach under the load. However a considerable degree of knee flexion is required even with a slightly inclined trunk.

A major criticism of attempting to lift with an erect straight back has been that, even if it did provide some measure of protection to the back, it would put other joints, notably the knee, at risk of damage, (Anderson 1) and would also be inefficient. On this last point, Carpenter (1938) in his experimental measurements of the power available from the legs when lifting at a range of angles of knee flexion showed that, once the angle of knee flexion dropped below 75 degrees, a significant impairment in lifting strength occurred. He concluded that the optimum lifting strength would be available with the thighs and legs making an angle at the knees of between 115 - 124 degrees. This finding is also supported by Jones (1972).

Klein (1961) conducted an epidemiological study in athletes who used exercises involving deep squatting (extreme flexion of the knee) to determine if such activity carried potential for harm. He concluded that such exercises caused instability of the knee ligaments with additional potential for damage to the knee cartilage.

Levine (1979) linked patellar cartilage degeneration to activities involving extreme flexion, particularly kneeling and squatting. Jesse (1979) demonstrated damage to the knee ligaments in a sample of professional weight lifters due - he said - to one particular style of lift involving extreme flexion of the knee.

Lowman and Young (1960) have postulated that hyper flexion of the knee may be implicated in chronic synovitis and the early onset of arthritic changes. In North America the National Federation of High School Athletic Associations and the Committee on the Medical Aspects of Sports of the American Medical Association have condemned exercises involving deep knee bends and squatting. (Harrison Clarke 1976)

Given that lifting techniques involving an erect straight back can be criticised on the grounds that hyperflexion of the knee produces a weaker and potentially harmful action the following review of illustrations found in training literature proved interesting:

The earlier illustrations shown in fig 18 can be criticised on the grounds that the actions shown appear clumsy, but the authors and illustrators have been accurate. The illustrations which follow have been taken from a review of training literature available internationally and show a number of ploys which have been used to circumvent the fact that a human being of average dimensions cannot keep a straight erect back, keep the angle formed between their thigh and leg greater than a right angle and still manage to reach under a load at floor level. (Pages 107-9)

A number of incidental criticisms are also included in the comments where it seems that the topic discussed could have led to the value of the training being eroded.

a) In a number of the cases illustrated the object lifted has already left the ground (pictures 1, 2, 3, 5, 10 and 12). This obviates the need to illustrate the preceeding stage of the lift, where the lifter was at the lowest point and had to reach under the load. The preceeding stage would have to have shown much more acutely flexed knees or a more inclined back (or both). In addition to this general comment the drum in picture 1 is shown hovering in the air.

b) A second way round the problem has been to illustrate an object with conveniently placed handles. (pictures 4, 7, 8) or to show the lifter just before he reaches the lowest point of the lift (Picture 6).

c) Picture 9 shows clearly the limit which can be reached by the hands with the knees not flexed more than a right angle even with some trunk inclination. It is not clear from the illustration which foot positions are recommended since the diagram and the photograph contradict each other.

d) Bearing in mind the restriction shown on how low the hands could reach in picture 9, pictures 13 and 14 seem at first sight to be a nonsense. In fact the desired effect has been achieved by altering the dimensions of the human frame. In picture 13 the man's arm is impossibly long, and this becomes clearer in the right hand picture where it is shaded in.

In picture 14 there seems to be a combination of arm growth and leg shortening in the left hand drawing. Picture 15 is a line drawing by way of comparison taken from a photograph of a kinetics instructor attempting the lift shown in 14.

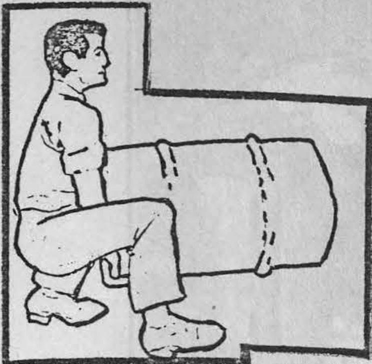
It also appears that there was some lengthening of the arms in the first frame of picture 7.

e) Many of the illustrations also show the feet as parallel (pictures 4, 6, 7, 8, 9).

f) One final example is picture 11 which was part of a Health and Safety Card series distributed free to Nurses with the magazine Nursing Mirror(1981). The caption on the right hand picture seems to contradict the illustration and in fact the distance between the centre of the load and the lumbosacral point is greater in the technique which is claimed to be correct.

It seems likely that the widespread dissemination of illustrations like these can only undermine the value of movement training, and exacerbate the confusion and misconceptions which bedevil the subject.

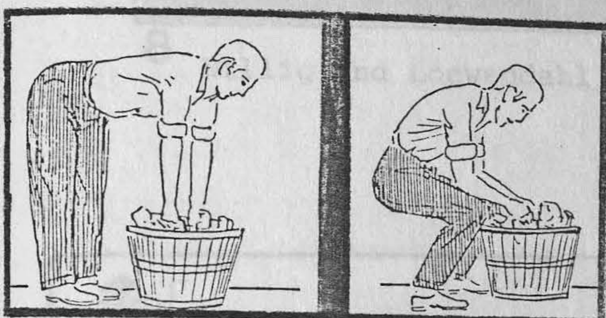
The pictures which have been numbered 1-14 and are discussed above can be found on the following four pages in figures 19, 20,21, and 22.



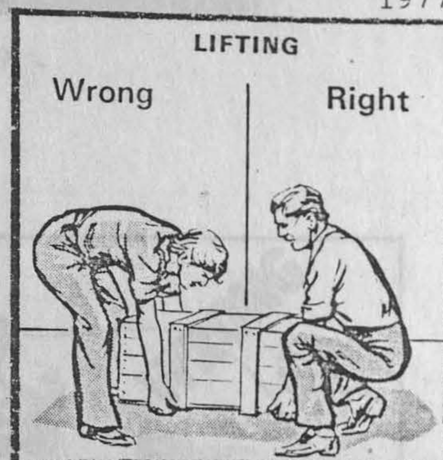
1 British Safety Council (Undated)

2 National Safety Council USA (1976)

3 Great Britain 1977



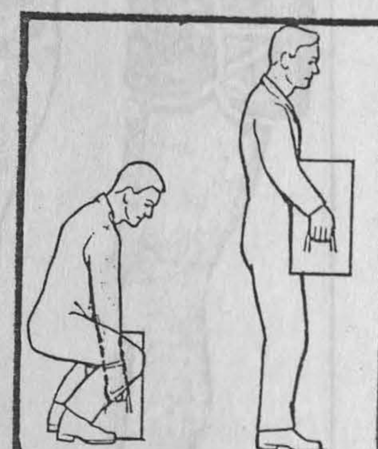
4 Kendall et al(1952)



5 Back Pain Association (1979)

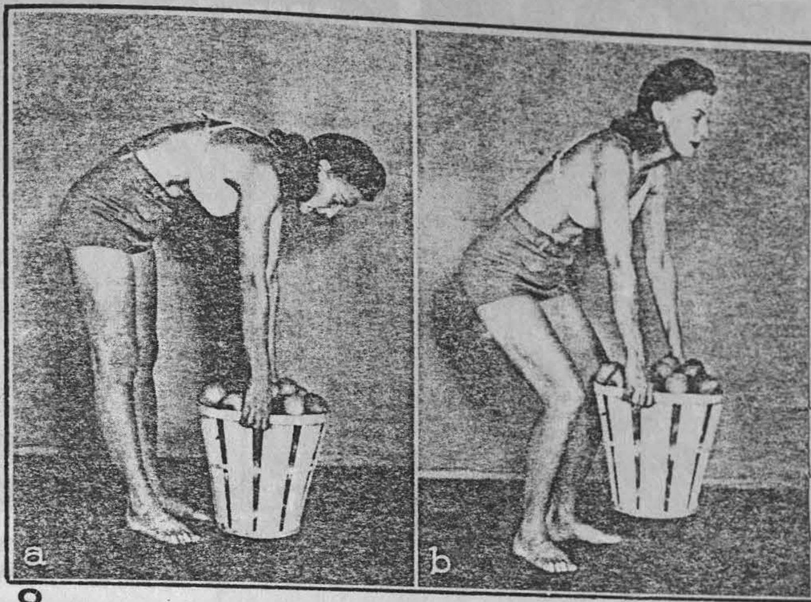
6 Womans Own (1977)

6 Department of Labor (USA) (1970)

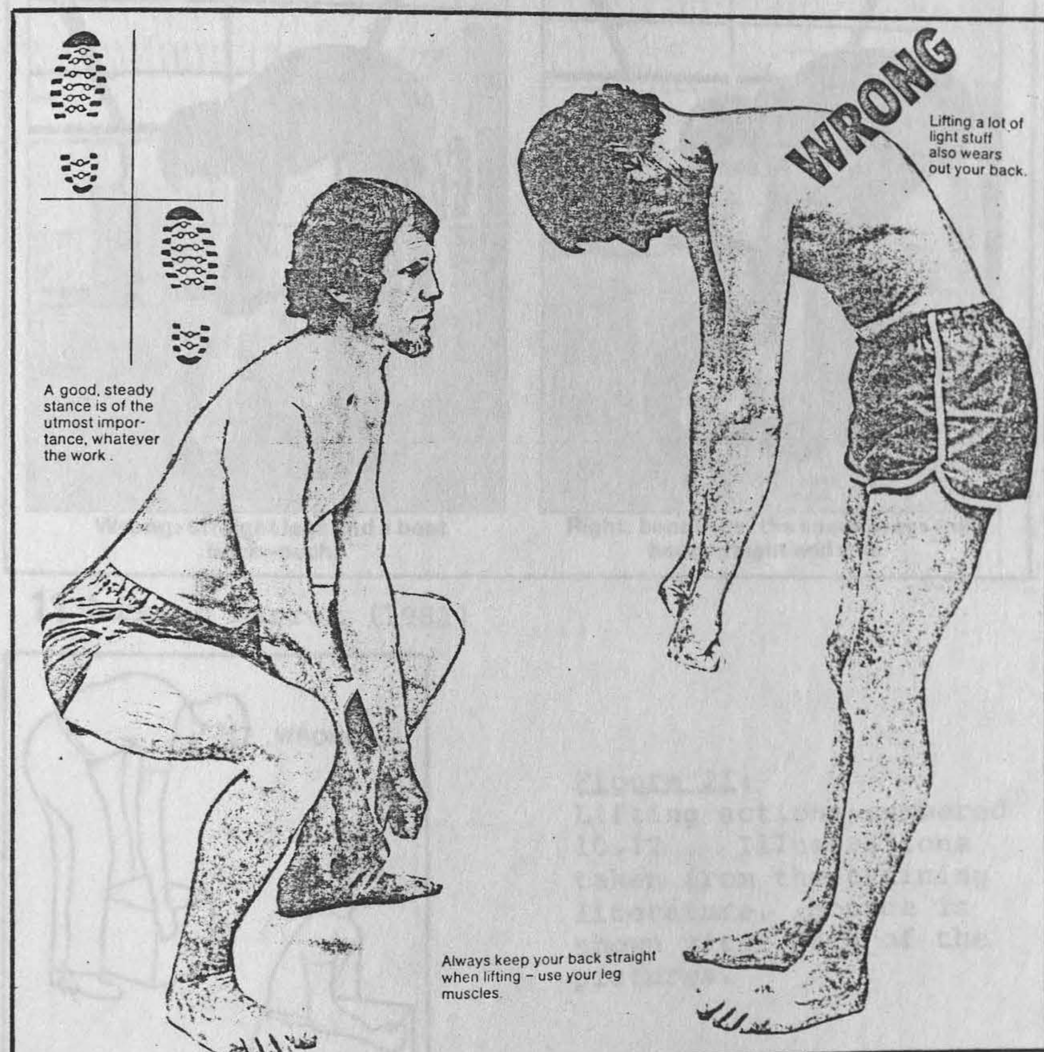


7 EITB (Undated)

Figure 19: Illustrations numbered 1-7 of lifting actions taken from the lifting training literature. Source is shown after each of the pictures.



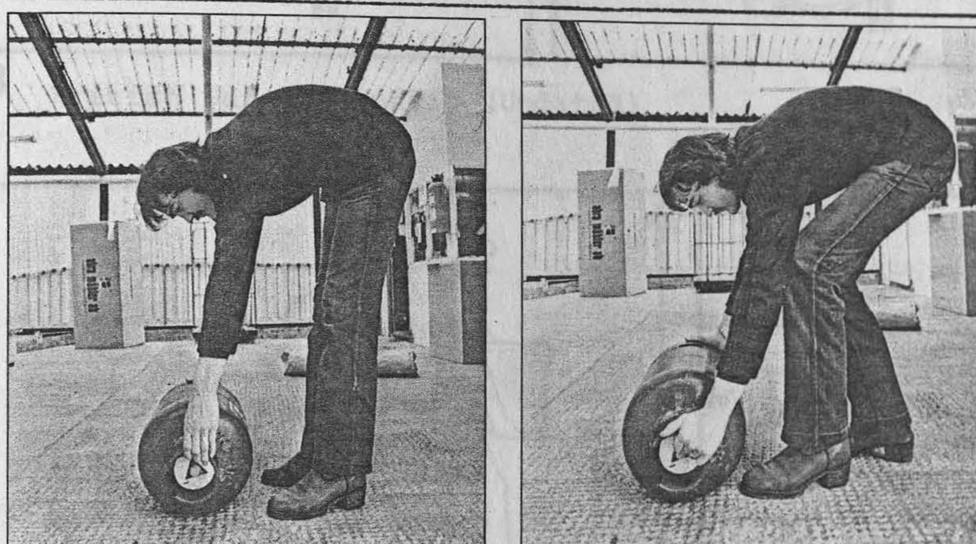
8 Billig and Loewendahl (1949)



9 Palmer (1979)

Figure 20 : Illustrations numbered 8-9 of lifting actions taken from the training literature. Source is shown after each of the pictures.

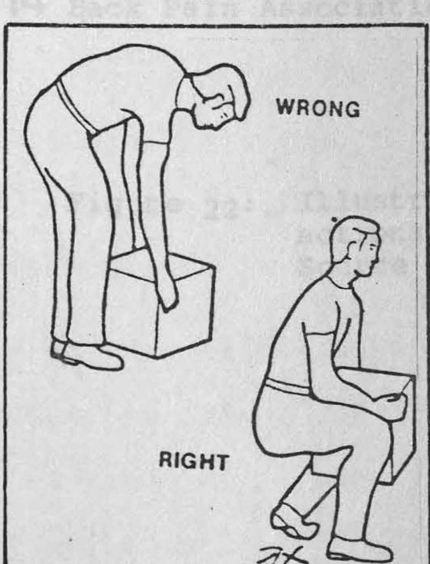
10 Great Britain (1958)



Wrong: straight legs and a bent back–ouch!

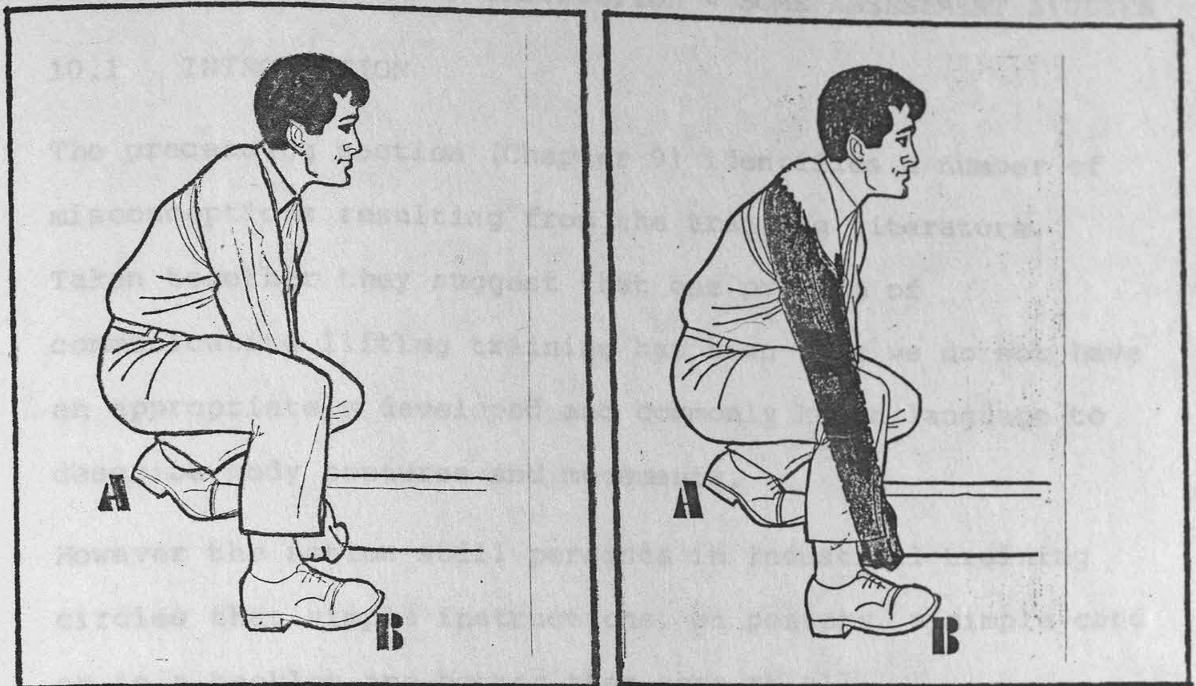
Right: bending at the knees keeps the back straight and safe.

11 Nursing Mirror (1981)

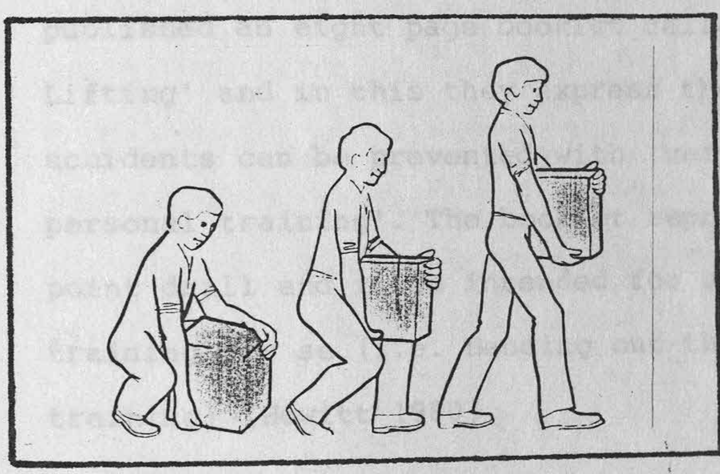


12 Back Pain Association (1975)

Figure 21:
Lifting actions numbered 10–12 . Illustrations taken from the training literature. Source is shown after each of the pictures.



13 British Safety Council (Undated)



14 Back Pain Association (1978)

The RoSPA instructor taken from the video screen.

Figure 22: Illustrations numbered 13-14 of lifting actions taken from the training literature. Source is shown after each of the pictures.

CHAPTER 10: LEVELS OF INSTRUCTION - SOME ASSESSMENT STUDIES

10.1 INTRODUCTION

The preceeding section (Chapter 9) identifies a number of misconceptions resulting from the training literature. Taken together they suggest that one problem of communicating lifting training has been that we do not have an appropriately developed and commonly known language to describe body postures and movements.

However the notion still persists in industrial training circles that simple instructions, on posters, a simple card or in a booklet are better than none at all.

For example, the Institute of Municipal Safety Officers have published an eight page booklet called 'Manual Handling and Lifting' and in this they express the view that handling accidents can be prevented with 'very little effort by personal training'. The booklet reproduces a classic six point drill and it is intended for use as a means of training per se (i.e. Handing out the booklet will constitute training) (Hewitt 1980).

10.2 OUTLINE OF STUDIES

In the light of the existence of such opinions in Safety professionals, two further studies were undertaken to examine three levels of such instruction which can be found in factories.

(i) Extremely simple instructions such as 'keep your back straight' (the poster approach) and small cards summarising the six point drill were examined as part of the pre training evaluation on ROSPA courses (see page 145).

(ii) A study of a popular training booklet issued by the Back Pain Association entitled 'Lifting - An Instructors Manual' (20 pages: 1978) This section reports the results of the second study.

10.3 TRAINING BOOKLET STUDY

10.3.1 INTRODUCTION

The 20 page booklet was first issued by the Back Pain Association in 1978. The manual quite rightly stresses that lifting training needs demonstration and supervision by instructors, but nowhere does it say that the instructors themselves should have been trained on a course, and evidence from personal interviews in this research showed that the manual is being used to prepare instructors with no additional material. The manual is also available in a poster format and I discovered cases of this and the booklet going straight to employees as an instruction course in lifting. This small study therefore looked at the comprehensibility of the booklet on its own.

10.3.2 METHOD

Ten students on the MSc course in the Department of Occupational Health and Safety were given copies of the manual and one week to study and practice its contents. The subjects had no previous exposure to the subject on their course. They were forewarned that at the end of a week they would be given an unspecified test of their understanding.

At the end of the week the subjects were given a number of tests.

(i) At several points the manual refers to the dangers of 'an ordinary stooping lift' or bending down in a stooping posture. Although there is a common assumption in the training literature that this is a term that has only one meaning I have shown evidence elsewhere (see page 90) that there is more than one interpretation. All the subjects were therefore asked to demonstrate their understanding of 'an ordinary stooping lift'. The result was recorded both on video and 35mm still photography.

(ii) The subjects were asked to demonstrate the lifting of a box from the floor to a table, following the methods recommended in the manual. This simple lift was covered extensively in the manual. Again the resultant lift was videoed and photographed.

(iii) The subjects were also given a written test to explore their understand ing of some of the concepts in the manual. Extracts comprising phrases or illustrations from the manual were shown to the subjects on an overhead projector and they were asked to write short notes, or answer specific questions as appropriate.

10.3.3 RESULTS: MAJOR FINDINGS

a) The confusion regarding what constitutes an ordinary stooping lift is clearly shown by the photographs (Fig 23) Subjects 3, 4, 5, 7 and 8 re-inforce the popular stereotype however subjects 1 and 2 appear to be performing a 'hybrid' lift which is something between a 'stoop' and a 'squat'. Subjects 6, 9 and 10 show a complete reversal. Their stoop

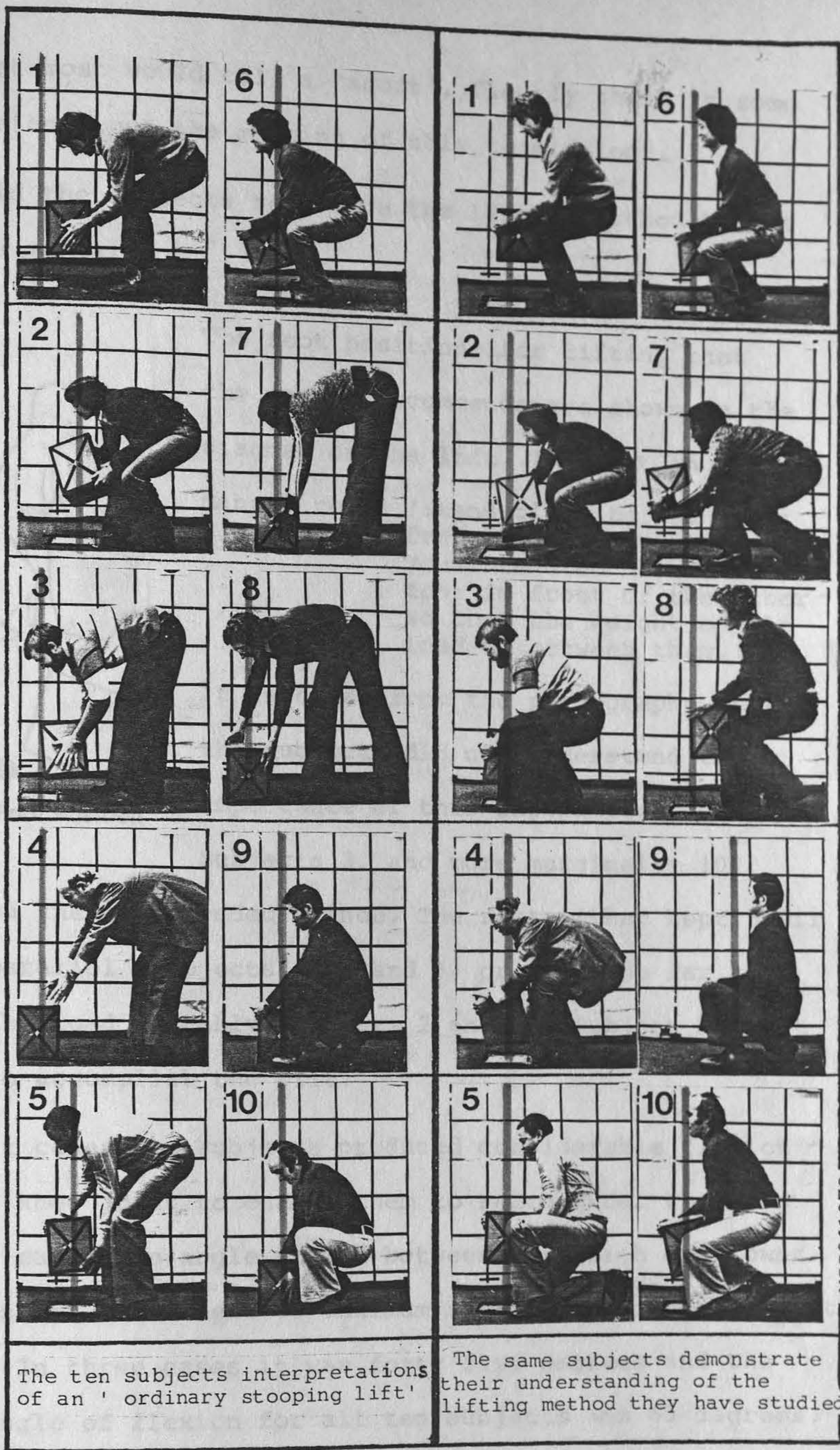


Figure 23: Photographs showing ten subjects from the Training booklet evaluation study demonstating their interpretation of the two lifting methods.

is what most would call a 'squat'. Clearly there is some confusion about the meaning of this terminology.

b) Did the subjects reproduce the lifting method taught in the manual?

B. Foot Position

The foot positions for lifting that the manual recommends are shown in the diagram on the left. The text in the manual reads 'Stand close to the load; feet apart facing the way you intend to move; one foot in front of the other so that the weight of the load is between them.'

It is clear from the photographs that the subjects did not understand the importance of this instruction. Only Subjects 3, and more marginally 10 adopted the recommended stance. The rest either kept their feet parallel (subjects 1, 4 and 6) or were too far away from the load (notably subjects 2 and 7). Subject 5 knelt down to accomplish the lift.

In most cases the subjects produced considerable flexion of the knee joint to enable them to reach under the load. In all cases the angle formed between the thigh and lower leg was, at the moment of maximum flexion less than a right angle. In three cases it was forty five degrees and the mean angle of flexion for all ten subjects was 65 degrees. The significance of knee flexion is discussed elsewhere in this thesis (see page 103).

c) Understanding of concepts

a) On page 8 the instructors manual discusses the role of abdominal pressure in relieving spinal stress stating that;

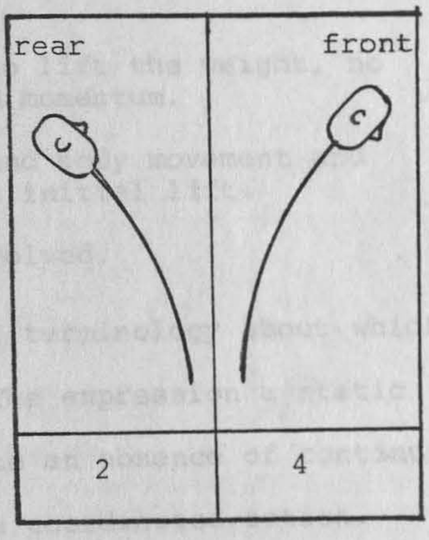
'It is most effective in relieving spinal stress if the lower back is kept a little flexed, and least effective if the spine is arched backwards at the time of lifting.'

The subjects were asked to draw a diagram of the sideways elevation of a spinal column

1) 'a little flexed'

2) 'arched backwards'.

In the case of 'a little flexed' the subjects all agreed that this meant a slight (5-10 degree) inclination of the whole spine. Although it is not clear if this is what the manual intended, the principles of kinetics would suggest that it should be interpreted to mean 'diminishing lordosis'. In the case of 'arched backwards', 2, subjects admitted they had no idea, 1 showed the whole spine erect and completely straight, and the other six subjects split into the two interpretations shown in the diagram on the right of this text.



b) One of the actions that the manual advises against is the use of a 'static or dead lift', advocating instead the use of body weight. The subjects were asked to describe a 'static or dead lift' and their answers are shown below:

Subject

1. A dead weight which has to be lifted from ground level.
2. A very heavy load.
3. Grasping the object, taking the strain, and then actually lifting as opposed to taking the strain and lifting in one movement.
4. Using more than one limb.
5. A load which has no k.e. and is difficult to lift or has to be lifted as quickly as possible.
6. The movement of the load is not smooth i.e. there are intermittent stoppages before it is fully lifted.
7. Using the vertical forces to lift the weight, no horizontal force to produce momentum.
8. Making use of body weight and body movement and the momentum created by the initial lift.
9. Straight up, no walking involved.

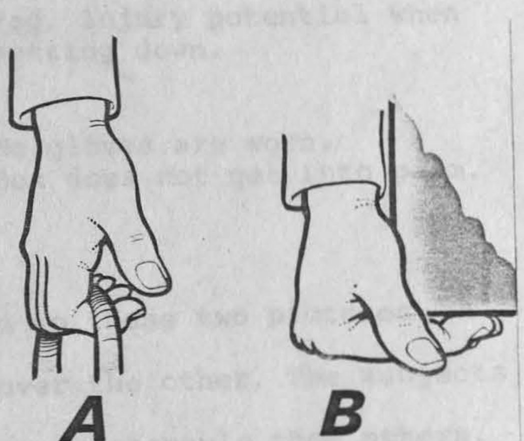
Clearly this is another example of terminology about which there is considerable confusion. The expression 'a static or dead lift' would seem to indicate an absence of continuity, and the lift would not be a smooth coordinated action. Several of the subjects definitions agree with this; notably 7, 8 and 9, but others have no element of this e.g. 1, 2 and 5. The subjects explanations of this term again show that in the absence of a shared definition there are clear opportunities for misunderstanding.

c) In discussing the function of the spinal cord the manual describes the function of the chest wall stating that 'the chest wall can be stiffened by holding the breath' and that this would raise the pressure in the chest and abdomen.

When the subjects were asked if this meant that the breath should be consciously held when a heavy load is lifted five of them said yes and the other four no (one did not know).

The proponents of Human Kinetics would argue against holding the breath during strenuous activity because of the increased risk of injury to a rigid structure (the chest 'cage'), the increase in blood pressure, and raising of pressure in intra-thoracic and intra-abdominal cavities to levels which may result in harm (hernia).

d) A final area of possible confusion surrounded the manuals section of 'grip'. The illustrations and text are reproduced on the right. Subjects were asked to examine illustrations A and B and state if each was good or bad, and why. Their answers are shown on the next page.



4) The Grip

How are you to handle the load? The safest grip is one in which the fingers are curled into a hook. Having to use the fingers straight with the palm of the hand under the load may be safe but it is very tiring. If there are no handles, a hook or sling might be used provided no damage is done to the load.

	A	B
1	<u>Good</u>, but load must be small.	<u>Good</u>, except for irregular loads.
2	A is the best because hook provides more force(?) and its softer	
3	<u>Good</u> because curled but area of contact is small therefore the pressure on the hand will be high causing discomfort.	<u>Bad</u> because edge of load is not close to the joint and therefore puts extra leverage on the joint.
5	Both are good depending what is being lifted.	
6	It depends and is difficult for him to tell which is good or bad.	
7	<u>Good</u>, the grip forms a hook which provides adequate and safe hold.	<u>Bad</u>, if the load is very heavy the fingers will fatigue easily.
8	Both A and B are useful it depends what you are lifting. A o.k. if handles.	B would prove tiring.
9	<u>Good</u> but strap should be made wider and stiffer.	<u>Bad</u>, injury potential when setting down.
10	Fingers insufficiently curled. Handle should rest on third not second bone.	No gloves are worn. Box does not get into palm.

It was not clear from the caption to these two pictures whether one was to be preferred over the other. The subjects show a range of opinions, some more reasonable than others. The 'kinetically' preferred hold would be B, a broader more diffuse grip without the pressure resulting from the narrow strap in A.

10.3.4 CONCLUSIONS

This study adds to previous sections which had identified a number of misconceptions in the training literature. From an evaluation of one training booklet it identified some problems associated with using language, and sometimes pictures to communicate instructions for performing movements.

It is not intended as a totally negative critique of the Back Pain Association's booklet. This publication contains many good points and is more comprehensive than similar booklets from other sources. However a number of potential sources of confusion were isolated and tested. The terminology employed was found to be wanting and it is likely that these examples are only part of a very broad universe of potential misconceptions. The study adds to the weight of evidence from the research as a whole that we lack a common and well understood language to describe and communicate posture and movement patterns.

CHAPTER 11: ASSESSMENT OF ROSPA TRAINING - QUESTIONNAIRE STUDIES

11.1 INTRODUCTION

Earlier sections of this thesis have indicated that Human Kinetics, lifting, and the aetiology of handling accidents are areas in which many misconceptions are prevalent. There were strong suggestions from the type of disagreement which existed between different authorities who had studied these areas that conceptual or attitude problems would be a fruitful area of study. Also at the level of the individual undergoing training it has been said by proponents of both Human Kinetics and other schools of thought that it is important to consider and to change the attitude of people towards movement. (Hooper and Allday 1975) (Glover and Davies 1961). However there were no studies to indicate what the original attitudes were that training should be designed to change. Therefore a questionnaire was designed as a pilot study to look systematically at attitudes to Human Kinetics, and movement and to collect information about the basis of judgements about good and bad postures and movements. Other sections of the questionnaire were designed to supply a superficial validation of the success of one weeks training in Human Kinetics in altering some of these variables.

11.2 DESCRIPTION OF QUESTIONNAIRE

The questionnaire was in three parts (see appendix 3)

(i) Question 12: A short semantic differential test to measure global attitudes towards Human Kinetics.

(ii) Question 13: Twenty one statements of opinion or fact for marking on a seven point scale of agreement/disagreement. The statements fell into two groups; those designed to be part of the assessment of Human Kinetics courses and a broader group designed to explore some of the misconceptions about movement training identified elsewhere in this thesis.

(iii) Question 14: Fifteen pictures of activities being carried out well or poorly on kinetic criteria. Subjects were asked to indicate which picture showed the better way of doing each activity and to state why it was the better way. The instructions to the questions directed them away from answering solely in terms of how the pictures differed, to an answer in terms of their reasons for selecting that picture. It was intended that this series of questions should yield information about the type and degree of misconceptions people hold regarding what constitutes 'good posture' and also give a measure of success of training in improving such judgements.

11.3 DERIVATION OF THE QUESTIONS

Question 12

The semantic differential technique using an adjective checklist has been widely tested and validated (Osgood 1957). For the purpose of this study it was selected to give a superficial validation of the course which could be reviewed immediately after the responses were collected. Any particularly severe problems identified could then have been followed up by interview before the subject(s) departed. The adjective pairs were chosen as the most appropriate from those which Osgood had used on training evaluation.

Question 13

The statements of opinion or fact were drawn from a number of sources. The majority came from the content of the training course and other written work about Human Kinetics. Other training literature was used as the source of statements relating to possible misconceptions about how best to train, or the nature of handling problems. The choice of making a statement positive or negative was randomised throughout the series, as was the position of the positive and negative poles in the order of presentation.

Question 14

The pictures were adapted from illustrations taken from a variety of publications about movement. They were double checked by the trainer at ROSPA to ensure that kinetic criteria were being accurately applied. In addition to this the picture series of 15 pairs were broken down into thirty separate pictures and these were presented to a sample of ten students, in random order and without any text or captions. They were instructed to study each picture and to describe what the person illustrated was doing and to demonstrate to the interviewer what movement had preceeded the one illustrated and what movement(s) were likely to follow the one illustrated.

This examination demonstrated that there were minimal problems with the pictures. The only major confusion stemmed from question 3B where two of the subjects thought that the man illustrated was 'peering into the drum' and 'taking its lid off' respectively. It was felt that once the picture was seen in the context of its companion with a caption that this problem would be solved, and no change was therefore made.

For the picture questions there was always the possibility that the subjects chose their response at random and then gave a plausible rationale for their choice. To test this assumption a Chi squared test was completed using a contingency table which compared observed and expected errors per question for all groups with the null hypothesis that respondents operated at random. The null hypothesis was rejected.

11.4 NUMBERS OF SUBJECTS AND THEIR SOURCE

The questionnaire was given to the following groups

(i) Two separate RoSPA courses. Sixteen subjects on each course filled in the questionnaire at the beginning of their week's training and again at the end.

(ii) Twenty nine trainee factory inspectors filled in Question 14 during their preliminary training course.

(iii) Sixty seven shop floor employees of an engineering company filled in a slightly truncated version of Questions 13 and 14 prior to being given a short (half day) training course by one of the ROSPA trained instructors.

Questions F and P were not included on the shop floor questionnaire, because they were not appropriate to a group which was not going to be given a post training evaluation or give training themselves. Question R was also removed at the insistence of the manager responsible for liaison.

11.5 RESULTS

11.5.1 TEXTUAL QUESTIONS

There are three major ways of looking at the sort of data generated by these scales. A mean for all subjects can show the position of the group on one measure. The measure can be split into a three point;positive / don't know / and negative groups. Finally since there is a tendency for groups filling in such scales to cluster around the mean (Osgood 1957) it is also useful to look at the amount of times that respondents use the polar values. In such cases it is possible to show that not only does the subject hold a belief (or misconception) but that they hold it clearly and confidently.

Page 127 shows the results of questions 12 and 13; the table shows how often subjects used polar values 1 and 7, and also shows the mean value for each group on the 7 point scale, for each question. In the table and the discussion of question 12 the seven questions it comprises are referred to by the initials IU, UH, CS, UI, FU, NU and ED respectively. The significances of the shifts in group opinion/attitude, pre-post training (indicated by asterisks in the table) were tested using a Wilcoxon matched pairs signed rank test (α=0.05).

Examination of the group means for the three samples showed good correlations (mean r=0.9 and r for any 2 columns = 0.8) indicating consistency of responses across the groups.

In fig. 24 it should be noted that although the columns for group use of polar values show actual numbers in each category, the group scale means enable comparisons between ROSPA and shop floor groups.

11.5.1.1 DISCUSSION OF RESULTS:

a) Question 12: The responses to this test formed part of the superficial validation of ROSPA training courses in Human Kinetics. As such the results were encouraging, but not surprising. Course participants came on the courses expecting them to be important, helpful, and interesting. The week's training re-inforced these beliefs, producing a significant shift for both courses on the last criterion, (towards interesting). Before the courses subjects felt that the subject area was an unfamiliar one, and the result of their training was a significant shift to familiarity.

GROUP USE OF POLAR VALUES											GROUP SCALE MEANS				
Group	ROSPA COURSES R26977				R90378				SHOP FLOOR		ROSPA COURSES R26977		R90378		SHOP FLOOR
PRE POST TRAINING	PRE		POST		PRE		POST				PRE	POST	PRE	POST	PRE ONLY
POLAR VALUE	1	7	1	7	1	7	1	7			$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$
12 I.U.	10	0	15	0	7	0	12	0			1.6	1.1	1.8	1.3	
U.H.	0	6	0	14	0	5	0	14			6.0	6.7*	6	6.6	
C.S.	1	2	0	2	0	0	1	1			4.4	4.7	4.0	4.1	
U.I.	0	5	1	12	0	3	0	8			5.8	6.5*	5.2	6.5*	
F.U.	1	4	4	0	0	6	2	0			4.7	2.6*	5.9	3.3*	
N.U.	11	0	11	3	12	0	9	0			1.6	2.3	1.4	1.8	
E.D.	1	0	1	2	0	0	1	0			3.5	3.6	4.4	3.9	
									1	7					
13 A	2	7	9	4	2	3	9	2	1	17	5.1	3.1*	5.0	2.9*	5.2
B	4	7	9	2	2	6	6	3	3	47	4.7	2.7*	4.9	3.5*	6.1
C	9	1	15	1	4	2	12	0	10	14	2.6	1.4*	3.5	1.3*	4.3
D	6	6	10	2	3	2	11	1	5	19	4.6	2.6*	4.0	1.8*	5.0
E	0	13	0	16	1	9	1	12	2	32	6.6	7.0	6.1	6.4	5.8
F	3	0	3	0	2	0	2	0	-		3.1	3.1	3.3	3.6	-
G	5	3	3	0	0	2	7	0	29	23	3.6	1.6*	4.6	1.8*	3.7
H	10	0	14	0	7	1	11	1	26	4	1.9	1.3	2.3	2.1	2.7
I	2	5	1	11	0	4	0	6	1	14	4.9	5.8	6.1	6.0	5.1
J	0	5	1	6	0	2	0	8	5	10	5.3	5.7	4.5	6.2*	4.7
K	8	0	15	0	9	0	11	0	32	1	1.9	1.2*	1.7	1.3	1.7
L	10	1	16	0	5	1	11	2	31	3	1.8	1.0	2.8	2.3	2.3
M	1	5	16	0	2	3	11	0	15	9	5.3	1.0*	5.1	1.6*	4.0
N	9	3	14	0	7	0	13	0	34	1	2.7	1.3*	2.1	1.4	2.2
O	3	4	9	3	0	1	7	0	7	11	3.9	2.8	4.6	2.4*	4.5
P	3	1	3	1	2	0	2	0	-		3.5	3.4	3.8	3.3	-
Q	0	9	1	10	1	10	0	12	2	36	6.3	6.3	6.1	6.8	5.9
R	9	0	6	2	5	2	4	0	-		2.1	3.1	3.4	2.9	-
S	6	2	15	0	4	0	12	2	13	6	2.9	1.1*	3.2	1.9	3.5
T	0	7	0	6	1	8	0	6	7	10	5.9	5.7	5.8	5.7	4.3
U.	1	6	0	16	1	4	3	11	6	14	5.2	7.0*	5.4	5.7	4.5

* = GROUP SHIFT SIGNIFICANT AT $\alpha = 0.05$

Figure 24: Questionnaire results. Group use of polar values 1 & 7 and group scale means for each question.

Although group means on the Necessary - Unnecessary scale remained clustered at the positive end of the scale small shifts towards the negative occurred in both cases due on the second course to three participants shifting to the negative polar value. Clearly kinetic teaching has the potential for dividing groups on some measures. This was also shown by the last two adjective groups Complicated - Simple and Easy - Difficult. The group means for both pre and post training measures were both at the centre of the rating scales. However further analysis showed that this resulted from a basic uncertainty pre training (shown by a clustering or responses around the centre point in the scale) being converted to polarisation (scores more extreme). This seems to suggest that some subjects found it easier and some harder than they expected. From the point of view of successful communication of training the latter group are more interesting. The figures show that between 10% and 25% of the subjects being trained as instructors assess the technique as difficult at the end of a week's course. However since there was no independent measure of individual subjects ability to assimilate novel concepts it is not clear if this finding draws attention to inadequacies in the course or the subjects.

b) Question 13: Elsewhere in this thesis attention is drawn to the prevalence of a number of incorrect stereotypes in training and other literature. The responses to some of the questions in this section show these stereotypes are not only communicated in the literature but are believed.

Questions A and D show that substantial numbers of people hold the misconception that Human Kinetics is a drill of movements, and adopts a mechanistic approach to movement. Training was successful in producing the desired shift to the negative end of scales on both these criteria. (At a statistically significant level.)

In a similar fashion the responses to <u>questions G and M</u> reflect stereotypes common in the literature. Both questions had the general effect of polarising the respondents. This is particularly clear in the shop floor sample with seventy eight per cent of the sample splitting themselves between the two polar values on question G. In the same group eighty two per cent of the sample were split between the polar values on question M. In short approximately half of any sample is going to consider that muscle building exercises are a good form of exercise and that touching the toes is a good exercise. Once again the kinetics training course produced significant shifts in the desired direction for both of these criteria.

Another strongly, but erroneously held belief is that Human Kinetics is essentially about lifting weights. (Question C) and about preventing back injury (Question O). Both questions produced considerable polarity. In the case of the shop floor sample 45% of the respondents used the positive pole on question C and 31% used the positive pole in question O. The week's ROSPA training produced significant shifts to the negative pole in both courses on both questions.

Question B shows the popularity of the stereotype that the back should be kept straight, with eighty five per cent of the shop floor group using the positive pole. It may seem paradoxical that the ROSPA post training groups showed a shift to disagreement on question B. However this reflects a subtlety of kinetics training that the question was not clearly worded enough to explore Kinetic teaching is that, although the back should be straight at the moment the load is taken, it does not, and in most instances should not, be straight throughout the entire lift. The question did not make it clear which aspect was being examined.

Questions E; H; I; J; K and N were designed primarily as validators of the success of training at getting over some of the kinetic concepts. They contained words which have specific meanings defined by the training, and which in the absence of training, tend to read as truisms. However in all cases training produced shifts in the desired direction and resulted in all the trainees being at the right end of the scale.

Questions S and U which were designed to give some measure of the reliability of the questionnaire show two things;

(i) The pre and post training measures on the ROSPA courses show that subjects respond reliably, and in both cases significant shifts are produced in the correct directions towards opposing poles; (the post training groups move towards disagreement with feet remaining parallel and towards agreement that one foot should be in advance of the other).

(ii) There is widespread confusion regarding the position of the feet. Considerable polarity of response was shown to both questions in the shop floor group. This is not surprising because as other parts of this thesis show, a common feature of the abundant training literature regarding lifting and handling movements available to workers as pamphlets, brochures and posters is conflicting or confusing advice regarding the positions of feet during handling actions.

<u>Questions F and P</u> examine beliefs regarding the simplicity of teaching lifting and the wider issue of the trainee's confidence to pass on to others what he has learnt. The examination of group means for both ROSPA courses shows that the trainees were unsure on both these measures; the means representing dispersion rather than polarity on each measure. In both questions the group means were just on the disagreement side of the centre point for both pre training measures and remained there post training. Before their course the trainees believed that it was not easy to teach people to lift and nothing they learnt changes that view. Two of the items on the semantic differential showed

that some trainees lack confidence to transmit what they have learnt. This observation was supported by the responses to question P, where between ten and twenty five per cent of the trainees clustered around the negative pole.

This could mean that not everyone will make a good kinetics instructor, and so implying the need for some sort of selection process for potential trainers, or that the training course was poorly executed. Given the good validation of the training course on other questions, and measures reported elsewhere in this thesis the former argument seems the stronger.

Examination of the responses for question L showed that all the means for all groups lay at the negative end of the scale - i.e. the subjects thought that sustained tension was bad for muscles. The post training measures on the ROSPA courses showed a shift to greater disagreement, although this was not significant, (not surprisingly considering the starting point). Given the negative connotations of the word 'tension' it is perhaps surprising that, in the shop floor sample, over 25 per cent of the respondents either did not know or fell into the agreement half of the scale.

It is possible that the prevalence of 'isometric' exercise and muscle building regimes have led some people to associate tension with positive attributes.

<u>Question T</u> put forward the belief that people who have been lifting for years resent being taught a new way. In all groups the mean lay on the positive side of the scale and training did little to shake their belief. However agreement was not complete and in the shop floor group 10 per cent of the respondents chose the extreme disagreement pole.

Only the two ROSPA groups completed <u>question R</u>. Although the majority disagreed with the notion that a lot of workers with back injury are malingerers a small proportion (15 per cent) agreed in both pre and post training groups. This is disturbing finding in a group of people who are part of a training process which is underpinned by the belief that injuries are real and can be prevented by appropriate re education in movement patterns.

11.5.2 PICTURE QUESTIONS RESULTS AND DISCUSSION

11.5.2.1 GROUPED DATA

The results for question 14 are summarised in figures 25 and 26 (see pages 141 and 142). Fig.25 shows errors of omission and commision for both ROSPA courses in pre and post training groups. These were defined as not answering the question, or selecting the incorrect picture as the better one respectively.

Fig 26 shows the mean percentage of errors for each question across all four groups who completed this section of the questionnaire (a total of 128 subjects).

Other results are given in summaries in appendices and these will be explained and referred to in the text.

Figure 25 shows that there were no ommission errors in the post training groups.

Examination of total errors pre and post training shows that the training courses were a considerable success when judged on this measure, with 91% of the errors converted to correct responses after training.

When errors per question are examined across all four groups pre training the level of failure ranged from 13% to 22%. The mean percentage of errors per question summed across all groups and questions was 18%. In individual groups some questions were wrongly answered by over 50% of the respondents. At this level the data clearly indicated that substantial numbers of the subjects held misconceptions about the nature of these judgements.

Analysis of the reasons subjects gave to justify their choice of the 'better' picture (posture) showed that they responded by giving differing levels of explanation.

11.5.2.2 LEVELS OF EXPLANATION OFFERED

The levels of explanation offered were as follows:

(i) The simplest was to describe salient aspects of the posture which conformed to their model of 'good posture' i.e. Back straight; head up; arms close to body.

(ii) A similar level of description involved justification of choice with predominantly superficial and generalised phrases referring to the results of postures. These were repetitions of the concepts given in the instructions i.e. the subjects would state that the posture involved more (or less) comfort; strain; or efficiency. The other concepts they used were, on the positive side, balance; stability; relaxed; control; natural; poise; support; strength; work; energy; power; thrust; force; grip; and on the negative side, cramped; tension; pressure; effort; compression; torsion; and risk of injury

(iii) A more sophisticated level of description was to combine (i) and (ii) and to say things like 'A is better because it involves less strain in the back'; 'more comfortable for the shoulders' etc.

(iv) The most complex level of description offered was to describe the position of a part of the body and its consequences in a cause and effect manner. e.g. 'The arm locked straight means more support for the body'; 'more thrust from a straight rear leg'.

Pre-training most explanations fell into category (ii) 53%; followed by category (i) 26%; category (iii) 15% and category (iv) 7%. However little importance should be attached to these raw figures because the questionnaire method of collecting information did not fully explore the level of description that each subject was capable of. An interview technique would have been required to do this. All the same it was an encouragement to the ROSPA trainer and a validation of the courses that, in the post training groups, 92% of the subjects answers were in categories (iii) and (iv).

The instances in which the subject, having made a correct choice of picture gave a correct but massively over simplified rationale for his choice were not analysed further as they were not felt to be very illuminating, given the limitations of the questionnaire format outlined above. However a scrutiny of the cases where subjects had made an incorrect choice was more revealing. Even though the level of description was often superficial (predominantly group ii) it still pointed to possible bases for the misconceptions regarding posture and movement.

Examination showed that the subjects errors were of two types.

11.5.2.3 TYPES OF ERROR MADE

Descriptions could involve:

a) Giving a reason involving correct identification of a criterion as 'good' but attaching it to a picture which illustrated a posture 'bad' on that criterion. This sort of misperception was a type of factual error. e.g. A subject states that one picture is better than the other because it involves less strain in the arms, but in fact the posture illustrated would involve more strain in the arms.

b) A more gross misperception where the subject said it was 'good' to be at one end of a criterion when in fact the good pole is at the other end of that criterion, e.g. the subject says that it is good to have strain in the arms.

Appendix 4 gives a listing of the total rationales given by subjects to justify incorrect choices of pictures and the number of times that each faulty explanation was used per picture, summed across all groups.

The major findings from appendix 4 are as follows:

(i) Anderson believed that many people misunderstood the basis of rest and relaxation and held the belief that a body which was allowed to sag was relaxed (Anderson 1). He argued strongly that sagging increases the load on spinal joints and deeper muscles, decreases free circulation of the blood due to the increased tension in muscles which are stretched and also leads to an increase in static muscular work to stabilise joints and the attachment of limbs.

His comments regarding the extent of this misconception are supported by the wrong answers to pictures 1; 11; 12 and 14 in which sagging, slumping or slouching postures are equated with being relaxed and this is labelled good.

(ii) There was a great deal of confusion regarding the use of the arms predominantly during lifting and the results showed that a major misconception here is that 'a greater use of the arms leads to less back strain' or the arms are 'taking the weight/strain'. It is as if the arms are seen as somehow separate from the rest of the body and the fact that any forces carried by the arms must ultimately be transmitted to the ground and that the shoulder joint and attachment points of arm muscles must be stabilised are disregarded. This finding is supported by other observations e.g. the shop floor observations (see page 193.) found that many people work with their elbows jutting out.

(iii) There were other misconceptions regarding the way that forces are transmitted through the body. Kinetically speaking an unskilled movement involves dissipating energy in contracting muscles not essential for the work being done, whereas the skilled performer employs a minimum amount of muscular effort. So, for example, straight or efficiently stabilised limbs should be used where possible to transmit forces from the point of application to the ground, and fatiguing static contractions of major surface muscles to stabilise limbs should be avoided, or reduced. The subjects did perceive that in many cases more work was done in certain limbs (kinetically wasteful).

However this was said to be good. They were thus adopting a 'brute force' approach to judging the quality of a posture. So for example 6A was said to be the better because the arms were 'more powerful'; Picture 8B was said to be the better because 'he is applying more force or pressure' (while it may look as if he is working harder, and he may well be expanding more energy, the force exerted cannot be greater than the weight of the body alone). 15B was said to show 'more power from the legs' or the 'strain is taken by the arms'; 14B was described as using 'power from the arms'.

(iv) It is an indictment of movement patterns and postures commonly found on shop floors that the justification 'It's more natural' was chosen to explain incorrect choices. See for example responses to pictures 1; 2; 4; 7 and 13).

(v) I can find no explanation that accounts for the finding on picture 13 that 6 subjects opted for the incorrect choice (b) on the grounds that it involved 'less stretching or reaching'. It seems that although they could appreciate that raising the arms above the head was going to involve work they could not appreciate that considerable static muscular work was going to be needed to keep the arms extended horizontally.

Figure 25. Table RoSPA questionnaire results - success of training.

	26977						90378					
	PRE			POST			PRE			POST		
	DON'T KNOW	WRONG	ERRORS	DON'T KNOW	WRONG	ERRORS	DON'T KNOW	WRONG	ERRORS	DON'T KNOW	WRONG	ERRORS
1	3	2	5	0	0	0	1	4	5	0	0	0
2	3	2	5	0	0	0	2	3	5	0	1	1
3	3	2	5	0	1	1	1	1	2	0	0	0
4	2	3	5	0	0	0	1	3	4	0	0	0
5	0	2	2	0	0	0	1	0	1	0	0	0
6	2	4	6	0	0	0	1	3	4	0	0	0
7	1	2	3	0	0	0	1	0	1	0	0	0
8	0	3	3	0	0	0	0	0	0	0	0	0
9	1	1	2	0	0	0	0	1	1	0	0	0
10	1	1	2	0	1	1	1	1	2	0	1	1
11	1	1	2	0	0	0	0	1	1	0	0	0
12	1	0	1	0	0	0	0	0	0	0	0	0
13	2	1	3	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	2	2	0	1	1
15	0	1	1	0	2	2	0	2	2	0	0	0
	20 TOTALS	25	45	0	4	4	9	21	30	0	3	3

QUESTION	R26977		R90378		TRAINEE INSPECTORS		SHOP FLOOR		MEAN %
	No	%	No	%	No	%	No	%	
1	5	31	5	31	12	24	15	22	27
2	5	31	5	31	12	7	29	43	28
3	5	31	2	13	3	10	13	19	18
4	5	31	4	25	12	24	22	33	28
5	2	13	1	6	4	14	12	18	13
6	6	37	4	25	15	52	20	30	36
7	3	19	1	6	0	0	2	3	7
8	3	19	0	0	8	28	9	13	15
9	2	13	1	6	4	14	9	13	12
10	2	13	2	13	0	0	4	6	8
11	2	13	1	6	2	7	4	6	8
12	1	6	0	0	2	7	4	6	5
13	3	19	0	0	7	24	13	19	16
14	0	0	2	13	6	21	6	9	11
15	1	6	2	13	7	24	8	12	14
NUMBER SUBJECTS	16		16		29		67		
ERRORS/SUBJECT	2.8		1.9		3.2		2.5		

Figure 26: Table of questionnaire results showing number and percent of errors on each question for RoSPA, trainee inspector and shop floor groups.

CHAPTER 12: ASSESSMENT OF ROSPA TRAINING - VIDEO ANALYSIS

12.1 INTRODUCTION

The questionnaire results reported in Chapter 11 provided a superficial validation of kinetics courses and demonstrated the ability of subjects to understand some kinetic concepts and recognize the differences between good and bad movements when judged visually on certain kinetic criteria.

The purpose of this section was to provide an assessment of the subjects' ability to learn kinetic movement skills. The primary method used to measure skills acquisition was to video record the subjects prior to training and again at the end of a week's training and score them using a specially designed scale and slow motion analysis.

12.2 CHOICE OF TASK STUDIED

The activity chosen for analysis was that of lifting a box, which was selected for the following reasons:

(i) it requires minimum space and equipment and is therefore easily standardised.

(ii) It is a single activity which covers a broad range of important kinetic criteria.

(iii) Earlier sections of this thesis have questioned the efficacy of other methods used to train this movement. Although it seems to be a simple act there is still much uncertainty and controversy surrounding the rival methods advocated. A question which runs beneath all such arguments concerns the quantity and quality of training required to produce any demonstrable change in the trainees' skills. By choosing a lift as the standard activity to assess kinetics it was possible simultaneously to collect answers to a number of subsidiary questions relating to the quality of industrial training. These results are described in section 12.5.

12.3 METHOD

The subject's task was to lift a smooth faced 35lb tote box (25 x 25 x 30 cm) from a standard position on the floor, and place it on a table 96 cm high.

Using available light the subjects were video recorded using a Sony Rover Camera. Additionally a black and white photograph was taken using a Minolta SRT101 camera and HP5 film, as the box left the floor. The cameras were to the subjects' left at right angles to the plane of the lift. Behind the subject was a white screen and under their feet a sheet, both with a black 25 cm grid on them. This was to give the recording vertical and horizontal axes and scale and to facilitate analysis of body segment movements.

The video tapes were replayed on a monitor using a 'National Panasonic' video edit unit. This had a slow-motion facility capable of a continuous range of settings, from normal speed to frozen frame. Most of the analyses were carried out using the setting whereby 1 frame bar at a time was fed to the monitor. 1 frame bar is equal to two complete scans of the picture, which in turn equals one field and there are 50 fields a second. This effectively puts a time base on the picture, allowing the time for a particular movement, or the acceleration of an object to be measured.

12.4 CRITERIA FOR ANALYSIS

Following a pilot study on 15 subjects pre and post training recordings were made on four courses covering 60 subjects. The video tapes were analysed using a series of criteria:

(1) 11 criteria derived from the content of the kinetic lift.

(2) Distance of the load centre of gravity from the base of the spine.

(3) Angles of body segments.

(4) Sequence of movement of body segments.

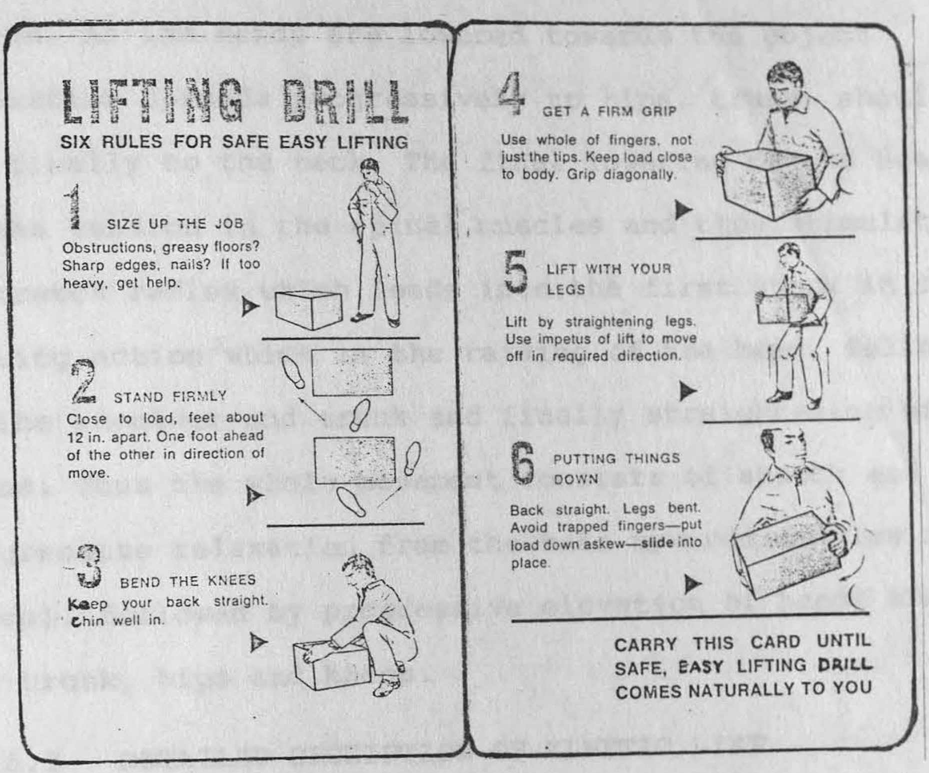
12.5 SUBSIDIARY STUDIES

Before describing the analysis criteria in detail it is necessary to introduce some of the subsidiary studies which were performed on the training courses.

Other parts of this thesis have identified a continuum of training complexity in lifting and handling, ranging from posters, through booklets and pamphlets to instructor based training courses of varying length. One of these levels has been examined already (the Back Pain Association lifting manual study; see page 112).

Two further levels of training were examined in this section of the data collection. In addition to the pre training measures of naive lift, and post training measures of kinetic lift the following measures were taken on two of the four ROSPA courses.

Immediately after the naive lift had been video recorded the subjects on one course were instructed to lift the box again keeping their back as straight as possible. On the other course the subjects were handed a six point drill card of the type normally distributed in wage packets (shown below) given five minutes to study it, and asked to lift according to the instructions shown on the card. In both cases the resulting lifts were video recorded and photographed according to standard protocol.



The drill card used. Both sides are shown actual size. It is a plastic backed card designed to go into a wage packet or overall pocket.

12.6 KINETIC CRITERIA

In order to explain the 11 criteria used to evaluate the video recordings of the box lift, a summary of a Kinetic Lift is given, followed by a detailed description of the criteria.

12.6.1 SUMMARY OF A KINETIC LIFT

In accord with other kinetic movements the first principle of the Kinetic Lift is that it is a base movement. Movement towards the object begins by relaxing both knees and advancing one foot towards (or past) the object to be lifted. As the hands are lowered towards the object relaxation spreads progressively to hips, trunk, shoulders and finally to the neck. The final lowering of the head causes tension in the spinal muscles and thus stimulates a stretch reflex which leads into the first stage in the lifting action which is the raising of the head, followed by the shoulder and trunk and finally straightening of the knees. Thus the whole movement consists of smooth and progressive relaxation from the base upwards (ankles and knees), followed by progressive elevation of head, shoulders and trunk, hips and knees.

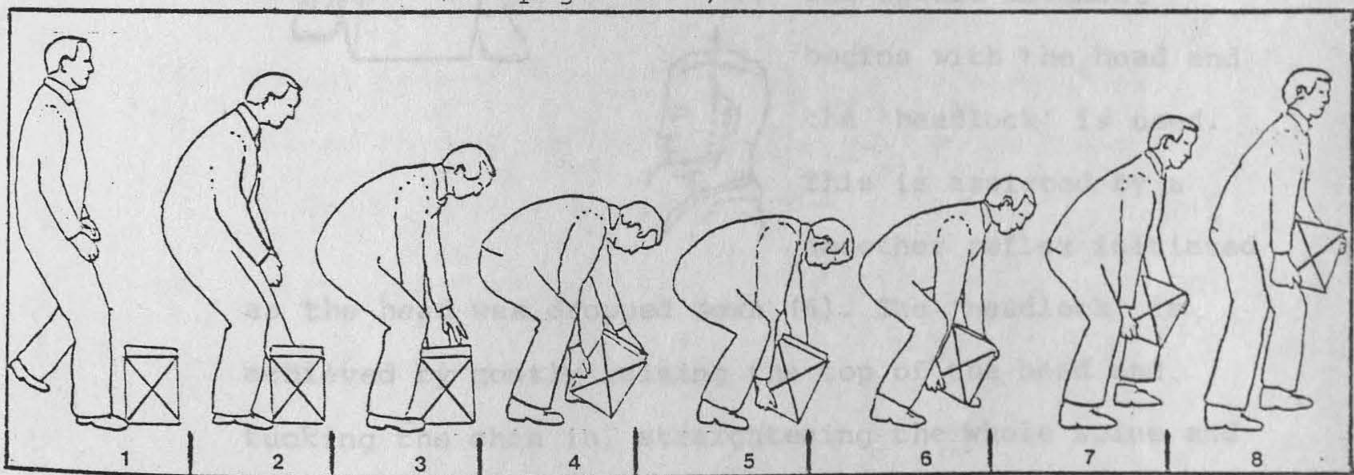
12.6.2 DETAILED DECRIPTION OF KINETIC LIFT

All kinetic actions are 'base movements'; these are defined as:-

'Actions which begin by relaxation of the knees and automatic adjustment of the feet, so that balance is maintained by relaxation and efficient adjustment of the body weight.' (Anderson 45). These are the opposite of 'top-heavy' actions which can be defined as actions 'in which the upper limbs, head or upper part of the body bend before the knees are relaxed and the feet move so that balance is maintained by stiffening of the lower limbs and back.' (Anderson op cit).

The drawing below illustrates 'stages' of the lift as demonstrated by the ROSPA instructor, together with descriptions of the lift. This figure fulfills two functions. First it helps to explain what a kinetic lift is. Second it shows how the eleven criteria used to assess the subjects' acquisition of this skill were derived. The criteria used for analysis are represented by the letters A - K shown in brackets and the numbers link the text to the frames shown in stages of the lift.

The line drawings which illustrate this section of the thesis were achieved by attaching an acetate overlay to the video screen and accurately tracing the outline of body segments. The acetate was then transferred to positive copy and photo-reduced. This technique was used to avoid the potential of distortion of body shape and limb size found in some training literature which had used freehand illustrations (see page 102)



(A) The approach is'base' the head and trunk are erect, the knees relax allowing the feet to adjust, forming a base into which the body can lower itself in a balanced fashion (1).

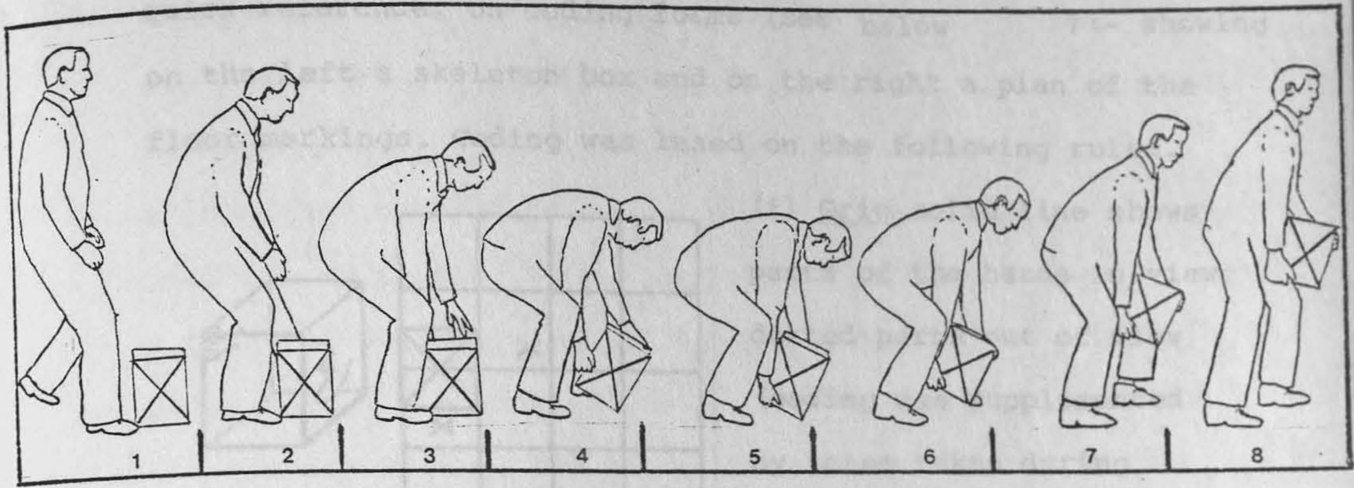
(B) One foot is behind the box and one to its side, both feet pointing forwards (2).

(C) The rest of the body begins to lower in a base fashion (from the base upwards) ankle and knee flexion (2) are followed by flexion of thigh and back (3) and finally:-

(D) The head is allowed to drop, allowing the shoulders to sag and thus the hands and arms to fall lower (4); the left hand can tilt the box and:-

(E) The right hand reaches under the box, the grip is oblique, and palmar (not just finger ends used). One hand is under the box supporting its weight (the right hand in 5). The other is ready to pull the box into the body (left hand 5). The head is the last part to drop, and therefore:-

(F) The upward movement begins with the head and the 'headlock' is used. This is assisted by a smoother reflex initiated as the head was dropped down (6). The 'headlock' is achieved by gently raising the top of the head and tucking the chin in, straightening the whole spine and not merely the neck. It further automatically raises the chest and conditions the shoulders for more efficient arm action. (Anderson undated).



(G) The back should therefore be straight throughout the UPWARD MOVEMENT (6).

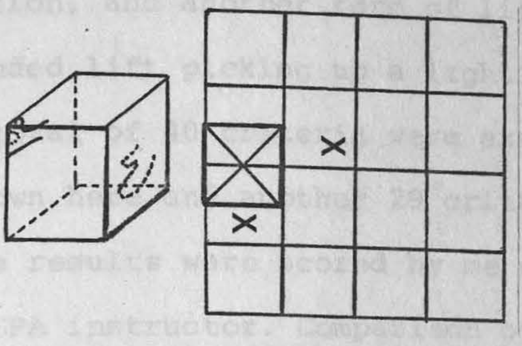
(H) The load bearing arm (right in 6) is straight to transmit force rather than to raise the box independently and the left as straight as possible but beginning to bring the load towards the body. The upward movement is therefore the reverse of the down and there is progressive extension of the body (7).

(I) Thrust from the rear foot (right in 8) begins the follow through as the subject moves in the direction in which he is going to walk.

(J) There should be no marked unstability of the box,

(K) or the person during the movement.

Criteria B and E. Hand and feet positions were recorded for quick reference, on coding forms (see below):- showing on the left a skeleton box and on the right a plan of the floor markings. Coding was based on the following rules.



(i) Grip solid line shows parts of the hands in view, dotted parts out of view (coding was supplemented by notes taken during the session to check on the hand away from the camera.).

(ii) Foot position × = centre of foot if pointing forwards

+ = for feet not pointing forwards, the cross is the foot centre, the long arm showing the direction of point

◄ = on 'tiptoe' (heel raised). Point shows direction.

12.6.3 ADDITIONAL NOTE: CRITERION C

In assessing whether or not the body lowered in a base fashion the following criterion was adopted; in order for the movement to be classified as 'base' the knee relaxation (flexion) had to begin before the hands were lowered by other means (back inclination / flexion). However using this dichotomy (Top heavy / Base) it was realised that a lot of subjects failed on it at the end of the course although many of them showed a marked improvement. An index of 'Top-heaviness' was therefore devised and this consisted of the number of degrees that the trunk inclined from the vertical (thus lowering the hands) before the knees began to flex.

12.6.4 VALIDATION OF KINETIC CRITERIA (A-K)

A pilot study was made by doing a post training video on one course of fifteen subjects. In addition to the standard lift the pilot study examined a pulling action, a pushing action, and another form of lift which was much faster (one handed lift picking up a light object such as a duster). A total of 40 criteria were examined, the 11 A-K criteria shown here and another 29 criteria for the other actions. The results were scored by me and one month later by the ROSPA instructor. Comparison of scoring showed good inter-rater reliability. Out of 600 observations (equals 15 subjects on 40 criteria) there were only 30 discrepancies. The majority (25) of the discrepancies occurred on the 29 criteria which did not subsequently appear in the main study because the movements they related to were not used in the final validation.

The other five discrepancies related to criterion C and concerned the decision about whether the body lowered in a base fashion or not. The introduction of the 'index of top heaviness' referred to above resolved these discrepancies. The dropping of the other three movements did not come about because of the discrepancies in scores. ROSPA could only make a thirty minute period available pre and post training which restricted the recording to one movement and the lift was selected for the reasons enumerated on page 143. It was necessary to record the subjects pre training to see if any of the 'kinetic criteria' were exhibited in 'naive' groups. In the summary of results which follows both pre and post training groups will be described.

12.6.5 RESULTS: KINETIC CRITERIA

The results are summarised in Figure 27 (o/leaf)

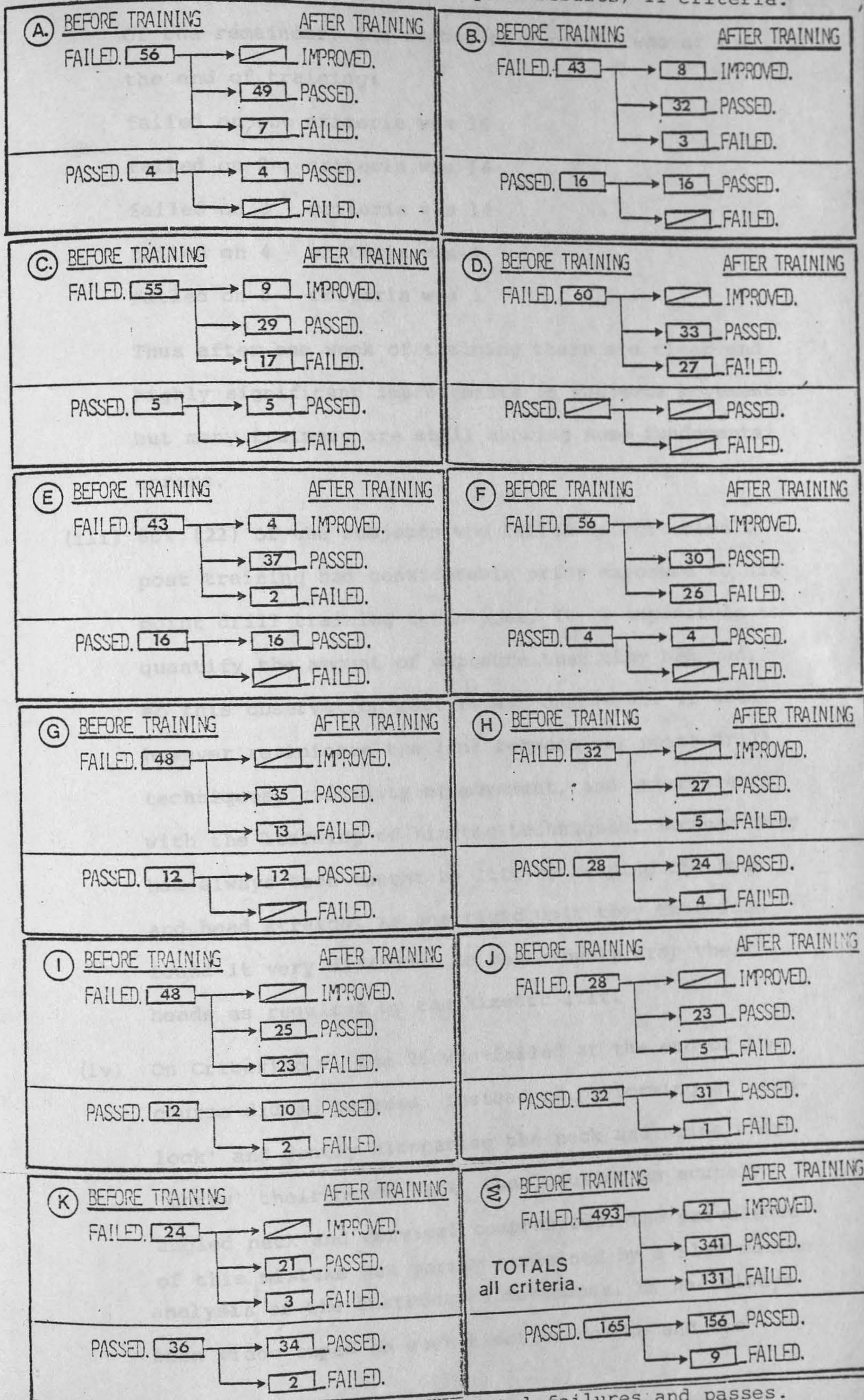
In the table kinetic criteria A-K are shown in the circles, and the numbers in the boxes refer to the number of subjects who failed or passed on that criteria. In cases where the improved box is filled in this indicates that the subject had moved towards the positive pole of the criterion on that measure (post training compared with pre training) but not far enough to justify a pass.

(i) On criterion C; of the 55 subjects who were top heavy at the start of the course the mean index of top heaviness (angle of inclin ation of back from vertical) was 45°. The 9 who improved moved from a mean index 55° to a mean of 35°.

(ii) The recorded changes in kinetic criteria show an overall improvement of 70% of the failed criteria converted to passes. However, the criteria which showed the least improvement, C (53%) and F (45%) (the top-heavy/base criterion and the head-lock) are two of the most important criteria of kinetics, which are fundamental to its whole philosophy; while criteria B and E, the foot and hand positions, which show most percentage improvement (B, 74%) and (E, 86%) are static and easily communicable criteria.

The number of subjects who passed on all criteria at the end of training was 6. A further 4 can be added if those subjects, who at least showed improvement on all criteria they did not pass, are taken into account.

Figure 27: Table showing Video analysis results; 11 criteria.



Pre and post training measures- total failures and passes.

Of the remainder, the number of subjects who at the the end of training:

failed on one criteria was 16

failed on 2 criteria was 14

failed on 3 criteria was 14

failed on 4 criteria was 4

failed on 5 criteria was 1

Thus after one week of training there are clear and highly significant improvements in subjects movements, but many trainees are still showing some fundamental errors.

(iii) 80% (22) of the subjects who failed on criterion D post training had considerable prior exposure to six point drill training techniques. It is impossible to quantify the amount of exposure that they had had, so this observation must remain anecdotal. It does however re-inforce the link between six point drill techniques, ridgidity of movement, and interference with the learning of kinetic techniques. Because they had always been taught to lift by keeping the back and head straight as one rigid unit they therefore found it very difficult to consciously drop their heads as required by the kinetic lift.

(iv) On Criterion F, the 26 who failed at the end of the course did so because, instead of performing a 'head-lock' and gently elongating the neck and spine they 'threw' their heads back, thus causing an acutely angled neck and cervical compression. The prevalence of this mistake was partly explained by a slow motion analysis of the instructors movements. He had always been video taped on each kinetics course and the analysis of his tape showed this manouevre to be the 'weakest link' in his lift, there being a tendency to 'throw' the head back rather than execute a good headlock.

(v) The marked improvements on measures J and K (instability of box and person respectively) confirm the observation made at normal speed that a kinetic lift is smoother and more stable.

12.7 OTHER CRITERIA: 12.7.1 INTRODUCTION.

The criteria 2,3&4 were used to assess not only naive and post training lifts, but also lifts following the simple 'straight back' instruction and the drill card presentation. (Called 'straight back' and 'six point drill' lifts respectively in the following discussion) The basis of these criteria are explained below.

12.7.2. CRITERION "2" DISTANCE OF LOAD

The amount of torque at any joint is dependent on the amount of force multiplied by the moment arm of that force, (Chaffin;1973) Several workers have demonstrated that this maxim means that the bending moment at the lumbosacral joint, and corresponding forces required on the muscles of the low back to counteract this torque, will increase as the distance (measured in the sagittal plane) between the load centre of gravity and the lumbosacral joint increases. Tichauer (1971)(1976); Park (1975).

A series of measurements were therefore made (criterion'2') of the distance between the load centre and the lumbosacral joint. This distance is is illustrated by measure d1 in figure 28 (o/leaf). Scaled measurements were made from the video replays along the horizontal line which joined a point vertically over the load centre (indicated by cross lines and a contrasting spot marker) with a point formed where an imaginary line in the sagittal plane coincident with the anterior surface of the flexed thigh intersected the surface of the back. This latter point normally falls between the skin overlying L3 and the palpable tip of the sacrum. In an ideal experiment external anatomical markers would have been used but time restrictions precluded this. A trial using such markers to compare video measures with physical measures using calipers demonstrated that the mean error in this measure did not exceed 5%. Repeat video measures confirmed this.

12.7.3 CRITERION'3' ANGLES OF BODY SEGMENTS.

The video replay was frozen at the moment the box left the floor and the angles 1-3(fig.28) measured using the continuous protractor shown.

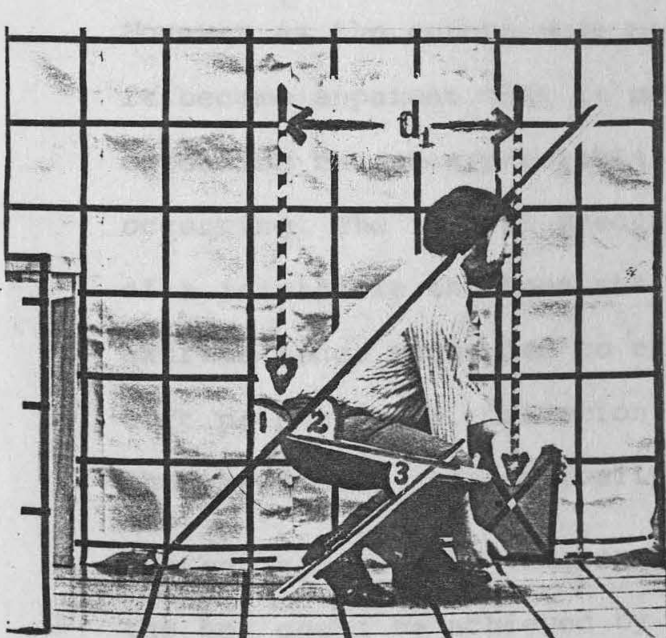
This protractor consisted of a fixed outer scale with a datum line for 0^{o} degrees, and a second datum capable of moving through 360^{o} attached at a central reference point. With the aid of this device, and marking the video screen with water soluble pens the following angles were measured.

(1) The inclination of the trunk axis from the vertical.

(2) The angle between the trunk axis in (1) and the thigh mid line.

(3) The angle between the thigh midline in (2) and calf ankle midline at the knee joint (knee flexion).

Angles 1 and 3 (in which I was most interested) could be measured with an accuracy of $\pm 3^{o}$. The thigh angle measurement (2) was less robust. This was because filming was only done from one side, and other observations showed that subjects kept right and left knee flexion the same, at the expense of different right and left thigh and ankle angles in assymetric lifting actions. For this reason thigh angle was discarded in later analysis.



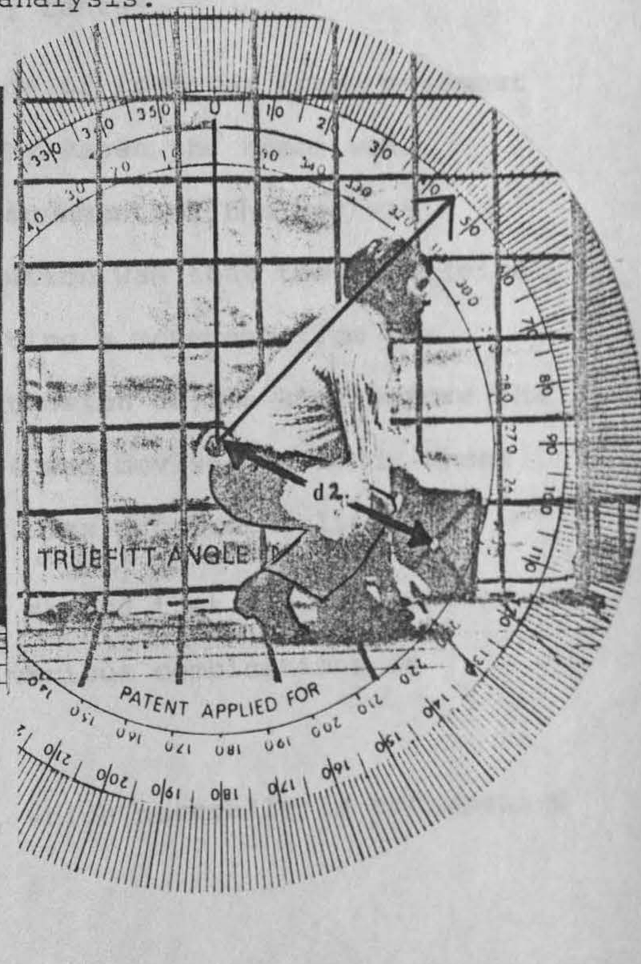


Figure 28:
Diagram showing how angles of body segments and distances were measured on video.

12.7.4 CRITERION '4' SEQUENCE OF MOVEMENT OF BODY SEGMENTS

This criterion evolved from the observations that a kinetic lift was smoother and more stable than other types of lift. It seemed that in some lifts, notably those in which the knees became hyper flexed at the lowest point of the lift, most instability occurred at the point where the knee first tried to extend from this position, often seeming to cause a delay in the lift. To test this further a series of measurements were taken of the time (in 1/50 second units) for the box to be raised through the first 50cm of the lift. The hypothesis was that a six point drill lift involving considerable knee flexion should be significantly slower due to the limbs (predominantly the knees) attempting to extend from the extreme inner range of their flexion. On this criterion the six point drill lift did prove to be significantly slower than the naive lift, and the Human Kinetic lift was significantly faster.

However as the counts were made of frame by frame movement it became apparent that in many cases the knees were extending but no appreciable movement of the box was occurring. The initial speculation was that the inefficiency of a joint like the knee starting a movement from its extreme inner range led to extension of the knee before the lift proper began. Criterion 4 was devised to study these phenomena more systematically. Its protocol follows.

Further analysis of the tapes showed that the movement of the box could be achieved by various combinations in different orders of:

(i) Extension of the knee, which naturally is accompanied by extension of the leg on the thigh (to prevent the subject falling over forwards), (L)

(ii) Extension of the thigh on the leg (indicated by the trunk inclination moving towards the vertical), (T)

(iii) Extension of the back (if it was initially flexed) (B)

(iv) Flexion of the arms at the elbows. (A)

A Classification shorthand was devised, based on the order in which these four factors operated. They were represented respectively by the letters L, T, B, and A. The following rules were observed: Actions which took place together (at the same time) were put in brackets together. Any action in which the joint(s) concerned passed through 50% of their range before other joints were mobilized was not bracketed. (This is a conservative criterion as in almost every case of independent action the joint(s) passed through more than 70% of their range before other actions started). If the actions could not be separated by the above criteria, but one, or one set, was still slightly ahead, linked brackets were used.

12.7.5 RESULTS FOR CRITERIA 2: 3 AND 4

12.7.5.1 CRITERION 2

An additional piece of evidence supporting Human Kinetics is furnished by the results of this section. The table on the following page (fig 29) shows that in the Human Kinetic lift the distance 'd_1' is significantly* smaller than in the subjects' naive lift (p 0.005). No such reduction is evinced by the six point drill method (p = N.S.).

* Students t test; Grouping data for courses R131178 & R26379 to compare pre training and six point drill. Grouping data for courses R80578 & R10778 & R131178 & R26379 to compare pre training and Human Kinetics.

Figure 29: Results for criterion 2.

COURSE CODE	SUBJECTS	N	Distance (d_1) cms	
			$\bar{X}$	S.D.
PRE TRAINING				
R80578	33 - 47	15	62	5
R10778	63 - 77	15	61	6
R131178	78 - 89	12	64	9
R26379	90 - 108	19	62	6
SIX POINT DRILL				
R131178	78 - 89	12	61	8
R26379	90 - 108	19	61	6
POST KINETIC TRAINING				
R90378 (pilot)	17 - 32	16	57	8
R80578	33 - 47	15	53	8
R10778	63 - 77	15	55	6
R131178	78 - 89	12	58	4
R26379	90 - 108	19	61	7
KINETICS INSTRUCTOR*	D.P.	5	50	4

*The last result reported in the table is that of the instructor. Over a two year period he was videod on 5 courses. His skill at this particular movement is reflected by his relatively small measure for 'd_1'.

12.7.5.2 CRITERION 3

All of these measurements were taken at the moment of the box left the floor. A great help in this stage of the measurement would have been a circuit which used a small switch underneath the box to fire a motor driven camera at the instant the box left the floor and simultaneously flash a bright light-emitting diode in the visual field of the video camera. Unfortunately this equipment was not available at the time the data was collected and the moment of leaving the floor had to estimated from visual examination of the video.

The results are summarised in fig 30 shown below and in the graphs of simultaneous frequency distribution (fig31) The numbers in each cell of the matrix on fig 31 refer to the number of subjects who showed that combination of knee and back angles.

COURSE CODE	NUMBERS		(1) INCLINATION OF TRUNK FROM THE VERTICAL (degrees)		(2) THIGH/ TRUNK ANGLE (degrees)		(3) THIGH/CALF ANGLE (FLEXION AT KNEE (degrees)	
PRE TRAINING		N	X̄	S.D.	X̄	S.D.	X̄	S.D.
R80578	33- 47	15	59	15	40	8	61	24
R10778	63- 77	15	53	18	47	10	66	28
R131178	78- 89	12	60	21	41	10	71	29
R26379	90-108	19	64	14	40	6	73	23
AFTER 'SIX POINTS' DRILL TRAINING								
R131178	78- 69	12	49	13	29	21	46	9
R2-379	90-108	19	50	19	45	11	31	61
AFTER HUMAN KINETICS COURSE								
R90378 (pilot)	17- 32	16	53	12	50	9	81	21
R80578	33- 47	15	60	10	47	10	66	15
R10778	63- 77	15	47	10	52	11	70	17
R131178	78- 89	12	56	15	42	7	71	22
R26379	90-108	19	68	12	46	4	91	15
KINETICS INSTRUCTOR on all 5 courses	D.P.	5	62	4	51	4	85	4

Figure 30: Table results for criterion '3' :
Back , thigh and knee angles , means and standard deviations.

Figure 30 shows the means and standard deviations of angles in naive (pre training), six point drill and post kinetic training. In the six point drill section course code R26379 was given the more simplistic instruction 'keep your back as straight as possible and the course coded R131178 was given the full drill card. These two groups are combined in the six point drill section of the frequency distribution (fig31)

Figure 31 Simultaneous frequency distributions of BACK and KNEE angles.

NAIVE LIFT.

BACK	1		3	1	1	2	3	2	3	6	5	5	12	10	4	≤58
30-34														1		1
35-39													1		1	2
40-44													1	3		4
45-49											2	2	2	4	2	12
50-54											1	1	4	1	1	8
55-59										2		1	2	1		6
60-64									1	2	1	1	1			6
65 69										1	1					2
70-74							2	1		1			1			5
75-79									2							2
80-84						2		1								3
85-89				1			1									2
90-94	1		3		1											5'
	133-39	126-32	119-25	112-18	105-11	98-104	91-97	84-90	77-83	70-76	63-69	56-62	49-55	42-48	35-41	KNEE

6.P.D. LIFT.

BACK	2	0	0	0	1	0	0	0	0	1	0	4	9	6	6	≤29
30-34													2		2	4
35-39													2	1		3
40-44												1	1	2	1	5
45-49												1	1	1		3
50-54										1			1	1	1	4
55-59														1	2	3
60-64												1				1
65 69												1	2			3
70-74																0
75-79																0
80-84					1											1
85-89	1															1
90-94	1															1
	133-39	126-32	119-25	112-18	105-11	98-104	91-97	84-90	77-83	70-76	63-69	56-62	49-55	42-48	35-41	KNEE

HUMAN KINETIC LIFT.

BACK	0	0	1	2	7	4	2	11	12	9	7	6	12	0	3	≤76
30-34															1	1
35-39											2	2	2		1	7
40-44										2	1	1	4		1	9
45-49								1		3	1	1	3			9
50-54								4	1		2	1	3			11
55-59								1	5	2		1				9
60-64						1	1	1K	3	2	1					9
65 69					2			1	2							5
70-74			1			2		2	1							6
75-79					2		1	1								4
80-84				2	3											5
85-89																0
90-94						1										1
	133-39	126-32	119-25	112-18	105-11	98-104	91-97	84-90	77-83	70-76	63-69	56-62	49-55	42-48	35-41	KNEE

Analysis of variance on the data presented in Figure 30 comparing inclination of the trunk from vertical for naive 'six point drill' and human kinetics groups showed highly significant (beyond 0.05 level) differences between both methods of lifting and subjects. The analysis of variance table is presented below;

Source of variation	Sum of squares	df	Variance	F
Between methods	3645	2	1822.5	16.6
Between subjects	14889	28	531.75	4.84
Interaction	6152	56	109.9	
TOTAL	24686	86		

A Tukey test confirmed that the significant between group difference was a result of the ' six point drill' lift where angle of inclination differed from either of the other two methods of lift. (which did not differ significantly from each other on this measure). The finding of a between subject difference confirms observations made of lifting behaviour that subjects produce widely different responses to the treatments. The frequency distributions (figure 31) suggest a linear correlation between degree of trunk inclination and degree of flexion at the knee. This was indeed the case and for this reason AOV was not repeated for knee flexion in criterion'3'. The coefficients of linear correlation were as follows;

(i) Naive back inclination/knee flexion....r= 0.67(p=0.01)

(ii)6PD back inclination/knee flexion..... r= 0.88(p=o.001)

(iii)Kinetic back inclination/knee flexion.r= 0.81(p=0.001)

The increased significance levels of r in (ii) and (iii) are because the back is straighter and the feet and arm positions are more standardised.

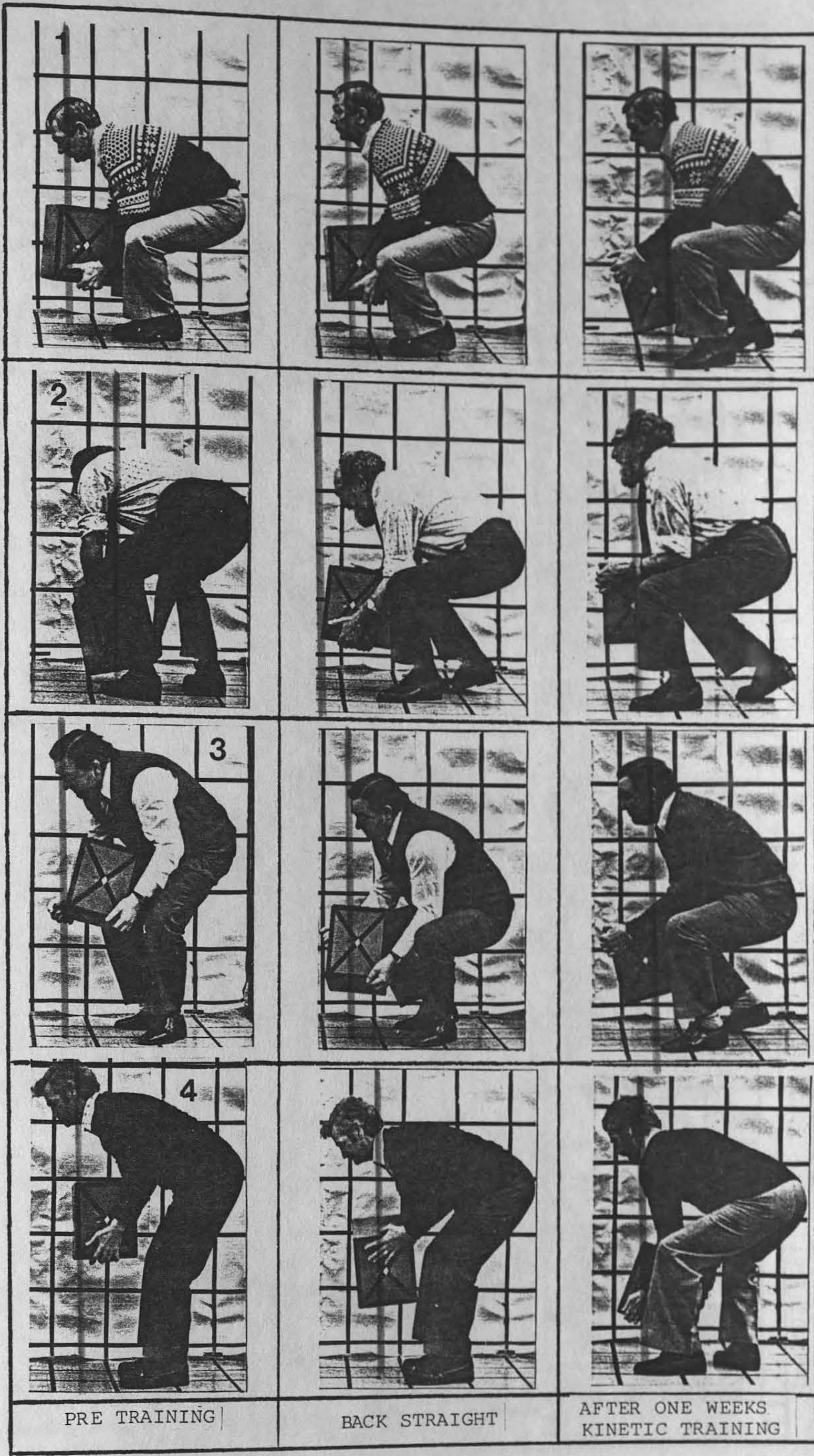
These results confirm that to reach under a load at floor level subjects have a choice of either flexing their knees or inclining their trunks. The 6PD training results in a trunk inclination which is significantly more erect, and hence more acutely flexed knees than either namive or kinetic lifts. This supports the contention that 6PD training may increase the risk of injury to the knee while trying to protect the back (see page 103). The results also contradict the common stereotype that a subjects naive lift will be performed by keeping the legs straight and 'stooping'. In fact as figure 31 shows the range of behaviours is much wider with approximately 40 per cent of the subjects performing a naive lift with considerable flexion of the knee (between 42 and 49 degrees of flexion). This can be confirmed by reference to figures 32 and 33 which show photographs for naive, six point drill. 'straight back' and Human Kinetic lifts for two complete ROSPA courses. The subjects are numbered 1-16 and A1-A8.

With reference to the photographs the following points are worth noting:

1) The red line on each photograph is drawn vertically through the centre of the box in its resting position. This line was also used on the video overlays and was a considerable aid in determining criteria like kinetic(I). The static nature of many of the naive and six point drill lifts is shown by the fact that in many cases the box moves up and backwards, whereas in the kinetic lifts the subjects tend to get much nearer to, and over the box, so that it moves forwards when lifted.

2) The simple instruction to keep the back as straight as possible does not seem to have much influence on the straightness of subjects' backs. However it does have a number of other results. In some subjects it produced bizarre results e.g. subject 16. In others it resulted in a more erect back, for example subjects 5, 8, 9, 10, 13 and 15. In some subjects it seemed to 'switch on' their memories about the way 'they are supposed to lift' and they perform the stereotyped 'good lift' e.g. subjects 6 and 11.

3) As an instructional device the six point drill card seemed to produce a good improvement when scored on its own internal criteria, with 50% of failed criteria converted to passes. The passes and failures pre and post training are shown on five criteria (defined in the way they are described on the drill card) in Figure 34(page 171)



INS260379

Figure 32: showing sixteen subjects (1-4 on this page) on one RoSPA course (1979) three methods of lifting

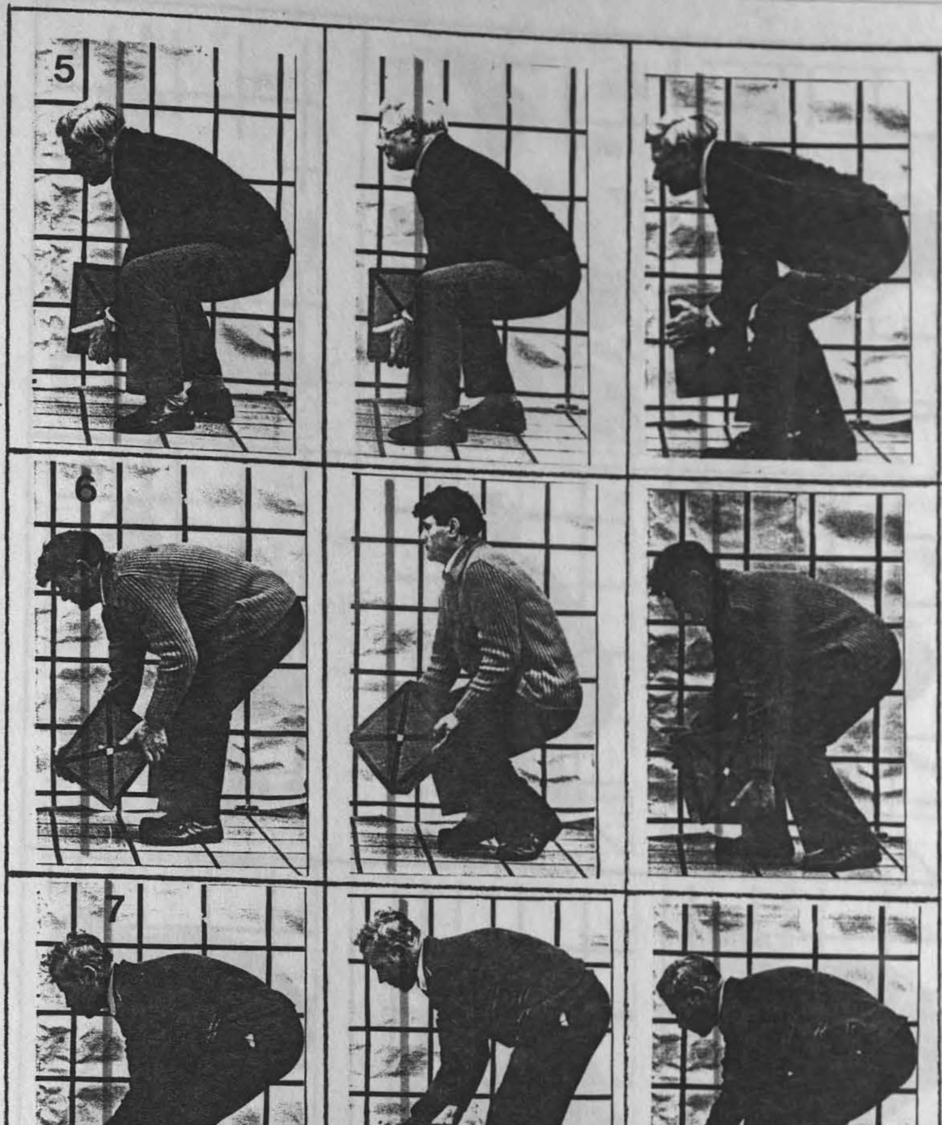


Figure 32: showing sixteen subjects (5-8 this page) on one RoSPA course (1979) ;three methods of lifting.

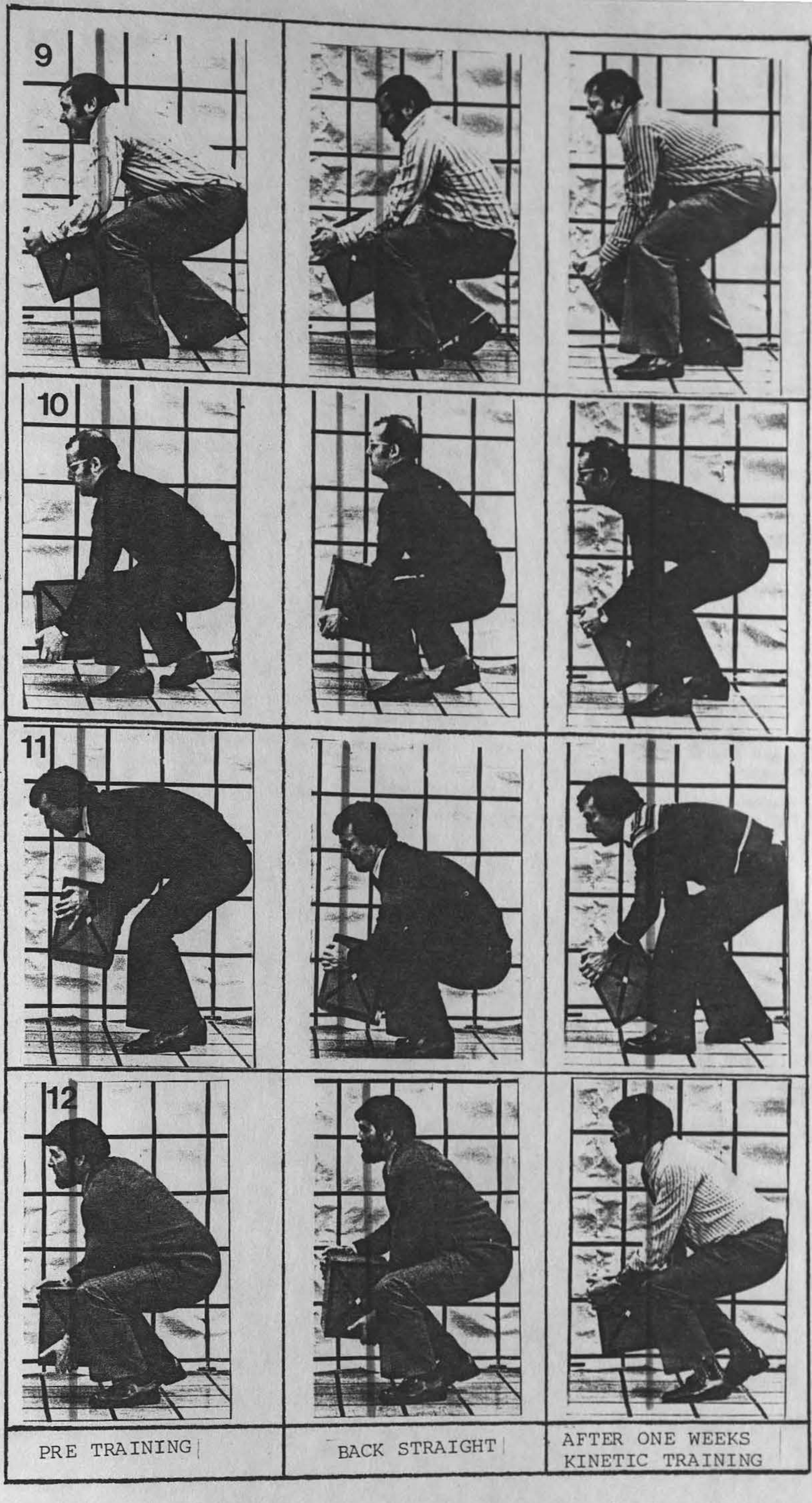


Figure 32: showing sixteen subjects (9-12 this page) on one RoSPA course (1979); three methods of lifting.

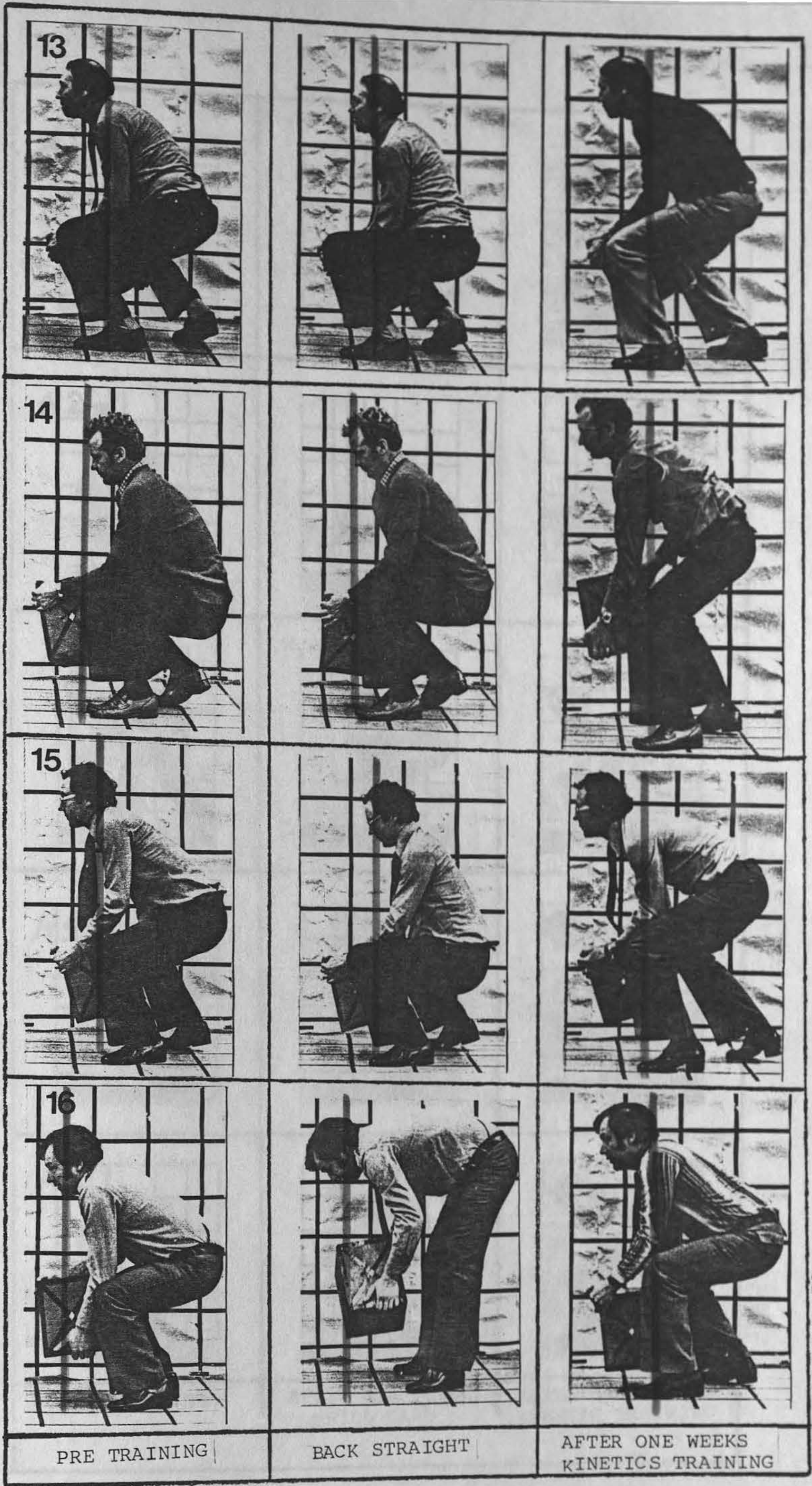


Figure 32; showing sixteen subjects(13-16 this page) on one RoSPA course(1979); three methods of lifting.

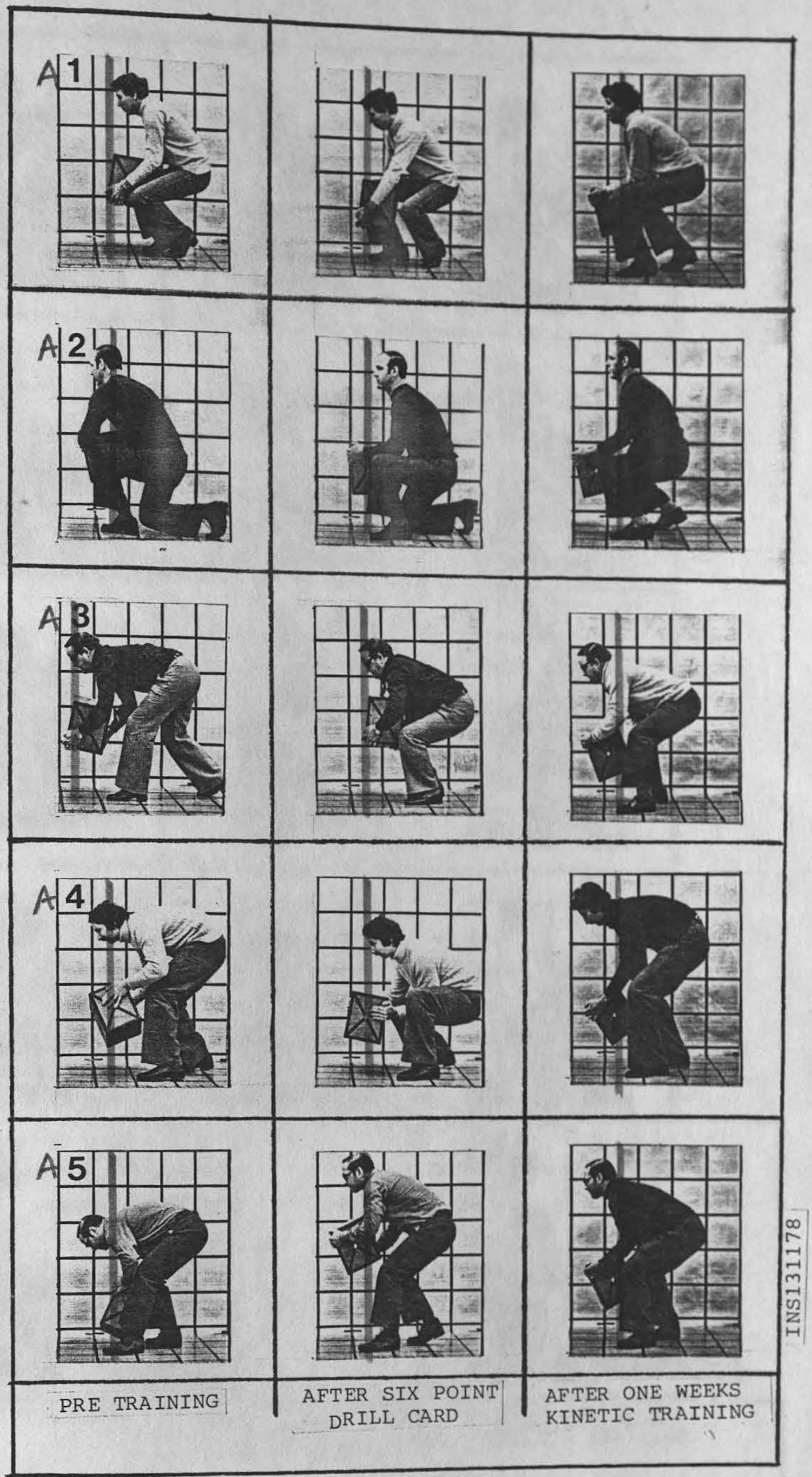


Figure 33: Photographs showing eleven subjects A(1-5 this page) on one RoSPA course (1978); three methods of lifting.

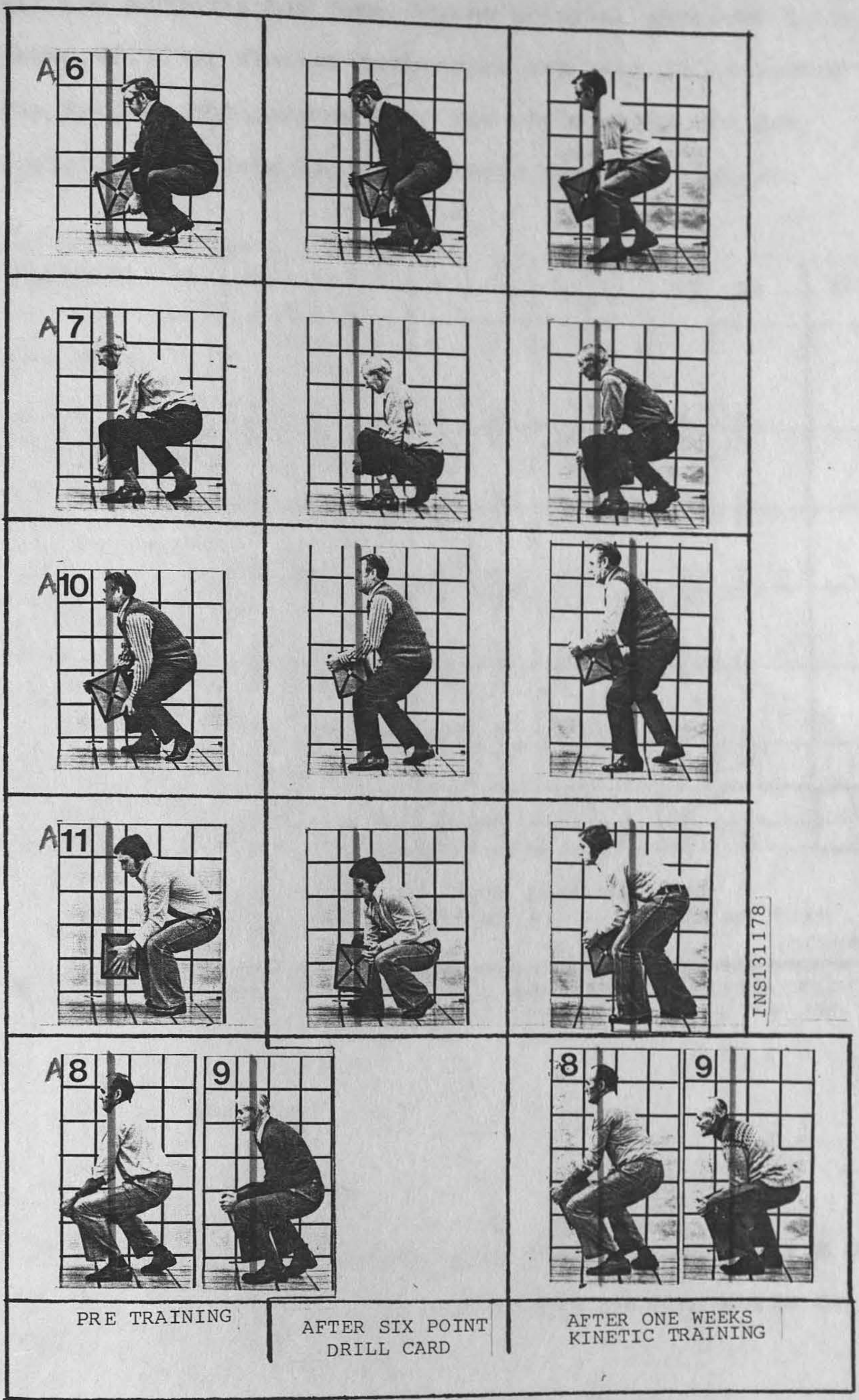


Figure 33: Photographs showing eleven subjects A(6-11 this page) on one RoSPA course (1978); three methods of lifting.

All the subjects had some degree of prior exposure to six point drill or similar techniques and this is reflected in the finding that summed over the whole group the pre training pass rate on the criteria examined was 42%.

SUBJECT CRITERIA	A;	1	2	3	4	5	6	7	10	11	Totals
Stand Firmly	N	X	X	X	X	O	O	O	X	X	3
	P	O	X	X	X	O	O	O	O	O	6
Straight Back	N	X	X	X	X	X	O	X	O	O	3
	P	O	X	X	X	X	O	O	O	O	5
Bend knees	N	O	O	X	X	X	O	O	O	O	6
	P	O	O	O	O	X	O	O	O	O	8
Chin In	N	X	X	X	X	X	O	X	X	O	2
	P	O	X	O	O	X	O	O	X	O	6
Firm grip	N	O	O	X	X	X	O	O	O	X	5
	P	O	O	X	X	O	O	O	O	O	7
Total passes:	N	2	2	-	-	1	5	3	3	3	19
	p	5	2	2	2	2	5	5	4	5	32

Legend: N= Naive lift; P= After reading card
X= Fails on that criteria; O= Passes on that criteria

Figure 34. Table of results for evaluation of 'six point drill' instructional card scored on its own criteria.

It must be stressed however that 'improvement' on six point drill criteria may be compatible with getting worse on kinetic criteria.

4) Subjects who had been exposed to a considerable amount of kinetics training in the past showed little change on 'straight back' and 'six point drill'. Examples here are subjects 5; 12, 13, A6. Subjects A8 and A9 who also had

considerable kinetics training refused to attempt the six point drill believing it to be dangerous, which is why there are only two photographs shown for them.

5) However as shown by the final section of the video analysis (criterion 4; which follows) a purely visual assessment based on any one stage of the lift, or even on the whole lift can be very misleading. Even the subjects with prior kinetic training who seemed to show little change over the three photographs are demonstrably different when analysed on other criteria.

12.7.5.3 CRITERION 4: SEQUENCE OF MOVEMENTS OF BODY SEGMENTS

Application of the shorthand described on page 159 resulted in the identification of 27 types of lift and these are shown in figure 35 together with the number of subjects exhibiting that type of lift in each of the categories 'naive', 'six point drill' and 'kinetic'.

12.7.6 DISCUSSION OF RESULTS: CRITERION 4

The occurrence of 27 types of lift indicates that classification of a lift by body position at the lowest point of the lift is a gross oversimplification.

There were 23 types of naive lift, 16 types of six point drill lift and 7 types of kinetic lift.

The coding for a good kinetic lift would be (LT).

Summing these and the 'second best' kinetic lifts which involved some back flexion and are coded (L T B) reveals that 78% of the subjects achieved these types post training, compared with (15%) pre training.

Shorthand notation: Type of lift action	Nº of subjects		
	NAIVE	6 POINT	KINETIC
(L T)	6	4	36
(L T B)	3	3	11
L(T B)	8	3	3
(A L)(T B)	4	6	–
(L T A B)	2	2	4
A L (T B)	4	2	–
(A L T)	2	–	4
L T	3	1	1
L (T B A)	4	1	–
A (L T B)	3	1	–
L T B	3	–	1
(L T) B	3	1	–
(B T) L	3	–	–
A (L T)	1	1	–
A B (L T)	2	–	–
A L (TXB)	2	–	–
L (T BXA)	1	1	–
A L T B	1	–	–
A L T	1	–	–
A (T B) L	1	–	–
A (T B)	1	–	–
(LXA) T B	1	–	–
(L TXA)	1	–	–
L T A	–	1	–
(LXA)(T B)	–	1	–
B (L T)	–	1	–
A (B TXL)	–	1	–

Figure 35: Table showing application of shorthand notation and the identification of 27 'types' of lifting action. The right hand column shows the number of subjects who manifest each type of action for each main group of lift.

In this analysis over 50% of the naive lifts and 40% of the six point drill lifts involved an action where the legs 'led' significantly. That is, extension of the knee significantly preceeded any other stages of the movement and transformed a posture which on a crude dichotomy ('stoop versus squat') appeared to be a squat into a stoop. To make this point more clearly figure 36 is included. This illustrates one subject following six point drill training. The picture series was drawn by placing acetate overlays on the video screen and making tracings of appropriate frozen frames.

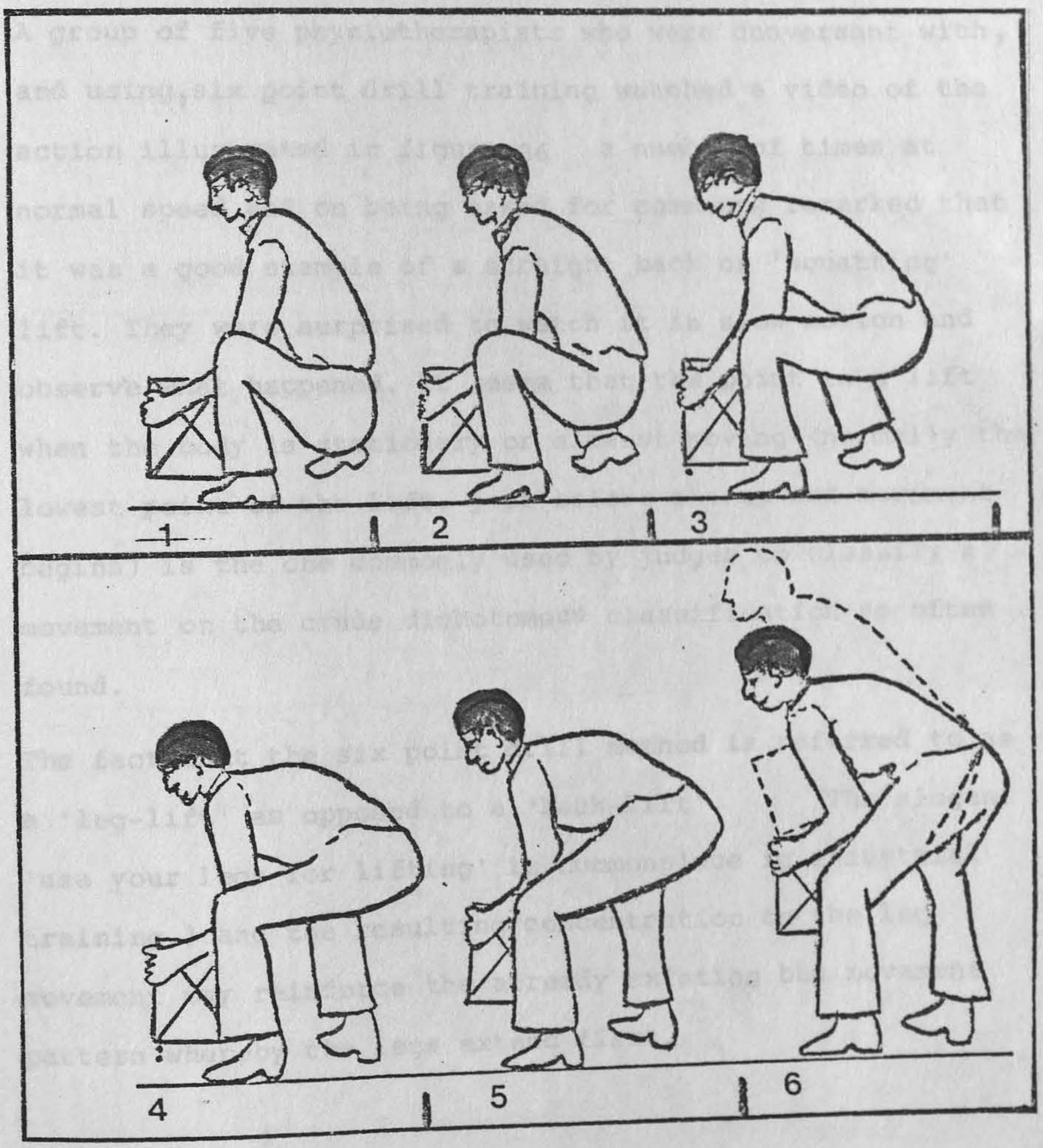


Figure 36: Illustration - a line drawing showing one subject who convertsa 'squatting' lifting action into a 'stooping' lifting action. Taken from video.

The subject attempts to keep a straight, and in this case almost erect back: (1) causing hyper-flexion of the knee. However the back still flexes in the cervical region (2) to enable the subject to get his hands under the load. The lift begins with arm flexion lifting the box just clear of the floor (indicated by a dot under the box), and in (4) the box is slightly higher (indicated by a second dot). The box remains in this position while the legs are almost fully extended (5), and finally the back straightens and the trunk returns to the vertical.

A group of five physiotherapists who were conversant with, and using,six point drill training watched a video of the action illustrated in figure 36 a number of times at normal speed and on being asked for comments remarked that it was a good example of a straight back or 'squatting' lift. They were surprised to watch it in slow motion and observe what happened. It seems that the point in a lift when the body is stationary or slowest moving (normally the lowest point of the lift, just before the upward movement begins) is the one commonly used by judges to classify a movement on the crude dichotomous classification so often found.

The fact that the six point drill method is referred to as a 'leg-lift' as opposed to a 'back-lift' (The slogan 'use your legs for lifting' is commonplace in industrial training.) and the resulting concentration on the leg movement may reinforce the already existing bad movement pattern whereby the legs extend first.

A final example which supports this argument, and shows the movement pattern in an occupational setting is demonstrated in fig 37.

The instructions on the left of the figure are from the Fire Service Drill book used to train firemen. When access was granted at a local firestation for a practical test, photographs were taken, using a fastwind camera to see if the two firemen shown in 'On the order five' were going to be able to stand up and maintain their trunk orientation as instructed. These firemen had received comprehensive training in the method illustrated in A. However their trunk inclination tended to increase throughout the lift until the final stages when a 'stoop' was effectively performed. The use of kinetic techniques with the head leading the movement would have obviated this tendency.

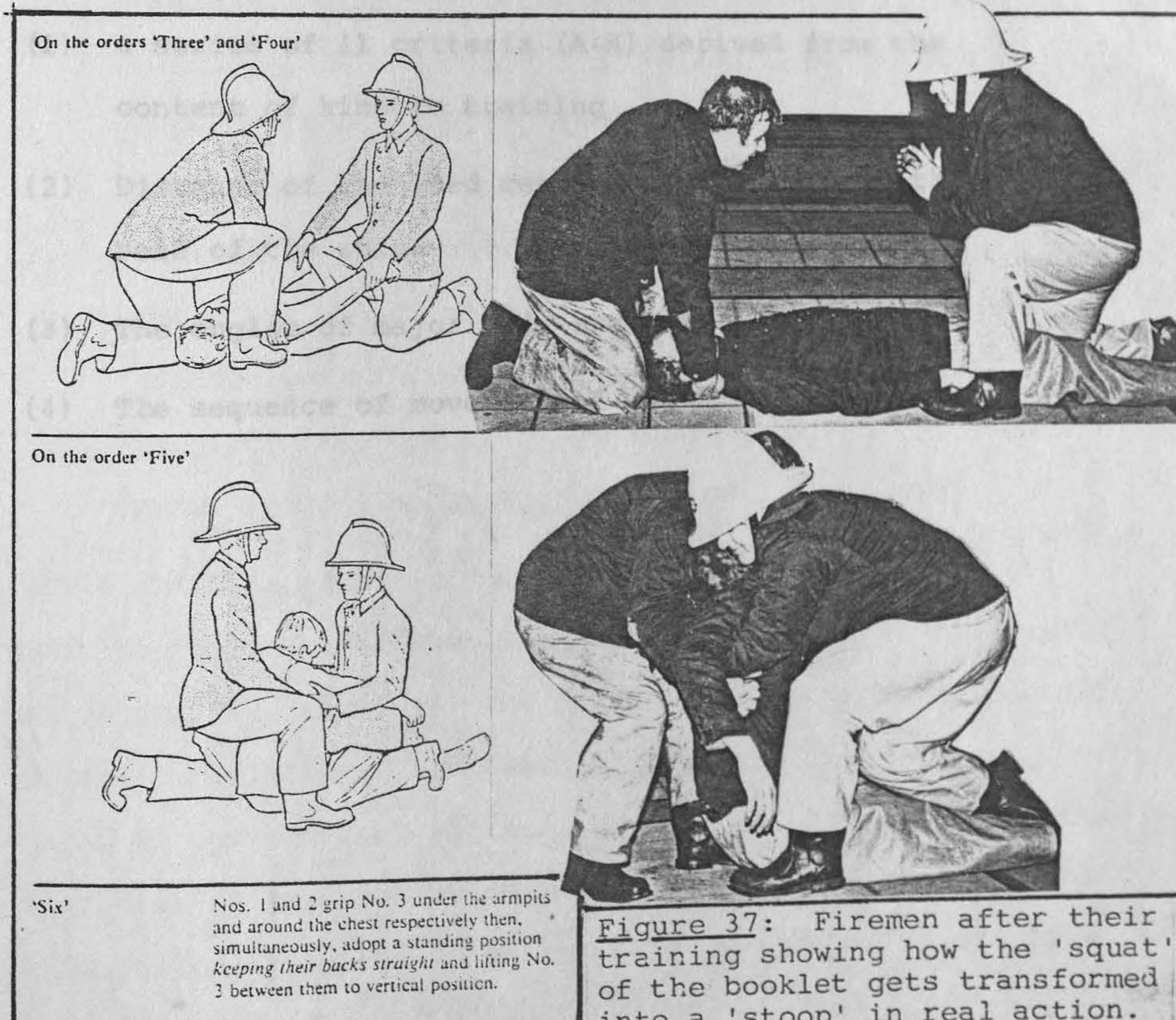


Figure 37: Firemen after their training showing how the 'squat' of the booklet gets transformed into a 'stoop' in real action.

A final comment on the movement patterns revealed by the shorthand classification (fig 35) concerns the number of subjects who use their arms for lifting in the early stages of naive and six point drill lifts. If kinetic principles are adhered to the coding A should not be appearing in any of the notations because forces should be transmitted down straight arms. Any muscular work in using the arms separately is wasted energy. In fact over 50% of the naive lifts exhibit this fault. This finding links in with other discussions of faulty arm use elsewhere in the thesis (see pages 138 & 203)

12.7.7 CONCLUSIONS OF THE VIDEO ANALYSES

The section examined the application of four main groups of criteria

(1) a series of 11 criteria (A-K) derived from the content of kinetic training

(2) Distance of the load centre of gravity from the base of the spine

(3) The angles of major body segments

(4) The sequence of movement of major body segments.

The broad findings fall into two main groups.

(i) Those which provide further validation for kinetics training courses

(ii) Those which identify misconceptions regarding movement, simple methods of training and classification of lifting styles.

(i) The kinetic criteria showed that the training courses resulted in a marked improvement. Notably 70% of the failed criteria were converted to passes. However, only 15% of trainees passed on all criteria. Against this background of significant improvement the analysis identified areas where more could be achieved. The training failed to produce much change in limb and trunk angles when compared with the pre training lifts. This was because the naive lifts were already like a kinetic lift rather than the stereotyped 'stooping' lift. An important finding in the post kinetic training groups was that the distance between the box centre of gravity and the base of the spine was signficantly reduced compared with naive groups. Work reported elsewhere in this thesis suggests that the torque forces acting on the lower spine would thus be proportionately reduced.

While the changes are encouraging in their magnitude, it must be reemphasised that the measures were taken immediately after training finished, and hence there is no assessment of the durability of the changes. Also the validation is based on one movement pattern, and no data could be collected on the other patterns which were covered on the course, still less on the extent to which learning might have generalised to movements not covered specifically.

(ii) The results of criterion 4 revealed major inadequacies in the classification of lifting movements. Any attempt to dichotomise into 'stooping' or 'squatting' lifts seriously misrepresents the true complexity, by using a static description of a dynamic movement, and by ignoring the very great scatter of lifts in between these extremes. Studies in the literature based on such simple classifications are likely to be unreliable in their findings.

The results also have implications for evaluating the success of any industrial training programme involving lifting (and possibly other movements). Trainers who rely on observation of the resultant movement may be mislead into thinking they have achieved their objectives. A slow motion analysis of video recordings may well prove these conclusions unwarranted.

CHAPTER 13

How applicable is Human Kinetics in practice? The shop floor evaluation package.

13.1 INTRODUCTION:

The retrospective analysis of handling accidents completed as part of the statistics section of this thesis suggested that the potential for kinetic training to prevent reportable injuries would be limited to a maximum of 60% of lifting accidents to the back. No estimate of its potential value in respect of other accidents was possible. This raised the question of general limits to the application of kinetic techniques to all movements, and the factors which would determine them.

Other studies have looked at the possible contributions of both worker behaviour and workstation design to the causation of handling accidents. Van Wely (1970) examined all the workstations in a factory employing 8,000 people which gave rise to musculo-skeletal problems requiring physiotherapy. He tried to make a division between cases where the workstation design was open to criticism on ergonomic criteria and those cases where the station was ergonomically sound but the worker did not use it properly. In the latter group he felt that expert guidance on 'correct' working postures might have obviated the problems.

He found bad design to be a factor in 80% of the cases studied and bad posture under the control of the worker in 58% of the cases. In 38% of the cases it was clear that both design and behaviour played a part in the problem.

Van Wely's criteria for correct 'postural use' were not clear from his study. However his findings add weight to the supposition that a limitation on the value of training, may be that the design and layout of the workplace will constrain the application of kinetic movements.

A study was therefore designed with the following objective:

> To evaluate the extent to which layout and design of a sample of workstations, and/or characteristics of objects handled prevented the application of Human Kinetic techniques.

The people sent on the one week's training course at ROSPA were being trained to act as instructors in Human Kinetics. One of the objectives of training was to encourage them to do a broad review of handling practices at their own places of work and to sort out priorities for training.

They were therefore interested themselves in making an assessment of the potential for training in any given task, and the extent to which design precluded improvement in posture or movement patterns.

Since early attempts during the research had shown that it was difficult for me to obtain access to companies to make studies of jobs in progress, it seemed politic to take advantage of this commonality of interest and to use the instructors to collect data.

It was therefore decided to organise this section of data collection by training volunteers from the ROSPA courses to act as investigators.

13.2 METHOD

In order to make the process as systematic as possible an evaluation package was designed which drew on the sections of ROSPA training dealing with analysis of priorities in training.

An important objective in designing the package was that the volunteers should accrue benefit from participating in the study and that its final design would help to consolidate their background knowledge of Human Kinetics, encourage them to structure pre training analysis in their own companies and develop appropriate training criteria in their own teaching programmes.

These considerations therefore imposed the constraints on the package (and the study) that it must be easy to apply in the industrial setting and that personnel could be adequately trained in its use in a period of no longer than 1½ hours (the extra time that ROSPA could make available to train volunteers).

The limitations imposed meant that the primary research objective of the evaluation study had to be subordinated somewhat to practical considerations. It was accepted that the evaluation could not be controlled as tightly as if one person had carried out all of the study, but the advantages of the increase in the number and range of jobs studied and the circumvention of the problem of research access outweighed the disadvantages. Every effort was made, as described below, to overcome shortcomings in standardisation of the results, through the training of volunteers and the detailed monitoring and follow up of the results they submitted.

13.3 THE EVALUATION PACKAGE DESCRIBED

(i) An explanatory introduction

(ii) Supplementary Human Kinetics Information

(iii) Job description listings (C and D)

(iv) Human Kinetics Checklist (B)

(v) Design Layout checklist (E)

(vi) Assessment forms (F)

Figs 38 and 39 set out the instructions (i) and the check-lists and coding frames (iii - vi). The latter have been reduced to quarter size in order to show them all together on one page for convenience.

13.4 INSTRUCTIONS FOR USE GIVEN TO TRAINEES

(i) The trainees were instructed to make a list of every work station or job in their works which involved systematic manual handling of goods. They were asked to complete an assessment on at least one person working at each work station, and if that proved impossible because of time restraints to choose a random sample (I did not want to alarm them with random number tables so they were asked to pick the amount of jobs that they could analyse from a hat containing numbers from their lists).

While the main focus of the study which concerned this research was the design constraints it was not feasible with the type of instructor encountered on the course to train them to recognise these directly. Ergonomics courses devote considerable time to the training of graduates to carry out the task with acceptable accuracy. I had only 1½ hours. Also I was not interested in all design constraints, only those which constrained posture and

INTRODUCTION

The object of this checklist is to enable you to make the following assessments;

As you go around your own factories you will spot handling which is kinetically poor. Firstly you should be able to say why it is poor i.e. what is wrong kinetically. Answering this question will help you to sort out the areas which merit most attention when you come to do some training.

The se cond question is what reasons are there for these poor movements? Is it that the workers involved do not know that there are less harmful ways of moving, or is it that the design of their work station is such that they cannot do any other way. There is another alternative here, but it is rare, and it is that they have some physical disability which prevents them moving kinetically.

In some cases it will be obvious that the work station design is poor, in others you may have to pose a question e.g. "Have you ever tried doing it this way?" and see what their response is.

This booklet is in six parts:

(i) Introduction
(ii) Supplementary human kinetics information
(iii) Job description listings
(iv) Human kinetics checklist
(v) Design layout checklist
(vi) The assessment forms

It all looks complex but once you get used to it assessment can be made quickly.

The assessment forms are used as follows:

1) Name and Department, this is so that the success of training may be evaluated, or further measures taken. If you are not happy about sending me names, just number the forms and keep a list of names yourself.

2) Try to give a brief description of the job.

3) Under action code (A - I) as appropriate.

4) Under object handled code (J - Z) as appropriate.

Underneath this are some boxes which you should try to complete whenever possible, or appropriate. They are for recording; The WEIGHT of an article handled, the number of times such articles are handled per shift (or the amount of times any handling operation is repeated.) and lastly the heights from and to which objects are handled and distances carried.

The most important section is the next one. There are ten spaces available for "Kinetic Faults", refer to check list and fill in codes.

Next to each of these boxes is another in the "Reason" column, refer to your "Design/Layout" checklist and enter the appropriate code, if any of these factors would prevent the job being done kinetically (try doing the job yourself, applying your training).

Finally try to assess the probable site of cumulative strain (if any) and scope for training (ring your response.)

Figure 38:
The instructions which accompanied the shop floor evaluation package.

B

KINETIC CHECK LIST

CODE

1. Is the action;
   - (1:1) Base
   - (1:2) Top Heavy
   - (1:3) Impossible to tell (halfway)

2. The six key analysis factors (pages 40-44)

Wrong Foot Positions

2:1 One foot is not advanced for balance
2:2 Inadequate thrust from the rear foot
2:3 Sideways movement without pointing of advanced foot

Hold

2:4 Concentration of pressure on finger ends
2:5 One hand not below article carried
2:6 Article not resting down on body (held away)
2:7 Hold not broad or diffused
2:8 Hold taken in the wrong way (skin tone)

Chin In

2:9 Head lock not used

Straight Back

2:10 Back bends or 'doubles up'
2:11 Back is kept consciously straight (as in drill training)

Elbows

2:12 Works with elbows out from the body

Body Weight

2:13 Body weight could be used more efficiently
2:14 Body weight is not transferred from foot to foot in sideways movements

Other considerations

3:1 Action is not smooth and rhythmic (page 19-20)
3:2 Excessive torsion or twisting of spine (page 29)
3:3 Acute angle of wrist in control and other actions (page 31)
3:4 Are there other sites of pressure, eg. knees, toes, in kneeling work if so specify these on form
3:5 Long periods standing on one leg
3:6 Arms reach out or up excessively

4 Can you think of anything else, if so add to list and use

4:1
4:2

E

DESIGN/LAYOUT CHECKLIST

CODE

(H.I) Bad Houskeeping

Workplace Layout

(W.I) Obstructions of floor
(W.2) Other obstructions to foot or leg movement
(W.3) Inadequate space for feet to move
(W.4) Not enough room for whole body to move in

Reach

(R.1) Involves reaching over something (horizontally)
(R.2) Involves reaching into something (over a high side)
(R.3) Involves high reaching
(R.4) Involves low reaching

(S.1) Work Station is too high (eg Bench or Machine Part)
(S.2) Work Station is too low

Container

(C.1) Design of container is poor for hold
(C.2) Design of handles is inadequate
(C.3) Object handled is just an awkward shape

Other

(O1) Bar, handle or lever is at an awkward angle
(O2) Bar handle or lever is too far away
(O3)
(O4)
(O5)

Figure 39:
The contents of the shop floor evaluation package ..Listings.

C

JOB DESCRIPTION LISTING

CODE	ACTION
A	Pushing
B	Thrusting
C	Pressing
D	Pulling
E	Lifting
F	Downpulling
G	Torsion
H	Pendulum
I	Gravitational

(See supplementary notes for definitions of these terms A - I)

D

Object handled

J	Box or Carton etc
K	Hand Tool
L	Machine Tool
M	Machine Control
N	Trolley, hand truck etc
O	Chain or rope etc
P	Raw material (lumps of metal etc)
Q	Components, work, finished product

OTHER

R

S

F

NAME DEPARTMENT

JOB DESCRIPTION (BRIEF)

ACTION | OBJECT HANDLED

WEIGHT | FREQUENCY (TIMES per SHIFT | HEIGHT from; to;

Distance carried.

KINETIC [illegible]	REASON	KINETIC FAULTS	REASON

PROBABLE SITES OF CUMULATIVE STRAIN.

SCOPE FOR IMPROVEMENT VIA TRAINING............ VERY GREAT. GREAT. REASONABLE. POOR. VERY POOR movement. However the instructors had spent a whole week learning to recognise good and bad posture directly and to practice good movement. It therefore seemed reasonable to expect that they would be able to approach the design constraints through a consideration of posture and movement.

The instructors were therefore told to examine tasks for all aspects of kinetically poor posture and movement and to note these first. They were then asked to make the judgement as to the reason for the fault, and to decide whether it lay in the design of the workstation or in the worker's lack of knowledge or skill.

The literature on attribution of responsibility (e.g. Jones et al 1971; Ross 1977; Buss 1978) shows that such attributions by an observer are subject to a clear bias towards over-estimating the responsibility of the actor and underestimating the influence of the environment (in this study under-estimating the importance of design constraints). An attempt was made to overcome this bias by telling the instructors to place themselves (either mentally - but preferably physically) in the position of the worker and to try to carry out the movement kinetically. It was hoped that this judgement as 'actor' which has been shown to produce an opposite bias to the 'observer' bias would cancel the latter out and result in a fairly objective assessment.

(ii) Supplementary Kinetic Information

The instructors normally leave ROSPA with a 102 page training manual and other supplementary publications (Anderson 45:46). The supplementary Human Kinetic information in the evaluation package cross-referenced all the terms employed in the coding to check definitions. In addition some of the more complex concepts in the package were directly cross-referenced to assist the instructors in making their evaluation decisions; for instance the judgement B3:1 'Action is not smooth or rhythmic' which requires a complex integration of factors is referenced to pages 19 and 20 of their manuals.

All of this information was intended as a backup to the special short course instructors were given on the use of the package as part of their ROSPA training.

(iii) Job descriptions

The evaluator was asked to code the action which was being performed, the object handled, its weight, the amount of times it was handled per shift, and, if it was carried, how far this was. If it was lifted, the heights to and from which it was lifted were recorded. The coding terms for the actions were explained in the notes and during the training.

(iv), (v) The checklists

The lists were designed to enable the evaluation to say what kinetic faults were present in a particular movement and to identify any workstation design criteria which would prevent that movement being performed kinetically.

(vi) Assessment forms

These were summary forms for recording all the data generated for each job. In addition to the above information the evaluators were also asked to make a subjective assessment of the possible scope for training on a five point scale and to record possible sites of cumulative strain. This latter judgement was included to help consolidate their background in Human Kinetics and is not included in analyses.

13.5 ORIGINS OF DESIGN AND KINETIC CRITERIA

(a) The design criteria were drawn from two sources:

(i) Spending one day moving round all the manual handling jobs in a large engineering works, attempting to do the tasks kinetically, and making notes on any design problems;

(ii) A review of the literature describing workstation design criteria for manual handling tasks (Chaffin and Ayoub 1975) (Fitzgerald 1969).

(b) The kinetic criteria were developed from the criteria used in the video assessment of ROSPA courses, (see page 146 and the criteria used in the picture questionnaire to separate kinetically good from kinetically bad movements (see page 226). The criteria were made as explicit as possible; for example the third category in criterion 1 was added because it was sometimes found difficult to tell whether a movement was top heavy or base without the assistance of slow motion video analysis.

The lists were left open ended so that the instructors were not inhibited from noting any faults that they found hard to categorise.

13.6 TRAINING INSTRUCTORS IN THE USE OF THE PACKAGE

The package was explained in detail to trainees participating by me aided by the ROSPA instructor. It was emphasised that it was designed to cover more than just lifting tasks and to this end they were shown a series of thirty slides of a variety of tasks, plus a specially prepared video tape on which each of the following tasks was repeated four times:-

(i) removing boxes from low and high stacks and turning to load them onto a conveyor.

(ii) dipping and agitating baskets of product in a cleaning solution.

(iii) using an abrasive hand grinder to smooth a weld.

(iv) operating a bench type ring-forming press.

(v) a lift in free space.

The subjects were 'talked-through' activities (ii), (iv) and (v), to illustrate where problems were occurring. They were allowed to freeze, or replay portion of the tape if they wished. They were then required to fill in the test package for activities (i) and (iii) in order to examine their competence in its use. (i) had many design problems and (iii) none. The results of this exercise were collected and collated to determine their reliability, and ensure that subjects were completing the packages correctly. The omissions and mistakes that were made were then explained to subjects before they departed.

On the two tasks there were 12 major kinetic faults and 12 more minor faults. The omissions on major faults across the 25 subjects were 2%, with 7.5% classifying design/layout constraints incorrectly. The omissions on minor faults rose to 26% with 9% incorrect classifications. These errors on minor faults seemed to be the result of paying too much attention to the multiplicity of major faults on task (i). While this level of reliability was not as high as desired it was felt that the good agreement on major faults warranted proceeding with the study.

13.7 THE SAMPLE STUDIED

A total of twenty five volunteers received training in the use of the packages on ROSPA courses R30679 and R15679. Six sets of results were returned in the 6 month follow up period. Telephone checks on the subjects who had not returned the packages revealed that in all cases this was because line management would not allocate time for them to complete the analysis, or indeed to do any training. (It is noted elsewhere in the thesis that the majority of people sent to ROSPA are not full time training staff.) The six packages returned covered 82 handling tasks carried out by approximately 1,000 people out of a total factory population of approximately 4,000.

Once the returned packages had been scrutinised the respondent was telephoned to double check the basis on which he had sampled job, the number of workstations covered by each of his analyses and also to clear up any apparent discrepancies.

13.8 RESULTS AND DISCUSSION

OBJECT HANDLED		No.
J.	Box or carton	18
K.	Hand tool	3
L.	Machine tool	2
M.	Machine control ..	4
N.	Trolley, hand truck etc.	2
O.	Chain or rope etc...	2
P.	Raw material (lumps of metal etc..	9
Q.	Components, work, finished product.	16
Other		
	Coil	1
	Sack	14
	Keg	3
	Equipment	3
	Drum	1
	Bagged product	1
	Gas cylinder	1
	Shoes	1
	Manhole cover	1
	Tray	2
		82

ACTIONS PERFORMED		No.
A.	Pushing	30
B.	Thrusting ..	4
C.	Pressing	5
D.	Pulling	23
E.	Lifting	55
F.	Down pulling..	1
G.	Torsion	13
H.	Pendulum	2
I.	Gravitational.	2
	TOTAL*	135

Fig.40.

Totals for parts C and D of the package, object handled and actions performed for the 82 handling tasks

* greater than 82 because 38 jobs involved more than one action

The handling tasks reported covered a broad range and a complete list is given in appendix 5 (page 231)

50% of the jobs involved some carrying of the object handled. In these cases the average distance carried was 4m. The average weight handled, summed over all 82 tasks was 21kg.

13.8.1 TOTAL FAULTS

A total of 371 kinetic faults were discovered on the 82 jobs, 268 of which (72%) were soluble by training and 103 of which (28%) could not be solved by training because of design or layout constraints. It should be noted at this point that because of the way in which the data were collected there is no indication of the extent to which changes in design might have made people more 'naturally' inclined to lift kinetically. Data are limited to estimates of the number of faults where design ruled out a kinetic way of moving. Thus the potential contribution of design may be underestimated by these figures.

Fig 41 shows the distribution of number of kinetic faults per job, and fig 42 the distribution of percentage of faults constrained by design among the total number of jobs. When the jobs were considered individually 35 (43%) could have been done completely kinetically within the existing design or layout, while on 6 jobs (7%) none of the faults could be removed by training because of bad design or layout.

In between those two extremes the distribution is roughly normal, showing that most of the remaining 41 jobs could be substantially improved by design changes and/or by training, with a slight 'skew' towards the training solution.

The histogram (fig 44) shows the relative frequency of each kinetic fault in the total sample, and further shows the proportion of times for each fault for which it can be eliminated by training and the proportion for which design is a bar to implementation of training.

The matrix (fig 43) shows the interaction between specific kinetic criteria and layout criteria. The figures to the right of the matrix are summarised in the histogram referred to above. See fig 39 for the meaning of the criteria codes.

The total figures are an indication of the more important kinetic criteria on which faults occur and the major design constraints for this sample of jobs.

13.8.2 KINETIC FAULTS

The findings support observations made elsewhere in this thesis regarding the percentage of people who do jobs in a top heavy fashion. The results showed that almost all operators were clearly or probably top heavy movers (1:2 and 1:3) 75 out of the 82 jobs studied showed this, of which 61 (81%) could have been corrected.

The commoner faults tended to be the ones which were considered more amenable to training. Of the top five criteria (taking 1:3 as part of 1:2) which accounted for 205 (55%) of the faults 162 (79%) were judged as soluble by training compared to - 106 (64%) of the remaining 166 faults.

The results of the section of this thesis which used the picture questionnaire to examine beliefs about posture and movement noted that a major set of misconceptions centered on the use of the arms. Postures showing inefficient use of the arms with the elbows jutting out were often incorrectly labelled good.

The finding from this shop floor study that the kinetic fault 2:12 'works with elbows jutting out from the body' is the second largest category of fault confirms the prevalence of this particular misconception and movement error.

The other most common kinetic faults were; not advancing one foot to form a stable base for balance (part of the reason for the prevalence of top heavy movement patterns) and working with the back either 'doubled up' (2:10) or used in such a way that torsion or twisting is concentrated in the lower spine (3:2).

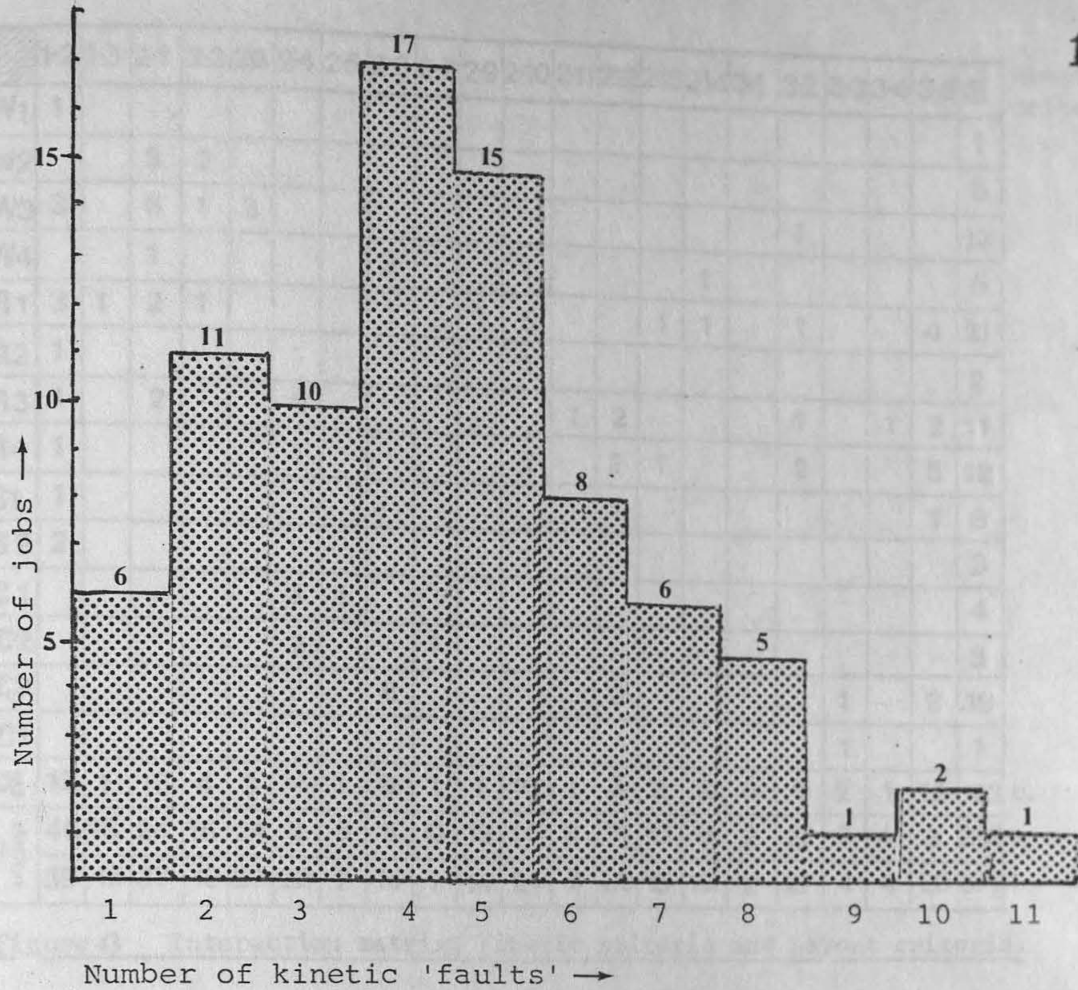


Figure 41: Histogram showing distribution of number of kinetic faults per job.

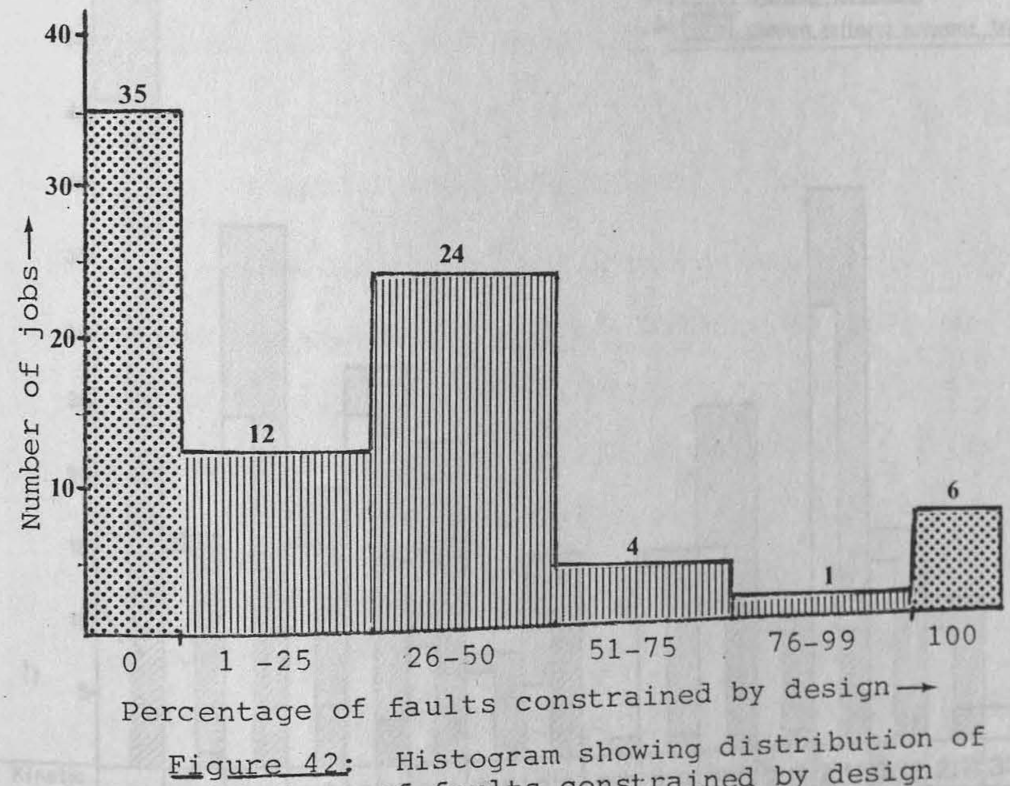


Figure 42: Histogram showing distribution of percentage of faults constrained by design among the total number of jobs.

	1·2	1·3	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·9	2·10	2·11	2·12	2·13	2·14	3·1	3·2	3·3	3·4	3·6	Σ	
W1	1																				1	
W2			3	2																	5	
W3	3		5	1	3												1				13	
W4			1					2			1				1						5	
R1	3	1	2	1				1		1	5			1	1		1			4	21	
R2	1										1										2	
R3	1		2			1						1	2				1		1	2	11	
R4	1					1					2		2	1			2			3	12	
S1	1												1							1	3	
S2	2										1										3	
C1						3	1														4	
C2						2			1												3	
C3						7		6					3					1		2	19	
O1																		1			1	
Σ	13	1	13	4	3	14	1	9	1	1	10	1	8	2	2	0	5	2	1	12	103	D„
design ↑	46	15	24	15	24	8	6	5	0	13	14	8	31	13	8	2	22	2	4	8	268	P„
	59	16	37	19	27	22	7	14	1	14	24	9	39	15	10	2	27	4	4	20	371	T„

Kinetic criteria.

Figure 43 Interaction matrix, Kinetic criteria and Layout criteria.

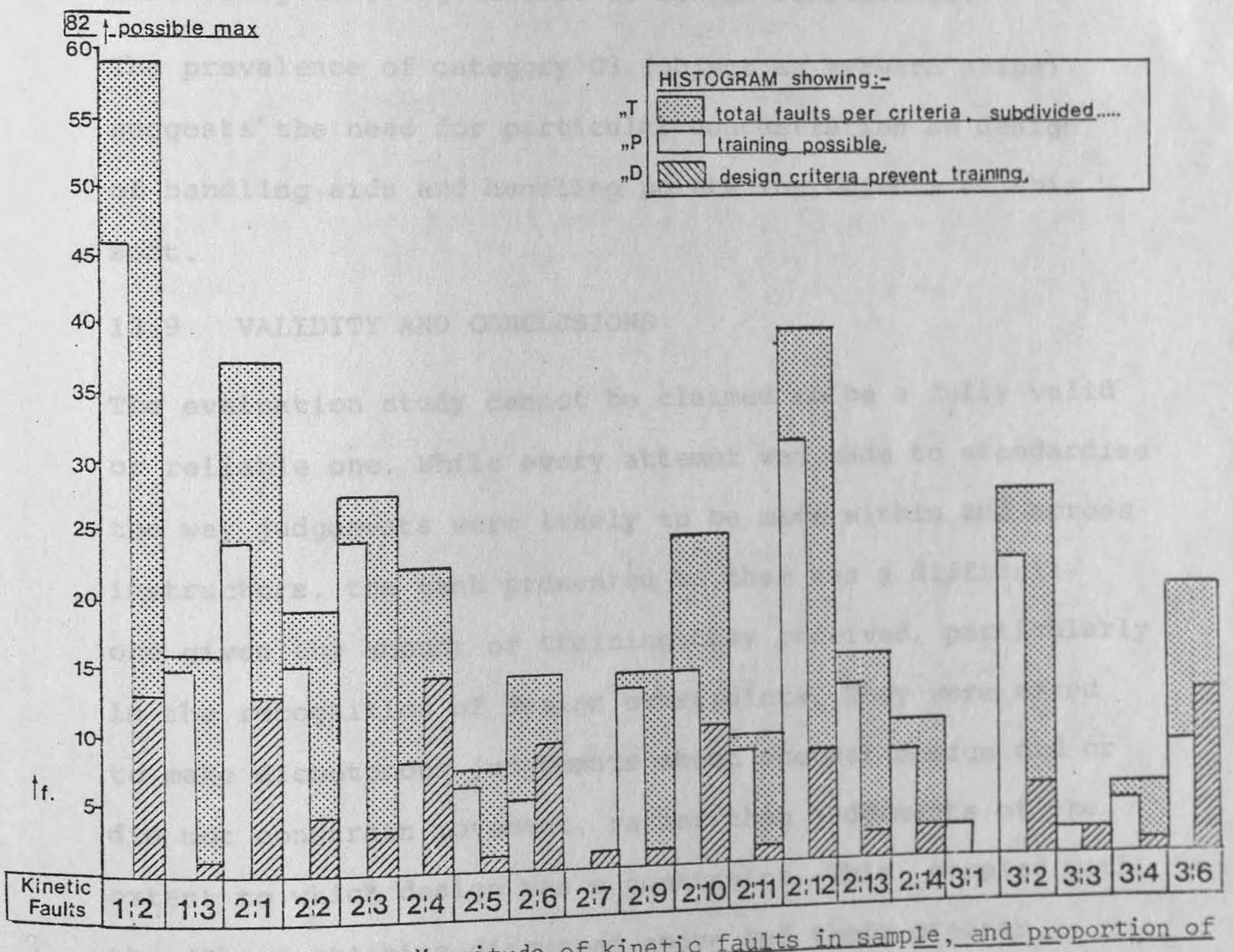


Figure 44 Histogram, Magnitude of kinetic faults in sample, and proportion of each fault which can be eliminated by training.

13.8.3 DESIGN FAULTS

The design faults which contributed to top heavy movement were mostly lack of room, and obstruction to good foot positioning.

The commonest design faults come under the category of badly designed reach envelopes (R1-4; S1, 2). These constituted 45% of design faults and prevented the application of a wide range of kinetic criteria. Other recently published research has also implicated reach envelopes in many badly designed handling tasks (Stubbs and Nicholson 1982).

Design faults were particularly apparent in relation to faults in 'holding' (Category C design constraints on faults 2:4 to 2:7). 57% of such kinetic faults were not soluble by training because of design constraints.

The prevalence of category C3 (object an awkward shape) suggests the need for particular concentration on design of handling aids and handling points for objects of this sort.

13.9 VALIDITY AND CONCLUSIONS

The evaluation study cannot be claimed to be a fully valid or reliable one. While every attempt was made to standardise the way judgements were likely to be made within and across instructors, the task presented to them was a difficult one given the amount of training they received, particularly in the recognition of design constraints. They were asked to make dichotomous judgements about whether design did or did not constrain movement, rather than judgements of the extent to which design was a constraint. This, coupled with the 'Observer' bias discussed above and their greater familiarity with movement analysis than with design analysis would, on balance, probably have made them underestimate the design constraints somewhat. However, despite these reservations the results support studies such as Van Wely's and the statistical analysis reported earlier in this thesis in demonstrating that the majority of jobs in industry cannot be carried out completely kinetically because of design constraints. On the other hand there is also room for improvement from training in the majority of jobs. The best estimate from the available data is that the contribution of each is about equal.

The detailed data on kinetic and design faults also support earlier parts of this thesis in identifying the prevalent problems in posture and movement.

Finally the feedback from the respondents confirmed the training objective of the package; that it had provided a useful and relatively simple tool in aiding training needs analysis.

CHAPTER 14: CONCLUSIONS AND INDICATIONS FOR FURTHER RESEARCH

14.1 CONCLUSIONS

This research sought to meet the following overall objectives:

(i) to examine the potential contribution of training in general and Human Kinetics in particular to the problem of handling injuries in industry;

(ii) to assess the validity of the concepts upon which Human Kinetics training is based;

(iii) to examine the success of the ROSPA courses in teaching Human Kinetics and to assess the obstacles to teaching;

(iv) to assess the applicability of the Human Kinetics taught on the courses to the problems encountered by the instructors in their companies.

The findings of the study are grouped and discussed under these same headings, dealing with (ii) to (iv) first.

The concepts which form the backbone of Human Kinetics were found to be valid. Although support from the literature falls short of proof, the kinetic model of chronic and acute pathology developing via the mechanism called cumulative strain is vindicated by current knowledge regarding the adaptability of connective tissue. Excess static muscular work has been implicated in many similar explanatory models of musculo-skeletal deterioration, and its reduction in many movements can be justified also on the grounds of minimising fatigue.

ROSPA courses achieved considerable success at turning trainees into potential instructors of Human Kinetics. The results of the picture questionnaire provided a superficial validation showing that the courses succeeded in getting the trainees to understand kinetic concepts and recognise the differences between varying methods of performing tasks which could be defined as 'good' or 'bad' on kinetic criteria. In making such judgements 90% of pre training errors were converted to correct responses after training with no omission errors in the post training groups.

Using video recordings, slow motion analysis and a scoring system derived from kinetic criteria to evaluate the success of training courses to alter the movement patterns of trainees it was clear that one week of training produced clear and highly significant improvements in subjects' movements. On kinetic criteria there was an overall improvement whereby 70% of pre training failed criteria were converted to passes. However, many trainees were still showing some fundamental errors and the written questionnaire had raised the possibility that some trainees lacked confidence to pass on what they had learnt to others. The implications of this latter finding are discussed in the section on future work (see page 208)

The retrospective analysis of statistics reported in Chapter 4, and the results of the shop floor evaluation package clearly demonstrated that the majority of jobs in industry cannot be carried out completely kinetically because the movements are hampered or otherwise interfered with by design constraints. There is scope for Human Kinetic training in the majority of jobs but the available data shows that any training effort must be matched by improvements in workstation layout criteria if this is to be implemented on the shop floor. The results show that it is possible to produce a comprehensive and valid set of criteria for studying these interactions and so to plan for improvements, and that it is possible to prepare a viable evaluation package for industrial use.

Chapter 1 introduced this thesis with a quotation from Brown's 1972 review. The full text of Brown's conclusion, based on an extensive literature search was as follows:

> 'In the 1930's a considerable body of opinion reached a conclusion that there was only one possible means of lifting an object whether this be heavy or light. This method has been variously described but can be simply stated as lifting with a straight back and bent knees. So enthusiastic have the advocates of this method been in regard to training programmes that nearly every major industry has adopted this method to the exclusion of any other regardless of the size, shape or weight of the object to be lifted. In spite of this intensive and almost universal programme, the number of back injuries in the terms of the percentage of all reportable injuries has remained the same.'

Brown's has been widely regarded as an authoritative review of the subject and yet it epitomises the misconceptions which this thesis has shown to exist and to confuse the discussion of the scope for training, and in particular for Human Kinetics, in reducing handling injuries. There are here the assumptions that:

1) training in lifting could be expected to reduce back injuries significantly;
2) that techniques of lifting, in which Brown includes Human Kinetics can be simplified in the way he describes.

The nature of Brown's 'intensive and almost universal programme' was examined in the opening chapters and it was found that overstrong links had been fostered in people's minds between handling accidents, lifting and back injury and that this had led to simplistic solutions. This thesis has discussed these simple methods under the broad heading of 'six point drill' techniques, which, in general take as their model a lift of a compact box-like object in free space from floor level.

Chapter 4 showed that even if training in these techniques was completely successful and they did indeed prevent back injuries they would not eradicate handling accidents. Available figures showed that the best estimate of lost time accidents caused by lifting and resulting in back injury is 25% of handling accidents or 5% of total three day lost time accidents, and that the number of these which are likely to be straight lifts of compact objects from floor level is likely to be much smaller.

The thesis showed that a further set of reasons why six point drill, and other simple training techniques which concentrate on lifting, are likely to undermine the value of all handling training is that they cannot be performed as instructed without instability and without discomfort and possible damage to the knee joints. This is because many of them are interpreted as an erect, straight back throughout the lift. The illustrations which accompany such instruction have also had to be distorted or presented in such a way that these shortcomings are disguised to the casual observer.

When this is added to the semantic and conceptual confusions which were shown to exist in the literature and illustrations surveyed, and in the minds of the subjects studied, it is not surprising that Brown should be so dismissive in his conclusion. This thesis has shown that simplifications such as the six point drill should be dismissed as largely useless, and, worse, harmful. Where Brown is wrong is in his equation of Human Kinetics with the six point drill.

The true scope for Human Kinetics is far wider than Brown implies, since it concerns itself not only with lifting but with all postures and movements concerned with handling (and indeed with all other aspects of work). Hence it could contribute to the reduction of all musculo-skeletal injuries during handling (still only a subset of total handling injuries) and during other activities. This thesis has not been able to explore this scope in full. What it has shown clearly are the obstacles to the realisation of this scope. The first, implied above is the large investment of time necessary to produce even the incomplete modification in movement patterns of the instructors trained on the ROSPA courses. The second is the limitation imposed by workplace design constraints on the application of kinetic movements which was demonstrated in the final part of the research. The third, and an obstacle of general relevance for all movement training, is that we do not have a commonly understood language to describe postures and movements. There is a lack of shared definition for terms commonly employed in training literature and this implies the need for a carefully considered approach to the design of any training literature in this area. This, coupled with the inadequacies found in static illustrations of postures and stages of movement, calls into question the value of any training which relies solely, or even largely on words and static pictures.

In considering positively the scope and required focus of training, the research identified a number of movement patterns or faults which were evident in significant numbers of the subjects. These included;

a. Top heavy movements: The majority of people studied exhibited this fault, tending to initiate bending or reaching movements with the head, arms and hands in such a way that the body's centre of gravity moved to the limit of, or out of its base of support and considerable static muscular work was required of major extensor muscles to prevent the person falling over forwards.

b. Foot positions: In lifting actions or handling movements performed in the upright position there was widespread confusion about the positioning of the feet, the most common fault being to keep a narrow stance with the feet side by side. This was where the training literature gave examples of conflicting methods and sometimes advocated such a stance.

c. Use of the arms: The questionnaire results, ROSPA video analyses and shop floor evaluation package results all showed that a common movement fault was to use the arms in a physiologically inefficient manner. Rather than keep the arms straight and efficiently stabilised for the transmission of forces there was a tendency to flex them, work with the elbows 'jutting' out, and stabilise them with excessive static muscular work, or use them independently in lifting actions. Chapter 11 examined some of the rationales that subjects gave to justify such movements, and also examined a number of other misconceptions regarding the nature of relaxation and the power available from muscles.

In addition to the conclusions relevant to the four main objectives of the thesis there was a further major methodological and theoretical conclusion.

It is commonplace in the training literature, and in academic investigations of lifting actions to dichotomise actions into groups labelled 'stooping' and 'squatting' (or synonymous terms) which are then compared on physiological or electrophysiological criteria. The results of the video analyses reported in this research show that division into such groups is such a significant over-simplification that doubt must be cast on the validity of any such study. There are in fact not two but a large number of distinct types of lift, and, without the use of slow motion video gross misclassifications are likely to occur. Broader implications in the same vein are that ergonomic or other studies which compare movements or postures need very closely defined terms to describe the movements studied if the results are to be capable of replication by other experimental workers. One solution would be if all such work was accompanied by photographs, drawings or other recordings of all the crucial stages necessary to discriminate a group of movements. This also reinforces the conclusion above that training cannot be done with the written word alone. The time taken to define fully terms used to describe movements would probably be less than that to produce good quality photographs, video tapes or other illustrations.

14.2 SUGGESTIONS FOR FURTHER WORK

The nature of the thesis presented here was a broad survey of Human Kinetics and its context. A number of areas had to be left unexplored in detail for two reasons:

(i) The literature reviews revealed shortcomings in certain areas of fundamental knowledge which it was outside my competence to rectify

(ii) Other gaps in current knowledge were revealed which may well have fallen within my competence to explore but where the amount of empirical research in terms of time or facilities required placed them outside the scope of this project. However some of the avenues were explored via pilot studies and these are reported in appendices.

A major need for further work which falls into the first category above regards the role of connective tissue metabolism in the aetiology of chronic muscle skeletal disorders. The mechanism proposed by Pickup (1978) and reported in Chapter 6, which implicate changes in the behaviour of fibroblasts as a result of tension in the pathology of connective tissue would reward further examination. In the broad area of chronic musculo-skeletal disorders an important need is commonly agreed classification of disorders which avoids some of the imprecise diagnostic labels such as 'fibrositis' or 'lumbago'.

Another area which would benefit from improving definitions is 'handling accidents' in their broadest sense. A comprehensive, well designed, prospective statistical study is needed to sort out the causes of these accidents.

An interesting area for further work would be the development of measures capable of making more direct evaluations of the deleterious effects of poor working postures or movement patterns. Two possible techniques were piloted as part of this thesis. The first was collecting subjective measures of discomfort via a technique called 'body mapping' and the second using measures of intra abdominal pressure to compare four lifting techniques. The body mapping studies while interesting, had to be discontinued due to a difficulty in obtaining access to factories to make observations. The intra abdominal pressure studies seem worthy of further exploration. Experience with both techniques is reported in appendices 5 and 6 respectively. (pages 233 and 235)

It would be useful if the shop floor evaluation package developed in this thesis could be linked to other measures such as the technique of body mapping or measurements of intra abdominal pressure. All three techniques stem from a common interest in producing tools that will provide answers which are applicable in industry. The whole area of research into lifting and handling problems would benefit from links being formed between parallel studies.

The thesis identified a number of obstacles to teaching and showed that problems can arise from the use of inappropriate illustrations to describe movement. Other work has indicated that Video makes a useful aid in training novel movement patterns by providing trainees with feedback on their skill development. A pilot study (see appendix 8 (page 244) suggested that this may also be true for Human Kinetics training and this area of skill development would merit further study.

Further work is needed to pursue the limitations on the applicability of Human Kinetics in the workplace, not only on design constraints but also on the possibility that anthropometrics, the 'design' of the worker, may be a limiting factor. A short pilot study reported in appendix 7 (see page 242) indicated that anthropometric variables may modify lifting styles.

A final area which needs further work is the next stage in the kinetics training link. The vast majority of the work reported in this thesis has depended on the ability of one person to get across kinetic concepts. What sort of person is required to make a good trainer in kinetics? Some results presented in appendix 9 (see page 246) demonstrate that the sort of person normally selected to attend ROSPA and be trained as an instructor is not necessarily a training specialist and does not initiate, or is not allocated the time to initiate, any in plant training. The communication of Human Kinetics from the ROSPA trained instructors to groups in their own factories requires more follow up studies.

INDEX OF APPENDICES.

APPENDIX

LIST OF ILLUSTRATIONS IN APPENDICES:

APPENDICES.

1


2


3


4


5


6


7


8


9


10


11


12


The 23 posters shown on this page and the next are all the posters in the RoSPA sales catalogue in the section for 'manual handling' They are numbered in rank order of numbers sold to industry over a 27 month period and the actual sales and average sales per month are shown in the table overleaf. The rank order of the poster in terms of sales was not influenced by its position in the catalogue. The top three sellers were positioned 14th; 15; and 10th respectively.

13


14


15


16


17


18


19


20


21


22


23


POSTER rank No.	Average sales per month.	Total sales	Poster rank No	Average sales	Total sales
1	138	3727	13	19	510
2	86	2318	14	18	497
3	60	1510	15	17	459
4	36	972	16	16	444
5	34	918	17	16	430
6	33	879	18	15	396
7	29	787	19	13	349
8	27	725	20	12	324
9	25	661	21	8	204
10	25	679	22	7	193
11	22	585	23	3	87
12	19	507			

Human Kinetics and Good Movement

T. McCLURG ANDERSON

VARIOUS interpretations of good body movement have arisen in the absence of an agreed definition of what constitutes a good movement. The resultant confusion can only be dispelled by establishing a yardstick by means of which a movement can be judged. Traditional ideas of movement in this country derive from the old Swedish type of physical exercise, in which the main emphasis was upon what were considered good positions and the powerful contraction of muscles, with little consideration for the quality of movement or the condition of the body tissues before, during, or after movement. Although the approach to physical exercise has been modified somewhat in recent years, the same conceptions of position and strength still seem to influence popular ideas of good movement. On the other hand, some favour rhythm as a basis of good movement without any clear definition of this term in a physiological sense. It would appear to the writer that the re-assessment of many terms employed in relation to physical activities, such as strength, relaxation, rhythm, speed, and stamina, is essential as a basis for proper understanding of the subject.

The physiological maxim, 'Structure and function are subservient to each other', must surely be a prime consideration in any attempt to define good movement. Since every movement involves structural changes in the body tissues recognition should be given to both immediate and long-term reactions to movements, both structural reactions and possible modifications of sensory and motor nerve patterns. Consequently, one must recognise that the basic patterns of normal day-to-day muscle habits, both active and postural, materially influence the condition of the body tissues and therefore the detailed manner in which they fulfil their functions. For the same reason, day-to-day habits determine to a considerable extent the disabilities likely to affect the tissues. For example, when muscles are subject to excessive tension in resting, postural or active functions, their natural elasticity and sensitivity will be reduced, with deterioration of blood and lymph circulations.

Cumulative Strain

It is unfortunate that, like so many other functional aspects of the human body, cumulative strain is most difficult to demonstrate by means of laboratory experiments, otherwise many existing conceptions of physical activities would probably have been altered many years ago. There is, however, ample evidence that structural deterioration of the body tissues results from excessive tension in different parts of the body. While improved working conditions have made less obvious many characteristic occupational deformities, there are many examples to be found in the 'flat back' of older miners, the Dupuytren's type of palmar contraction among steelworkers, and the lopsided shoulders of many professional boxers. Mechanisation in industry has reduced the amount of hard labour but it has increased the tendency to cumulative strain, as well as the types of occupational disabilities. Older farmers, for example, tended to develop osteoarthritis in the hips due to constantly leaning forward and twisting, on the left hip in particular, in such actions as shovelling and ploughing. The modern farmer rather tends to develop strain and sometimes arthritis at the lumbo-dorsal junction in the spine when a deeply bucketed seat fixes the pelvis and lumbar spine as he bends and twists his upper trunk to look backwards over his tractor.

Immediate reaction to excessive muscular

* As is made clear on page 47 of the thesis Anderson always maintained that his work was mis interpreted by other authors. The inclusion of this - one of his more concise papers- gives the reader an opportunity to look at Andersons work directly, rather than my interpretation of it.

The lines are numbered for ease of reference.

tension and its relation to cumulative strain can be demonstrated by practical experiments. For example, when the fist is clenched as firmly as possible, with forearm flexed, for about 30 seconds and the fingers are then allowed to relax slowly, it will usually be found that they remain more flexed than normal. Some of the tension remains as a 'hangover', and if this type of action is repeated constantly from day to day, without ever stretching the tissues, normal extension of the fingers will become more and more restricted. Connective tissue as well as muscle fibres will become shortened and it is then reasonable to expect that some capillary occlusion will occur in the tissues concerned. It is, in the experience of the writer, deterioration of this kind occurring in neck, shoulders, and lower back that accounts for the frequency of disabilities and restricted movement in those areas.

Definition of Good Movement

The views expressed in this article are based upon the author's definition:

'A good movement is one which fulfils its function efficiently with the minimum of effort and the minimum of cumulative strain.'

Minimum effort refers to the type of muscle work involved in producing and regulating movements, as co-ordination of muscular action should relate to reciprocation between:

(a) muscles which contract and actively shorten to produce movement and those muscles which must elongate to allow it to take place;

(b) muscles concerned in maintaining and re-adjusting balance throughout movement;

(c) muscles which stabilise the spinal joints and the bases of the limbs during movement.

The most expensive form of muscle work, in terms of energy expended and cumulative strain, is that which involves sustained contraction of muscles. It is for this reason that housewives find the most tiring jobs in the home are working at the sink and ironing, when standing with the feet side by side and bending the upper trunk. In this case the lower-limb and back muscles are in a state of sustained tension to maintain balance, and movement is more or less restricted to the upper limbs and upper trunk. When movement of the trunk or lower limbs does occur there is almost complete absence of reciprocal relaxation so that, for example, both flexor and extensor muscles contract strongly and resist each other. Habitual performance of this type of action results in gradual build-up of excessive tension and stiffening of the body tissues—cumulative strain. It is for this reason too that the misguided idea of developing 'strength' by what has been referred to at different periods during the past 50 years or so as 'static', 'dynamic', 'synergic', and 'isometric' muscle work is in the long term harmful, as it encourages excessive effort in normal day-to-day actions and will develop cumulative strain in neck, trunk, and the bases of the limbs. This type of misguided idea in strengthening muscles, in the experience of the writer, predisposes to many injuries and other disabilities in sports circles.

Over forty years ago, for example, the writer investigated a large number of expert cricketers who had suffered from 'cricketer's finger', in which there is partial avulsion of the long extensor tendon attached to the base of the distal phalanx of a finger. Without exception, every player concerned received the injury when trying to catch a ball following a spell of batting. Intense gripping of a bat resulted in a 'hangover' in which the fingers were less extended than the player thought they were, so that the ball impacted on the end of a finger, usually the fourth finger. It was also found that a considerable number of the players involved were in the habit of strengthening the grip by means of 'grip dumb-bells'. Other examples of injury stimulated by misguided efforts to strengthen the grip are the strained wrists and 'tennis elbows' afflicting many golfers.

Body Balance

Obviously, the question of good balance should be considered in relation to physical activities, not only in regard to maintaining stationary positions but also the re-adjustment of balance while movements are actually taking place. Even the slightest movement of a limb will change the centre of gravity so that balance has to be re-adjusted accordingly, and it is in this connection in particular that confusion arises. If we accept the principle of 'minimum effort' in relation to good movement, then the same principle should apply to balance, and again we must have a clear definition of what we mean by good balance. Fundamentally, there are two ways of maintaining balance: (a) by simply stiffening the lower limbs and back, or (b) by relaxing the lower limbs so that the feet can adjust themselves to safeguard balance. The author's interpretation of good balance is:

> '*A controlled condition maintained without muscular stiffening and efficient adjustment of body weight by muscular relaxation.*'

In view of the above definition the girl in Fig. 1 is not in a good balanced condition because excessive muscular effort is involved in maintaining the upright position, as is reflected in the stiffened lower limbs. This girl is of course conforming to certain 'positional' rules, but functionally she would be better balanced by relaxing her knees as if sitting straight down. In this way her knees could be stabilised without general stiffening and she would then be adaptable to change of balance without undue muscular effort.

The skater in Fig. 2a is 'overbalanced' so that needless muscular stiffness prevents good movement. The skater in Fig. 2b is well balanced because there is no unnecessary muscular tension and for this reason he is capable of good movement.

First Principle in Good Movement

Fundamentally, all movements performed in the upright position are either top-heavy or base movements (Figs. 3a and 3b). Top-heavy movements are those which begin by bending of the head, upper trunk, and upper limbs, so that the lower limbs and back stiffen to prevent the body falling. This leads to a rather staccato type of movement which concentrates stresses in the shoulders, neck, and lower back, with resultant cumulative strain in those areas. At the same time, sustained tension in the lower limbs leads to circulatory deficiency, loss of resilience, and predisposition to injury in the lower limbs and back.

The first principle in good movement is that:

> '*A good movement always begins as a base movement and is segmental in character.*'

In contrast to the initial stiffening of the lower limbs in a top-heavy movement, a good movement begins by relaxation of the lower limbs so that one foot can move reflexly to safeguard balance. It should be appreciated that merely bending the knees is not necessarily relaxing the lower limbs and it is in this distinction that the trained person can tell the difference between one who imitates good movements and one who is actually capable of performing them. In the first case the knees tend to bend excessively and there is obvious awkwardness in the movement, as in contrast to the smooth diffusion of movement throughout the

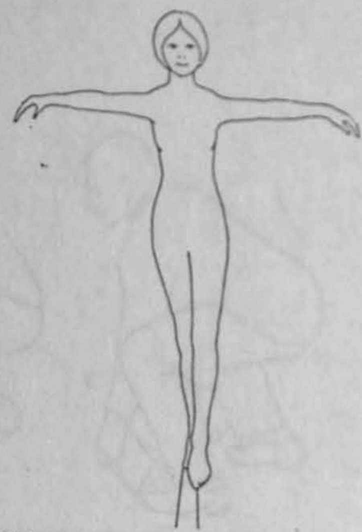


Fig. 1: Girl gymnast, balance maintained by excessive lower-limb tension

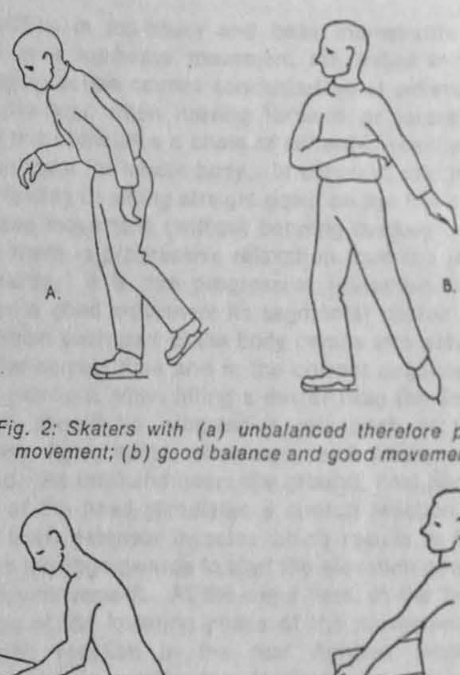


Fig. 2: Skaters with (a) unbalanced therefore poor movement; (b) good balance and good movement

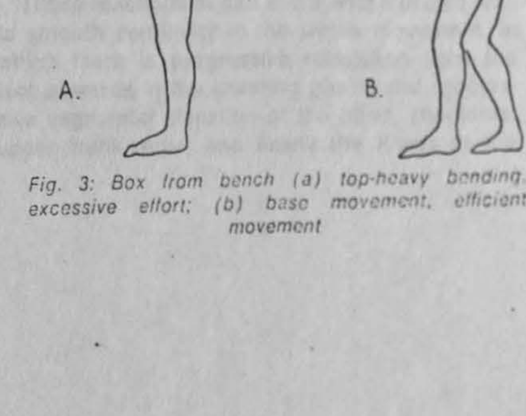


Fig. 3: Box from bench (a) top-heavy bending, excessive effort; (b) base movement, efficient movement

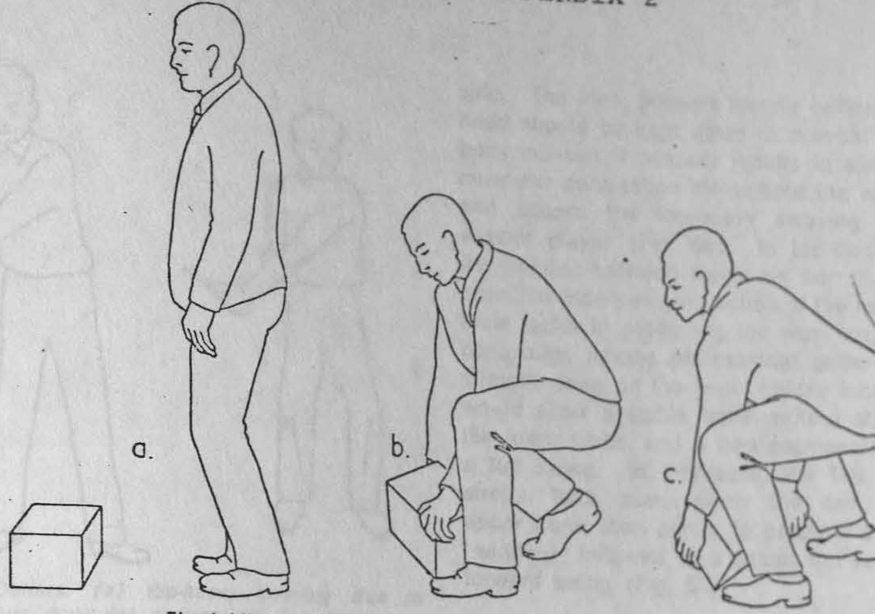


Fig. 4: Lift from floor, key stages: (a) initial lower-limb relaxation; (b) progressive relaxation; (c) initial elevation phase

whole body in a good base movement. In a good movement the action in the knees is rather a ' giving ' or unlocking of the joints, and the extent to which the knees bend is determined reflexly by the nature of the action taking place. The quicker or more vigorous the action has to be the more the knees will bend as the limbs relax.

The distinction between top-heavy and base actions is most obvious when moving to one side. In the top-heavy action the lower limb on the side to which movement takes place immediately stiffens so that the body has to pivot round the stiffened limb. This, in fact, is the main cause of so many ankle, knee, and groin strains in football and other sports. Initial relaxation of the lower limbs in a base movement permits the foot on the side to which movement takes place to move and point in that direction. The effect of this is that the turning action is accomplished more quickly and with less effort than is possible in a top-heavy movement, although it may appear to the untrained eye to be slower. The more vigorous, unbalanced bending and twisting action of the upper trunk in a top-heavy movement gives a false impression of speed. It is in fact the smoothness of the base movement that leads to all good movements being characterised by the ease with which they are performed.

Segmental Character

The key factor which differentiates the muscular reactions in top-heavy and base movements is that in a top-heavy movement the initial head-bending action causes concentration of pressure on the toes when moving forward or laterally, and this stimulates a chain of stiffening reactions throughout the whole body. In contrast, one has the feeling of sitting straight down on the heels in a base movement (without bending backwards), and there is progressive relaxation from the feet upwards. It is this progressive relaxation that gives a good movement its segmental character, in which each part of the body comes into action at the correct time and in the correct sequence. For example, when lifting a duster from the floor there should be progressive relaxation of the knees, hips, spine, shoulders, and finally the head. As the hand nears the ground, final bending of the head stimulates a stretch reaction in the trunk extensor muscles which results in the head moving upwards to start the elevation phase of the movement. At the same time, in the final stage of the lowering phase of the movement a stretch reaction in the rear Achilles tendon stimulates a continuous forward and upward movement as the hand takes hold of the duster.

Those reactions of calf and spinal muscles lead to smooth continuity in the whole movement, in which there is progressive relaxation from the feet upwards in the lowering phase and progressive segmental elevation of the head, shoulders, upper trunk, hips, and finally the knees in the

Fig. 5: Golfers: (a) top-heavy swaying due to simultaneous muscular contraction; (b) good segmental movement

upward phase of the movement. It is the fact that this segmental feature of good movement appeared to be so commonly ignored that caused the author to stop the issue of his instructional material some years ago, unless to people he had trained personally. Illustrations in this material showed the stage at which the hands took the load, and at this stage the back was straight, as it should be. Because the actions preceding this stage were ignored the idea arose that the back should be straight throughout the whole movement. This leads to a stiff erect back and excessive strain in the knees, conditions which a good movement would prevent. This misinterpretation brings out the difference between imitating positions occurring during movements and really understanding good movement.

Fig. 4 shows the three key stages in the kinetic method of lifting a box from the floor, in which there is:

(a) relaxation of both knees as the movement begins;

(b) the hand reaching its lowest level as a result of progressive relaxation, including relaxation of head and back;

(c) start of the upward phase of the movement in which initial raising of the head automatically stimulates straightening of the back at the correct time.

The principle of base and segmental movement should operate in all circumstances, even in an unnatural movement like the golf swing, in which the feet must remain more or less side by side. The idea, popular among golfers, that the head should be kept down to prevent excessive body movement actually results in simultaneous muscular contraction throughout the whole body and causes the top-heavy swaying action of a poor player (Fig. 5a). In top-class players, the conflict between top-heavy bending and the essential wide swinging action of the hands is the main factor in producing the very frequent back complaints among professional golfers. Sitting straight down on the heels before looking down would allow a stable base without stiffening of the lower limbs, and a free segmental action in a full swing. In this case, the left hand can stretch back successively the arm, shoulder, upper trunk, then pelvis, to produce an effective 'wind-up' followed by a segmental recoil in the forward swing (Fig. 5b).

Analysing Movements

Most common errors in trying to assess movements are presuming that various parts of the body should be in certain stereotyped positions and thinking about the body merely in terms of mechanics. Certainly positions are important in so far as they reveal the condition of the body tissues, but to set what might be called a 'positional' standard of right and wrong is misleading and often harmful. The old idea of 'brace back your shoulders and stick out your chest' may appeal to some, but it leads to stereotyped strutting which is the antithesis of good free movement.

While the body could be considered primarily as a mechanical structure it commonly reacts in opposition to mechanical principles, and it is those reactions with which we should be concerned in assessing movements. For example, if an inanimate structure becomes unbalanced it will fall in the direction in which it is unbalanced, whereas the human body usually does the opposite. This can be seen in the case of a child making its early efforts to walk, with feet widely spaced for balance, it has to look down because it has not yet acquired the muscle sense which enables it to feel that its feet are moving in the right direction. By looking down at its feet the child becomes unbalanced forward, but unlike an inanimate structure it usually falls backward because of the protective reactions of its muscles. It is significant too that when the child does fall its legs 'give' so that it sits down on its bottom, whereas most adults have a 'long' fall and risk of head injury because their legs stiffen. The difference arises because most

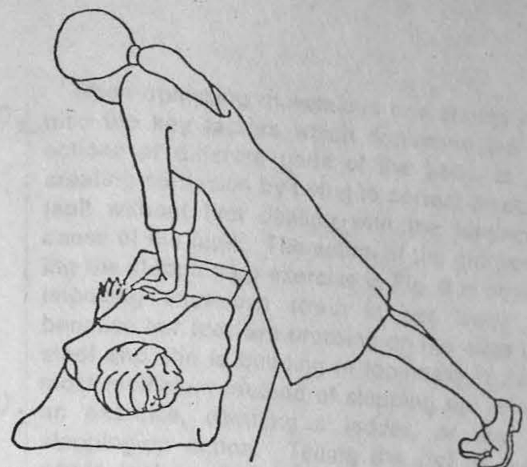


Fig. 6: Down-pressing, undue strain and lack of control

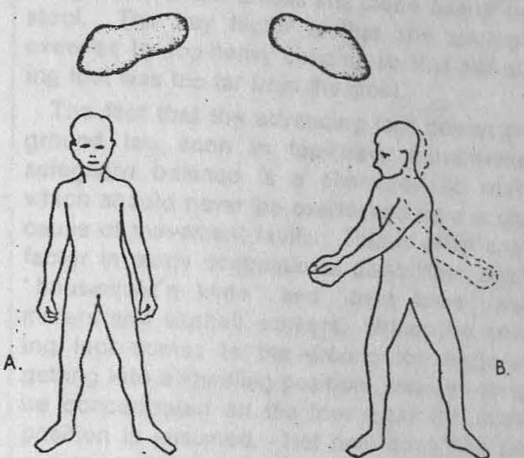


Fig. 7: Foot positions determined by objective of movement; (a) standing still—bad position; (b) lateral movement—good position

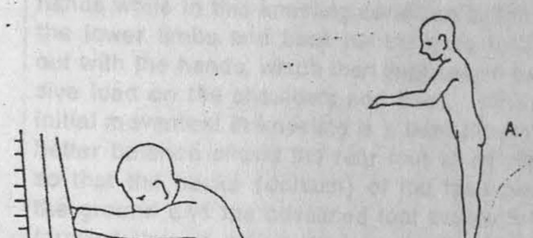


Fig. 8: Pushing—initial phase of movements determines efficiency: (a) top-heavy movement; (b) base movement

adults have acquired the habit of top-heavy bending, with stiffening of the lower limbs, so that the natural protective reactions of muscles are inhibited. It is interesting to recall in this connection that 'drunk' men are less likely to be hurt because they 'buckle' when falling.

When the body becomes so overbalanced that most of the body-weight is leaning beyond the feet, it does tend to fall in the direction in which it is unbalanced, because protective muscular reactions cannot operate effectively. In this case the feet will tend to slip, and excessive stiffening of the lower limbs will be necessary to prevent this from happening. The down-pressing action in Fig. 6 is a particularly bad movement from this point of view and, apart from the lack of control in the down-pressure, there is excessive strain in the chest, abdomen, and back. In this case the danger of slipping is great, and this type of movement would not be acceptable in industrial circles.

The difference between good and bad movements is frequently subtle and the distinction often cannot be made without knowing: (a) the purpose of the action involved; (b) how the movement was initiated. Take the positions of the feet shown in Fig. 7 for example. Is this good or bad? Actually it can be both good and bad, depending upon the reason for the feet being placed in this way. If the feet have assumed their positions to allow the hands to move from side to side, then the positions are good! If the same positions are adopted when the person is going to stand still then they are bad!

The pushing action in Fig. 8 may be good but it may also be bad, according to how the movement started. If the pushing action started by top-heavy bending and leaning forward as the hands reach out, then the action is wrong, as the object would tend to be pushed into the ground so that resistance would be increased. At the same time, excessive effort would be expended in safeguarding balance and in preventing the spinal and upper-limb joints from 'buckling'. When the action begins as a base movement the object tends to be pushed over the ground, while both spinal and upper-limb joints would be more stable without stiffening of the muscles controlling them. This principle applies to all pushing actions and is an important point when teaching industrial movements.

When analysing movements one should recognise the key factors which determine the interactions of different parts of the body, to avoid creating confusion by trying to correct an obvious fault without first dealing with the fundamental cause of the fault. The action of the girl performing the stepping up exercise in Fig. 9 is obviously imposing excessive strain in her lower limbs because her toes are pressing on the edge of the stool and she is bending in top-heavy fashion; a most inefficient method of stepping up, either as an exercise, climbing a ladder, or any other stepping-up action. Telling the girl to put her whole foot on the stool would tend to increase the general strain unless she stood nearer to the stool. The key factor is that she started the exercise by top-heavy bending so that her standing foot was too far from the stool.

The fact that the advancing foot comes to the ground too soon in top-heavy movements to safeguard balance is a characteristic reaction which should never be overlooked as a probable cause of movement faults. This is often a prime factor in many occupational disabilities, such as 'housemaid's knee' and 'beat knee' among miners and asphalt workers. When the advancing foot comes to the ground too early while getting into a kneeling position, pressure tends to be concentrated on the toes after the kneeling position is assumed. Not only does this create excessive tension in foot and calf but it also concentrates pressure on the rather pointed apex of the patella (Fig. 10a). If working with the hands while in this kneeling condition stiffness in the lower limbs and back necessitates reaching out with the hands, which then imposes an excessive load on the shoulders and back. When the initial movement in kneeling is a base movement, better balance allows the rear foot to be placed so that the backs (dorsum) of the toes rest on the ground and the advanced foot moves further forward than it would do in a top-heavy movement. Kneeling in this way not only prevents strain in foot and calf but also prevents concentration of pressure on the apex of the patella, which in this case is quite clear of the ground. Further, strain in the shoulders and back is reduced when working with the hands while kneeling in this way, because more movement of the lower trunk can take place to allow the hands to be closer to the body. The further the hands have to reach out from the body the more inefficient they become, especially when performing movements which require fine control.

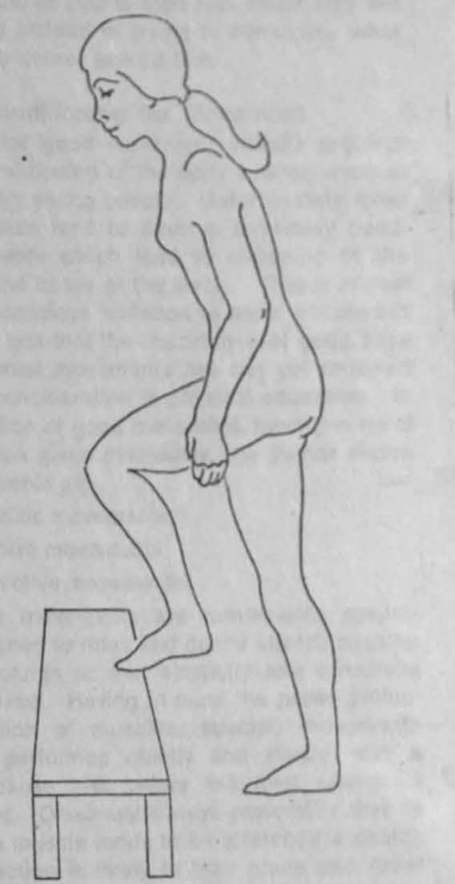


Fig. 9: Stepping exercise—excessive toe pressure due to top-heavy bending

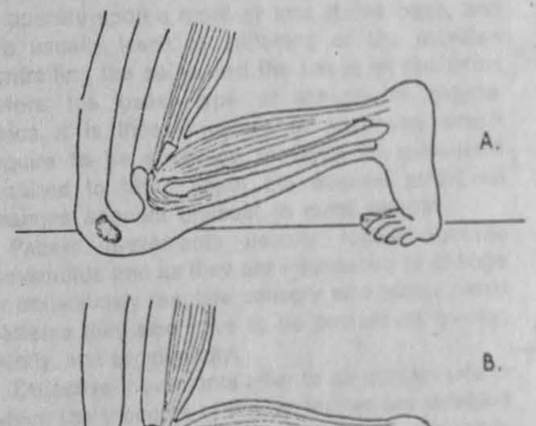


Fig. 10: Kneeling: (a) strain and patellar pressure, (b) base movement, diffusion of pressure

Upper-limb Movements

The nature of upper-limb movements depends primarily upon whether the body as a whole operates on top-heavy or base principles. In top-heavy movements the shoulders sag and are therefore unstable, while the hands pronate, the arms rotate inwards, and the elbows jut outwards. This imposes excessive load on the neck and back and is the most common factor in producing shoulder disabilities. If the humerus is rotated inwards while the hand is raised, the greater tuberosity tends to be pressed against the overlying acromion process and this is the main cause of subacromial bursitis and 'spring-clean shoulder'. In a base movement the shoulders are better balanced; there is less tendency to hand pronation, inward rotation of the humerus, and jutting out of the elbows. Outward rotation of the humerus means that the greater tuberosity is relatively clear of the acromion as the hands are raised and, while the shoulders are more stable, there is more free movement as the hands move upwards. For this reason, it is most important that when raising the hands they should start the upward movement before the elbows move, so that the humerus is rotated outwards. A simple experiment of holding a coat out in front of the chest with the palm facing downwards and the elbow out, and then with the palm upwards and the elbow in, so that the humerus is rotated outwards, gives the impression that the coat is lighter in the second position, provided the coat is not resting on the ends of the fingers in the second position. Having the elbows close to the body, so that the arms are rotated outwards, should be a basic principle in teaching hand movements.

Teaching Movements

When teaching movements attention should be focused upon contrasting physical sensations resulting from good and bad movements, rather than visual impressions of positions assumed during movements. Certainly, pupils have to see the movements to be acquired in the first instance, but in the author's experience a more effective method of teaching is to have the bad movement performed first and get pupils to feel where excessive tension is created. This is followed by good movement so that the different physical sensations can be appreciated distinctly, and in this respect the teacher must make sure that there is no compromise between the contrasting movements. This, in the author's experience, is the most effective method of improving muscle habits, as pupils then feel when they are going wrong instead of trying to remember what the good movement looked like.

Conditioning for Movement

Training for good movement usually requires some re-conditioning of the body tissues, even in comparatively young people. Unfortunately, even school-children tend to develop top-heavy bending movements which lead to stiffening of the spine and the bases of the limbs. This is in part due to unconscious imitation of older people but also to the fact that the importance of good base and segmental movements has not yet received adequate consideration in physical education. In the cultivation of good movement, having in mind the definition given previously, the author classifies movements as:

(1) specific movements;

(2) pattern movements;

(3) objective movements.

Specific movements are movements specifically designed to relax and gently stretch specific body structures so that elasticity and sensitivity are increased. Having in mind the prime protective function of muscles, specific movements must be performed quietly and slowly, with a definite pause just before the final stretch is introduced. One must always remember that as soon as a muscle tends to be stretched a stretch reflex reaction is likely to take place and resist the final stretching phase of the movement, hence the need for the pause to allow the muscles to 'give' and so prevent discomfort.

It has also to be recognised that muscles have to operate upon a more or less stable base, and this usually leads to stiffening of the muscles controlling the spine and the bases of the limbs before the usual type of movement begins. Since it is those muscles in particular which require to be stretched the type of movement required to bring about the desired structural changes appears unusual to most people.

Pattern movements usually follow specific movements and as they are introduced to change or consciously regulate sensory and motor nerve patterns they also have to be performed quietly, gently, and segmentally.

Objective movements refer to all movements in which the thoughts of the performer are directed towards some objective external to the body itself, such as playing with a ball, walking, and performing some form of work.

APPENDIX 3

I would be grateful if you would fill in this form, it will help us improve training courses. No information will be passed on to anyone except the course tutor Mr Payne.

1 Name

2 Company

3 Address and Phone No.

4 Position in company

5 Who originally made the decision to send you for training in human kinetics?

6 Why was it felt that kinetics would be useful?

7 What are the major handling problems in your own company?

8 Within your own company who do you think it is most important kinetics should be taught to, and why?

9 When you have been trained here, and go back to your company, how long will it be before you start training employees?

10 Have any other methods of lifting/handling been taught within your company?

11 If so, have there been any problems with them?

12 Here are some shorter questions, on each line, please put a ring around one of the numbers according to how you feel about human kinetics at the moment.
For example on the first line;
If you feel human kinetics is very important ring 1;
Important ring 2; Fairly Important ring 3;
Neither important nor unimportant ring 4; fairly unimportant ring 5; unimportant ring 6; very unimportant ring 7:

HUMAN KINETICS

IMPORTANT	1	2	3	4	5	6	7	UNIMPORTANT
UNHELPFUL	1	2	3	4	5	6	7	HELPFUL
COMPLICATED	1	2	3	4	5	6	7	SIMPLE
UNINTERESTING	1	2	3	4	5	6	7	INTERESTING
FAMILIAR	1	2	3	4	5	6	7	UNFAMILIAR
NECESSARY	1	2	3	4	5	6	7	UNNECESSARY
EASY	1	2	3	4	5	6	7	DIFFICULT

13 Here are some similar questions, but this time there are a series of statements followed by a scale; representing strong agreement at one extreme, and strong disagreement at the other. The mid point of the scale (4) means you neither agree or disagree.
PLEASE RING THE NUMBER WHICH REPRESENTS YOUR STRENGTH OF AGREEMENT OR DISAGREEMENT WITH EACH STATEMENT.

	STRONGLY DISAGREE						STRONGLY AGREE
(A) Human kinetics is a drill of movements	1	2	3	4	5	6	7
(B) During all lifting the back should be kept straight	1	2	3	4	5	6	7
(C) Essentially human kinetics is about lifting weights	1	2	3	4	5	6	7
(D) Human kinetics considers the body as a machine	1	2	3	4	5	6	7
(E) The essential part of any movement is the way it begins	1	2	3	4	5	6	7
	STRONGLY DISAGREE						STRONGLY AGREE

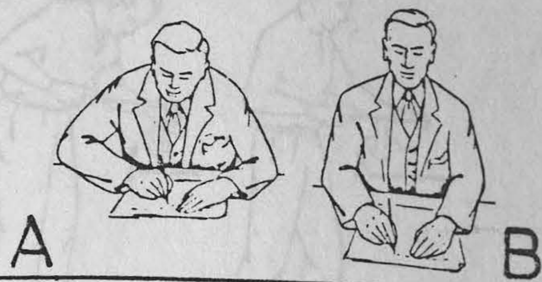
	STRONGLY DISAGREE						STRONGLY AGREE
(F) It is easy to teach people how to lift	1	2	3	4	5	6	7
(G) Muscle building exercises such as weight lifting, are a good form of exercise	1	2	3	4	5	6	7
(H) In a good movement as much muscular power as possible should be used	1	2	3	4	5	6	7
(I) Human kinetics is a method of thinking	1	2	3	4	5	6	7
(J) The form and structure of the human body is determined by day to day activity	1	2	3	4	5	6	7
(K) A good muscle is a big muscle	1	2	3	4	5	6	7
(L) Sustained tension is good for muscles	1	2	3	4	5	6	7
(M) Touching the toes is a good exercise	1	2	3	4	5	6	7
(N) Strength is produced only by sheer muscular effort	1	2	3	4	5	6	7
(O) Essentially human kinetics is about stopping back strains	1	2	3	4	5	6	7
(P) I should have no trouble teaching employees what I learn here this week	1	2	3	4	5	6	7
(Q) The leg muscles are more powerful in lifting than the arm amd back muscles	1	2	3	4	5	6	7
(R) A lot of workers with back injuries are just malingerers	1	2	3	4	5	6	7
(S) When standing, bending or looking down the feet should remain parallel	1	2	3	4	5	6	7
(T) People who have been lifting for years resent being taught a "new way"	1	2	3	4	5	6	7
(U) When performing most handling movements one foot should be in advance of the other	1	2	3	4	5	6	7
	STRONGLY DISAGREE						STRONGLY AGREE

The instructions for use of the picture questions are shown below;

14) In this final series of questions, two pictures are shown for each question. Each picture shows a different way of going about each activity. Would you, in each case indicate which method you feel is BEST, and record your answer A or B on dotted line available. Then say why, in your opinion it is better than the other, make your answers as detailed as possible don't just "spot the differences". What are the consequences for the people involved in terms of comfort, strain, efficiency? Feel free to arrow or shade in parts of the pictures to illustrate your answers.

In the picture questions which follow the kinetically preferred answer has been filled in.
The overlay of small type gives the kinetic justification for the choice of that picture as the more appropriate way of performing the activity illustrated.

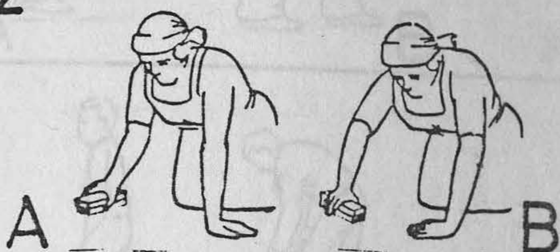
1



THE BEST POSTURE FOR WRITING IS..B....
WHY?

Doubling up over the pen as in A leads to elbows being pushed out from side, causing wrist to be extended, this in turn means that the pen is held more with the tips of the fingers and thumbs. Therefore the gripping area is smaller,the pen is gripped more tightly, and as in other cases the excess finger end pressure leads to excessive tension in bending (flexion) muscles throughout the body.

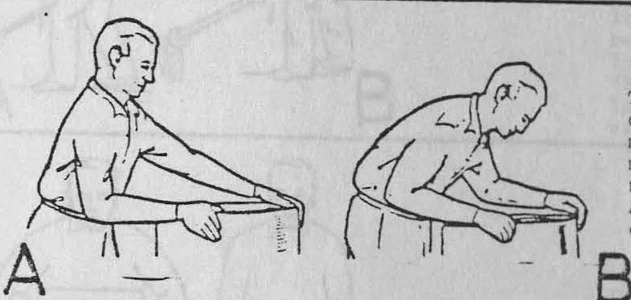
2



THE BEST POSTURE FOR SCRUBBING THE FLOOR IS.A....

The hand lock action in A (supination) takes the load off the arm muscles and leads to a direct transmission of weight by stabilising arm (left arm in B constantly trying to collapse) in muscular terms the triceps and brachialis no longer need to stabilize the elbow, by extending the elbow and supinating the forearm the elbow becomes hyperextended. Stabilisation is thus by body weight and stretched forearm flexors.

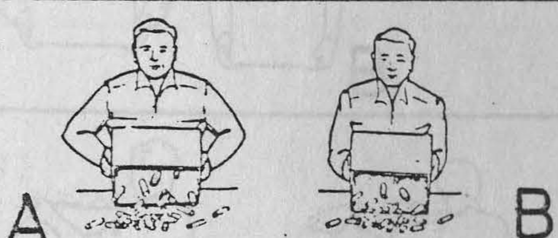
3



THE BEST WAY TO TILT THE OIL DRUM IS..A...
WHY?

The doubled up position in B increases strain on arms, shoulders, and abdomen. The arm muscles are doing work which could be done more effectively by body weight. There is also needless abdominal strain and risk of hernia. In A the straight arms permit effective transmission of body weight.

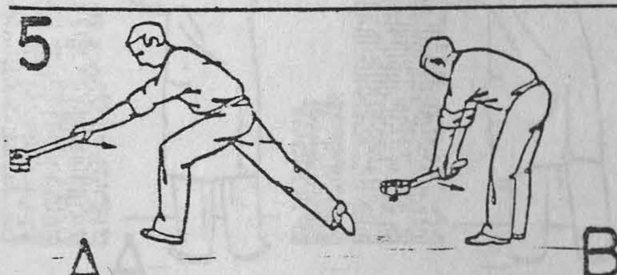
4



THE BEST WAY TO EMPTY THE BOX ONTO THE BENCH IS..B.....
WHY?

A is working with elbows jutting out and this puts excessive load on arms, shoulders and back. In A the the shoulders are in very weak position to take the load. In B shoulders are in a stronger position and the body will move more naturally <u>with</u> the load

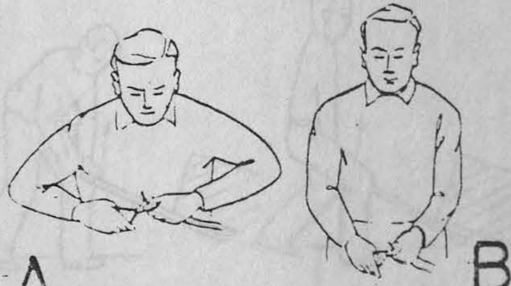
5



THE BEST WAY TO MANIPULATE THIS LARGE SPANNER IS..A.....
WHY?

B risks abdominal strain and also damage to legs if the spanner slips. Putting one foot well back and allowing front knee to bend increases use of body weight and allows a better safeguard for balance.

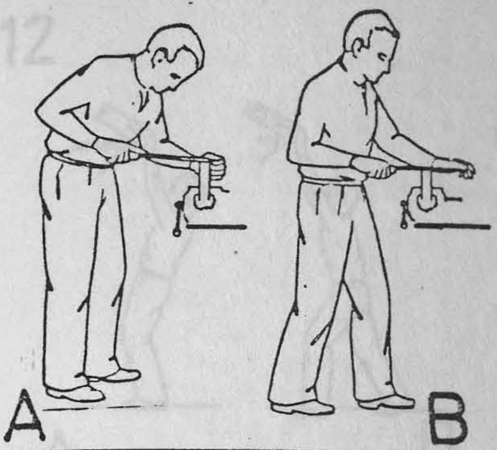
6



THIS ELECTRICIAN STRIPPING A WIRE WOULD BE WISE TO USE METHOD....B....
WHY?

A shows the tendency to bring work close to the eyes, the elbows jut out and therefore the muscles of arms and shoulders are under constant load and the wrist extension means that even the hands are strained unnecessarily. The tendency to do this is often greater with light objects, but the cumulative effect(strain) is very detrimental.

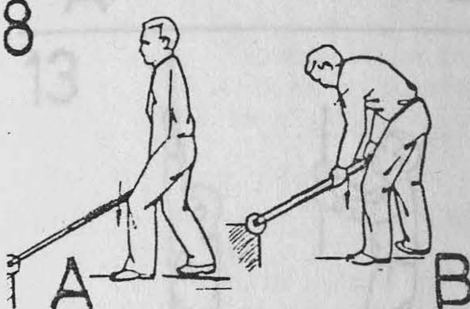
7



WHICH IS THE BEST POSTURE FOR DOING THIS HEAVY FILING JOB? .B...........
WHY?

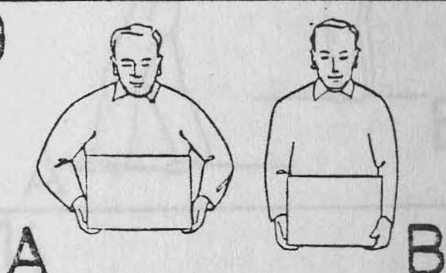
A is working in a fashion which will produce maximum cumulative strain. In B apart from raising the vice the stance has been adjusted to produce a 'base' rather than a 'top heavy ' (A) action. Also in B he is closer to his work and elbows are in to side.
A subsidiary point is the index finger position. In A it is poor because it causes a more forecful action of the arms inward rotating muscles. Hold is more 'palmar' in B.

8



WHICH IS THE BEST WAY OF PRESSING DOWN ON THE LEVER BAR?..A.......
WHY?
When pressing muscles alone can never apply a force equal to that of the body weight. B may feel that he is putting in more effort but most of it is wasted, also in B the danger of losing balance means that muscles will be reflexly stiffened to safeguard balance. A has feet well placed and therefore uses body weight (it is a base action) Also the use of 'head lock' in A straightens spine, and aids straight arms in direct transmission of weight.

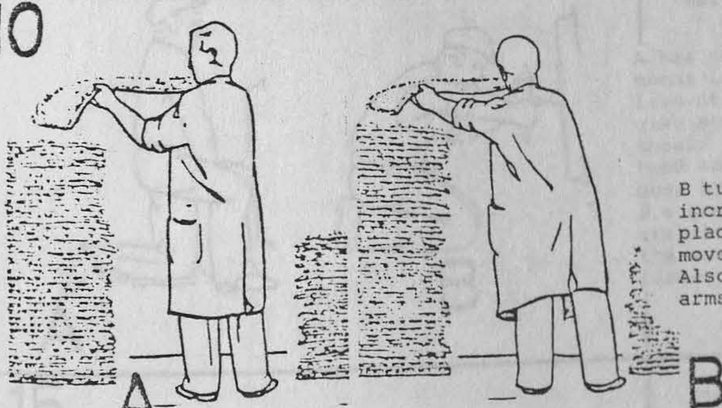
9



THE BEST WAY TO CARRY A BOX IS..B...
WHY?

Elbows into side, straight arms , direct transmission of weight down onto body. Palmar hold pulling box onto body .

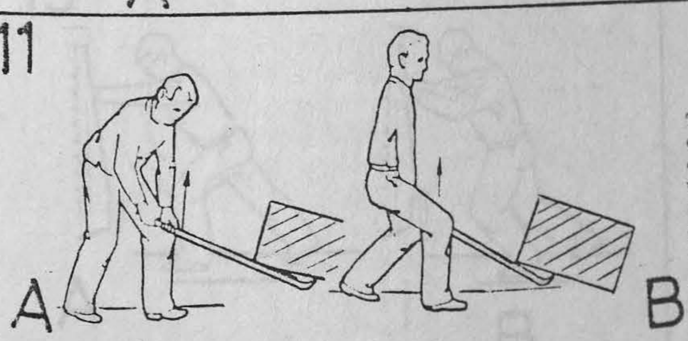
10



THIS MAN IS LIFTING MATS FROM THE PILE ON HIS RIGHT, INSPECTING THEM, THEN PUTTING THEM ON THE PILE ON HIS LEFT, THE BEST WAY TO DO THIS IS
..A.......

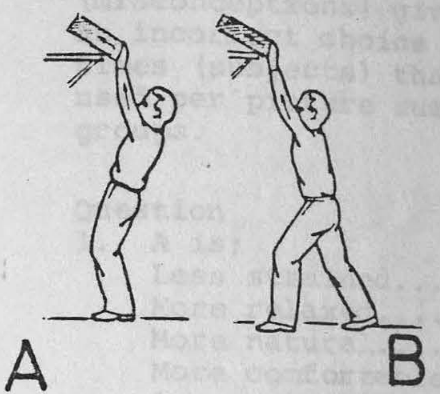
WHY?
B turns and reaches over a rigid left leg, this increases torsion on lower spine. In A the foot placement (left foot turned to left leading movement) allows a natural follow through . Also no need to carry load so much on extended arms. NOT TURNING ON A RIGID BASE LEG.

11



THE BEST WAY OF LIFTNG WITH A CROW--BAR IS...B.....
WHY?
The leg muscles are more powerful than the arm or back muscles. A is unbalanced and must depend on arm and back, as the load comes up the strain will increase. B has a good base action, and less risk of slipping, is directly over the bar and is making good use of leg muscles. Also the straight arms again mean direct transmission of forces without effort wasted stabilising joints.

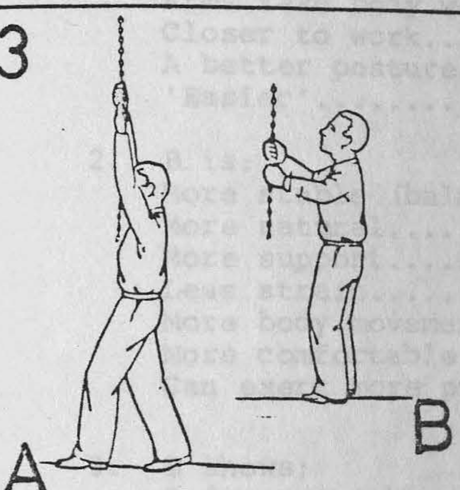
12



THE BEST WAY TO THRUST THIS BOX ONTO A HIGH SHELF IS..B....
WHY?

One foot advanced for balance and rear foot straight for good thrust. Power is coming from the legs and not the back and arms.

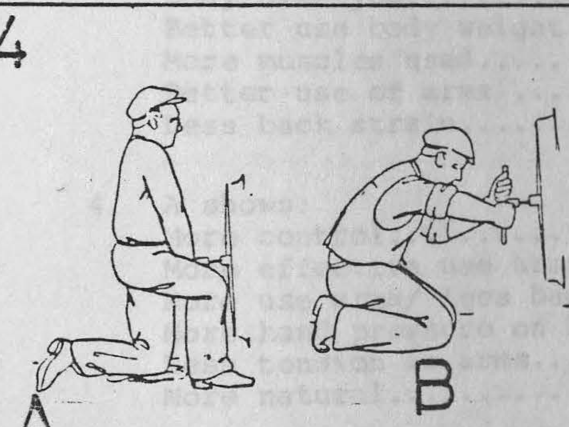
13



THE BEST WAY OF DOWN PULLING ON THE CHAIN IS....A...
WHY?

A is starting with the arms well overhead and placing one foot well in advance this allows the movement to be accomplished by relaxing the knees and using bodyweight.

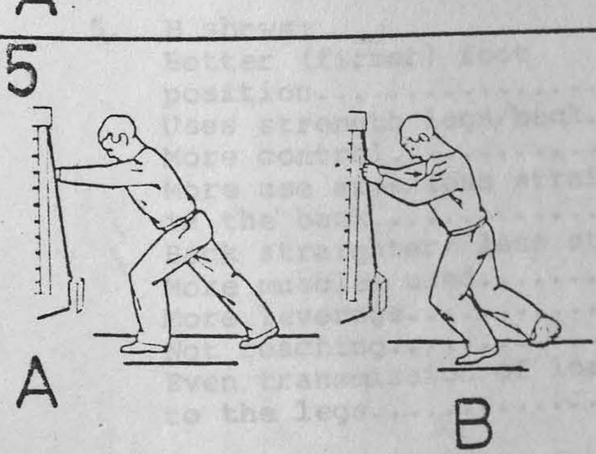
14



THIS ENGINEER TAPPING A HOLE WOULD BE BETTER OFF IN POSTURE .....A.....
WHY?

A has provided a soft surface to kneel on. This means less concentrated pressure and therefore less stiffening. The right foot is advanced to give stability to the body and check balance should the tool slip or break. B is making the hand and forearm muscles do work which in A is done by the bigger arm and shoulder muscles. In B a great deal of energy is dissipated in stabilising elbow and shoulder joints because of the outstretched arms. A is closer to the job, forces pass down a straight forearm.

15



THE BEST WAY TO PUSH THIS HEAVY BOOK CASE IS....A....
WHY?

B leads to severe strain in the lower back abdomen and right foot. In A the arms are straight, one foot is advanced for balance. the chin is tucked in (Head lock) to stabilise shoulders and straighten the spine.
In A the 'arm lock' is used. Outward rotation of the arms automatically stabilises shoulder girdles (by firm compression of the scapulae agianst the posterior chest wall) Therefore body weight and leg action replaces muscular work of arms and shoulder muscles.

Appendix 4: A listing of the total rationales (misconceptions) given by subjects to justify an incorrect choice of picture and the number of times (subjects) that each faulty explanation was used per picture summed across all experimental groups.

Question

1. A is;
   Less strained........... 6
   More relaxed............ 9
   More natural............ 4
   More comfortable........ 3
   Arms take body weight... 2
   Closer to work.......... 2
   A better posture........ 1
   'Easier'................ 1

2. B is;
   More stable (balanced).. 10
   More natural............ 5
   More support............ 4
   Less strain............. 4
   More body movement...... 2
   More comfortable........ 1
   Can exert more pressure. 2

3. B shows;
   Body over job........... 6
   Better use body weight.. 5
   More muscles used....... 2
   Better use of arms 1
   Less back strain........ 1

4. A shows;
   More control............ 9
   More effective use arms. 7
   More use arms/ less back 3
   More hand pressure on box 2
   Less tension in arms.... 2
   More natural............ 3

5. B shows;
   Better (firmer) foot position................ 7
   Uses strength legs/back. 2
   More control............ 2
   More use arms/less strain in the back..............1
   Back straighter/ less strain 2
   More muscles used........2
   More leverage............1
   Not reaching.............2
   Even transmission of load to the legs............ 1

6. A shows;
   More control............6
   Arms more powerful, efficient/ stronger.....10
   Better leverage......... 3
   Easier use of arms...... 4
   Less strain in arms..... 1
   More comfortable........ 1
   Uses stomach muscles as well....................– 1
   Closer to vision........ 1

7 A is;
   More natural............1
   Less strained.......... 1
   More comfortable....... 1
   Less body movement......1
   Body weight over vice.. 1

8. B can;
   Apply more force....... 9
   Makes better use of body weight........... 9
   Can apply more pressure 3
   Less strain.. on back ..2
   .. on stomach..1

9 A shows;
   'Better' use of arms....1
   More use of arms relieves back strain............ 7
   Arms take main weight.. 3
   Whole body support..... 1

10 B shows;
   Feet more apart....... 1
   Less back strain with the arms more bent.... 1

11 In A the;
   Body is more relaxed... 1
   Better use body weight. 1
   Better balance......... 1
   A would be OK if feet were together......... 1

12. In A;
   The body is more relaxed 1
   There is less strain.... 1

Appendix 4 continued...

13. B shows;
Less stretching(or reaching).... 6
Less back work (strain)......... 2
Better balance.................. 1
More natural.................... 1
More force can be applied....... 1
More control.................... 1
Less strain on shoulders........ 1
Body weight on both legs........ 1

14. B shows;
More power from the arms........ 3
A better view................... 3
More relaxed.................... 1
Uses more muscles............... 1
Full use of shoulders........... 1
More comfortable and efficient.. 1

15. B shows;
Better use of(more power from) legs 3
Strain is taken by the arms......3
More muscles share the load......2
Less muscle tension............. 1
Uses shoulders as well as arms to push.............................1.

APPENDIX 5.

The 82 Jobs examined in the shop floor evaluation package.

1 Moving coils to store using a barrow.
2 Offloading empty fibre kegs from container to warehouse.
3 Moving parcels to a stationwagon.
4 Donning a B A set.
5 Loading frozen food parcels to a van.
6 Loading frozen food parcels to 3rd level of van.
7 Offloading empty 45g drums from lorry to stack.
8 Offloading empty 45g drums from lorry to storage rack.
9 Loading sacks of product to a 20' container wagon.
10 Filling sacks with product and moving to pallet.
11 Filling sacks with product and moving to pallet
12 Filling sacks with product and moving to pallet.
13 Loading 4' foam bundles to 40' container.
14 Loading 4' foam bundles to 40' container.
15 Loading kegs of product to 20' lorry
16 Loading reactor with sacks of raw materials.
17 Lifting sacks of raw material to reactor traw-way.
18 Loading sacks of raw material to lift from pallet.
19 Loading container wagon with bagged product.
20 Loading empty cartons into skip.
21 Feeding foam to grinder.
22 Moving kegs of product to pallet from roller conveyor.
23 Loading 8' lengths of foam to container.
24 Moving a gas cylinder.
25 Loading steel flat strip to rack.
26 Removing and replacing footwear in racks.
27 Packing meal containers into boxes.
28 Lifting a man-hole cover.
29 Hatch loading (emptying bags down a chute).
30 Feeding a machine with boxed product.
31 Lifting boxed product from a bin and sorted into racks.
32 Removing bags from machine, sealing, and dragging away.
33 Filling a cleaning machine with dirty bags.
34 Removing clean bag from a skip, and examing.
35 Lifting full sacks onto a chain transport system.
36 Pushing a large wheeled box into an elevator.
37 Leaning over and cutting open sacks on a conveyor.
38 Dragging heavy bags to the back of a cehicle.
39 Moving trays of product from test area to bench.
40 Packing components into a large box for despatch.
41 Loading packed boxes onto scales for weighing.
42 Moving piles of trays to take samples from each.
43 Removing sacks of granules from shelving to truck.
44 Loading a drying machine with product from sacks.
45 Loading Jigs of components onto automatic plating plant.

46 Lifting machine vice from rack to milling machine.
47 Filing of correspondence into high cabinets.
48 Filing of customers correspondence on low shelving.
49 Stacking timber (2 men).
50 Bandsaw - asiding cut pieces of timber.
51 Cutting blocks on a dimension saw.
52 Removing assembled furniture from bench to ground.
53 Pulling to tension and stapling to secure webbing.
54 Cutting cloth using a vertical electric knife.
55 Sewing a bag cover.
56 Inspect and bundle sewn cover.
57 Assembling wires to form a coil spring unit.
58 Fitting fabric onto a frame.
59 Drum sanding pieces of wood.
60 Spray polishing wood.
61 Filling small bags with packing.
62 Securing crates in a container for transport.
63 Wrapping a drum with waterproof covering.
64 Lifting and locating a bar into take-up roller.
65 Positioning tension wheel straps to a bar.
66 Rolling up a large blanket of material.
67 Rolling up blanket (with front rollers).
68 Washing a large blanket.
69 Pushing drums into an oven.
70 Locating track into an oven.
71 Lifting lumps of viscous material out of mixing tanks.
72 Cutting up raw materials and feeding to machine.
73 Pushing boxes of scales into stacking machine.
74 Carrying boxes 140 yards.
75 Lifting lumps of raw material to a machine.
76 Lifting lumps of raw material to a machine.
77 Lifting lumps of raw material to a machine.
78 Removing job from a machine.
79 Locating and lifting a take up bar on a machine.
80 Positioning wheels on a machine.
81 Buffing finished pieces of work.
82 Loading small tins of work into a machine.

APPENDIX 5. BODY MAPPING

In the original plan for the project it had been proposed to use the technique of body mapping (Corlett and Bishop 1976) to plot the areas of the body which suffered pain or discomfort after periods working in particular postures or with particular handling methods.

The objective of the body mapping study was to try to examine directly the deleterious effects of postures and movements which were defined by kinetics as bad, compared to those defined as good. The hypothesis investigated was that bad kinetic movement would lead, after a period of work, to aches, pains or discomfort which the subject could record on a body map. The body map used was one designed by me for the purpose. It is shown at the end of this appendix. Its two parts were designed to collect information about subjective feelings of discomfort and the second any existing chronic musculo-skeletal disorders.

The body map was distributed and individually explained to a sample of 15 hairdressers, 10 cleaners and 20 firemen at the end of their respective shifts to examine the potential of the technique. The results from these pilot studies were promising in that the technique had good face validity and some correlation between poor movement and localisation of mapped discomfort was shown. Further analysis showed however that this correlation was confined to younger and less experienced operators. With older workers and those who had spent a number of years on the same job no such discomfort relationship was found.

In any event it proved impossible to pursue this line of enquiry as the necessary access to carry out industrial studies was not forthcoming.

The results of the pilot study, if accurate, do however cast some doubt on the value of body mapping as a technique. Currently it is seen as a way of providing 'direct evidence of the benefits of ergonomic changes' in for example machine design (Corlett and Bishop 1976). It has been used in shop floor studies, although its validation as a tool has been largely based on laboratory studies (Kirk and Saoyama 1973) using naive subjects. It is likely that use of the technique with subjects habituated to one working task will produce results which underestimate the problems of the habituated task in relation to those of the new one.

It had been hoped that the technique would throw light on the early stages of damage due to cumulative strain. In so far as the hypothesis upon which this hope was based remains valid, it would appear that poor movement produces pain and discomfort within the first few weeks of starting to use it. After this it would seem that the discomfort disappears, but the damage process carries on until, usually a number of years later, it manifests itself again in chronic musculo-skeletal disorders. Whether this disappearance of pain is explicable by a 'pain threshold' which is raised by habituation, or whether it is a short-term adaptation of the muscles which leads on to the irreversible stiffening process, remains a question for further study.

.. XXXXXXXXXXXXXXXXXXXXXXXXXX.....

DEPARTMENT ....

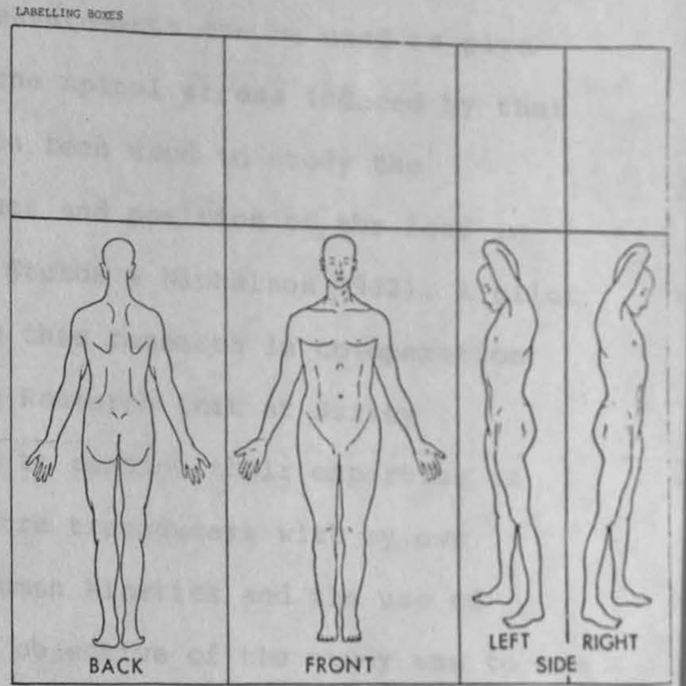
JOB ....

AGE .... LENGTH OF SERVICE.............

Below is a list of words labelled A-J, these are commonly used to describe feelings of discomfort. Combined with this list is a scale of numbers in order that the intensity of each feeling may be recorded. An extremely intense feeling would be 7, and a barely noticeable one would be 1. To the right of these are outlines of the human body with a box above each.

The purpose of all this is to enable you to record how you feel at the end of the shift. Look at the list A-J, do any of these words describe how any of your muscles feel? If so shade in the affected area on the body diagram. It is very important that you only shade the exact area of discomfort .... Try moving the affected part, or pressing it with your fingers to find the exact boundaries. When you have done this label each shaded area in the following way:- In the labelling boxes put a figure and a number to represent each shaded area and draw a line from the label to the shaded area. For example if you felt that a muscle in your arm was extremely stiff you would shade it and label it (F) for stiff and 7 for extremely, the label would therefore be F.7. in the box above the picture shaded. Similarly a slight pain would be A2, or medium soreness C.4.

	EXTREME						BARELY NOTICEABLE
A. PAINFUL	7	6	5	4	3	2	1
B. ACHING	7	6	5	4	3	2	1
C. SORE	7	6	5	4	3	2	1
D. TENDER	7	6	5	4	3	2	1
E. TENSE	7	6	5	4	3	2	1
F. STIFF	7	6	5	4	3	2	1
G. UNCOMFORTABLE	7	6	5	4	3	2	1
H. CRAMP	7	6	5	4	3	2	1
I. PINS AND NEEDLES	7	6	5	4	3	2	1
J. TINGLING	7	6	5	4	3	2	1
	EXTREME						BARELY NOTICEABLE

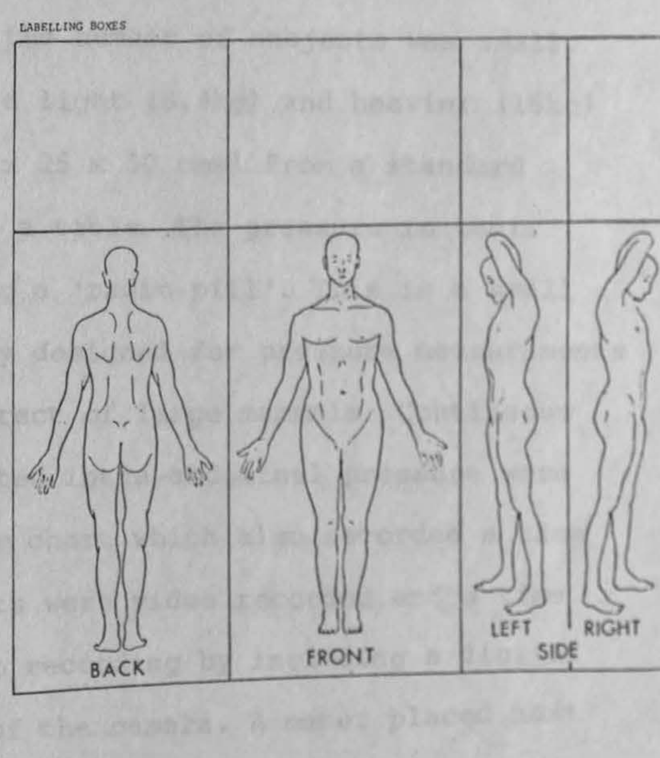


This diagram shows both sides of the 2 part form devised for the body mapping study. The first part looks at immediate discomfort and the second chronic musculo skeletal pain. The examples shown here have been reduced to one quarter of their actual size.

The second part of this questionnaire is completed in much the same way to the first. This time the question asked is ... Have you had or do you suffer from any of the disorders in the list A-L? If so shade in the part of your body affected on the body diagram and label it with the appropriate letter in the labelling box. To complete the label would you indicate next to the letter, when and for how long you were affected. This could be phrased started 19... and cleared up 19... or, intermittent since Feb. 19..., or started July 19... and still suffering. Finally some of the items in the list (eg. strains and sprains) could have been caused by a specific incident or accident and in such a case could you also say in your label what this was.

A ARTHRITIS
B RHEUMATISM
C FIBROSITIS
D LUMBAGO
E SCIATICA
F NEURALGIA
G SLIPPED DISC (PROLAPSED DISC)
H HERNIA, RUPTURE, OR PROLAPSE
I VARICOSE VEINS
J BRONCHITIS
K HEADACHES
L ANY SERIOUS SPRAINS OR STRAINS

Thank you for your patience and co-operation.



APPENDIX 6. INTRA ABDOMINAL PRESSURE

Davis (1977) proposed that during a given manual effort, intra abdominal pressure measurements can be used to give an accurate indication of the spinal stress induced by that activity. This technique has been used to study the relationship of spinal stress and position of the load in relation to the body (e.g. Stubbs & Nicholson 1982). A pilot study was undertaken during this research in co-operation with the Materials Handling Research Unit at Surrey University. The study aimed to combine their expertise at using intra-abdominal pressure transducers with my own experience of training in Human Kinetics and the use of video analysis. The overall objective of the study was to see if Human Kinetic lifting produced significantly lower intra-abdominal pressures when compared with other methods of lifting.

METHOD

As this was a pilot study the number of subjects was small. Four male students lifted a light (6.4kg) and heavier (16kg) smooth faced tote box (25 x 25 x 30 cms) from a standard position on the floor onto a table. The pressure in their abdomens was measured using a 'radio pill'. This is a small radio transmitter specially designed for pressure measurements in the gastro intestinal tract of large mammals. Continuous recordings of the transmitted intra-abdominal pressure were recorded on a pen and paper chart which also recorded a time base. The subjects movements were video recorded and a time base was added to the video recording by including a digital clock in the visual field of the camera. A meter placed next to the digital clock also showed intra-abdominal pressure on the video tape. There were thus two systems for linking pressure changes to video recorded movement. First the linked time bases on both paper and video record and second the direct appearance of the pressure meter in the visual field of the video camera. The subjects were also photographed at the moment the box left the floor.

Each subject lifted each box three times under each of the following conditions:

(i) Their 'naive' lift

(ii) A full stoop (legs kept as straight as possible)

(iii) After 'six-point drill', 'back erect', training

(iv) After a four hour intensive training in kinetic lifting from the ROSPA instructor.

The six point drill lift was accomplished by referring the subjects to the drill card discussed on page 146 of the thesis. The Human Kinetic lift was the same as that described on pages 147-50 of this thesis. Due to the nature of the tasks performed and the need for training it was not possible to randomise the order of presentation. However lifts (ii) and (iii) were repeated in the afternoon session, after the final kinetic lift, as a check. Trunk inclination, thigh and knee flexion, and the distance of the box centre of the gravity from the base of the spine (measured in the horizontal plane d1. and the actual diagonal distance d2. (see fig 28) were measured from the video recordings (as performed on page 157). The time (t) taken in 1/50 second units for the box to move the first 50 cm of the lift was also measured.

RESULTS

The results are summarised in figure 45 and the graph (figure 46). The table shows time (t), the angles of back, knee and thigh flexion the distances d1 and d2 and the intra abdominal pressure. These are means for all three lifts of each subject under each condition. The series of photographs in figure 47 also shows one example of each type of lift for all four subjects and the peak intra abdominal pressure for that lift. The digital clock and pressure meter can be seen in the lower right of these photographs.

DISCUSSION

The results did not show that a kinetic lift produced significantly lower intra-abdominal pressures than other methods of lifting. One surprising result of this study is that the supposedly extremely harmful 'full stop' lifts produced relatively low IAP's.

It was possible that the peak intra-abdominal pressure may be correlated with any of the following variables. Speed of lift (time, t); Distance of box centre of gravity from base of lumbar spine (d1, d2); Angles of flexion of back, knee or thigh; or type of lifting action. Nicholson my co-worker with the Surrey group used a computer programme (The Statistical Package for the Social Sciences - SPSS) to search for significant interactions between the seven dependent variables, for all ninety lifts individually.

The programme took pairs of variables in sequence and tested for significant correlation using Kendall and Spearman significance tests. IAP was found to be correlated with

Figure 45: Table of results for the intra abdominal pressure study.

time t 1/50sec units	Back angle (degrees)	Knee flexion (degrees)	Thigh angle (degrees)	distance d_2 cms	distance d_1 cms	Intra abdominal pressure mm. mercury	Type of lifting action and weight
15	53	45	45	57	50	16	Naive Light
16.5	55	43	36	55	50	22	Naive Heavy
15	45	35	37.5	40	40	26	6.P.D. Light
14	43	43	40	46	41	32	6.P.D. Heavy
23	106	132	94	84	46	11	Stoop Heavy
14	47	88	83	54	42	9	Human Kinetics Light
14	66	70	52	57	40	24	Human Kinetics Heavy
9.3	68	85	35	70	53	87	Naive Light
10.7	72	87	37	69	50	117	Naive Heavy
20	60	77	35	64	50	56	6.P.D. Light
16	52	68	33	63	45	50	6.P.D. Heavy
11	103	143	40	90	48	38	Stoop Light
16	102	153	53	89	47	64	Stoop Heavy
10	52	60	37	49	38	45	Human Kinetics Light
11	58	60	33	52	41	77	Human Kinetics Heavy
10	89	113	28	68	45	61	Naive Light
14	87	113	27	68	45	86	Naive Heavy
13	47	55	33	48	38	45	6.P.D. Light
17	50	55	23	50	40	61	6.P.D. Heavy
14	95	172	68	85	48	30	Full Stoop Light
17	100	170	60	86	45	63	Full Stoop Heavy
15	60	82	50	64	54	52	Naive Light
19	60	80	52	68	56	63	Naive Heavy
15	42	65	53	59	47	40	6.P.D. Light
17	42	62	50	60	50	44	6.P.D. Heavy
18	100	140	40	98	48	32	Stoop Light
15	100	137	47	95	53	40	Stoop Heavy
11	57	57	40	59	40	45	Human Kinetics Light
10	58	60	42	60	40	60	Human Kinetics Heavy

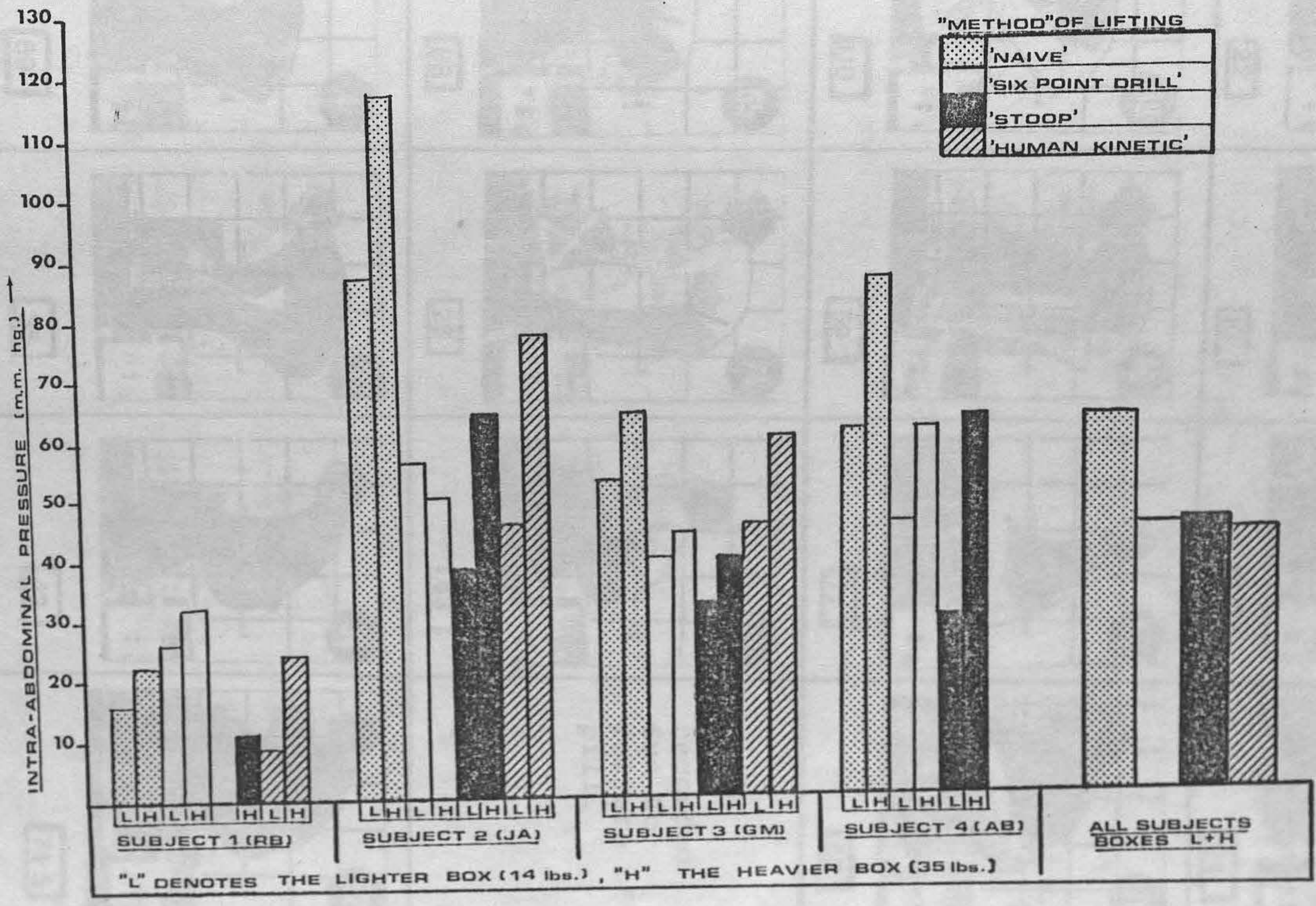


Figure 46: Histogram- showing results for intra abdominal pressure study for each subject by method of lifting and all subjects.

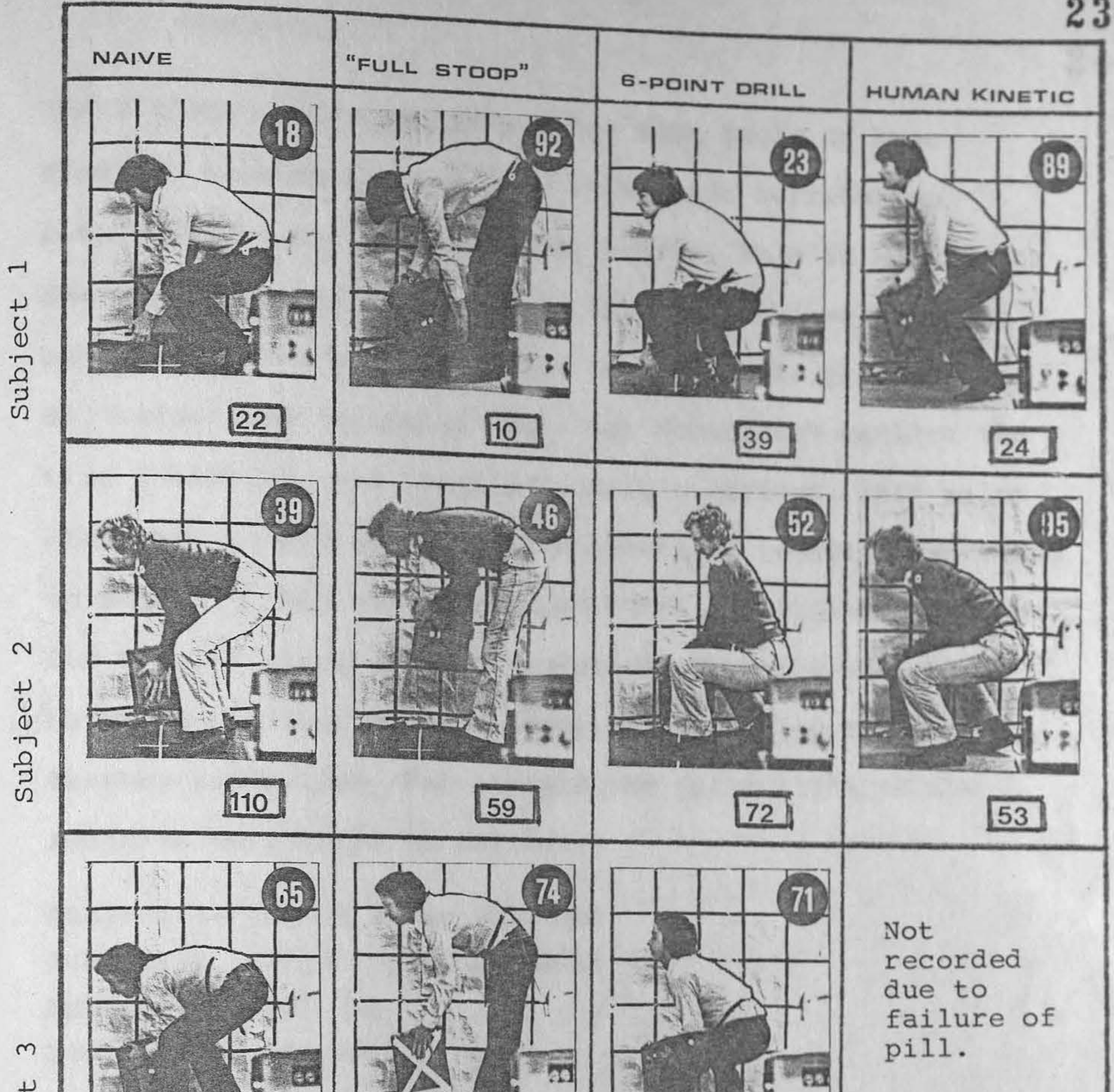


Figure 47: Reproduction of photgraphs showing one example of each of the four lifting methods for each subject. The peak intra abdominal pressure for that lift is shown in the square underneath it. (mm. Hg.) (The number in the circle is just the lift sequence number.)

($\alpha = 0.001$) every variable other than angle of knee flexion. However there was no systematic correlation between IAP and type of lifting action. This is mainly for reasons discussed elsewhere in this thesis (see page 172 namely that the classification of lifts into groups such as 'naive' and 'stooping' does not accurately reflect the true complexity and range of possible actions. This pilot study was completed before the shorthand notation described on page 172 had been developed. When the video recordings for the IAP study were re evaluated using the shorthand notation the four broad categories of lifting could be further subdivided. For example the naive lifts of the subjects were coded as follows:

Subject 1 (L T X B) or (LT) (B)
Subject 2 (A) (L) (TB) or (A)(L) (TB)
Subject 3 (LT) (B)
Subject 4 (LT) (B)

Subject 2 (as can be seen from the photographs) exhibits the common fault of using the arms independently in lifting actions. The trunk has to form a stable base for the action of the arms by stabilising the shoulder muscles and their attachments. It is possible that this stabilising action could have an effect on intra abdominal pressure, as trunk muscles are contracted. This implies that, if this technique is to be used for the comparison of complex movements like lifting, it may be necessary to control carefully the contribution of each component which could modify intra-abdominal pressure in a series of trials.

With such a small number of subjects showing such a wide variety of lifting actions it is impossible to draw any firm conclusions from this study. However the technique would seem worthy of further exploration and a number of incidental methodological conclusions arose from this study. Once again the value of slow motion video analysis was proved, especially linked to the IAP measurements. It has been the case in past studies of physiological measures linked to specific movements to assume that the peak measure occured at the stage of the movement commonly assumed to be the most stressful, i.e. in lifting actions to assume that the peak intra-abdominal pressure recorded on the paper trace coincided with the moment that the box left the floor. While our study showed this to be true in the majority of examples there were notable exceptions. The subject mentioned above who used his arms to lift independently rather than to transmit forces showed a small peak in IAP at the moment the box left the floor which was almost doubled half way through the upward movement (presumably associated with his arm use). In the same subject and in one other the first step which immediately followed the lift produced a peak pressure higher than that from lifting. Although this may have just resulted from a 'shock wave' in the abdominal viscera it would have been difficult to separate from the lifting peak without the slow motion video analysis.

APPENDIX 7 ANTHOPOMETRIC CRITERIA - THE CORMIC INDEX

Observations made during ROSPA training courses suggested that it might be easier for some people to perform certain kinetic movements on account of their body build. A short pilot study based on some of the ROSPA video analysis data showed that anthropometric criteria may influence lifting styles.

A number of indices are used in anthropometric literature to produce single figures which combine two or more body dimensions. One such is the Cormic Index (eg Croney 1971) which relates sitting to standing height.

$$\text{The Cormic Index} = \frac{\text{seated height} \times 100}{\text{standing height}}$$

An answer of 45% would indicate a short trunk and relatively long legs and one of 55% a longer trunk to relatively shorter legs (Croney op cit).

The Cormic Index was used to look at the relationship between anthropometric dimensions and angle of body segments during different methods of handling.

A pilot study was carried out on one ROSPA course (R26379). Unfortunately the derived index range was small. (51.6% · 56%, $\bar{x}$ = 53.8, SD = 1.19). However the correlations between the index and the following were calculated for naive, six point drill and kinetic lifts.

(i) inclination of trunk axis from the vertical

(ii) the angle between the trunk axis and the thigh mid line

(iii) the angle between the thigh mid line and the calf ankle mid line at the knee joint.

Of these the Cormic Index was found to have a positive correlation with inclination of the trunk axis from the vertical for (a) naive and (b) six point drill lifts.

(a) $r = 0.5 (p < 0.1)$

(b) $r = 0.68 (p < 0.005)$

This suggests that subjects with longer trunks and shorter legs tend to incline their trunks more from the vertical than subjects with longer legs and a shorter trunk, regardless of leg or thigh flexion. It would be interesting to examine this more closely over a wider range of each measure. It may simply be that subjects with short legs also have short arms and so need to incline their trunks more to get their hands under the box. It does however indicate that anthropometric dimensions are a further variable which complicates analysis and modification of handling patterns.

APPENDIX 8 VIDEO AS A TRAINING AID

Sections of this thesis have indicated the difficulty of communicating movements or postures using just language or static pictures. Trainees on courses need to be able to practice movements and get feedback about their performance. A short pilot study was performed to evaluate the effectiveness of video as a training aid.

Trainees on ROSPA courses where I had used video to study movements were enthusiastic about the use of video for feedback and said that they found it invaluable in practising movements. In order to quantify its 'usefulness' courses R131178 and R26379 were subject to the following trial. On the Thursday preceeding the final Friday assessment all the subjects had their normal practice session recorded. Approximately half of the subjects in each group were shown and 'talked through' their video recordings, the rest receiving only verbal feedback from the instructor (they were allowed to see their recordings after the final Friday assessment). On course R131178 five subjects received video feedback (FB) and seven did not. On course R26379 seven subjects received video feedback and eleven did not. The improvement scores of the two groups over the course on the kinetic criteria were compared. The results are presented below:

	No Feedback	Video Feedback
Failures → Passes	11.1	12.4
Failures → Improvements	1.3	2.2
Failures → Failures	4.1	1.9
Passes → Passes	5.1	5.6
Passes → Failures	0.2	0

Mean Scores for 2 groups summed over 2 courses.

The differences between groups are in the predicted direction but fall well short of significance. However it would be interesting to complete a larger more carefully controlled trial of this hypothesis.

APPENDIX 9 ROSPA TRAINEES & FOLLOW UP TRAINING

In the conclusions it was mentioned that some subjects may lack confidence to pass on the teachings of Human Kinetics to third parties. This may to some extent reflect the calibre of trainees selected to go on Human Kinetics courses. The general questionnaire reported on page 121 of this thesis asked all the subjects to state their normal job titles. The results of this are shown below.

Table ___ Job Title of ROSPA Course Participants

	Number
Training instructor	20
Safety officer	12
Training officer	7
Senior instructor	4
Foreman	3
Lecturer	3
Area equipment inspector	3
Physiotherapist	3
Supervisor	2
Training instructor/Safety officer	2
Training manager	2
Area manager	2
H.G.V. driver	2
Manual handling instructor	2

And one (1) each of the following:

Safety technician
Safety foreman
Regional safety manager
Safety/Fire advisor
Safety/training engineer
Safety/security advisor
Training/efficiency officer
Manager fire/security dept.
Security sergeant
Security officer
Staff supervisor
Labour (Safety rep)
Senior plant operator
Night manager
Stores controller
Personnel services supervisor
P.E. instructor
Loader instructor
Medical attendent/welfare officer
Labourer
Assistant plant manager
Branch manager
Works supervisor

It is significant that only half of the people selected for training as instructors mention training as one of their major functions. Even if they do learn Human Kinetics from the ROSPA instructor they may lack the communication skills to effectively pass on the teaching to others. It was originally proposed to follow up the second stage of the ROSPA training and see how a sample of instructors interpreted the techniques and theory to third parties. When I tried to pursue this it had to be abandoned as a full study because, over a fifteen month period regular phone call checks on 25 instructors revealed that none had been able to do any follow up training in their own place of work because line management would not allocate time for this to be done. It did prove possible to sit in on one set of training courses provided by a major service industry who employed two ROSPA trained instructors. In each case the instructors ignored most of their ROSPA training and produced a classic 'six point drill' training session. However to be fair to them they were allocated twenty minutes to train a group of twenty people. Given such time restraints they had little choice but to simplify ruthlessly. It is possible that limitations on time made available for training could be a major reason for the emergence of 'drill' approaches.

REFERENCES

Note on the bibliography

The Human Kinetics references come first (Anderson T McClurg) and are numbered (1-50). The rest of the references follow the normal convention.

Anderson T McClurg

1 Human Kinetics and analysing body movements 1951 London: William Heinemann medical books Ltd

2 Prophylactic physiotherapy British Journal of Physical Medicine 1954 (July): 1-4

3 Human Kinetics in schools, hospitals and industry British Journal of Physical Medicine 1955 (April): 1-6

4 Human Kinetics in strain prevention British Journal of Occupational Safety 1970 8 (93): 248-250

5 Human Kinetics and good movement Physiotherapy 1971 (April): 169-176

The faculty of physiotherapists (The Scottish physiotherapy hospital) formerly of 29 Waterloo Street, Glasgow C2 and later of 170 Hope Street, Glasgow C2 produced the following texts under authorship of Anderson.

6 The Scottish physiotherapy hospital, a four page explanatory pamphlet (seeking £25,000 building construction fund.)

Industrial fatigue, strain and injury (a series of six leaflets reprinted from "Colvilles' Magazine") Printers Clark D J 34-38 Cadogan Street Glasgow C2

7 Leaflet No 1 "Basic Movements in Strains and Injuries"
8 Leaflet No 2 "Teaching Kinetic Methods"
9 Leaflet No 3 "Cumulative Strain"
10 Leaflet No 4 " Counteracting Cumulative Strain"
11 Leaflet No 5 "Hand Mechanics"
12 Leaflet No 6 "Posture"

13 Principles of Physiotherapy "Chronic Bronchitis" 1961 (May): 13pp.

14 "Debunking the Disc" - Ethical Implications 1967: 16pp.

15 Examination papers for the Faculty of Physiotherapy 1964 (Decenber): 17pp.

16 The Kinetic approach to "Spastic" conditions (The text of a lecture given to the annual conference of the Faculty of Physiotherapists 1956 (May): 7pp.

The Institute of Human Kinetics (formerly of 6 Royal Crescent Glasgow C3) produced the following leaflets under the authorship of Anderson.

17 Apprenticeship training - synopsis of views 1950: 5pp.
18 The use of wall charts 1957 (December): 3pp.
19 Objectives and responsibilities of resident physiotherapists 1957 (November): 3pp.
20 Advice to patients in a rest home 1957 (November): 4pp.
21 Physiotherapy Equipment: 5pp.
22 Human Kinetics 1957 (December): 2pp.
23 Armchair exercises: 5pp.
24 Constipation 1958 (September): 5pp.
25 Handling patients: 3pp.
26 Housework with ease (film strip notes): 6pp.
27 Strain prevention - Introducing Kinetic methods of handling 1960: 4pp.
28 Human Kinetics in Industry (film strip notes): 11pp.
29 Human Kinetics (Notes to supplement a 44 slide instruction programme): 19pp.
30 Human Kinetics (Notes to supplement a 20 slide instruction programme): 6pp.

31 The Neuromuscular mechanism (Notes for a filmstrip prepared for Scottish Instructional Films, Glasgow) 35 slides: 11pp.

32 The industrial application of Human Kinetics (A memorandum prepared for the Industrial Welfare Society) 1954 (June): 5pp.

33 "Introducing Kinetics techniques", An instruction programme prepared for the safety and training officer, United Glass Ltd 1954.

34 Basic principles and practice of golf Publishers The Golf School SE Andrews Fife Scotland: 28pp.

35 Human Kinetics in golf - methods of approach: 4pp.

36 Human Kinetics in golf - positioning and conditioning for the swing: 5pp.

Correspondence from Anderson to the author:-

37 Personal communication 1977 (23rd September).

38 Personal communication (including a review of the book "Backache relieved" by Fahrni WH) 1977 (7th October)

39 Personal communication 1977 (9th October)

40 Personal communication (including a review of the paper Back pain prevention by Hayne G R) 1977 (14th October)

41 Personal communication 1977 (26th November)

<u>Correspondence from Anderson to others</u>:-

42 Review of "A computerised simulation model of postures during manual materials handling" - by Park K (University of Michigan) (1973 1st November)

43 Correspondence to the Medical Adviser of a nationalized industry 1977 (December 15th)

44 Review of the book "You and your back" By Dr Delvin D

45 Communication to D A Payne of the Royal Society for The Prevention of Accidents 1974 (12th February)

46 Human Kinetics for instructors - The manual currently (1981) in use on Royal Society for The Prevention of Accidents Instructor training courses: 102pp.

47 Human Kinetics - the reduction of fatigue, strain and injury - published by ROSPA: 22pp.

48 Why produce your own aches and pains - a pocket pamphlet produced by ROSPA - editions 1 and 2 (ref. 1517)

49 Preparatory paper for ROSPA course in Human Kinetics published by ROSPA: 13pp

50 Safer manual lifting and handling a summary for 'appreciation courses' published by ROSPA: 2pp

REFERENCES OTHER THAN ANDERSON

Abbatiella A A An objective evaluation of attitude change in training Training and Development Journal 1967 (November): 23-34

Abbot J Why breadth in the programme? British Journal of Physical Education 1978 9 (5): 128-129

Aberg U Elgstrand K Magnus P Lindholm A Analysis of components and prediction of energy expenditure in manual tasks The International Journal of Production Research 1968 6 (3): 189-196

Abraham WM Exercise - induced muscle soreness The Physician and Sportsmedicine 1979 7 (10): 57-60

Akeson WH An experimental study of Joint Stiffness Journal of Bone and Joint Surgery 1961: 1022-29

Anderson G Örtengren R Nachemson A Quantitative studies of the load on the back in different working postures Scandinavian Journal of Rehabilitation Medicine 1978 Supplement No 6: 173-181

Aniansson A Grimby G Hedberg M Rundgren A Sperling L Muscle Function in old age Scandinavian Journal of Rehabilitation Medicine 1978 Supplement No 6: 43-49

Anon New Rules for Lifting National Safety News 1977 (May): 56

Anon (Undated) Safety instructions for fitters assemblers and millwrights The Engineering and Allied Employers National Federation Safety Booklet No 6

Anon Safer manual handling Bulletin (Ceramics, glass and mineral products industry training board). 1974 29 (May): 1

Anon Lifting method endorsed by IAPA Accident Prevention 1979 (March): 4

Anon Stay young by good posture New Scientist 1979 1979 (17 May): 544

Anon Deep knee bends in exercise programs Modern Athlete and Coach 1977 15 (1): 15;17

Anon Industrial Backache Safety Maintenance 1962 (Sept): 47-48

Ariel G B Resistance exercises and muscle-fiber typing Track Technique 1977 70: 2239-2240

Armstrong T J Chaffin D B Faulkner J A Herrin G D Smith R G Static work elements and selected circulatory responses American Industrial Hygiene Association Journal 1980 41 (April): 254-260

Ayoub M M Human movement recording for biomechanical analysis International Journal of Production Research 1972 10 (1): 35-51

Back Pain Association You and Your Back 1975 Grundy House Teddington TW11 8TD

Back Pain Association: How to prevent back pain - common sense rules 1979 Grundy House Teddington TW11 8TD

Back Pain Association: Lifting instructors manial 1978 Grundy House Teddington TW11 8TD

Balensweig I Unusual vertebral injuries Archives of Surgery 1926 (January): 29-45

Barlow W Psychosomatic problems in postural re-education The Lancer 1955 269 (6891): 659-664

Barnard J Edgerton V R Peter J B Effect of exercise on skeletal muscle - Contractile properties Journal of Applied Physiology 1970 28 (6): 767-770

Barnes W S The relationship between maximum isometric strength and intramuscular circulatory occlusion Ergonomics 1980 23 (4): 351-357

Beard R Guardian special report - The Spine The Guardian Friday December 17th 1976: 9

Becket H M A Textbook of Orthopaedics 1959: Stamford

Bevan R J A simple camera synchronizer for combined cinephotography and electromyographic Kinesiology for use with a pen recorder The Research Quarterly 1972 43 (1): 105-113

Billig H E Loewendahl E Mobilization of the human body (Newer concepts in body mechanics) 1949 London: Oxford

Birmingham (1979) High Court District Registry Queens Bench Division Action No 317 9th February 1979 - Birch and the Post Office (1976-B- No 09499)

Blair W. The evaluation and management of backache in general practice Journal of the College of General Practitioners 1963 6: 355-72

Bloom W Fawcett D A Textbook of Histology. 1962 Pennsylvania: Saunders

Bond M B Low back in-uries in industry Industrial Medicine 1970 39 (5): 28-32

Booth F W Gould E W Effects of training and disuse on connective tissue Exercise and Sports Science Reviews 1975 Vol 3 (ISBN0-12-227403-2): 83-112

Bourne G H The Structure and function of muscle Volume I Structure 1960 London: The Academic Press

British Companies Size Report C and D Partners 1978 Kent

British Safety Council Kinetic Handling Undated 62-64 Chancellor's Road London W6 9RS

British Safety Council Kinetic Handling Undated 62-64 Chancellor's Road London W6 9RS

Brooke J D Whiting H T A (Editors) Human movement - a field of study 1973 London: Henry Kimpton

Brown J R Factors contributing to the development of low back pain in industrial workers American Industrial Hygiene Association Journal 1975 36 (1): 26-31

Brown S R Flexibility - A different view New Zealand Journal of Sports Medicine 1975 3 (4): 21-22

Buchthal F Kaiser E Factors determining tension development in skeletal muscle (Acta Physiol Scandinavia 8: 38-74 1944)

Burger G C E Permissible load and optimal adaptation Ergonomies 1964 7 (4): 397-417

Burry H C Lesions of tendons and their attachments New Zealand Journal of Sports Medicine 1978 6 (1)

Buss A R Causes and reasons in attribution theory: A conceptual critique Journal of Personality and Social Psychology 1978 36 (11): 1311-1321

Capretta J The condition called muscle bound The Journal of Health and Physicial Education 1932 (3)

Carlsöö S The static muscle load in different work positions: An electromyographic study Emergencies 1961 4:192-211

Carpenter A A study of angles in the measurement of the leg lift Research Quarterly 1938 9: 70-72

Carter C A Suppling: The myth of mobility exercising Track Technique 1978 (73): 2329-2331

Carvagna G A Dusman B Margaria R Positive work done by a previously stretched muscle Journal of Applied Physiology 1968 24 (1): 21-32

Croney J Anthropometrics for Designers 1971 London: B T Batsford Ltd New York: Van Nostrand Reinhold Company

Chaffin D B Ayoub M M The problem of manual materials handling Industrial Engineering 1975 (July) : 24-29

Chaffin D B Localized muscle fatigue - definition and measurement Journal of Occupational Medicine 1973 15 (4) : 346-354

Chaffin D B Physicial fatigue: What it is - How it is predicted The Journal of Methods - Time Measurement 14 (3) : 2¼-28

Chaffin D B Park K S A longitudinal study of low-back pain as associated with occupational weight lifting factors American Industrial Hygiene Association Journal 1973 34 (12): 513-525

Chaloner J Stability Exercises Physiotherapy in Sport 1978 2 (1): 12-16

Clark R D Chief Education Officer, Gloucestershire County Council: Personal Communication 14th February 1980

Clemmesen S Some studies on muscle tone Proceedings of the Royal Society of Medicine 1951 44 : 637-646

Cooper R R Alterations during immobilization and regeneration of skeletal muscle in cats Journal of Bone and Joint Surgery 1972 54: 919-953

Corlett E N Bishop R P A technique for assessing comfort in industry A Report of the Department of Engineering Production University of Birmingham 1976

Corlett E N Bishop R P A technique for assessing postural discomfort Ergonomics 1976 19 (2): 175-182

Corlett E N Manenica I The effects and measurement of working postures Applied Ergonomics 1980 11 (1): 7-16

Coville C A Relaxation in physical education curricula
Physical Educator 1979 36 (4) : 176-181

Cunninghams text book of anatomy Edited by Couper Brash J
9th ed 1951 London: Oxford University Press

Cureton T K Flexibility as an aspect of physical fitness
Research Quarterly 1941 12 : 381-91

Curran C Isometric, isotonic, isokinetic strength training
International Swimmer 1977 14 (4) : 20-21

Cyriax J British Medical Journal 1954 Advice on weight
lifting 4867 933

Daniel J W Fairbank J C T Vale P T O'Brien J P
Low back pain in the steel industry: a clinical, economic
and occupational analysis at a North Wales integrated steel
works of the British Steel Corporation Journal of the
Society of Occupational Medicine 1980 30 49-56

Davies B T Training in manual handling and lifting
Proceedings of the International Symposium of Safety in
Manual Materials Handling State University of New York
at Buffalo 1976 19th-21st July

De Lacerda F Anatomical analysis of basic abdominal
exercises Journal of Physical Education and Recreation
1978 75 (5): 114-115

Del Ray P Feedback provided through video - taped display
Physical Educator 1972 29 (3): 118-19

Department of Education and Science Safety in Physical
Education 1973 DES Safety Series No 4 London: HMSO

de Trense M Are you sitting comfortably? Occupational
Health 1976 (October): 470-473

De Vries H A Method for evaluation of muscle fatigue
and endurance from electromyographic fatigue curves
American Journal of Physical medicine 1968 47 (3): 125-135

De Vries H A Evaluation of Static stretching procedures
for improvement of flexibility The Research Quarterly
1962 33 (2) : 222-229

Diem A Present situation of physical education and
sport in the education of youth International Journal
of Physical Education 1976 13 4: 21-23

Eagle R A Pain in the Back New Scientist 1979 84 (1177): 170-171

Edginton D W Edginton V R The Biology of Physical Activity 1976 Boston: Houghton Mifflin

EITB (undated) Engineering Industry Training Board P O Box 176 54 Clarendon Road Watford WD1 1LB

FYT Booklet No 1 "Training Practice for first year trainees - Broad Based Training - Terminology, tools, and techniques"

Fahrni W H Backache relieved through new concepts of posture 1966 Illinois: Charles C Thomas

Feldenkrais M Awareness through movement 1975 New York: Harper and Row

Feldenkrais M Body and mature behaviour 3rd ed 1973 New York: International Universities Press Inc

Ferguson D An Australian Study of telegraphists cramp British Journal of Industrial Medicine 1977: 280-285

Fitzgerald K J Engineer manual handling out of the job Materials Handling - 1969 (June): 25-27

Floyd W F Silver P H S The Function of the erectores spinae muscles in certain movements and postures in man Journal of Physiology 1955 129: 184-203

Floyd W F Ward J Posture in Industry International Journal of Production Research 1966 5 (3): 213-224

Floyd W F Qard J Posture in industry International Journal of Production Research 1967 5 (3) : 213-224

Fugl-Meyer A R Postural muscle fibre composition Scandinavian Journal of Rehabilitation Medicine 1978 supplement No 6: 66-68

Gibbon A The case for physical education - An overview Bulletin of Physical Education 1978 14 (3): 5-10

Glennon D P Human error causation or victim derogation - a contingency theory Control 1978 5 (2): 47-63

Glover J R Davies B T Manual handling and Lifting The Journal for Industrial Nurses 1961 13 (6): 1-12

Goldberg A L Etlinger J D Goldspink D F Jablecki C Mechanism of work-induced hypertrophy of skeletal muscle Medicine and Science in Sports 1975 7 (4) 248-261

Goldthwait J E Brown L T Swaim L T Kuhns J G Body mechanics in health and disease 1971 3rd ed Philadelphia: J B Lippencett Company

Gollnick P D Armstrong R B Enzyme activity and fibre composition in skeletal muscle of untrained and trained men Journal of Applied Physiology 1972 33 (3): 312-319

Gollnick P D Armstrong R B Effect of training on enzyme activity and fibre composition of human skeletal muscle Journal of Applied Physiology 1973 34 (1): 107-111

Gollnick P D Hermansen L Saltin B The muscle biopsy still a research tool The Physician and Sports Medicine 1980 8 (1): 49-55

Goss C M Anatomy of the Human Body 1973 Philadelphis: Lea and Febiger

Gould B S Collagen Biosynthesis 1968 New York: Academic Press

Grandjean E Hunting W Ergonomics of posture - review of the various problems of standing and sitting posture Applied Ergonomics 1977 8 (3): 135-140

Gray F E Hanson J A Jones F P Postural aspects of neck muscle tension Ergonomics 1966 9 (3): 245-256

Grays Anatomy - descriptive and applied Editor Howden R 18th ed 1913 London: Longmans Green and Company

Grays Anatomy - descriptive and applied Editors Johnston T B and Whillis J 30th ed 1949 London: Longmans Green and Company

Great Britain: The Health and Safety Commission Consultative Document Proposals for Health and Safety (Manual Handling of Loads) Regulations and Guidance: 1982 London: HMSO

Great Britain: The Electricity Countil: "Easy does it" The Chief Safety Officer Electricity Council 30 Millbank London SW1

Great Britain Ministry of Labour and National Service (Safety Pamphlet No 16) 1943 London: HMSO

Great Britain Health and Safety Executive Lifting and Carrying 1958 London: HMSO

Great Britain Department of Education and Science Safety in Practical Departments 1973 London: HMSO

Great Britain Department of Education and Science Safety in Physical Education 1973 London: HMSO

Great Britain Department of Education and Science Safety in Further Education 1973 London: HMSO

Great Britain District Councils and County Council of Hereford and Worcester Joint Working Party on Safety in lifting and handling Safety Booklet No 12: 1977 (August)

Great Britain Home Office (Fire Department) Fire Service Drill Book 1977 London: HMSO

Great Britain 1980 Parliamentary debate - Back Pain HC dep 18 Jan 1980 col 2173-2184

Gutman G M Herbert C P Brown S R Feldenkrais versus convential exercises for the elderly Journal of Gerontology 1977 32 (5): 562-572

Hadler N M Clinical investigations into the influence of the pattern of usage on the pattern of regional musculoskeletal disease Arthritis and Rheumatism 1977 20: 1019-1025

Haisman M F Winsmann F R Goldman R F Energy cost of pushing loaded handcarts Journal of Applied Physiology 1972 33 (2): 181-183

Hajek N M Godbey M E Hines M H Functional changes in muscle and nerve resulting from prolonged states of shortening Archives of Physical Medicine 1947 28 (11): 690-695

Hansson Jan-Erik Principles for work requirement analysis Scandinavian Journal of Rehabilitation Medicine 1978 Supplement No 6: 7-13

Hayne C R The physiotherapist in modern industry 1947-1976 Unpublished dissertation for the Fellowship of The Chartered Society of Physiotherapy

Hayne C R Pass on the lifting message Occupational Health 1979 (July): 351-355

Harrison Clarke H (Editor) Joint and body range of movement Physical Fitness Research Digest 1975 5 (4): 1-22

Harrison Clarke H (Editor) Exercise and the knee joint Physical Fitness Research Digest 1976 6 (1): 1-17

Harrison Clarke H (Editor) Posture Physical Fitness Research Digest 1979 9 (1): 1-23

Hereford, M E M Advise on weight lifting 1954 British Medical Journal 1954 4863 703

Hershenson A Cumulative injury A National Problem Journal of Occupational Medicine 1979 21 (10): 674-676

Hewitt L Institute of Municipal Safety Officers Personal Communication 7th Feb 1980

Himburg S Kinetic methods of manual handling in industry International Labour Office (I L O) Occupational Safety and Health Series No 10 1967

Hodgson S Anatomy of back pain Occupational Health 1973 January: 9-12

Holding D H Journal of Experimental Psychology 1954 (48): 375-80

Holland G J The Physiology of flexibility Kinesiology Review 1968: 49-62

Hollingshead W H Functional Anatomy of the limbs and back 1960 Philadelphia: W B Saunders and Co

Hooper E G Allday A H Report of the working group on lifting and handling The Electricity Supply Industry Working Group 1975

Hopkinson R G Subjective judgements - some experiments employing experienced and inexperienced observers British Journal of Psychology 1955 46: 262-272

Hosler W W Videotape: a research tool? Journal of Physical Education and Recreation 1977 48 (9): 53

Houston M E The use of histochemistry in muscle adaptation: A Critical assessment Canadian Journal of Applied Sport Sciences 1978 3 (2): 109-118

Howorth M Becket A texture of orthopedics Stamford Conn 1959 pp 199

Imrie J A "The working Back" (Film and pamphlet) The Back Care Centre 214 Laird Drive Toronto Ontario Canada

Inglis B The book of the back 1978 London: Ebury Press

Ingjer F Brodal P Capillary supply of skeletal muscle fibers in untrained and endurance-trained women European Journal of Applied Physiology 1978 38: 291-299

Institute of Municipal Safety Officers (IMSO) Accident Control Manual Lifting and Handling March 1979 IMSO 129 Kingsbridge Road Morden Surrey England

International Labour Organisation Maximum Permissible weight to be carried by one worker 1964 ILO Occupational Safety and Health Series No 5 Geneva

Jackson D H Reeves T J Sheffield L T Isometric Effects on treadmill exercise response in healthy young men American Journal of Cardiology 1973 31: 344

Jackson J M Biomechanical hazards in the dockworker Annals of Occupational Hygiene 1968 11 (2): 147-157

Jacobson E Progressive relaxation 11th ed 1968 Chicago: University of Chicago Press (Medway Reprint 1974)

Jesse J P Misuse of strength development programs in athletic training The Physician and Sportsmedicine 1979 7 (10): 46-52

John Player and Sons Physiotherapy Department 1974 Lift Lively a basic guide to handling

Jones D F Back Injury research a common thread American Industrial Hygiene Association Journal 1972 (Sept): 596-602

Jones E E Kanhouse D E Kelley H H Nisbett R E Valins S Weiner B Perceiving the causes of behaviour 1971 Morris Town New Jersey General Learning Press

Jørgensen K Poulsen E Physiological problems in repetitive lifting with special reference to tolerance limits to the maximum lifting frequency Ergonomics 1974 17 (1): 31-40

Joseph J Mans posture - electromyographic studies 1962 Springfield Illinois USA: Charles C Thomas Inc

Kahn A Low back pain - an apologia Journal of the Arkansas Medical Society 1969 66 (2): 79-80

Kane J E Curriculum development in physical education 1976 London: Crosby Lockwood Staples

Karhu O Kansi P Kuorinka I Correcting working postures in industry A practical method for analysis Applied Ergonomics 1977 8 (4): 199-201

Karlsson J Sjödin B Teseh P Larsson L The significance of muscle fibre composition to human performance capacity Scandinavian Journal of Rehabilitation Medicine 1978 Supplement No 6: 50-61

Kassab S J Drury C G The effects of working height on a manual lifting task International Journal of Production Research 1976 14 (3): 381-386

Kendall H O Kendall F P Boyton D A Posture and Pain 1952 London: Bailliere Tindall and Cox Ltd

Kerr A Safety-first! Manual lifting and carrying Associated Union of Engineering Workers Journal 1979 (Sept): 19

Kilbom A Circulatory and ventilatory effects of combined static and dynamic activities Scandinavian Journal of Rehabilitation Medicine 1978 Supplement No 6: 99-104

King R Slipped disc syndromes Industrial Safety 1979 (April): 14-16

Klein K K The deep squat exercise as utilized in weight training for athletics and its effect on the ligaments of the knee Association for Physical and Mental Rehabilitation Journal NT 1961 15: 6-1

Konz S A Bhasin R Foot position during lifting American Industrial Hygiene Association Journal 1974 35 (12) 785-792

Koskela A Noro L Oja P Observations concerning problems connected with lifting Work Environment Health 1968 5 (1): 39-41

Kotani PT Ichikawa N Wakabayashi W Yoshii T Koshimune B S & M Studies of spondylosis found among weight lifters British Journal of Sports Medicine 1971 6 (1): 4-8

Kottke F J Evaluation and treatment of low.back pain due to mechanical causes Archives of Physical Medicine and Rehabilitation 1961 (June): 426-440

Kraus H Pseudodisc - The problem of backache. Proceedings of the Rudolf Virchow Medical Society of New York 1964 23 50-57

Kraus H Raab W White P D Hypokinetic Disease 1961 Springfield Illinois USA: Charles C Thomas

Kulund D N Dewey J B Brubaker C E Roberts J R Olympic weight-lifting injuries Physician and Sportsmedicine 1978 6 (11): 111-119

Kuorinka I Koskinen P Occupational rheumatic diseases and upper limb strain in manual jobs in a light mechanical indusry Scandinavian Journal of Work Environment and Health 1979 5 (Supplement 3): 39-47

Kurpa K Waris P Rokkanen P Tennis elbow Scandinavian Journal of Work Environment and Health 1979 5 (Supplement 3) 15-18

Kurpa K Waris P Rokkanen P Peritendinitis and tenosynovitis Scandinavian Journal of Work Environment and Health 1979 5 (Supplement 3): 19-24

Le Bato L T Should tension control classes be included in the curriculum? Physical Educator 1971 28 (2): 96-97

Lee M Wagner M Fundamentals of body mechanics and conditioning Philadelphia WB Saunders and Co 1949 (pp 106-110)

Leighton J R Flexibility characteristics of males ten to eighteen years of age Archives of Physical Medicine and Rehabilitation 1956 37: 494-99

Levine J Chandromalacia Patellae The Physician and Sportsmedicine 1979 7 (8): 41-49

Liemohn W Factors related to hamstring strains Journal of Sports Medicine and Physical Fitness 1978 18 (1) 71-76

Lloyd A J McClaskey E B Subjective assessment of effort in dynamic work Journal of Motor Behavior 1971 3 (1): 49-56

Locke L F Jensen M Prepackaged sports skills instruction A review of selected research Journal of Health, Physical Education and Recreation (JOHPER) 1971 (September): 57-59

Logan G A Dunkelberg J G Adaptations of muscular activity 1964 California: Wadsworth Publishing Incorporated

Lowman C L Postural stress and strain in occupational therapy American Journal of Occupational Therapy 1948 2 (April): 87-89

Lowman C L Young C H Postural fitness: Significant and variances 1960 Philadelphia Lea and Febiger

Luopajärvi T Prevalence of tenasynovitis and other injuries of the upper extremities in repetitive work Scandinavian Journal of Work Environment and Health 1979 5 (Supplement 3): 48-55

Maeda K Occupational cervicobrachial disorders in an assembly plant Kurume Medicine 1975 22 (4): 231-239

Magnuson P B Coulter J S Workmans backache International Clinics 1921 31 (4): 215-253

Magora A Taustein I An investigation of the problem of sick-leave in the patient suffering from low back pain Industrial Medicine 1969 38 (11): 80-90

Manning DP Shannon H S Injuries to the Lumbosacral region in a gearbox factory Journal of the Society of Occupational Medicine 1979 29: 144-148

Mason I D Branton P Effects of posture instability on monitoring performance Proceedings of the Ergonomics Society Annual Conference 1977 The Ergonomics Society

Mason I D The Collected Thoughts of HMFI concerning Manual Handling 1900-1974 Publication of The Department of Occupational Health and Safety 1977 (b) The University of Aston Birmingham

Mason I D Hazard Awareness in lifting and handling museum group Transactions Number 13 1978: 14-19

Mason I D Human Kinetics and Good Movement Occupational Health 1978 (January): 22-25

Mason I D Don't strain yourself - Questions and Answers about Human Kinetics 1980: Royal Society for the Prevention of Accidents

Mason I D Payne D A Manual Handling, Ergonomics and Movement Training - Have we got it right? Proceedings of the Occupational Safety and Health Conference 1981 Birmingham ROSPA

Maunsell B R Exercise and prevention of low back problems New Zealand Journal of Health Physical Education and Recreation 1972 5 (2): 51-55

Mawson L M The origin and development of movement education Canadian Journal of the History of Sport and PE 1975 6 (1): 1-11

May J Oh my aching back Occupational Safety and Health 1976: 17-18 and 34-35

Meldrum A Planning the programme Scottish Journal of Physical Education 1979 7 (3): 5-9

Mercel D I Corlett E N Operator performance in relation to press design A Report of the Department of Engineering Production, University of Birmingham 1978

Merton P A Pampiglione G Strength and fatigue Nature 1950 166: 527-528

McCafferty W B Horvath S M Specificity of exercise and specificity of training: A subcellular review Research Quarterly 1977 48 (2): 358-371

McFarland R A Injury - a major environmental problem Archives of Environmental Health 1969 19 (August): 244-256

MacKenzie C The Action of muscles Paul E Hoeber Inc 1940

McLaughlin T M Dillman C J Lardner T J A Kinematic model of performance in the parallel squat by champion powerlifters Medicine and Science in Sports 1977 9 (2): 128-133

McLaughlin T M Lardner T J Killman C J Kinetics of the parallel squat The Research Quarterly 1978 49 (2): 175-189

Miller A A versatile body builder New Scientist 1980 (February 14th): 470-473

Millar A P An early stretching routine in hamstring muscles Australian Journal of Sports Medicine 1975 7 (5): 107-109

Miller R L Bend your knees! National Safety News 1977 (May): 57

Morehouse L Mill A Physiology of Exercise St Louis C V Mosby Co 1963

Morgan R E (Chairman) The concept of physical education British Journal of Physical Education 1970 1 (4): 81-82

Müller E A Vetter K Blümel E Transport by muscle power over short distances 1979 Ergonomics 22: 222-225

Nachemson A Ortengren R Andersson Quantitative studies of back loads in lifting Proceedings of the International Symposium of Safety in Manual Materials Handling 1976 Buffalo New York July 19-21

Nagi S Burk R Potter H R Back disorders and rehabilitation achievement Journal of Chronic Disorders 1965 18: 181-197

National Safety Council Life Safely 1976 444 North Michigan Avenue Chicago Illinois 60611

Noro L Medical aspects of weight carrying Industrial Medicine and Surgery 1967 (March): 192-195

Nursing Mirror Health and Safety Cards: 2 1981 Supplement to Nursing Mirror IPC Press Ltd

Onishi N Nomura H Kazuhiro S Fatigue and strength of upper limb muscles of flight reservation system operators Journal of Human Ergology 1973 2: 133-141

"
Ortengren R Andersson G Broman H Vocational electromyography: Studies of localized muscle fatigue at the assembly line Ergonomics 1975 18 (2) 157-174

Osgood C E The measurement of meaning 1957 Urbana University of Illinois Press

Osgood R B Back strain - an accident or a disease? Journal of Industrial Hygiene 1919 1: 150;157

Osman T Easing the strain on your back - how to avoid backache The Sunday Times (colour supplement) 7 November 1976: 32-33

Palmer IP Husqvarna Forestry Technique 1979 Sweden Jonkoping

Palmer R Physical education in schools: current issues and solutions Physical Education Review 1978 1 (2): 101-110

Park K S Chaffin D B Prediction of load-lifting limits for manual materials handling Professional Safety 1975 (May): 44-48

Peres N J C Human Kinetics is new aid in manual handling Australian Factory 1960 (April): 46-52

Perrot J W Anatomical factors in occupational trauma The Medical Journal of Australia 1961 1 (3): 73-83

Phillips R Wither Orthopaedics? Hospital Life 1976 (Jan): 5

Pickup A J Collagen and behaviour: a model for progressive debilitation IRCS Journal of Medical Science 1978 6: 499-502

Pleasants F Kinesthesis: that uncertain feeling Physical Educator 1971 28 (1): 36-38

Polidoro J R Professional preparation programs of physical education teachers in Norway, Sweden and Denmark Research Quarterly 1977 48 (3): 640-646

Poulsen E Studies of back load, tolerance limits during lifting of burdens Scandinavian Journal of Rehabilitation Medicine 1978 Supplement No 6: 169-172

Poulsen E Jørgensen K Back muscle strength, lifting and stooped working postures Applied Ergonomics 1971 2 (3) 133-137

Rasch P J Allman F L Controversial Exercises American Corrective Therapy 1972 26 (4): 95-97

Rayner C Oh my aching back Womans Own 1977 June 11th: 28-29

Rcn (The Royal College of Nursing Working party on back injury) The Royal College of Nursing 1979 April : London Cavendish Square

Robertson A M The challenge of the painful back - an Industrial and Medical problem Transactions of the Society of Occupational Medicine 1970 20: 42-49

Robinson B J P Senior Training Adviser, Engineering Industry Training Board Personal Communication 2 April 1980

Robson H E A concept of physical fitness Physiotherapy in Sport 1978 2 (1): 16-17

Rohmert D Determination of relaxation allowances in industrial operations The Production Engineer 1966 45: 578-580

Ross L The Intuitive psychologist and his shortcomings distortions in the attribution process Advances in Experimental Social Psychology 1977 10: 173-220

Rothstein A L Effective use of videotape reply in learning motor skills Journal of Physical Education and Recreation 1980 51 (2): 59-60

Schiltz J H Cramps: Facts and fallacies Journal of Physics Education and Recreation 1976 47 (2): 57

Schultz P Flexibility the day of the static stretch The Physician and Sportsmedicine 1979 7 (11): 109-117

Scott M G Analysis of human motion 2nd ed 1963 New York: Meredith

Selvik G A stereophotogrammetric system for the study of human movements Scandinavian Journal of Rehabilitation Medicine 1978 Supplement No 6: 16-20

Seth J Production section of Her Majesty's Stationary Office St Crispins Duke Street Norwich NR3 1PD Tel: 0603 22211 A Personal Communication 2nd December 1980

Sever J W Backache due to industry and disease The Boston Medical and Surgical Journal 1925 192 (14): 647-658

Simons D G Muscle pain syndromes American Journal of Physics Medicine 1975 54 (6): 289-311

Simonson E Physiology of Work Capacity and Fatigue 1978 Springfield Illinois U S A Charles C Thomas

Simpson C Safe manual lifting and carrying Engineering 1970 13 (November): 512-13

Simri U The variety of concepts of physical education and their influence on objectives of physical education FIEP Bulletin 1978 48 (1): 11-16

Smales A HSE Library Telephone 01 262 3277 X 220 Personal communication Feb 1980

Snook S H Campanelli R A Hart J W A study of three preventive approaches to low back injury Journal of Occupational Medicine 1978 20 (7): 478-481

Snook S H Cirielle V M Low back pain in industry American Society for Safety Engineers Journal 1972 17 (4): 17-23

Snook S H Irvine C H The evaluation of Physical tasks in industry American Industrial Hygiene Association Journal 1966 (May): 228-233

Stanier D I The function of muscles around a simple joint Journal of Anatomy 1977 123 (3): 827-830

Stubbs D A Nicholson A S Manual handling and back injuries in the construction industry: an investigation Journal of Occupational Accidents 1979 2: 179-190

Stubbs D A Nicholson A S Force limits in manual work Materials Handling Research Unit University of Surrey 1982

Taylor B Muscle fiber typing Track Technique 1979 77 2442-2445

Thomson K The intrinsic value of physical activity Bulletin of Physical Education 1977 13 (4): 5-8

The Times 1000 Times Books 1978 London

Tichauer E R Miller M Nathan I M Lordosimetry: A new technique for the measurement of postural response to materials handling American Industrial Hygiene Association Journal 1973 34 (1): 1-12

Tichauer E R Biomechanics sustains occupational safety and health Industrial Engineering 1976 8 (2) 46-56

Tichauer E R A pilot study of the buomechanics of lifting in simulated industrial work situations Journal of Safety Research 1971 3 (3): 98-115

Tiegel E Ueber Muskelcontractur in Gegensatz sur contraction Pflueger's Archives F D ges Physiol 1956 45: 2095

Troup D The biology of back pain New Scientist 1975 Jan 2: 17-19

Tugman R E Weight-lifting Industrial Welfare 1943 (November): 169-171

The United States of America: Department of Labor "Teach them to lift" 1970 (Revised) Bulletin 110

Van Wely P Design and disease Applied Ergonomics 1970 1 (5): 262-269

Vasey J R Crozier L W Basic Movement patterns and their relationship to occupational physical problems Journal of Human Movement Studies 1975 1: 104-110

Videman T Effects of motion load changes on tendon tissue and articular cartilage Scandinavian Journal of Work Environment and Health 1979 5 Supplement 3): 56-67

Vorobiev G Injury Prevention Yesses Review of Soviet Physical Education and Sport 1977 12 (3): 70-74

Wakes Miller C H Diseases of sprout pickers Occupational Health 1976 June: 300

Ward T Knoweldon J Sharrard W J W Low back pain Journal of the Royal College of General Practitioners 1968 15: 128-136

Waris P Occupational cervicobrachial syndromes Scandinavian Journal of Work Environment and Health 1980 6 (Supplement 3): 3 - 14

Waris P Epidemiologic screening of occupational neck and upper limb disorders Scandinavian Journal of Work Environment and Health 1979 5 (Supplement 3): 25-28

Watkins W W The "last straw" factor in low back disability Radiology 1947 48: 20-28

Wayne N D Weight lifting British Medical Journal 1954 4870 1098-1099

Wells R L Improve flexibility to prevent injuries Athletic Journal 1979 60 (2): 54-55

Whitney R J The strength of the lifting action in man Ergonomics 1958 1 (2): 101-128

Williams M Wissner H R Biomechanics of human motion 1962 London: W B Saunders

Wingate P (Editor) The Penguin Medical Encyclopedia Second edition London: Penguin Books