

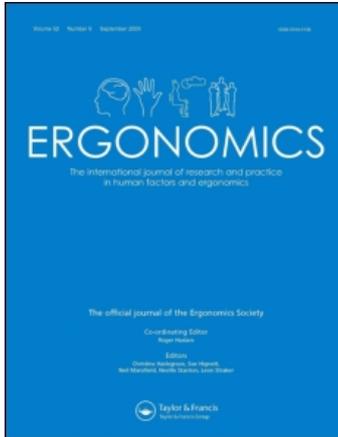
This article was downloaded by: [Univ Degli Studi di Milano]

On: 14 February 2011

Access details: Access Details: [subscription number 919295221]

Publisher Taylor & Francis

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Ergonomics

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title~content=t713701117>

Guidelines for designing jobs featuring repetitive tasks

R. Bergamasco; C. Girola; D. Colombini

Online publication date: 10 November 2010

To cite this Article Bergamasco, R. , Girola, C. and Colombini, D.(1998) 'Guidelines for designing jobs featuring repetitive tasks', Ergonomics, 41: 9, 1364 – 1383

To link to this Article: DOI: 10.1080/001401398186379

URL: <http://dx.doi.org/10.1080/001401398186379>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.informaworld.com/terms-and-conditions-of-access.pdf>

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Guidelines for designing jobs featuring repetitive tasks

R. BERGAMASCO†, C. GIROLA† and D. COLOMBINI‡

†Embraco-Aspera S.r.l, Via Buttiglieria, 6 - Riva presso Chieri, Turin, Italy

‡EPM Research Unit, Via Riva Villasanta, 11 - 20145 Milan, Italy

Keywords: WMSDs; Designing jobs; Repetitive tasks; Structural measures; Organizational measures.

Preventive measures aimed at minimizing the occurrence of work-related musculoskeletal disorders of the upper limbs (WMSDs) associated with repetitive tasks can be divided into three categories: structural, organizational and educational. Whenever specific risk and injury assessments have shown the need for preventive action, this is most often implemented within the framework of a range of assorted measures. In particular, structural measures involve optimizing the layout of the work area and furnishings, and the 'ergonomic' properties of work tools and equipment. Such measures serve to alleviate the problems caused by the use of excessive force and awkward postures. The authors refer to the principles guiding such structural measures, in the light of the extensive literature that has been published on the subject. Organizational (or reorganizational) measures essentially relate to job design (i.e. distribution of tasks, speeds and pauses). They serve to alleviate problems connected with highly repetitive and frequent actions, excessively lengthy tasks and inadequate recovery periods. Very few relevant findings are available: the authors therefore illustrate in some detail a practical trial conducted in a major engineering firm. The objective was to lower to acceptable limits the frequency of certain repetitive tasks performed using the upper limbs. The trial made it possible to identify a suitable plan and schedule of measures taking into due consideration the impact of the plan on production levels (and costs). The fundamental principles guiding the adoption of specific educational and training programmes for the workers and their supervisors are presented and discussed.

1. Introduction

When both exposure assessment and the study of work-related musculoskeletal diseases have revealed a significant risk associated with repetitive and/or strenuous movements of the upper limbs in various work environments, the need arises to implement specific measures aimed at re-designing jobs and procedures. These measures are often urgent and complex. Their efficacy depends on three types of coordinated and virtually simultaneous actions being carried out: structural modifications, organizational changes and personnel training. While the structural measures are almost universally accepted and widely recommended, actions involving organizational changes do not always meet with unanimous consent, nor does the scientific literature provide concrete examples. Instead it merely supplies general and routine advice such as: 'reduce excessively high job frequencies', or 'introduce adequate breaks or job alternatives'.

This paper aims to provide some concrete guidelines for re-designing jobs and preventing disorders caused by repetitive movements of the upper limbs. Reference will be made to the three areas mentioned above, and specific indications will be given for each area, based on the abundant literature already available on structural

Table 1. The three classes of measures for preventing WMSDs.

Structural measures

- Optimal arrangement of workplace, furnishings and layout
- Choice of ergonomic instruments or tools

These measures seek to improve aspects related to:
use of force; awkward posture and movements; localized compression

Organizational measures

- Ergonomic job design (speed, breaks, rotating alternative tasks (totally or partially))

These measures seek to improve aspects related to:
movements performed at high frequency and repetitively for prolonged periods;
absence or shortage of adequate rest periods

Training and re-training

- Adequate information on specific risks and injuries
- Guidance on correct method of performing tasks and techniques
- Suggestions concerning breaks

These measures serve to support the previous two.

modifications; a section is also devoted to the subject of possible organizational changes, already investigated and applied in some field experiments; finally, guidelines are supplied for personnel training and re-training programmes designed to support the previous two classes of actions, i.e. structural and organizational. Table 1 shows the three classes of measures for preventing WMSDs, with summaries of their aims and methods.

2. Structural measures

These primarily concern ways of finding an optimal arrangement for the workplace, furnishings and the overall lay-out of the environment and ergonomic work tools. In general, these measures aim to improve aspects related to awkward posture and movements, localized compressions of the anatomical structures of the upper limbs, and the use of excessive force. Structural measures thus seek to reduce the consequences of the most important risk factors, 'posture' and 'force', and of other additional risk factors.

2.1. *Criteria for limiting the risk factor 'posture'*

As far as the posture risk factor is concerned, the main principle to be kept in mind is to avoid prolonged movements or positions that force the joints to exceed 50% of their maximum range (Drury 1987). Re-designing the job, in this case, means allowing the worker to maintain posture or joint motion below 50% of the maximum specific range for each joint.

In the paper contained in this issue dealing with exposure analysis (Colombini), the author recommends the use of a check-list to describe and assess posture by evaluating and quantifying joint range regarded as significant in terms of duration (i.e. accounting for at least one-third of the job cycle) and that exceed 50% of the maximum joint range. Thus, using the same check-list used to carry out job analysis, it is a relatively simple matter to detect critical postures and, accordingly, to propose structural modifications of the workplace.

Figure 1 shows the main hand and arm positions and, for each of the main joints and movements, the angles deemed to be unacceptable. In order to ensure

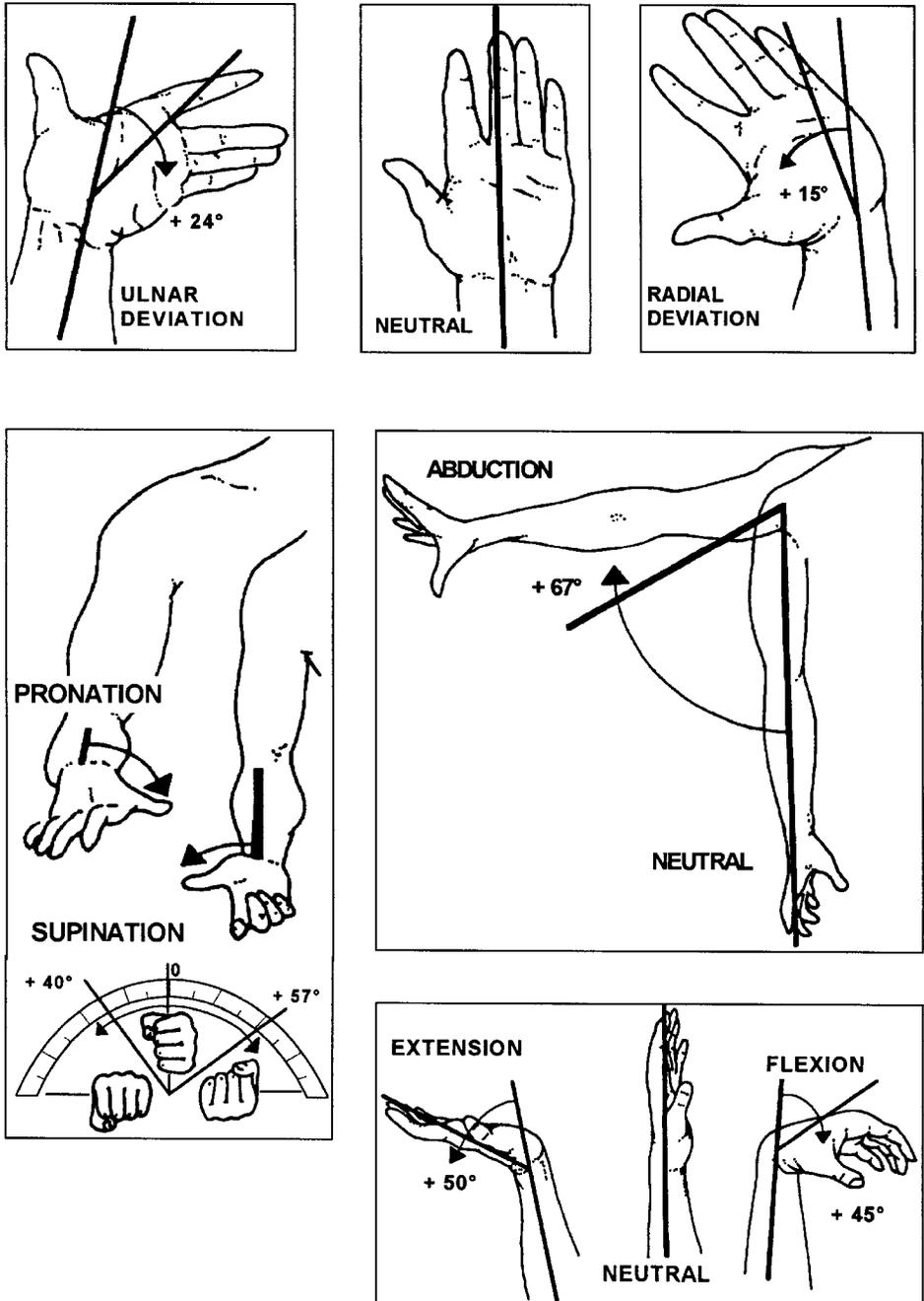


Figure 1. Positions of the arm and hand deemed to be unacceptable.

the correct position of the upper limbs, it is first essential to correctly design the workplace, emphasizing:

- (1) suitable work bench height when either standing or sitting;
- (2) suitable chair height for seated positions; and

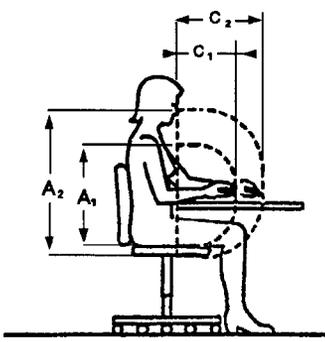
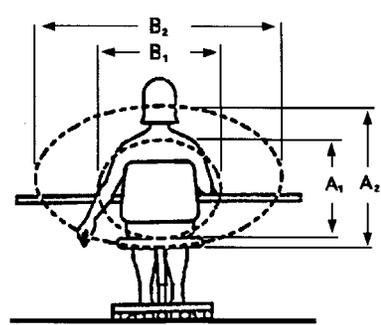
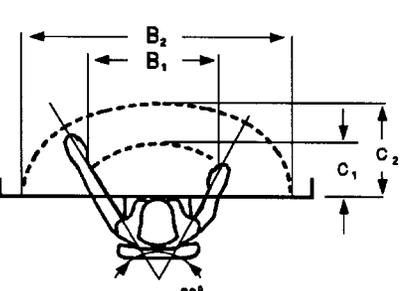
POSTURE	MEAS.	VALUE (MM)	
	A1	505	NORMAL WORK AREA: HEIGHT
	A2	730	MAXIMUM WORK AREA: HEIGHT
	B1	480	NORMAL WORK AREA: WIDTH
	B2	1310	MAXIMUM WORK AREA: WIDTH
	C1	170 290	NORMAL WORK AREA: DEPTH
	C2	425	MAXIMUM WORK AREA: DEPTH

Figure 2. Anthropometric requirements for designing workplaces at machinery.

(3) suitable operating areas for the upper limbs.

Figure 2 shows the preliminary data collected by the CEN/TC 122/WG1 'Anthropometry' Group, on the anthropometric requirements for designing workplaces at machinery (CEN 1996). The measurements are estimated to cater for the needs of 90% of the European population (from the 5th female percentile to the 95th male percentile). As regards borderline operating areas for the upper limbs, the adoption of the 'normal' operating areas (A1-B1-C1) instead of the 'maximum' areas (A2-B2-C2) ensures that the upper limbs (especially the scapulo-humeral joint) are not strained.

Check-lists 1 to 4 in the appendix supply the main design principles (Eastman Kodak Company 1983) for preventing awkward posture and/or movements harmful to the shoulder (check-list 1), the elbow (check-list 2), the wrist (check-list 3), and the hand and fingers (check-list 4).

2.2. Criteria for limiting the risk factor 'force'

The main principle involved here is to avoid overstraining the muscles, as can be assessed by subjective perception during the execution of a task (demand for more force than the individual can develop) (Colombini, this issue). It should also be noted that when the upper limbs, especially the wrist and hand, have adopted an awkward posture, the ability of the muscles in the strained segment to apply force is drastically reduced. For example, the force that can be developed in pinching movements is only 25% of the total grip force of the hand in such cases; moreover, grip force gradually diminishes as the wrist departs from the anatomical position (check-list 5) (Drury 1987, Putz-Anderson 1988).

In order to intrinsically reduce excessive strain, the following recommendations can be made:

- (1) avoid even occasional contractions exceeding 50–60% of the maximum individual capacity (score of 5–6 on the Borg scale); and
- (2) on average, no muscle-tendon unit should be exerted for more than 15% of its maximum capacity in any given shift (score of 1.5 on the Borg scale, calculated as a weighted score for the duration of the task).

The lower the degree of muscular exertion, the longer the permitted duration of the exertion. In addition, the lower the degree of muscular exertion, the greater the number of movements that can be made in performing a repetitive task with consequent positive repercussions on 'productivity' levels.

Generally speaking, it is possible to reduce the need for force by using power-driven tools, mechanical grippers and holders, more efficient levers in positions better suited to the stronger muscle-tendon units and, finally, by automating the entire action. Instruments and tools must meet a series of requirements in order to limit the above-mentioned risk factors — *posture* and *force* — thus also reducing the risk of accidents in the workplace.

An ergonomic instrument or tool should:

- (1) avoid having to deviate the wrist by more than 50% of its normal range;
- (2) avoid repetitive movements using a single finger;
- (3) avoid handpieces requiring grips awkward to the development of force;

- (4) avoid pulling movements and striking actions;
- (5) avoid localized compressions; and
- (6) avoid the transmission of mechanical vibrations.

Ergonomic instruments or tools should also be coated with a slip-proof finish and should neither conduct heat nor have sharp edges, pointed tips or potentially harmful shapes.

3. Organizational measures

Measures typically involving changes to the organization of labour become necessary when it has been ascertained that jobs feature excessively frequent technical actions and/or inadequate functional recovery periods. Measures designed to improve these two fundamental risk factors (frequency and recovery periods) can often interfere with 'productivity' and therefore are less readily accepted by employers. The authors have recently acquired a considerable amount of practical experience that may supply useful suggestions for embarking on the organizational restructuring of specific working activities.

In a large metal-working factory featuring assembly lines, a significant prevalence of upper limb disorders was detected (Carpal Tunnel Syndrome, tendinitis, etc.) in most cases attributable to repetitive tasks performed with excessive frequency. On the advice of the local health unit, the company asked the authors to carry out a detailed risk analysis in order to develop options for re-designing workstations more ergonomically.

The exposure assessment identified the following problem areas.

- (1) High-frequency actions (38–40 technical actions per minute).
- (2) In general, minimal use of force: force peaks of between 4 and 5 on the Borg scale were demanded by only a few actions that could be easily singled out during the job cycle. In almost all cases, the company quickly found specific solutions for bringing the use of force to within acceptable limits.
- (3) Posture seldom 'extreme' and therefore easily corrected by making some structural modifications to the workstation.
- (4) Recovery periods taken primarily for physiological reasons rather than for the purpose of alternating jobs. The daily schedule included two morning breaks (10 and 15 min, respectively), a 30-min lunch break, and one 10-min afternoon break. One simple change involved optimizing the recovery periods: the total duration of the physiological breaks was already sufficient; by simply redistributing the breaks, it was possible to ensure adequate recovery periods, without altering their overall duration. The company undertook to redistribute the physiological breaks (35 min = 10+ 15+ 10 min) so as to obtain four breaks (two in the morning and two in the afternoon).

In this case, the last problem that needed solving was the high frequency of the technical actions. The first and most obvious intervention (most obvious for the ergonomist, but certainly not for the company!) was to reduce the pace of the task (with a consequent decline in 'productivity'). This solution was kept as a last resort, in the event that the frequency of the task could not be reduced by any other means.

After several meetings with the production engineers, safety officers and supervisors, a first objective was defined: to identify methods for reducing the number of technical actions required to complete a job cycle, without compromising output. In other words, this meant optimizing—in terms of quality and quantity—the technical actions needed to complete the cycle characterizing the task.

The production engineers, particularly those directly involved in designing how tasks are carried out (e.g. in accordance with Time and Motion methods; Barnes 1968) were already quite proficient in seeking to optimize the actions that needed to be performed to complete a task. Their experience and research, however, was generally aimed at reducing the number of actions performed and shortening the duration of the task, thereby increasing the number of pieces produced. Through valuable co-operation between the ergonomist and the production engineer, it was possible to use the fundamental experience of the engineer not to enhance 'productivity', but to improve working conditions and thus the health of the workers. Having established, in agreement with the management and plant engineers, that the aim was to reduce the number of actions without reducing output, the first step was to identify the means and methods of achieving the objective.

The videotapes made for the exposure assessment (Colombini, this issue) were analysed by a task force comprising the ergonomist, the production engineer and plant supervisor. Each task was revised several times, after critically examining the way in which the actions were performed. In order to reduce the number of actions contained in a cycle, the procedure described below and summed up in table 2 was used.

3.1. *First phase: analysis of 'useless' technical actions*

During this phase, it is decided whether all the technical actions actually observed to be performed are strictly necessary. It is thus possible to single out 'useless' actions performed by the operator and even actions that could be designed out of the task. In practice, this means detecting the following.

- (1) Any 'useless' actions added by the operator, e.g. when assembling a piece, the operator occasionally strikes the piece more often or screws the piece

Table 2. Brief recommendations for reducing the frequency of technical actions.

1	AVOID USELESS ACTIONS ⇒added by the worker ⇒due to technical flaws ⇒due to obsolete technologies
2	PERFORM ACTIONS USING BOTH LIMBS
3	REDUCE REPETITION OF IDENTICAL ACTIONS BY ⇒introducing pre-assembled parts ⇒introducing semi-automatic manufacturing systems ⇒replacing the process with hi-tech solutions
4	REDUCE 'AUXILIARY' ACTIONS BY ⇒creating intersections between conveyor line and operating area
5	SPLIT JOBS or increase the number of workers performing any given job

more tightly than required: two strokes might be necessary, while the operator actually performs 4, 5 or 6 strokes. In this case, the operator must be trained to perform no more than the useful actions actually required to perform the task.

- (2) Whether any actions added by the operator are entirely arbitrary or in fact conceal a manual flaw, e.g. a faulty pin does not fit snugly so the operator needs to strike it several times to force it into the correct position. Once the manual flaw has been identified, it can be eliminated, and the number of actions required to perform the task can be reduced.
- (3) 'Obsolete' actions.

In the course of time, assembly lines may undergo small changes to the machinery or to the product, rendering certain actions 'obsolete'. Therefore it is extremely useful to check the way in which operators perform their tasks whenever machinery or products are modified.

3.2. *Second phase: analysis of upper limb use when performing technical actions*

Once all 'useless' actions have been eliminated, the next step is to optimize the distribution of the various actions between the two upper limbs. Workers often tend to favour their dominant limb. Simple low-precision actions (e.g. picking up workpieces and placing them on the machining line) may be performed equally by both limbs, thus reducing the frequency with which the dominant limb is used.

3.3. *Third phase: analysis of 'identical' technical actions*

During this phase, it is seen whether workers are repeating identical actions for a significant portion of the job cycle. As already mentioned, repeating the same joint motions is likely to overload specific muscle-tendon units. Together with the engineering staff, it was observed that the repetition of identical technical actions can often be avoided by introducing a specific mechanical device, e.g. the worker picks up a number of screws and places them one at a time (total 10) into position, giving each one a single manual turn to secure it. In this case, the use of an automatic screwdriver would be useful. For manual polishing jobs, an electric polisher could be used.

By virtue of their being identical, these sets of actions are generally performed at very high speeds and therefore significantly increase the total frequency of the action within the job cycle. On the other hand, when identical technical actions have been identified but no suitable tools can be introduced and, at the same time, the action frequency considerably increases the total frequency, one of the following solutions may be adopted:

- (1) eliminate the specific manufacturing step altogether, by having the part pre-assembled elsewhere (*simple solution; but make sure this does not lead to another high-risk job being created*);
- (2) introduce a semi-automatic step to replace the technical actions (*high-cost solution*);
- (3) re-examine the phase scientifically to find alternative solutions capable of fully by-passing the specific action sequence (*hi-tech solution that often also improves the product*); e.g. before welding, wire terminals must be gathered together and wound using a pinch grip and very rapid prono-supination

movements of the elbow. It was discovered that a different type of weld does not require the wires to be manually pre-wound.

3.4. *Fourth phase: analysis of 'auxiliary' actions*

It must be checked whether in passing from one cycle to the next, any 'auxiliary' actions are performed, e.g. in order to start assembling several components onto a new piece (cycle start), the worker must first remove the component from the conveyor belt, rotate it, set it down on his/her work bench and then start the actual assembly. The worker then picks up the finished piece, rotates it and replaces it on the conveyor belt. This type of movement from the belt to the bench and vice versa can often cause physical strain.

It is generally useful to have the conveyor belt and operating areas cross each other in such a way as to avoid the worker having to pick up and replace pieces. It is equally helpful for the piece to reach the worker 'facing the right way' so as to minimize handling.

3.5. *Fifth phase: when jobs need to be split*

Despite carefully reviewing actions, sometimes their frequency remains excessively high (up to 60 actions/min). In such cases, jobs need to be split. Table 2 sums up the procedures identified and adopted by the authors in conjunction with the team from the factory, in an effort to reduce action frequency. Table 3 gives an example of the check-list relating to the modifications introduced by the company to re-design an entire production line. Although these recommendations are not exhaustive, the procedures achieved considerable improvements: the actions diminished in frequency from 38–40/min (line average) to 30/min.

Figure 3 features a graph produced by the engineering personnel in the factory depicting the monitoring of technical actions before and after re-designing the whole production line. The action frequency levels are shown for each workstation along the assembly line, and indicate the right and left limbs separately. The new frequency levels measured on the re-designed line are shown in bold. Furthermore, mean frequencies and relative standard deviations were also calculated. As can be seen from the results, not only did the mean frequency levels decrease (in particular for the right hand), but the standard deviations also dropped dramatically: in other words, the most dangerous frequency peaks were eliminated.

It should be kept in mind that a frequency of 30 actions/min — with no other risk factors involved — is assumed to be the highest acceptable frequency (Colombini, this issue). Several workstations still feature frequency levels higher than this threshold. In this case, it is necessary to at least introduce hourly job switches, so that the workers performing jobs that might still potentially overload the upper limbs can alternate with less strenuous jobs.

Since the same manufacturing line features workstations with relatively low action frequencies, it will not be difficult to arrange for workers to switch jobs regularly. In essence, job switching is very useful for reducing the risk of exposure to the frequency factor, since it enables workers:

- (1) to alternate between workstations at low risk and workstations at higher risk for frequency; and

Table 3. Modifications introduced when re-designing an entire production line.

No. work station	Activity	Analysis actions/min		Modifications	Status	Objective actions/min	
		Right	Left			Right	Left
10	Remove bracket from box	42	26	1) Modify boxes 2) Sliding shelves	Test in progress Implemented	36	20
	Remove and position shaft			3) Personnel training 4) No gauge rotat. (frequency control)	Implemented 30/09/96		
20	Cylinder-piston clearance	27	58	1) Sliding shelves 2) Alternate workers on stations 10 and 20 3) New cylinder bore gauge 4) Increase clearance tolerance	Implemented Implemented Being studied Implemented	29	34
30	Unscrew connecting rod screws	39	26	1) Reduce spring load to unscrew 2) Personnel training	Implemented Implemented	33	33
40	Connecting rod-pin clearance	56	46	1) Personnel training 2) Eliminate clearance inspection	Implemented Being studied	28	24
50	Assemble connecting rod-piston	50	33	1) Elimination of one washer 2) Personnel training	Being studied Implemented	35	33
60		50	33			35	33
70	Lubricate shaft-piston Position gaskets and spring caps	30	27			30	27
80	Screw connecting rod Position screw & spring caps	20	29	1) Support system for motor+ piston	31/10/96	20	24
90	Position ext. bracket Insert screws	35	28	1) Screw feed and tightening with 2nd automatic screwdriver	1 [^] test not OK 2 ^o test in progress	30	20
100	Assemble valve/plate	46	26	1) Rationalize work	31/06/96	32	32
101	Assemble valve/plate	47	27	1) Rationalize work	31/06/97	33	33
102	Assemble valve/plate	48	28	1) Rationalize work	31/06/98	34	34
103	Assemble valve/plate	49	29	1) Rationalize work	31/06/99	35	35

Table 3. continued.....

No. work station	Activity	Analysis actions/min		Modifications	Status	Objective actions/min	
		Right	Left			Right	Left
104	Assemble valve/plate	50	30	1) Rationalize work	31/06/100	36	36
105	Assemble valve/plate	51	31	1) Rationalize work	31/06/101	37	37
120	Load assemblies on pallets	31	27	1) Turn shaft at next workstation	Implemented	21	27
130	Load stators on assemble Remove from box	28	23	1) Modify boxes for better posture	Tests in progress	28	23
140	Position stator screws Load rotors on line	36	41	1) Personnel training	Implemented	38	38
150	Inspect air gap Pick up and upturn piece	52	26	1) Personnel training 2) Manipulator	Implemented Being studied	31	37
160	Measure locite and insert suction tube	15	10	1) Insertion of valve	Implemented	mean value (No. 160+ 170)	
170	Scart boxes Insert cluster	54	62	2) Every hour alternate workers on stations 160 and 170		35	36
180	Inspect suspensions Insert gasket	48	26	1) Improve efficiency of spring attachment station	Being studied	33	26
190	Position coil and screw on	31	28	2) Personnel training	Implemented	31	28
200	Balance springs Check stator burners	37	22	1) Personnel training 2) Replace push-button with pedal	Implemented Implemented	32	22
210	Load compressor on Olivotto conveyor	26	21	1) Give extra recovery time for load handling	Implemented	26	21

solution implemented; solution not yet implemented.

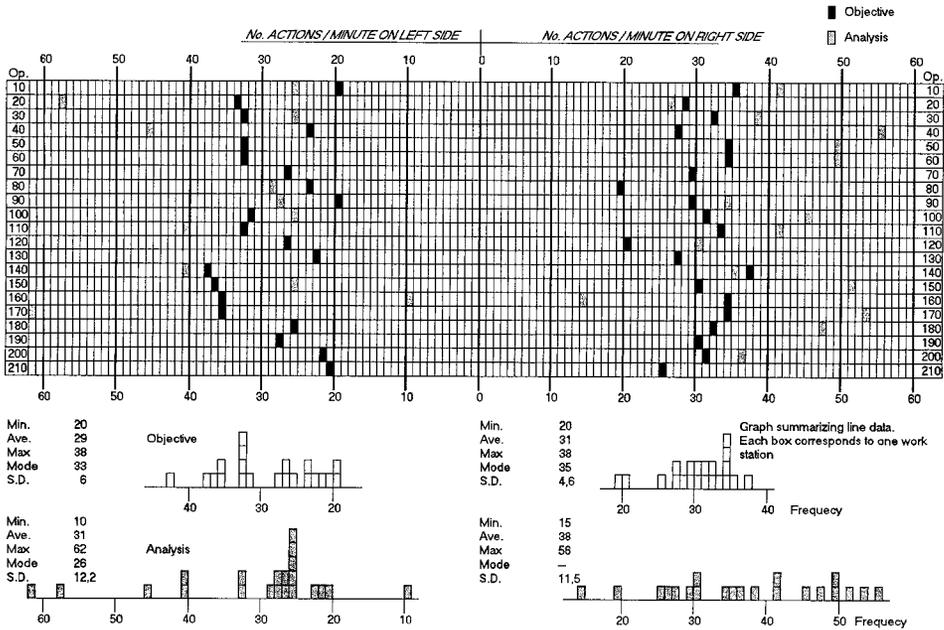


Figure 3. Monitoring frequency of technical actions before and after the re-design of an assembly line.

- (2) to alternate between workstations in which the use of the upper limb changes (left and right).

In addition to alternating jobs in order to prevent disorders due to repetitive movements, the presence of adequate recovery periods is of critical importance. Elsewhere in this issue it is extensively reported that rest periods can be optimized by ensuring a ratio of work periods to recovery periods of 5:1, within each hour of repetitive work (Colombini).

Often factories schedule long enough recovery periods (i.e. actual breaks and/or non-repetitive tasks) but these are poorly distributed throughout the duration of the repetitive task. It is therefore suggested to:

- (1) optimize the distribution of official breaks: it is preferable to shorten each individual break, but to increase their frequency;
- (2) arrange, if possible, for rest periods to be scheduled at the end of an hour of repetitive work;
- (3) avoid the scheduling of rest periods too close to meal breaks and the end of shifts, in order to 'exploit' these as recovery periods;
- (4) rotate workers in non-repetitive tasks, so as to obtain an optimal distribution of repetitive and non-repetitive tasks, thus ensuring a good work/recovery period ratio.

Figure 4 shows a flow diagram relative to a study on risk factors which, consequently, also involves designing modifications in terms of their priority —

the aim being to optimize the results and minimize undesirable effects on 'costs' and productivity. Alongside re-designing jobs according to predefined priorities, it is also necessary to embark on a health monitoring programme for the workers. This will not only keep track of the effectiveness of the modifications introduced, but also in some cases highlight the need to re-prioritize decisions and changes.

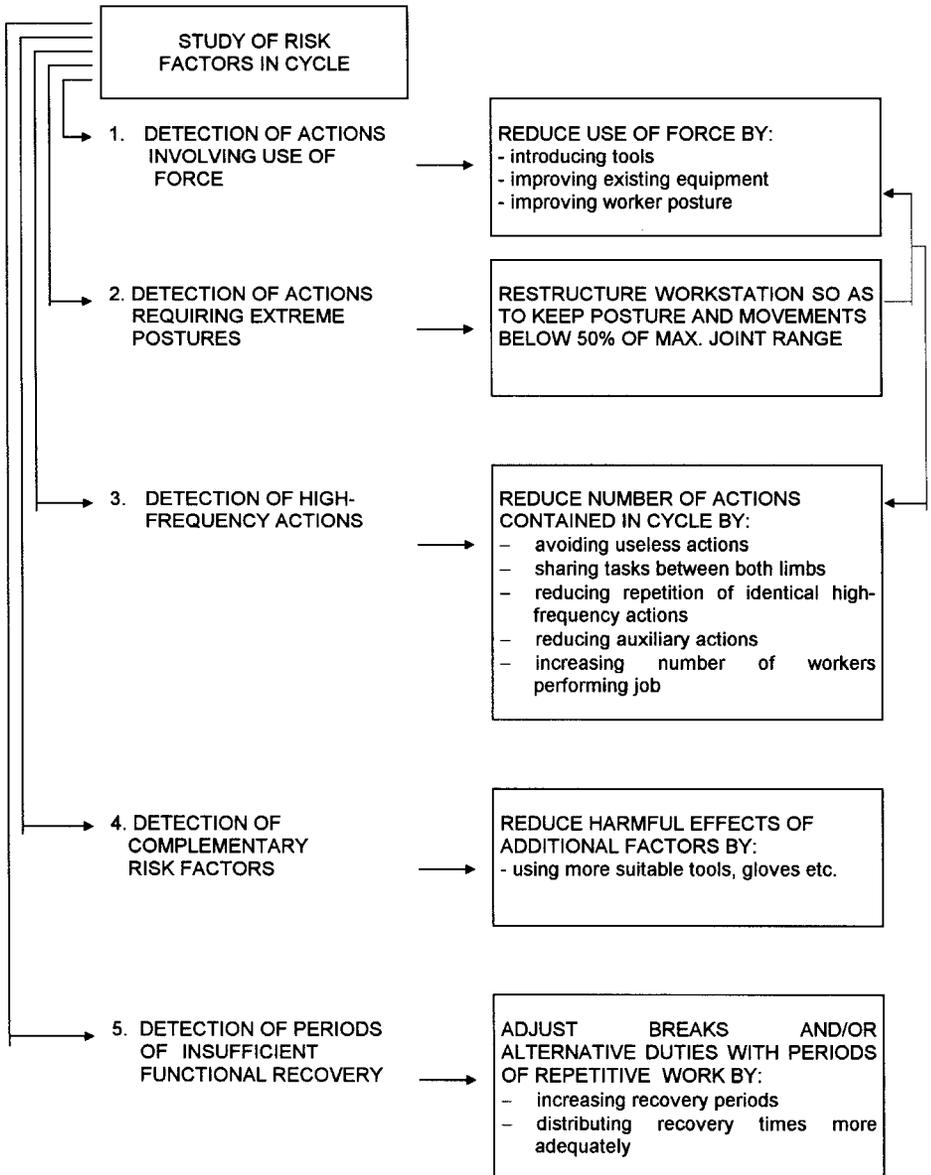


Figure 4. Flow diagram of a study on risk factors.

4. Training programmes

Different types of training programmes must be tailored to the following three categories of employees:

- (1) factory workers (operatives);
- (2) production engineers and supervisors (process generators); and
- (3) management (strategic organizers).

4.1. Training for factory workers

Workers must be informed of the risks and damage associated with repetitive tasks, in order to justify and motivate the need for such tasks to be performed correctly and in the proper order. Workers must therefore be suitably trained to:

- (1) perform tasks in the required order;
- (2) use both limbs whenever possible;
- (3) avoid adding useless actions;
- (4) grip objects correctly;
- (5) notify the supervisor whenever new actions need to be performed; and
- (6) contact the health officer as soon as 'early warning signals' are noticed.

4.2. Training for production engineers and supervisors

As for the previous category, the training process is based on a clear understanding of the specific risks and injuries as well as the medico-legal implications associated with occupational diseases. Engineers must be well trained to 'detect' risk factors associated with repetitive tasks, and to re-design old jobs or design new jobs in order to avoid them. In the light of the continuing evolution taking place in modern manufacturing systems, production engineers must realize that the process of checking for risk factors must go hand in hand with technological developments. It is necessary for engineers and, above all, supervisors, to organize periodical meetings with workers in order to gather information on any practical problems emerging in the performance of the various tasks. Their prompt detection and elimination will prevent unnecessary damage to workers' health, and often lead to a better product.

Thus the production engineer is a key figure in the training process, receiving training and insight from expert consultants and providing practical training for the workers. It is thus the responsibility of the production engineer to:

- (1) suitably design how a task must be performed, above all optimizing the technical actions in terms of human health, and not just productivity;
- (2) teach workers how to perform tasks correctly;
- (3) periodically check that tasks are being performed correctly;
- (4) periodically talk with workers about the possible onset of problems while performing tasks;
- (5) check that technological innovations do not cause increased risk factors; and
- (6) attend to new workers and ensure that they are given proper training for their tasks, especially complex ones.

4.3. *Training for management*

Managers need to be involved in the training process, which must be carried out by experts; managers must be able to provide trainers with a thorough picture of the risk factors present in the work cycle, as well as possible strategies (manual, organizational, pertaining to training and occupational health care), which together ensure that such factors are minimized and effectively managed.

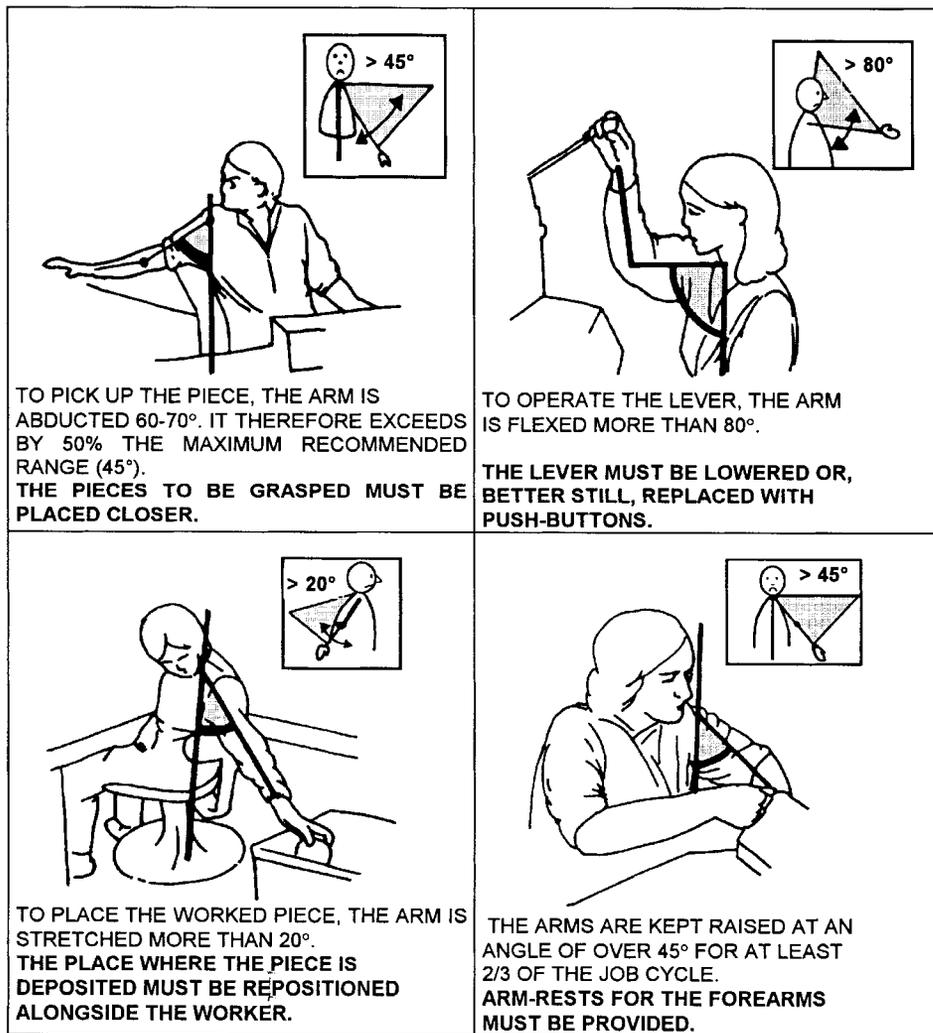
This knowledge, in addition to a clear understanding of their responsibilities, including criminal liability, will enable managers to make the best possible decisions for the organization and management of the production process.

References

- BARNES, R. M. 1968, *Motion and Time Study. Design and Measurement of Work*, 6th edn (New York: Wiley).
- CEN 1996, *Safety of Machinery. Anthropometric Requirements for the Design of Workplaces at Machinery*, CEN/TC 122, no. 279 (CEN).
- DRURY, C. G. 1987, A biomechanical evaluation of the repetitive motion injury potential of industrial jobs, *Seminars on Occupational Medicine*, **2**, 41–49.
- EASTMAN KODAK COMPANY 1983, *Ergonomic Design for People at Work*, vols 1 and 2 (New York: Van Nostrand Reinhold).
- PUTZ-ANDERSON, V. 1988, *Cumulative Trauma Disorders—A Manual for Musculoskeletal Disease of the Upper Limbs* (London: Taylor & Francis).

Appendix. Check-lists showing principal recommendations for (re)designing workstations and details of wrist and hand postures that give rise to significant loss of grip force

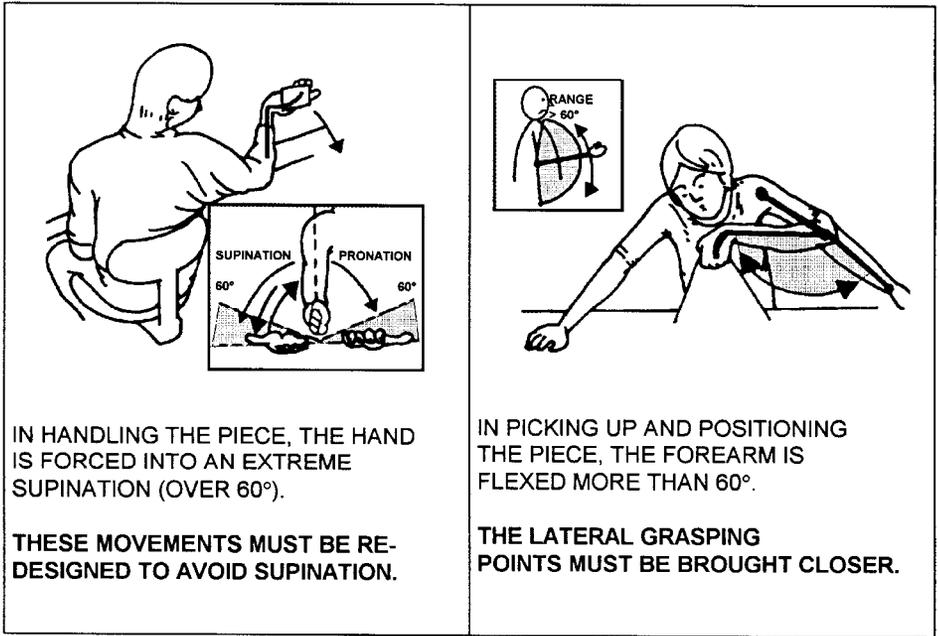
Check-list 1. Principal recommendations for (re)designing workstations: how to avoid harmful postures and movements for the scapulo-humeral joint (shoulder) (3) (4).



IN GENERAL:

- DO NOT EXCEED 50% OF THE RANGE OF JOINT MOTION FOR SIGNIFICANT PERIODS OF TIME (1/3 OF THE CYCLE);
- DO NOT KEEP THE LIMBS RAISED WITHOUT SUPPORT AT AN ANGLE OF 45° FOR PROLONGED PERIODS OF TIME (2/3 OF THE CYCLE);
- DO NOT REPEAT THE SAME ACTION FOR PROLONGED PERIODS OF TIME (2/3 OF THE CYCLE).

Check-list 2. Principal recommendations for (re)designing workstations: how to avoid harmful postures and movements for the elbow joint (3) (4) (6).



IN GENERAL

- DO NOT EXCEED 50% OF THE MAXIMUM JOINT MOTION RANGE FOR SIGNIFICANT PERIODS OF TIME (1/3 OF THE CYCLE).
- DO NOT REPEAT THE SAME ACTION FOR PROLONGED PERIODS OF TIME (2/3 OF THE CYCLE).

Check-list 3. Principal recommendations for (re)designing workstations: how to avoid harmful postures and movements for the wrist joint (3) (6).

FLEXION

EXTENSION

+45°

+45°

EXTENSION

FLEXION

IN OPERATING THE LEVER, THE WRIST IS FLEXED AND EXTENDED TO AN ANGLE GREATER THAN 45°. IT WOULD BE ADVISABLE TO REPLACE THE LEVER WITH A PUSH-BUTTON.

+15°

+25°

RADIAL DEVIATION

ULNAR DEVIATION

WHEN USING THE TOOL, THE WRIST IS BENT RADIALLY TO AN ANGLE GREATER THAN 15°.

IN GENERAL:

➤ AVOID ADOPTING POSITIONS THAT ARE MORE THAN 50% ABOVE THE MAX. JOINT RANGE FOR PROLONGED PERIODS OF TIME (1/3 OF THE CYCLE).

➤ AVOID REPEATING THE SAME MOVEMENT FOR PROLONGED PERIODS OF TIME.

+45°

+45°

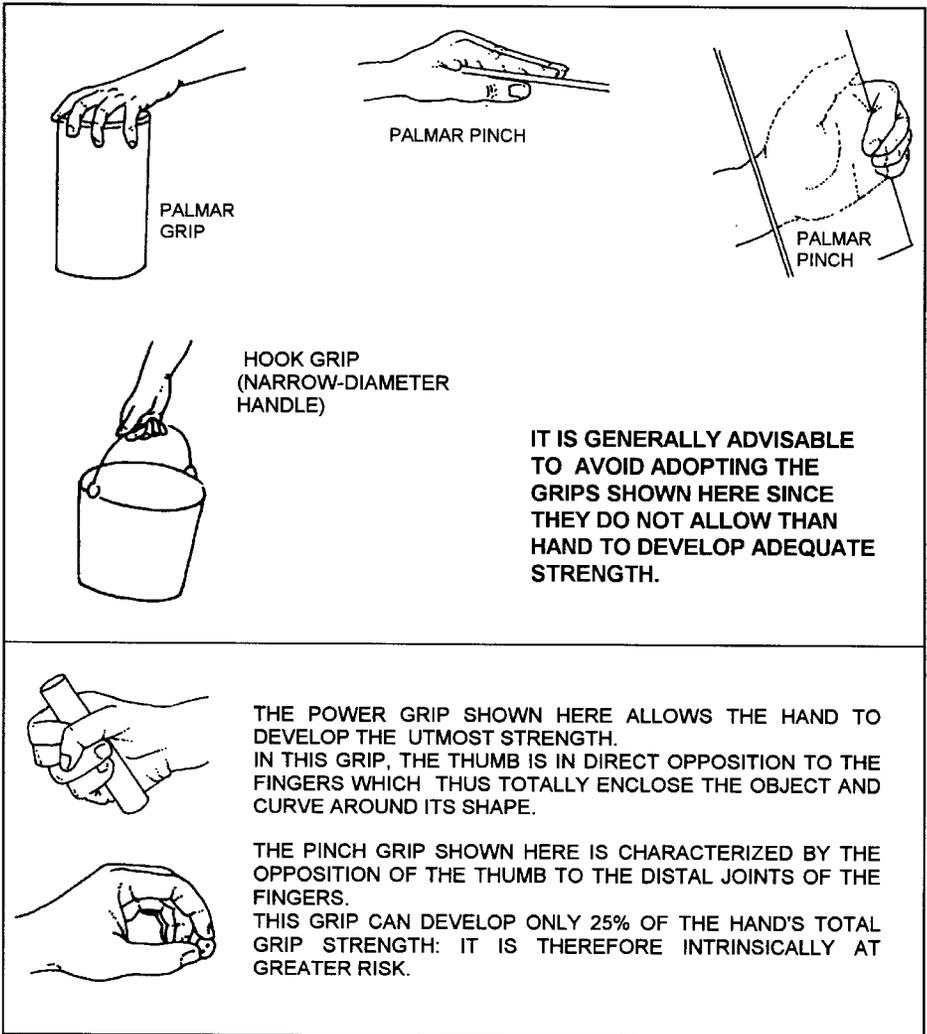
EXTENSIONS

FLEXIONS

WHEN USING THE TOOL, THE WRIST IS FLEXED TO AN ANGLE GREATER THAN 45°.

IN SUCH CASES, THE TOOLS SHOULD BE REPLACED BY OTHERS WHICH ALLOW THE WRIST TO BE KEPT VIRTUALLY STRAIGHT (ANATOMICAL POSITION).

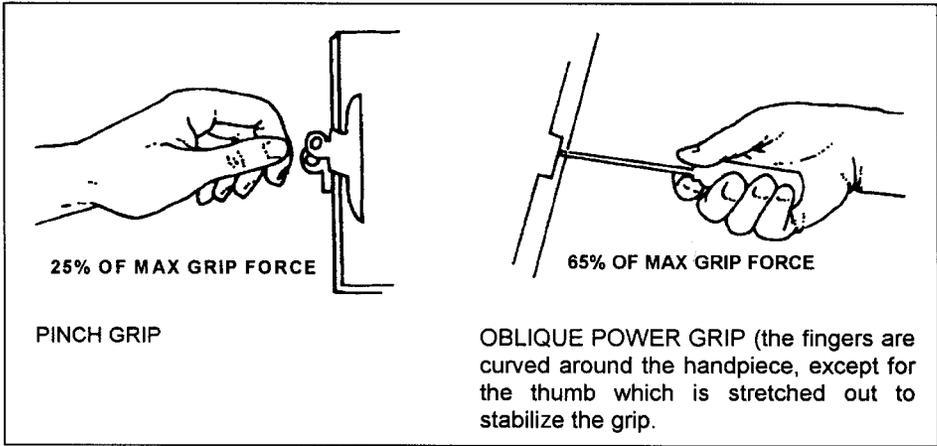
Check-list 4. Principal recommendations for (re)designing workstations: how to avoid harmful postures for the fingers and hand (4) (6).



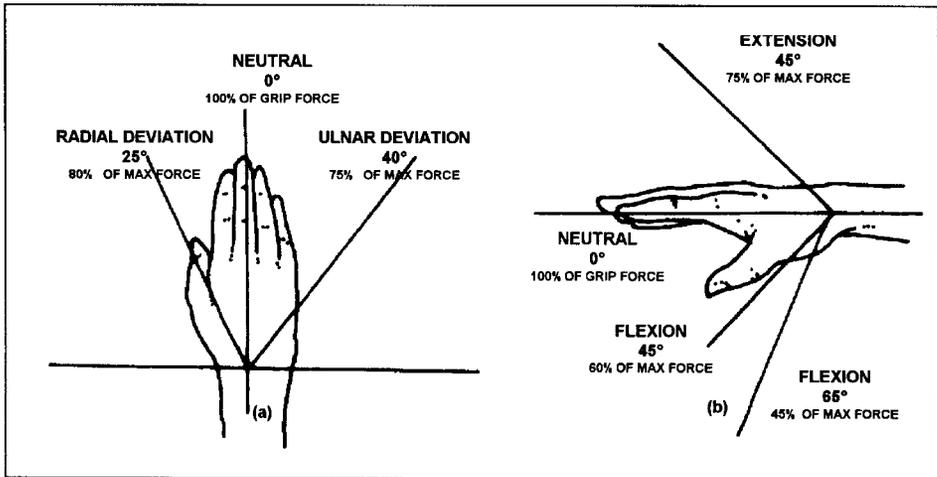
IN GENERAL:

- AVOID USING THE PALMAR PINCH AND GRIP AND HOOK GRIP FOR SIGNIFICANT PERIODS OF TIME (1/3 OF THE CYCLE).
- AVOID ADOPTING THE LESS FAVOURABLE GRIPS FOR PROLONGED PERIODS OF TIME (2/3 OF THE CYCLE).
- AVOID REPEATING THE SAME MOVEMENT INVOLVING THE SAME FINGER/S FOR PROLONGED PERIODS OF TIME (2/3 OF THE CYCLE)

Check-list 5. Wrist and hand postures which give rise to significant loss of grip force (4) (6).



A) SIGNIFICANT LOSS OF GRIP FORCE ASSOCIATED WITH DIFFERENT TYPES OF GRIP.



B) SIGNIFICANT LOSS OF GRIP FORCE ASSOCIATED WITH DIFFERENT WRIST POSITIONS.