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Human stature, health and workplace design. An ethical dilemma

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Practical relevance

Automotive assembly implies high postural load, particularly on operators of short stature. A conflict may appear between health concerns and employability of women on these grounds.

Fahrzeugmontage ist mit hohe Körperliche Belastungen vereint, besonders so auf kürze Werker oder Werkerinnen. Ein Konflikt kann unter Sorge der Gesundheit und die Anstellungsfähigkeit der Frauen dabei erscheinen.

Summary

A study was undertaken in an automotive assembly plant in order to find out if short or long stature of operators implied a higher risk to acquire musculoskeletal disorders due to extreme work postures. The study was initiated since a female applicant had challenged a decision of the company to deny her employment on the basis of a stature criterion (<163 cm or >195 cm), applied by the company on the basis of health concerns. The study concluded that there was an elevated risk in operators shorter than 160-165 cm to acquire problems in the neck, shoulders or low back due to exposure to work in awkward postures.

1 Introduction

The user centred approach is one of the generally recognised fundamentals of ergonomics. Conceptualisations such as “Fitting the Job to the Worker” “Design for All”, “Inclusive Design”, and have been highlighted throughout the history of ergonomics (e.g., Grandjean 1988, Kuorinka 2000, Karwowski 2006). Ergonomics is, according to IEA (2003), “the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people.”

The implication is that the human environment should be designed, as far as possible, in an inclusive way. This view is also reflected in the standardisation literature. For instance, in ISO 6385 (2004) “Ergonomic principles in the design of work systems” it is stated: “It is recommended to design a work system for a broad range of the design population in order to meet the needs of workers with various characteristics, including people with special requirements, as far as possible. Thus the development of special solutions for individuals can be minimized.”

One of the areas most relevant to the principles of inclusive design is workplace design in relation to the anthropometry in the user population. For instance, the European standard EN 614-1 stipulates adherence to 5% and 95% percentiles. However: ”Where health and safety aspects are important, wider percentile ranges shall be used, according to the risk assessment, at least to the 1st and/or 99th percentiles. As equipment is designed for use by both men and women, the relevant percentiles for men and women shall be used.” EN 1005-4 (2005) says, “A design shall accommodate the full range of possible users. When considering the postures and the movements of the operators, it is important to determine the range of body dimensions of the user population…”

In practice, it is not unusual that conflicts develop between productivity oriented concerns and implementation of the principle of inclusive design, for instance as articulated in the standardisation literature. In physically demanding jobs involving heavy materials handling, it is common that technical, organisational and economical obstacles limit the employability of a wide range of individuals. It is therefore important to analyse the rationales in such conflicts, in particular when the conflict is between legitimate concerns of an ergonomics nature.

The present study aimed at identification and analysis of rationales in a conflict that appeared between concerns of an ergonomics nature in the design of a work system in an automotive assembly plant.

1.1 The problem

A study was undertaken in the assembly flow of the Volvo Cars manufacturing plant in Göteborg, Sweden, in order to elucidate if there was a risk for persons of short stature to acquire musculoskeletal problems due to improper working postures. The background was that the company had adopted a lower stature limit of 163 cm, and an upper limit of 195 cm, on the basis of recommendations put forward by the occupational health services of the company. It had been advocated that people of too short or too long stature may risk their health due to the awkward working postures needed to assume in order to fulfil work tasks. These company guidelines, which had been adopted with support from the labour union, had been challenged by a person who was shorter (159 cm) than the required stature, and who had been denied employment on these grounds.

It was decided to carry out a study in the assembly flow in order to find out to what extent the stature requirement was justified from an ergonomics and health protection point of view.

1.2 Stature and musculoskeletal problems

The relation between human stature and risk to acquire work related musculoskeletal problems has not been researched extensively (NIOSH 1997).

It was noted by Ulin et al. (1993) in a laboratory study that significant gender differences in work posture were related to stature. They concluded that the lack of workplace accommodation to the range of workers' height and reach may, in part, account for the apparent gender differences in terms of perceived exertion and discomfort. Schierhout et al. (1995) found that short stature was significantly associated with pain in the neck and shoulder but not in the forearm, hand and wrist, or back, among workers in eleven South African factories. In a study of newspaper employees, Bernard et al. (1994) found that stature was not a factor for musculoskeletal disorders in the neck, shoulder, or hand and wrist. Likewise, Kvarnström and Halden (1983) found no relationship between neck/shoulder disorders and body height in a Swedish engineering company with more than 11,000 workers. However, Landau et al. (2008) showed that there was a higher occurrence of musculoskeletal complaints in the head-neck shoulder region in automotive assembly workers of short stature (≤164 cm), working under unfavourable conditions (job rating equal to or exceeding 3.0 according to EN 614-1).

It can be hypothesised from the few scientific studies available that in jobs where short stature does not entail extreme work postures, this factor does not present a problem (Bernard et al. 1994). In the study by Kvarnström and Halden (1983) a multitude of different jobs were included; this means that an eventual effect of postures linked to stature was most likely diluted and not possible to identify. The most conclusive study is the one by Landau et al. (2008), indicating that small stature may indeed be a significant problem for operators in automotive assembly.

It can be noted that also at the Saab Automobile plant in Trollhättan, Sweden, similar stature criteria for employment in the final assembly have been introduced, on the basis of health and flexibility concerns (Enqvist 1997). Here, 165 cm and 195 cm were chosen as limits.

2 Material and method

2.1 The production system

The assembly plant was organized as a continuous, serial production flow without buffers. The assembly tasks were grouped into balances (workstations), which were geographically defined. As soon as the working tasks on one car in one workstation had been completed, the next car arrived to the workstation, and a similar or identical set of work tasks was performed again. There were usually no pauses in between successive cars; the operators (typically 2-3 persons per balance) continued without interruption. Each workstation comprised only a small number of work tasks. The cycle time on the assembly line was of the order of one minute.

This type of layout is typical for all automotive assembly plants with volume production around the world. The traditional and most common work organization scheme is that operators are carrying out work at one or at very few workstations, and work there for entire shifts without much variation. Such a system means that some operators will carry out particularly taxing work tasks, and that they stand a higher risk of acquiring work related disorders as a result of this exposure. The project company had instituted a job rotation scheme, which meant that operators circulated between balances of different ergonomic character (Törnström et al. 2008). This development was intended to create variation at work and to reduce the risk for operators to acquire chronic ailments in the musculoskeletal system. It also made the operators more flexible, since they were qualified to carry out work at a number of workstations along the production flow. According to company policy, all operators should be eligible for work anywhere on the production flow. The job rotation scheme was also intended to enhance productivity and quality (Törnström 2007).

The job rotation scheme meant that an operator spent 30 minutes at a time on a balance. During an 8 hour shift, he or she might work at up to 16 balances. However, the job rotation did not necessarily involve 16 different balances; the operator might rotate between 5-6 balances, which means that each balance was returned to 2-3 times per shift.

A main rationale behind the job rotation scheme was that a balance that had been rated highly demanding on one or several parts of the body (neck, shoulders, back, elbows, hands, hip joint, knee/ankle) should not be succeeded by work on another balance that was highly demanding on the same body part, but that there should be a succession of work stations introducing a variation of tasks over a working shift. The work task assessment system, the so-called BME Model, was based on the "cube model" (Sperling et al. 1993, Kadefors 2005), which takes into account combinations of posture, force, and repetition for each body part. Balances were classified as red, yellow or green, depending on severity. Two "red" balances should not follow upon each other in the job rotation scheme. For a detailed description of the BME assessment system and its rationales, see Törnström et al. (2008).

The entire production flow comprised about 600 balances. Four product cars, two sedans and two SUVs, were present on the line. Each one of them had a great number of variants, but the essential ergonomic difference was related to the two main types of products: sedans or SUV, due to the different sizes of the body of the cars. The relative occurrence of them on the production line varied from day to day depending on demand.

2.2 Method

Based on the ergonomic assessments carried out of the workstations along the production line, 35 balances where work postures had been rated "highly demanding" were picked for further, detailed analysis. This screening procedure, carried out by an experienced production engineer, was carried out for reasons of capacity; some balances were excluded from analysis, since it was clear from the previous assessment that they did not induce high workload (classified as "green"). Another exclusion criterion was when high demands occurred, but where no relationship could be foreseen with stature (for instance high hand load in operation of tools) and where the postural load was rated low. This means that the set of balances comprised in the analysis served the aims to (a) document if there were balances where health risks due to stature might occur, and if so, (b) identify the types of situations occurring where stature might be a problem.

A task analysis was carried out of each one of the balances picked. All identified working tasks where stature possibly could play a role were documented as follows:

1. Identification of where in the production flow that the situation occurred (balance and assembly task).
2. Photographic documentation of the working posture.
3. Assessment of forces associated with assembly tasks.
4. Assessment of working height and distance.
5. Comments based on operators' and supervisors' experience with respect to difficulties to see and reach, and if work on the balance had induced health related problems.

In each one of the problem situations, a biomechanical analysis was carried out in order to study the effect of variations in stature between operators. This analysis was made employing the biomechanical analysis program, *Static Strength Prediction Program* from University of Michigan, U.S.A., version 4.3 (2001). This analysis programme contains a computer manikin, which can be specified by gender, body weight and stature. On the basis of the available documentation for each problem situation, the body postures that operators of different stature needed to assume in order to carry out the work tasks, were studied. This analysis was based on the notion that in order to carry out the tasks, the operator's feet needed to be placed firmly on the floor, and the hands (or the hand) needed to be positioned at a certain point in space. (According to corporate regulations, and for reasons of safety, it was not allowed for operators to climb on the car or other structures, or to use footstools or ladders on the flow.)

The analysis programme calculated also the biomechanical forces on body segments and joints, and compared these forces with the force outputs of a population of operators. However, since external forces were not primarily related to stature, and no heavy materials handling occurred, analysis focused on the body postures.

An essential aspect in the evaluation was to study to what extent the job rotation scheme instituted served to safeguard operators of short stature from an elevated risk to acquire musculoskeletal problems. To this end, the BME mapping of the assembly flow was referred to. At the time of the investigation, 9635 tasks had been classified. Of these, 2235 had been classified as "Red", and 1968 as "Yellow". They were distributed over the entire flow, and according to the company ergonomists, there was no reason to believe that the sample drawn for posture analysis would deviate from the characteristics of the assembly at large in terms of severity.

2.3 Evaluation criteria

In Sweden, the main legal document to be consulted in the area of ergonomics is the Swedish Ordinance 1998:1, "Ergonomics for the Prevention of Musculoskeletal Disorders." This document contains Provisions, which are mandatory, and Guidelines, which are not mandatory; instead they serve to elucidate the meaning of the Provisions. They include also an evaluation model based on a triple-zone system (Red=Unsuitable, Yellow=evaluate more closely, Green=acceptable), so as to provide an easy indication of working conditions which are clearly hazardous or which entail negligible risks, as the case may be.

An authoritative account relevant to the present purpose was also found in the international standardisation literature on ergonomics (ISO and CEN). Standards are a result from a consensus process taking into account the amalgamated scientific knowledge available at the time, and on practical experience gained by the participating experts. They aim at prevention of work related disorders. Another legitimate concern is that the workplace design needs to make possible for the operator to carry out the work as required and with the quality needed: for instance to reach and see. Poor work postures may impair this possibility.

A large portion of the European standardisation literature relevant to the area of ergonomics is found within the frameworks of the Safety of Machinery directives. A main objective of these directives is to provide health and safety guidance to designers, producers and users of different types of machinery. In the present context, some recommendations emanating from the Safety of Machinery directives have been invoked so as to provide guidance in the more general case that the operator is exposed to a series of work tasks and tools in the course of a work shift. An underlying assumption is that it is the accumulated postural workload that matters, even though this may occur as a result of exposure not to identical, but to similar work tasks. Recommendations from standards applied in this way may well be more sensitive to elucidating risk patterns than relying exclusively on legislative documents.

It should be noted that international standards are advisory, not compulsory.

The identified problem situations were grouped into four type situations, depending on the character of the postural load:

A. Work with the hands above the head.
B. Work outside natural reach.
C. Work in crouched or flexed posture.
D. Work with the neck in extreme flexion/extension or rotation.

2.3.1 Assessment rationale Type situation A

Work with elevated arms is a recognised risk factor with respect to ailments in the shoulder and neck. The scientific documentation supporting this notion is vast. Causative mechanisms include high biomechanical loading and impaired blood flow in vulnerable structures, causing inflammatory, painful reactions.

The Swedish Ordinance 1998:1, stipulates, “Prolonged or frequently recurring work …with the hands above shoulder height … shall be avoided.” This is part of the mandatory section of the document. In the guidelines section, work situations with the hand at or above shoulder height “during a significant part of the shift” are identified as *unsuitable*.

The European standard EN 1005-4 (Part 2, Evaluation of working postures and movements in relation to machinery) states as *not acceptable* work with the arm elevated >60 degrees more than 2/minute.

The international standard ISO 11226 "Ergonomics – evaluation of static postures" defines a work posture as static if it is maintained for more than 4 seconds. Work with the upper arm forward flexed more than 90 degrees or adducted more than 60 degrees is *not recommended*.

2.3.2 Assessment rationale Type situation B

One of the cornerstones in ergonomics is that the materials handling should be carried out in optimal working zone, with the hands positioned between knees and shoulder and close to the trunk. The background for this established recommendation is that the risk to acquire work related problems in the low back increases when there is exposure to lifting with the hands in high or low levels, or in twisted postures (e.g., Waters et al. 1993).

The Type situation B involves work outside natural reach. It means that the operator has to stretch out and assume an extreme work posture in order to be able to complete the assembly task. This implies in most cases a high load on the low back, but also that the load on the neck may increase, since the operator needs to see what he or she is doing at the point of assembly.

In the Swedish Ordinance 1998:1 work with the hands outside ¾ of maximal arm reach is termed *unsuitable*.

The aspect of reaching is addressed in different ways in the standardisation literature. For instance, in the European standard EN 1005-2 it is stated: ”Manual handling of loads can lead to a high risk of injury to the musculoskeletal system if the loads to be handled are … handled in awkward postures”. Handling of objects at a distance more than 63 cm horizontally between the hand and the midpoint between the feet is *not recommended*. In EN 1005-4 ”Evaluation of working postures in relation to machinery”, forward flexion exceeding 60 degrees more than 2/minute is termed *not acceptable* (exception: if there is full trunk support).

In the international standard ISO 11226 "Ergonomics – evaluation of static postures" forward flexion more than 60 degrees is *not recommended*.

2.3.3 Assessment rationale Type situation C

Work in crouched or kneeling postures induces high biomechanical loading on elements of the musculoskeletal system much like in Type situation B, but here it is the taller operators who are at risk because they have to assume more awkward work postures in confined spaces.

The Swedish Ordinance 1998:1 states in the mandatory section of the instrument: “Prolonged or frequently recurring work with the trunk of the body bent or twisted … shall be avoided.” “Work in a kneeling, crouching or squatting position can sometimes be necessary, but it augments the risk of overloading individual parts of the body… It is essential for work postures of this kind to be kept to a minimum.” As examples of work positions of this nature, the same documents defines as aggravating, “if the space is insufficient, with the result that the employee is prevented from working with suitable postures - too cramped, not enough headroom etc., and if the handling has to be done with the trunk bent or twisted or, worse still, with the trunk both bent and twisted”.

In the European standard EN 1005-4 (Evaluation of working postures and movements in relation to machinery) it is stated that work in awkward postures, e.g., squatted, standing with legs flexed, unsuitable weight distribution between feet, work in extreme joint angles; all these are *not acceptable* if they occur more often than 2/min.

The international standard ISO 15534-1 contains principles for determining the dimensions required for openings for whole-body access into machinery. It states that openings for entry in kneeling posture should be the anthropometric measure plus 100 mm; this may present for smaller cars a conflict in the case of tall operators.

2.3.4 Assessment rationale Type situation D

Work in neck extension or in extreme rotation is a documented risk factor for neck pain, provided that this situation occurs frequently or static over long periods of time.

In the NIOSH report "Musculoskeletal Disorders (MSDs) and Workplace Factors (1997) it is stated: "There is *strong evidence* that working groups with high levels of static contraction, prolonged static loads, or extreme working postures involving the neck/shoulder muscles are at increased risk for neck/shoulder MSDs."

The Swedish Ordinance 1998:1 states that work with the neck simultaneously bent and twisted is *unsuitable*, if it occurs during a significant part of the shift.

In the European standard EN 1005-4 (Evaluation of working postures and movements in relation to machinery), backward flexion occurring more than 2/min is termed *Not acceptable.*

In the ISO-standard 11226 (Ergonomics – Evaluation of static working postures), work in neck extension >25 degrees is *Not recommended*.

2.3.5 The time factor

In an assessment of the health risks linked to postural workload, it is necessary to take into account the time factor: assuming an awkward or taxing work posture once or twice per work shift does not necessarily imply an elevated risk.

The assessment model contained in the Swedish Ordinance 1998:1 refers to a full working shift. This normally consists of 4-8 hours a day. The expression "a significant part of the shift" means according to this source, "that the work posture occurs without interruption, or with only very short interruptions, for more than half the shift." On the subject of repetitive work, a situation where the work cycle is repeated several times a minute for at least half the shift, is termed "unsuitable". A work cycle is defined "as the time elapsing from the moment one begins machining/processing an object until the same operation recurs with the next object is the duration of a work cycle as that term is commonly used in industry. It is not unusual for the same working movements to be repeated several times within a working cycle of this kind, i.e. for the "technical working cycle" to consist of several "kinetic cycles". It is "kinetic cycles" of this kind that are referred to here."

In international ergonomic standardisation, the time factor is addressed mostly in general terms. The umbrella standard ISO 6385 (Ergonomic principles in the design of work systems) only recommends to avoid repetitiveness, "which may lead to unbalanced work strain and thus to physical disorders."

3 Results

Figure 1 shows for an assembly task inside the motor room photographic documentation of an operator of stature 168 cm, and Figure 2 the computer manikin manipulated so as to comply with the photo, for different statures. In this example, the calculated degree of forward flexion exceeds 60˚ for operators shorter than 155 cm.

Figure 1. Assembly of battery cable in motor room. Vertical distance foot-hand: 84 cm, horizontal distance foot-hand 99 cm. Operator stature: 168 cm.

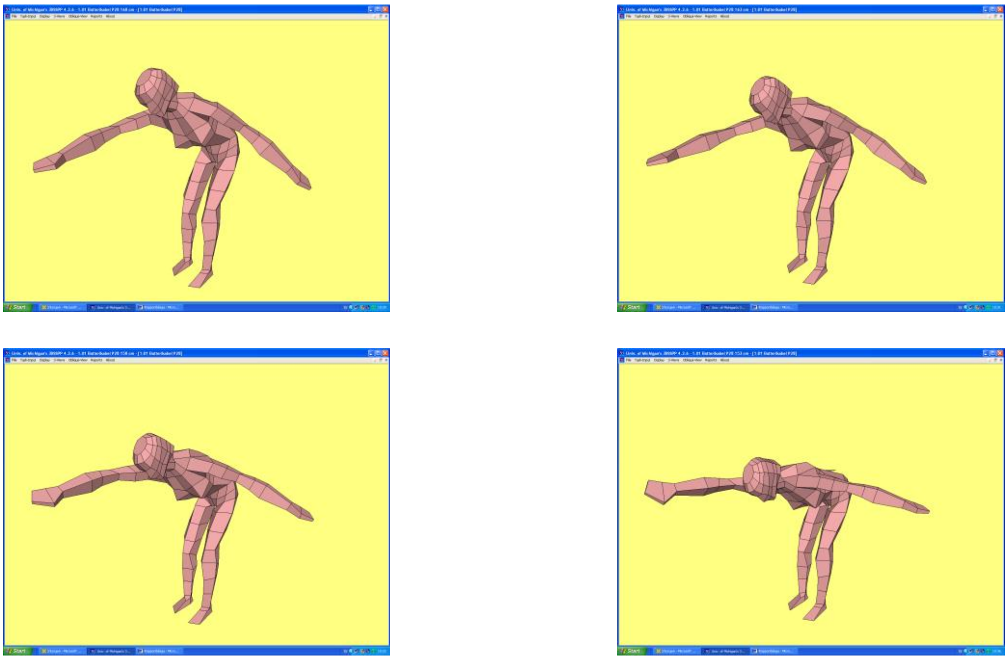
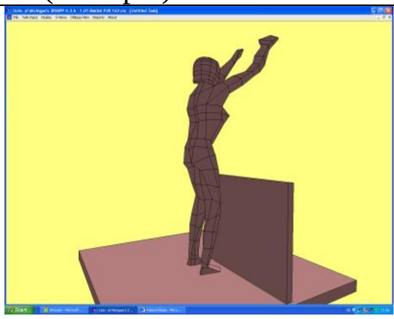
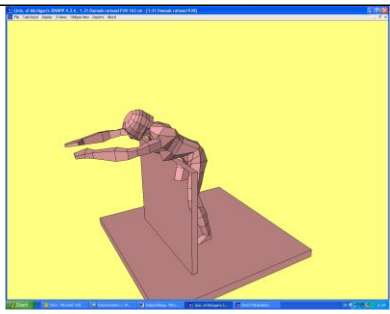
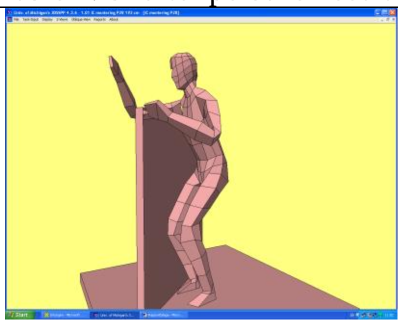
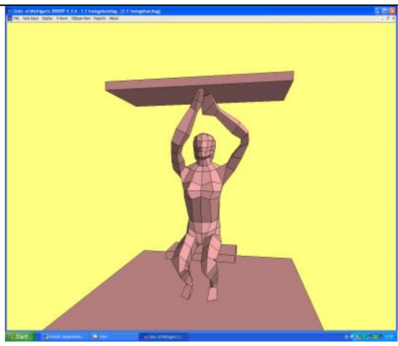


Figure 2. Computer manikin, same assembly task as in Figure 1, different statures. From top: statures 168 cm, 163 cm, 158 cm, 153 cm.

Table 1 shows the occurrence of the different type situations in the set of balances analysed.

Table 1. Occurrence of type situations

Category	Problem location	Type situation (example)
A. Work with the hands above the head	Motor room 2 Car exterior 10 Car interior 5 Luggage compartment 3	 Assembly of rear list, back door. Operator stature: 163 cm. Shorter operators have to stretch even more overhead.
B. Work outside natural reach	Motor room 3 Car exterior 1 Car interior 3 Luggage room 4	 Assembly in motor room, steering axis. Operator stature: 163 cm. Shorter persons need to stretch.
C. Work in crouched or flexed posture	Motor room 0 Car exterior 3 Car interior 2 Luggage room 0	 Clips assembly, inner roof. Operator stature: 193 cm. A tall person needs to work bent or to flex and twist in order to see to assemble.

D. Work with the neck in extreme flexion/extension or rotation	Motor room 2 Car exterior 4 Car interior 1 Luggage room 3	 Assembly in car interior, entrance rail. Operator stature: 163 cm. The operator works sitting. The task is taxing for all operators, but the neck load is aggravated for short persons.

Type situation A is plentiful in the entire material. Assembly tasks inducing overhead work occur in the car interior with the operator sitting, or standing outside, reaching into the car. Particularly straining work with hands above the head occur on the hood and rear door. Overhead tasks are found also on the part of the flow where the car is elevated. There are many situations where operators of short stature cannot reach to assemble without stretching overhead in the extreme. Even though a definite stature measure where problems start to occur is difficult to identify, it is clear that operators shorter than about 165 cm are likely to be exposed to postures implying elevated risk to acquire musculoskeletal problems.

There are many situations in the analysed material that exemplifies Type situation B. The most frequent situation is in assembly in the motor room or in the rear compartment, where extreme forward flexion of the back is often required. The recommended limits for maximal flexion angle are exceeded in many cases for operators shorter than 160-165 cm.

Also Type situation C occurs on many balances. A large portion of the work consists of assembly in the car interior. This means for a tall operator (over about 190 cm) to a large extent work in a crouched or flexed postures. Assembly in sedans, which are lower framed, imply that the operator has to enter the car through an opening that is too small for a tall person. The entrance is over a high threshold. There is also in external assembly situations where tall operators need to flex and/or twist in order to be able to carry out the task.

Type situation D occurs in overhead assembly where the neck needs to be extended backwards in order for the operator to see to assemble. Short operators are disadvantaged in this situation. There are also external assembly tasks where a tall operator needs to flex forward and extend or twist the neck in order to see the point of assembly. Assembly in motor room or rear compartment imply for short operators that they often need to work outside natural reach (Type situation B), and that the needs to be extended (see Figures 1 and 2).

It is noted that Type situations A, B, and D occur frequently in the sample of balances covered in the study. They can be found in assembly both in the car interior and exterior, and in the motor room and the luggage compartment. These situations concern almost entirely short persons. Type situation C, however, does mainly concern tall persons. This type situation has a lower occurrence than the other three.

In conclusion, there are many situations in the production flow where the postural exposures imply an elevated risk to short (below 160-165 cm stature) and to some extent, tall operators (over about 190 cm) to acquire musculoskeletal problems.

4 Discussion

4.1 Ergonomic characteristics of the production flow

Work in production systems in car industry is recognised generally as tough. Final automotive assembly is characterised as repetitious, straining and stressful. The prevalence of musculoskeletal problems in operators in car industry is high (e.g., Zetterberg et al. 1997).

In a review of the ergonomic conditions at the new Opel Rüsselsheim plant, Schaub et al. (2003) identified a number of situations in the assembly where high postural workload occurred due to poor matching between body stature and workplace layout, for instance in overhead assembly underneath the car body, and in visual inspection of the car exterior. Other situations where stature could be a problem included assembly in the car interior and in the motor room. It was concluded that there was a need for technical redesign, and/or for introduction of a job rotation scheme where high load, “red” balances did not follow upon each other (see also Törnström et al. 2008).

It should be noted that compared to car industry in general, the production system studied in the present project had been subject to considerable ergonomic development. For instance, the chassis and body marriage had been made automatic, eliminating arduous overhead work. The instrument panel was pre-assembled and put in place by robots, eliminating taxing lifting tasks. The car was elevated in several workplaces on the flow in order to reduce work in awkward postures. These and other precautions had been introduced so as to reduce the risk for operators to acquire work related musculoskeletal problems. There is always a potential for improved ergonomic conditions in an assembly plant; Schaub et al. (2008) gave a number of examples illustrating technical measures undertaken at Opel Rüsselsheim in order to alleviate some of the ergonomic problems identified. Also the job rotation system adopted a Volvo and the BME ergonomic assessment model developed served the purpose to make the assembly work more adapted to the capacity of the operators than would be the case in a traditional work organisation, where operators are married to one or to very few workplaces.

The BME analyses showed that despite all ergonomic precautions at the workplaces, there were still many “Red” and “Yellow” balances distributed across the production flow. These classifications had been made with respect to operators in general, irrespective of stature. The posture analyses carried out in the present study identified many assembly tasks where in particular short operators were exposed to working postures, clearly in conflict with ergonomic standards and regulatory instruments, in particular The Swedish Ordinance AFS 1998:1: “Prolonged or frequently recurring work with the trunk of the body bent or twisted and with the hands above shoulder height or below knee level shall be avoided.”

The frequency of working tasks inducing exposures of this nature cannot be assessed with certainty for each individual operator, taking into account his or her job rotation schedule. Repetition occurred for each balance at least 1/minute for 30 minutes. The same balance was usually returned to at least once per day, which means that the same task was repeated at least 60 times per day. In addition, it was common that several tasks inducing similar postural loads were carried out on the same balances, for instance then several nuts needed to be tightened in order to place a part in the car; this would tend to multiply the frequency of exposure; this is what is referred to in the Swedish Ordinance 1998:1 as “kinetic cycles”. Taking into account that highly taxing postural loads occurred on many balances especially for short operators, the total daily exposure may well reach levels indicated in the regulatory instruments.

4.2 The working population

The “Design for all” approach aims at elimination of obstacles that user groups may encounter when they wish to have access to a product, a service, or an environment. In the present case, it was highlighted that more women than men were denied employment: Based on information acquired from the Swedish Bureau of Statistics, it was estimated that 27% of the female and 2% of the male population would fall short of the 163 cm stature requirement. With respect to the 195 cm limit, about 1% of the male population would be excluded. Of the operators on the assembly line about 40% were women. There were no statistics available as to the stature of the operators in the company, or of health problems that could be related to stature. (In an international context, there are marked differences between populations in different countries. In the study by Landau et al. (2008), about 10% of the assembly worker population were shorter than 164 cm, even though females constituted only 8% of the workforce.)

The company did not make any distinction between male and female operators in terms of risk evaluation or adaptation to a lower muscular force capacity in women. According to company policy, men and women would have equal access to work and employment, including the final assembly. The job rotation system, and the BME assessment model, was helpful in order to facilitate implementation of this policy.

The posture analysis undertaken was carried out on group level, with operators’ stature as the division variable. There are admittedly individual variations that can influence the risk for an operator to acquire work related musculoskeletal ailments: for instance, his or her physical fitness, experience, or working techniques. However, it can be advocated that it is not feasible for an automotive company to judge an individual’s risk on the basis of such fairly nebulous characteristics. Any limitation of accessibility, whenever applied, needs to be based on clear and unambiguous criteria.

4.3 The ethical dilemma

As Delleman (1999) points out, a working posture is determined by the characteristics of the worker, the workstation, and the operation. In the Swedish Ordinance 1998:1 it is stated: “The employer shall ensure that work which is physically monotonous, repetitive, closely controlled or restricted does not normally occur. If special circumstances require an employee to do such work, the risks of ill-health or accidents resulting from physical loads which are dangerous to health or unnecessarily fatiguing shall be averted by job rotation, job diversification, breaks or other measures which can augment the variation at work.”
In the present case study, based on the company’s view that ambitious ergonomic measures had already been implemented at very high costs, it had been decided to address the remaining problems not by workstation measures, but by organisational measures: this had

resulted in the job rotation scheme, in accordance with the recommendation put forward in the Swedish Ordinance.

The non-discrimination argument put forward should of course not be taken lightly. Women should not be denied access to employment due to poorly designed workstations. But at what expense? The Swedish Ordinance 1998:1 says in its mandatory section: “The employer shall as far as is practically possible design and arrange work and workstations in such a way that the employees can use work postures and working movements which are favourable to the body”. The wording “as far as is practically possible” reflects that in practice, compromises are sometimes necessary. Such compromises may be based on the lack of economical or technical resources to fully implement the general accessibility ambition. There is an important disclaimer in the Swedish Ordinance: “Several sections of these provisions include the words “as far as is practically possible” or suchlike…. There must, generally speaking, be a reasonable balance between the cost of a measure stipulated and the total benefit which that measure confers.”

Even though the company’s position was based on individual health concerns, it should not be overlooked that other legitimate aspects could play a role as well. The case study investigation had demonstrated that there were situations in the assembly flow that implied an elevated health risk for in particular, shorter operators. It may be argued that the company could endeavour to identify situations that would be ergonomically safe, irrespective of stature, and employ short persons for work on these parts of the production flow only. This, however, would limit the benefits of the ergonomic job rotation for other operators, since they would not have full access to the “easy” balances anymore.

The main ethical dilemma that occurred in the case study thus lies in the conflict between health concern and accessibility: the right not to be exposed to health hazards at work, versus the right not to be discriminated on the basis of sex.

5 Conclusions

The following conclusions were drawn as a result of the study:

- Operators of short stature are exposed to awkward work postures. They run an elevated risk to acquire work related disorders in the musculoskeletal system.
- Based on health concerns and from a prevention point of view, some stature limits must be applied in the assembly system. It is not possible to state that limits must be exactly 163 and 195 cm, but the study does not contradict their reasonableness.
- The problem situations are not confined to certain parts of the flow, but are distributed all over the workshop.
- A number of situations were identified where also persons in the stature range 163-195 cm may be at risk due to task and workplace characteristics. This finding presents a challenge for continued ergonomic work aiming at prevention of musculoskeletal disorders.

The study has identified type situations that are common in the assembly flow, and which imply an elevated risk for persons of short or long stature due to high postural workload. These situations occur in the car interior and exterior, in the motor room and in the rear compartment. The same types of assembly situations are likely to occur in all manual car assembly plants with volume production all over the world, for instance as demonstrated in the study by Schaub et al. (2003). There might be mediating conditions: smaller cars, even more ambitious ergonomic precautions, and different technical and organisational flow designs. Nevertheless, the basic conflict between health concerns and employability is likely to remain generic in automotive industry.

As shown in the present case, a seemingly neutral condition, based on legitimate health concerns, may have a political connotation that violates basic principles of equality.

Epilogue

The Swedish Labour Court, who took up the case, ruled in favour of the plaintiff. In the judgement it was said that the company had not demonstrated that the measures taken had been "appropriate and necessary". A very modest damage was paid by the company, which indicated that the court considered that the losing party had good reasons to adopt his position, even though these were insufficient to win the case.

The conclusion was that the stature requirement in fact discriminated women from employment, and that it should be abolished on these grounds.

The court judgement implied that the company had to abolish the stature criterion, even though it had demonstrated that shorter people did run an elevated risk to acquire musculoskeletal problems due to poor work postures in the production flow.

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