Observational Methods for Analyzing Working Postures in Agriculture

S. Pinzke

Abstract

This article aims to review selected methods for analyzing working postures. Special emphasis is put on field methods, applicable to agricultural tasks, which are easy to learn and use. The review will therefore focus on observational methods. It covers methods for studying whole body postures and techniques that only analyze one part of the body. The methods require equipment ranging from highly technical and computer-based ones down to a simple approach using paper and pencil. The advantages and the disadvantages of the described methods are discussed as well as their usability in agricultural studies.

Keywords. Observational methods, Working postures, Musculoskeletal disorders, Agriculture, Farmers.

International as well as national statistics indicate that agriculture is one of the most hazardous industries, with high prevalence of musculoskeletal problems (Nat. Board of Occupational Safety and Health and Statistics Sweden, 1994; Nat. Safety Council, 1990; U.S. Dept. of Labor, 1989). Several health and safety hazards are associated with farming, one of the occupations in the agricultural industry (Ehlers et al., 1993; Lundqvist and Gustafsson, 1992; Thelin, 1980; Zhou and Roseman, 1994).

Despite mechanization and automatization of the jobs due to intensive rationalization during recent years, several physically demanding work tasks are still to be found in agriculture (Ahonen et al., 1990; Havel and Zimova, 1981; Tomlinson, 1970; van Dieen, 1993; van Dieen and Hildebrant, 1990), especially for females (Stål et al., 1996a,b).

Work-related problems in the musculoskeletal system have been studied for different kinds of agricultural tasks in, e.g., dairy farming (Gustafsson et al., 1994; Stål and Pinzke, 1991), working in swine confinement buildings (Christensen et al., 1992; Holness and Nethercott, 1995), poultry houses (Lundqvist, 1995), greenhouses (Lundqvist, 1988; Gustafsson et al., 1989; Lundqvist and Pinzke, 1996), loading, lowering and transportation (Tuure, 1992), rice cultivation (De and Sen, 1992), in mushroom culture (Oude Vrielink et al., 1995), citrus harvesting (Conlan et al., 1995), pear and apple orchard work (Sakakibara et al., 1987), and hoeing operations (Nag and Pradhan, 1992). In a study by Hildebrandt et al. (1995), it was shown that musculoskeletal symptoms of low back and neck-shoulder were high in most branches of Dutch agriculture, especially in protective vegetable growing and arboriculture. Also

The author is Stefan Pinzke, PhLic, Division of Work Science and Technology, Dept. of Agricultural Biosystems and Technology, Swedish University of Agricultural Sciences, PO Box 88, S-230 53 Alnarp, Sweden; e-mail: <stefan.pinzke@jbt.slu.se>; WWW: <http://jbt-08.jbt.slu.se>.

in fishery (Törner, 1991) and forestry (Gellerstedt, 1993; Harstela, 1987), branches closely related to agriculture, high prevalence of musculoskeletal symptoms mainly from the back, the shoulders and the knees were reported.

Beside the suffering for the individual, the problems cost enormous sums of money for society and industries in the form of sick leave, rehabilitation, and early retirement (Kuorinka et al., 1990; Liukkonen, 1989).

It is documented that there is a relationship between awkward postures and pain, symptoms, and injuries in the musculoskeletal system (Aarås et al., 1988; Burdorf et al., 1991; Corlett and Manenica, 1980; Grandjean and Hünting, 1977; van Wely, 1970). Poor postures typically include reaching behind, twisting, working overhead, kneeling, forward or backward bending, and squatting. Posture is also important for the performance of tasks (Bhatnager et al., 1985; Corlett, 1981; Corlett and Manenica, 1980). Poor postures are related to injuries in tasks which are static in nature, long-lasting, and demand exertion of force (Haslegrave, 1994; Westgaard and Aarås, 1984).

Farming can be described as a highly varied occupation with many different daily tasks. Manual materials handling for farm workers often include the lifting of heavy loads, moving and carrying equipment, static muscle work, and repetitive movements—all of which are risk factors for back injuries and other joint disorders (Bobick and Myers, 1995; Murphy, 1992; Parton, 1990; Penttinen, 1987). The working posture has been indicated as the factor causing the highest loads and which leads to a high prevalence of musculoskeletal problems. However, in some cases, there still seems to be a lack of criteria for judging when a posture is harmful.

The working situation and working postures vary considerably on different farms. On small, family operated farms, positive factors include the variations in work tasks and short time in one particular job while low professional skill in specialized jobs and poorly designed equipment, which also leads to awkward working postures, are negative factors. The situation is often the opposite on larger farms with employed personnel. Tractor or machine operation, transport and handling tasks, and milking are typical work situations where working posture may cause problems (Sjöflot, 1987).

There is need to find simple methods for early identification and quantification of postures causing the musculoskeletal disorders in order to form a basis for appropriate preventive and interventive measures. It is also important to have measurements available for assessing the changes after reorganization of the work and after introducing new working methods and techniques. Easy-to-use field methods are required first of all for screening studies generating information that will stimulate in-depth research on particular problems.

The aim of this article is to review methods for analyzing working postures. Special emphasis is put on field methods applicable to agricultural tasks which are easy to learn and use. The review therefore will focus on observational methods, a group of measurements classified between direct measurements and self-report techniques. Such factors as cost, exactness, capacity, versatility, and generality will be taken into consideration. The advantages and the disadvantages of the described methods are noted as well as their usability in agricultural studies. The review may be a guide for researchers, engineers, ergonomists, as well as occupational health professionals, and others in the field of agricultural health and safety to choose appropriate observational method.

A number of techniques are
physical work load.

The methods can be divided i

- Direct measurements. M
  or technical devices for
  movements.
- Observational methods
  performances directly at t
  These methods depend on
- Self-report techniques. T
  discomfort, etc., noted on c

The methods require equipm
based ones to a simple approach u
between these three main strate
Mathiassen (1994). Cost and exa
order of the categories, while ca
increase with the order.

In the more comprehensive wo
combination of techniques from th

During the last 15 years, se
measuring methods for studying w
have been published (Atha, 1984;
Kilbom, 1994; Kilbom et al., 1986b
attention to the usefulness of t
environment.

Direct methods include measures
(EMG); (2) musculoskeletal loadin
respiratory loading based on, e.g.,
(4) body and load movements by
optoelectronics, acoustic and elec
(CAD), and expert systems; and (5)
pressure, intra-abdominal pressure, in

The direct measurements often
consequently, expensive. On the oth
reliable, accurate, and valid data t
require expert personnel and the mea
manner that they hinder the work pr
Samuelson, 1987). In agriculture, di
measures have been used to indicat
1986; Christensen et al., 1992; Je
Tomlinson, 1970; Tuure, 1992). H
buildings, often means dust and gase
equipment. Optical methods demand
individual is in a restricted area with
example, a milker who walks from co
the animals or equipment in the stabl
suitable measurements in the agri
e.g., tractor driving, milking, and gree
under controlled conditions where dir

Measurements

A number of techniques are available for measuring the posture, movements, and physical work load.

The methods can be divided into the following three categories:

- Direct measurements. Methods which require some sort of instrumentation or technical devices for measuring physical load, working postures, and movements.
- Observational methods. Visual observations of working postures and performances directly at the workplace or indirectly from video or cine film. These methods depend on the judgement of an observer.
- Self-report techniques. The employee's own experience of work load, pain, discomfort, etc., noted on questionnaires, checklists, interviews, and diaries.

The methods require equipment ranging from highly technical and computer-based ones to a simple approach using paper and pencil. Some important differences between these three main strategies are discussed in an article by Winkel and Mathiassen (1994). Cost and exactness are factors that decrease with the described order of the categories, while capacity, versatility, and generality are factors that increase with the order.

In the more comprehensive work analysis systems that nowadays exist, there is a combination of techniques from the above categories.

During the last 15 years, several more or less comprehensive reviews on measuring methods for studying working postures, motion, and physical work load have been published (Atha, 1984; Colombini et al., 1985; Hagberg et al., 1995; Kilbom, 1994; Kilbom et al., 1986b; Nordin, 1982). None of these pay any particular attention to the usefulness of these techniques in the agricultural working environment.

Direct methods include measures of: (1) muscular activity by electromyography (EMG); (2) musculoskeletal loading by biomechanical analysis; (3) metabolic and respiratory loading based on, e.g., heart rate, oxygen uptake, and blood pressure; (4) body and load movements by goniometry, inclinometers, accelerometers, optoelectronics, acoustic and electro-magnetic devices, computer-aided design (CAD), and expert systems; and (5) compressive and reaction forces by intradiscal pressure, intra-abdominal pressure, intra-muscular pressure, and force platforms.

The direct measurements often require advanced technical equipment and are consequently, expensive. On the other hand, they are quantitative and offer more reliable, accurate, and valid data than self-reports. These direct methods often require expert personnel and the measuring devices must usually be applied in such a manner that they hinder the work procedure to different degrees (Wangenheim and Samuelson, 1987). In agriculture, direct methods such as EMG and physiological measures have been used to indicate work load (Ahonen et al., 1989; Arborelius, 1986; Christensen et al., 1992; Jensen et al., 1995; Nag and Pradhan, 1992; Tomlinson, 1970; Tuure, 1992). However, the environment, especially in farm buildings, often means dust and gases which may easily damage expensive technical equipment. Optical methods demand good lighting conditions and that the studied individual is in a restricted area with free sight. Farming involves mobile work. For example, a milker who walks from cow-to-cow is often in a hidden position behind the animals or equipment in the stable. Direct methods are therefore not particularly suitable measurements in the agricultural environment. Several work tasks, e.g., tractor driving, milking, and greenhouse work, can be simulated in a laboratory under controlled conditions where direct measurements more easily can be used.

A number of *self-report techniques* exist for collecting data from the workers' own experiences of their work environment. The methods include questionnaires, interviews, diaries, checklists, ranking, and rating methods.

Descriptions of methods of rating physical work load during agricultural work can been found in the literature (e.g., Jensen et al., 1995; Pinzke and Stål, 1990; Stål et al., 1996a).

The most common method for collecting subjective data is the questionnaire, which has the advantage of producing large amounts of information at low cost from large numbers of people (Sinclair, 1990). Questionnaires for analyzing exposure often contain questions about posture, motion/repetition, material handling, and work organization, and also the duration of these items (Hagberg, 1992).

The Standardized Nordic Questionnaires have been developed for the analysis of musculoskeletal symptoms (Andersson et al., 1985; Kuorinka et al., 1987). Several studies of work in agriculture or in branches closely connected to agriculture, have been conducted using these questionnaires, e.g., fish-processing industry factory (Ohlsson, 1995), cutters and machine operators in forests (Gellerstedt, 1993), and dairy farming (Gustafsson et al., 1994; Pinzke and Gustafsson, 1995). The questionnaires provide, of course, less detailed information than systematic physical examinations and therefore should be used only as a screening instrument to assess musculoskeletal disorders.

A major limitation of questionnaires is that they may require well-trained personnel for collection, interpretation, and coding of the data. Surveys also rely on the worker's recall or recognition and willingness to report health conditions (Saldana et al., 1994). Although questionnaires seem to be the most appropriate instrument in epidemiological studies (Winkel and Mathiassen, 1994) and their use of studying cumulative exposure over time, the reliability and validity for assessment of postural load are not very high compared with observational methods (Burdorf and Laan, 1991; Kilbom, 1994).

Checklists are used, often by trained ergonomists, to get a quick look at the job performed and the risk factors involved. The benefit of checklists is that they do not rely on workers recognizing symptoms before action can be taken (Hagberg et al., 1995). Checklists consist of items that the observer wants to register and expects to occur at the workplace.

Observational Methods

Some early methods for defining postures and movements were the Benesh notation system (Benesh and Benesh, 1956) and the Labanotation (Laban, 1956). These systems were based on drawings illustrating the movements of ballet dancers. The Benesh movement notation has also been used to study sitting behavior (Kember, 1976). Both systems are time-consuming to use and difficult to learn.

The posturegram method developed by Priel (1974) is a numerical definition of postures. It gives information on the position and angle of each body limb in three co-ordinate planes in relation to a given standard position. The posturegram method is easier to learn but provides low speed of recording.

A more advanced and faster technique for recording working postures is the posture targeting method (Corlett et al., 1979). It is a method for recording whole body postures by making marks on a chart in the horizontal and vertical planes, indicating the positions of different limbs with reference to a standard position. A model for sitting postures based on the posture targeting method was presented by Gil and Tunes (1989).

ollecting data from the workers' own e methods include questionnaires, ıg methods.

work load during agricultural work et al., 1995; Pinzke and Stål, 1990;

subjective data is the questionnaire, ounts of information at low cost from ıestionnaires for analyzing exposure n/repetition, material handling, and se items (Hagberg, 1992).

ıve been developed for the analysis of 1985; Kuorinka et al., 1987). Several losely connected to agriculture, have .g., fish-processing industry factory rs in forests (Gellerstedt, 1993), and nzke and Gustafsson, 1995). The information than systematic physical y as a screening instrument to assess

hat they may require well-trained ling of the data. Surveys also rely on ıgness to report health conditions es seem to be the most appropriate and Mathiassen, 1994) and their use reliability and validity for assessment vith observational methods (Burdorf

ımists, to get a quick look at the job nefit of checklists is that they do not action can be taken (Hagberg et al., rver wants to register and expects to

. and movements were the Benesh ıd the Labanotation (Laban, 1956). ıng the movements of ballet dancers. en used to study sitting behavior ng to use and difficult to learn.

l (1974) is a numerical definition of nd angle of each body limb in three d position. The posturegram method ling.

recording working postures is the It is a method for recording whole the horizontal and vertical planes, reference to a standard position. A targeting method was presented by

A computerized system for measuring loads on the body during static tasks has been described by Tracy and Corlett (1991). The posture and external forces can be input with an extended posture targeting method or by the optoelectronic system CODA-3 (Movement Techniques Limited, 1987).

A review of selected observational methods in work posture analysis. Observational techniques have been developed for different purposes and are therefore different in many aspects. On going through the journals and literature in ergonomics over the past 10 years, several methods of observation are found. Some of the well-known and most cited methods are described in the APPENDIX.

General criteria for observational methods. It is not easy to give a detailed specification of demands constituting a 'good' observational method for work analysis. This will depend on the character of the work situation, if the work is mobile or sedentary, lighting conditions, if the job is varied or monotonous, repetitive or static. The choice of method also depends on whether a part of the body or the whole working posture is being studied, if the time lapse is of interest, and how accurate the angle measures and time intervals must be.

Observation can be done directly at the workplace or via video recordings. The advantage of direct observation is that postures can be recorded more accurately because the observer can move to a position for optimal vision. The disadvantage is that only a few variables can be assessed and the work pace must be slow. The advantage with video registration is that it can be analyzed repeatedly. Therefore, many factors can be registered, even at a high work pace (Burdorf and Laan, 1991; Kilbom, 1994).

The accuracy of observations depends on the viewing angle of the observer and the actual body angle studied. In a study (Douwes, 1991), direct observations were compared with observations from photographs. The result was that the accuracy decreased for both methods if the viewing angle deviated from the perpendicular to the body angle plane. Deviations of viewing angle of 0 to 5° and 60 to 90° give mean observation errors of 3° and 9°, respectively, for direct observation and 5° and 10°, respectively, for indirect observation.

The most accurate observations are performed in real-time and continuously. A registration is made when an event occurs or a posture is changed. The frequency and amount of time that the worker spends in each defined posture can be calculated. Time sampled observations are performed at regular or random intervals and give an approximation of the frequency and the duration. The higher the sampling frequency, the more accurate the observation study will be. Task sampling means that the observer has to assess the most difficult posture and movement during a work task.

Important criteria to consider when assessing different methods of measurement include validity, reliability, and sensitivity.

The *validity* of a method (external validity) denotes its ability to measure what it aims to measure. This, in general, is difficult to assess directly. Only through long experience or by epidemiological studies, can the external validity of a method be obtained. Usually the validity is tested by comparing a method with other more accurate and valid measurements (internal validity).

High *reliability* of a method means that the same observer will obtain the same results after repeated tests (intra-observer reliability) when studying the same work situation. Inter-observer reliability implies that different observers using same method should receive identical results.

The *sensitivity* indicates how well the method reacts to changes in the measured variable. The validity, reliability, and sensitivity must be tested before a method can be fully trusted.

One other criterion to consider when choosing a method is its reactivity; how the method interferes with the work task studied. The reactivity can influence both the validity and the reliability (Johansson, 1996).

Other criteria concerning availability and usefulness can be formulated, e.g., if the method is inexpensive, easy to learn and use, computerized, portable and flexible. It is also an advantage if the method is widely used so that data from one study can be compared with data from other studies using the same method.

Most of the observational methods described are computerized either from the beginning or have later been computer-aided. The computers have the ability to register the observations (the different working postures and the time when they are assumed), perform the calculations and the analysis, as well as to present the results in tables and figures. The usability of a computerized method is principally determined by the software. The programs should be inexpensive and easy to learn and use, even for those who have limited computer experiences. User-friendly methods should be well-documented and include easy manuals for guiding of both the software and the hardware. Several advantages are obtained if the recording procedure can be performed at the workplace. The registrations will be less time-consuming, and the observer can move to a position for free sight, concentrate on the assessment of the working posture, and leave the time-keeping to the computer. The computer then must be portable, either a pocket computer for recording the data, which later are transferred to a stationary computer, or a laptop which also can perform the analysis. The disadvantage with direct observations in the field compared with observations from video film is that only a few variables can be assessed and the work pace must be slow. Time-lapse sampling methods like OWAS (Karhu et al., 1977) and WOPALAS (Hellsten, 1985) recommend an observation every 30 s in the field, while from video film the recommended observation interval is every 3 s. If the method is computerized, the calculations, presentations, and the analyses, even more complicated ones, will be executed much faster and more accurately.

Table 1 is an overview of the described observational methods in the APPENDIX. It is indicated if the methods are manual or computerized, direct or video-based, and whether they are based on task or time sampling or continuously in real-time. Since this article is focused on work positions, the number of classes for the limbs and postures are listed. Numbers of other components are also included. The tasks and the aims for which the methods were originally applied, and their suggested usability in agriculture, are described.

If the method is manual the registrations and calculations are done by hand. The only tools needed are pen and paper. Often the registrations are performed on special pre-printed forms.

If the method is computerized both the registrations and the analysis are computer-aided. Postures and tasks can be registered directly at the workplace on a hand-held computer and later be analyzed on a stationary one.

Most of the methods listed in table 1 are also included and described with respect to validity and reliability in earlier review articles (Kilbom, 1994; Kilbom et al., 1986b; Wiktorin, 1995).

References are listed under the name of the method in table 1. The letter 'g' denotes that the reference gives a general description of the observational method, the letter 'c' if the method is, or later on, has been computerized, and the letter 'e' if

Table 1. Descri

Method Name (Reference) g General c Computerisation e Evaluation a Agricultural	Manual	Computer	Direct	Video	Task Samp	Time Samp	Real Tim	
OWAS g,e (Karhu et al., 1977) c (Kivi and Mattila, 1991; Mattila et al., 1993) a (Lundqvist, 1988; Oude Vrielink et al., 1995; van der Schilden, 1989; Zegers, 1987)	X	X	X	X	X	X		
WOPALAS g (Hellsten, 1985) c (Pinzke, 1994) a (Lundqvist, 1990)	X	X	X	X	X	X		
TRAM g (Milner, 1980)	X		X			X		
ARBAN g (Holzmann, 1982) c (Holzmann and Wangenhein, 1983)		X		X		X		
RULA g,e (Axelsson and Karltun, 1995; McAtamney and Corlett, 1993)	X	X	X	X	X			
Keyserling g,e (Keyserling, 1986)		X		X			X	
PWSI g,e (Chen et al., 1989)		X		X		X		S L S L
VIRA g,e (Persson and Kilbom, 1983) c Pinzke, 1994)		X		X			X	N S U S cl
PEO g,e (Fransson-Hall et al., 1995)		X	X	X			X	A N T K S

ɔd reacts to changes in the measured
must be tested before a method can

ıg a method is its reactivity; how the
'he reactivity can influence both the

fulness can be formulated, e.g., if the
mputerized, portable and flexible. It
l so that data from one study can be
same method.
1 are computerized either from the
The computers have the ability to
ɔostures and the time when they are
is, as well as to present the results in
:d method is principally determined
ısive and easy to learn and use, even
s. User-friendly methods should be
iiding of both the software and the
cording procedure can be performed
ıe-consuming, and the observer can
ɔn the assessment of the working
ɔuter. The computer then must be
e data, which later are transferred to
› can perform the analysis. The
compared with observations from
ed and the work pace must be slow.
hu et al., 1977) and WOPALAS
30 s in the field, while from video
3 s. If the method is computerized,
/en more complicated ones, will be

ıtional methods in the APPENDIX.
ıterized, direct or video-based, and
ɔr continuously in real-time. Since
nber of classes for the limbs and
; are also included. The tasks and
ɔlied, and their suggested usability

ılculations are done by hand. The
· registrations are performed on

;istrations and the analysis are
ed directly at the workplace on a
ionary one.
:luded and described with respect
s (Kilbom, 1994; Kilbom et al.,

nethod in table 1. The letter 'g'
on of the observational method,
:omputerized, and the letter 'e' if

Table 1. Description of selected methods of observation

Method Name (Reference) g General c Computerisation e Evaluation a Agricultural	Manual	Computer	Direct	Video	Task Samp	Time Samp	Real Time	Posture, No. of Classes	Other Compo-nents	Applied for	Usability in Agriculture
OWAS g,e (Karhu et al., 1977) c (Kivi and Mattila, 1991; Mattila et al., 1993) a (Lundqvist, 1988; Oude Vrielink et al., 1995; van der Schilden, 1989; Zegers, 1987)	X	X	X	X	X	X		Head 5 Upper arm 3 Back 4 Legs 7	Weight classes 3	Identifying harmful postures	All mobile work
WOPALAS g (Hellsten, 1985) c (Pinzke, 1994) a (Lundqvist, 1990)	X	X	X	X	X	X		Head 5 Upper arm 4+4 Back 4 Legs 13	Weight classes 6	Identifying harmful postures	All mobile work
TRAM g (Milner, 1980)	X		X			X		Arms 3 Back 3 Position of the body weight 10 Posture severity 3	Workstation factors as Noise Climate Lighting Accessibility	Heavy process industry	All mobile work especially inside a farm building
ARBAN g (Holzmann, 1982) e (Holzmann and Wangenhein, 1983)		X		X		X		Head Arms Back Legs	Static muscle load Dynamic muscle force Vibrations The factors are rated with 10 levels Borg scale	Building work	All mobile work that can be videotaped
RULA g,e (Axelsson and Karltun, 1995; McAtamney and Corlett, 1993)	X	X	X	X	X			Upper arm 4 Lower arm 2 Wrist 5 Neck 4 Trunk 4 Legs 3	A score system depending on: Postures Muscle use Force	Assessment of upper limb disorders	Hand and machine packing operations in, e.g., pot plant production
Keyserling g,e (Keyserling, 1986)		X		X			X	Shoulders 3+3 Trunk 5 Lie Sit 3		Postural analysis of the trunk and shoulders in automobile assembly operations, based on time studies	Dynamic postures and activities that can be video taped
PWSI g,e (Chen et al., 1989)		X		X		X		Hand 4+4 Standing Leaning Sitting Lying	Body location 4 Body orientation 4 Thermal load 7 External load 4 Acceleration 4	Analysis of physical work stress	Compare different work methods or systems in cost of physical work stress, e.g., loose versus tied cow holding
VIRA g,e (Persson and Kilbom, 1983) c Pinzke, 1994)		X		X			X	Neck Shoulder Upper arm Self-defined classes		Analysis of movements and postures of short-cycle and repetitive seated assembly work	Analysis of arm movements during tractor driving or on other farm machines
PEO g,e (Fransson-Hall et al., 1995)		X	X	X			X	Arms 2 Neck 3 Trunk 2 Kneeling Squatting	Lift weight classes 5 Manual handling 5	Analysis of postures and manual materials handling	Applicable to most work tasks in agriculture

Table 1. (cont.) Description of selected methods of observation

Method Name (Reference) g General c Computerisation e Evaluation a Agricultural	Manual	Computer	Direct	Video	Task Samp	Time Samp	Real Time	Posture, No. of Classes	Other Components	Applied for	Usability in Agriculture
HAMA g (Christmansson, 1994)	X			X	X			Upper arm Forearm Shoulder Wrist Elbow in 10 degrees of deviation from neutral positions	Basic motion 10 Type of grasp 13 External load Perceived exertion using Borg's RPE-scale	Studies of assembly tasks. Analysis of upper limb movements and risk for work-related musculoskeletal disorders	Analysing most work tasks in agriculture with focus on the upper limbs
TRAC g (Ridd et al., 1989) e (Frings-Dresen et al., 1995b; van der Beek et al., 1992)		X	X		X	X	X	Optional, e.g., Gross body posture and/or Fine body posture	Optional, e.g., Activities (pull, push, lift) Load handled	Analysis of self-defined working postures and activities	Applicable to most work postures and activities in agriculture
The Observer g (Hikspoors et al., 1995; Noldus Information Technology, 1996)		X	X	X	X	X	X	Optional	Optional	Analysis of self-defined events as activities, postures, movements and positions.	Applicable to most work postures and activities in agriculture
Graf g,e (Graf et al., 1995)		X	X			X		Shoulders 2 Spine 2 Trunk 3 Legs 6 68 seated positions		Assessment of seated activity and postures	Suitable for study postures in sedentary work tasks, e.g., tractor driving and on other farm machines
Stetson g,e (Stetson et al., 1991)	X		X	X			X	Wrist extension 2 Wrist flexion 2 Ulnar deviation 2	Hand exertion using power tool, pinch grip, high force, palm as striking tool, "involuntary" wristdeviation	Analysing hand exertions	Analysis of ergonomic risk factors on hand-intensive jobs, e.g., milking or pot plant handling
Cube model g (Sperling et al., 1993)	X		X	X	X				Time demands 3 Precision demands 3 Force demands 3	Classification of work with hand tools	Guide for choosing hand tool in the market or analysis of problems associated with work with hand tool
Foreman g,e (Foreman et al., 1988) e (Foreman and Troup, 1987)		X	X	X			X	Standing 8 Stooping 4 Squatting 5 Walking 5 Sitting 5 Forward leaning 7 Kneeling 5 Miscellaneous 4		Posture and activity analysis Recording and analysing gross body movements in nursing	Analysing the frequency and the duration of activities relevant to spinal loading, e.g., lifting heavy sacks
AET g,e (Rohmert and Landau 1979) c (Landau, 1995) a (Landau and Reus, 1979)	X	X	X		X			The position of trunk and head in standing or sitting postural work	Total 216 items Working system 143 Task analysis 31 Analysis of demands 42	Work system analysis Stress is analysed and determined by tasks, demands, environmental conditions and required skills	To get an profile analysis of the work, the workplace and individual profiles Enables comparison of work conditions within a farm or between farms and individuals

Table 1. (cont.) Desc

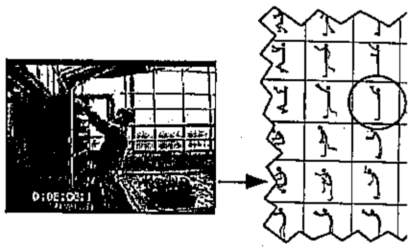
Method Name (Reference) g General c Computerisation e Evaluation a Agricultural	Manual	Computer	Direct	Video	Task Samp	Time Samp	Real Time
EWA g (Ahonen et al., 1989)	X		X		X		
PLIBEL g (Kemmlert and Kilbom, 1987) e (Kemmlert, 1995)	X		X		X		

the method has been tested for vali
before a reference means that the me

Examples and Illustrations

An observational technique inclu
itself, which can be conducted either
the classification procedure; (c) codi
into a computer; and (d) the result
from a computer.

The observational methods descri
systems. Several methods, *OWAS, W*
PLIBEL use a set of standard postur
backwards, back bent and twisted wit
Another common system of class
angle intervals (fig. 2). This type c



a b

Figure 1–The main steps in an obser
classification; (c) the coding; (d) the result

...po-	Applied for	Usability in Agriculture
... motion 10 ... of grasp 13 ...nal load ...ived exertion ...; Borg's RPE-	Studies of assembly tasks. Analysis of upper limb movements and risk for work-related musculoskeletal disorders	Analysing most work tasks in agriculture with focus on the upper limbs
...onal, e.g., ...vities (pull, ..., lift) ...d handled	Analysis of self-defined working postures and activities	Applicable to most work postures and activities in agriculture
...ional	Analysis of self-defined events as activities, postures, movements and positions.	Applicable to most work postures and activities in agriculture
	Assessment of seated activity and postures	Suitable for study postures in sedentary work tasks, e.g., tractor driving and on other farm machines
...d exertion using ...er tool, pinch grip, ... force, palm as ...ing tool, "involun-..." wristdeviation	Analysing hand exertions	Analysis of ergonomic risk factors on hand-intensive jobs, e.g., milking or pot plant handling
...e demands 3 ...ision demands 3 ...e demands 3	Classification of work with hand tools	Guide for choosing hand tool in the market or analysis of problems associated with work with hand tool
	Posture and activity analysis Recording and analysing gross body movements in nursing	Analysing the frequency and the duration of activities relevant to spinal loading, e.g., lifting heavy sacks
...al 216 items ...rking system 143 ...k analysis 31 ...lysis of demands	Work system analysis Stress is analysed and determined by tasks, demands, environmental conditions and required skills	To get an profile analysis of the work, the workplace and individual profiles Enables comparison of work conditions within a farm or between farms and individuals

Table 1. (cont.) Description of selected methods of observation

Method Name (Reference) g General c Computerisation e Evaluation a Agricultural	Manual	Computer	Direct	Video	Task Samp	Time Samp	Real Time	Posture, No. of Classes	Other Components	Applied for	Usability in Agriculture
EWA g (Ahonen et al., 1989)	X		X		X			Neck-shoulder 5 Elbow-wrist 5 Back 5 Hips-legs 5	14 items in a 4 or 5 graded scale such as worksite, activity, lifting, accident risk, lighting, noise etc.	Task analysis Workplace analysis Defining and evaluating work conditions in the workplace	To get an overall assessment of the work and the workplace. Enables a comparison of work conditions within a farm or between farms
PLIBEL g (Kemmlert and Kilbom, 1987) e (Kemmlert, 1995)	X		X		X			5 body regions: Neck/shoulder, upper back Elbows,forearms, hands Feet Knees, hips Low back	Questions including the design of the workplace and manual handling	Task analysis Identify risk factors for musculoskeletal injuries of a specific body region	To get an overall assessment of the work and the workplace. Enables a comparison of work conditions within a farm or between farms

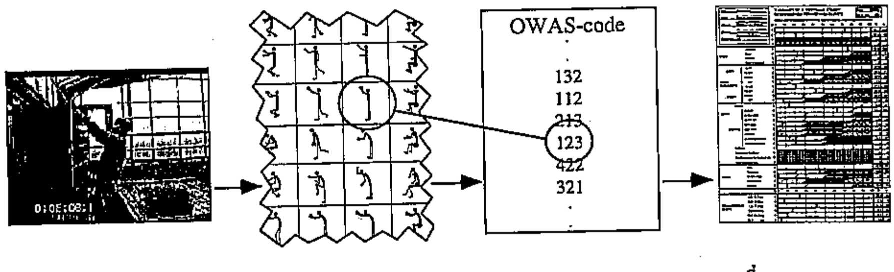
the method has been tested for validity, reliability, and/or sensitivity. The letter 'a' before a reference means that the method has been used in agricultural studies.

Examples and Illustrations

An observational technique includes four main steps (fig. 1): (a) the observation itself, which can be conducted either directly at the workplace or from video film; (b) the classification procedure; (c) coding the observations on special forms or directly into a computer; and (d) the result from an analysis calculated by hand or output from a computer.

The observational methods described in this article have different classification systems. Several methods, *OWAS, WOPALAS, TRAM, PWSI, Graf, AET, EWA,* and *PLIBEL* use a set of standard postures (fig. 1b) or an ordinal scale (e.g., neck bent backwards, back bent and twisted without support) for the classification.

Another common system of classification is to divide the postures in different angle intervals (fig. 2). This type of classification is used by *ARBAN, RULA,*



a b c d

Figure 1–The main steps in an observational method: (a) the observation; (b) the classification; (c) the coding; (d) the result.

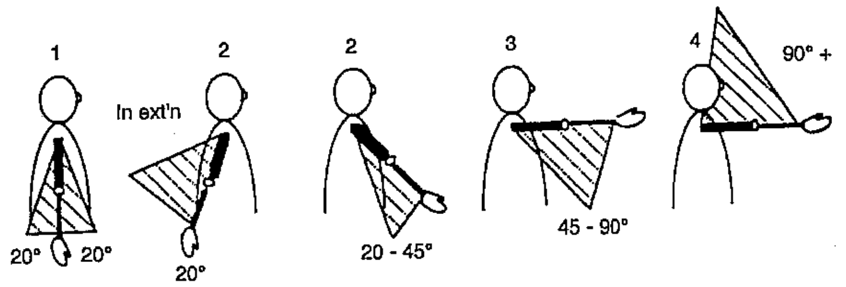


Figure 2–The interval scale for posture classification, exemplified by the RULA method.

Keyserling, VIRA, PEO, HAMA, and Stetson. The *Forman* method and most of the other described methods also use a dichotomous scale (e.g., standing, sitting, kneeling, walking) in addition to the classification.

The coding procedure can be performed either on special forms (fig. 3) or directly into the computer on predefined keys (fig. 4).

Figure 5 and 6 show two examples of output from the methods PWSI and WOPALAS.

The observational methods can record postures or activities either time-sampled, task-sampled, or in real-time.

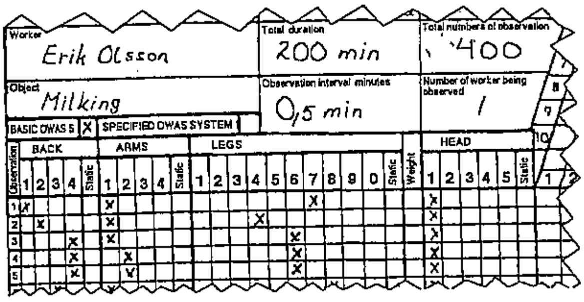


Figure 3–Manual OWAS coding form.

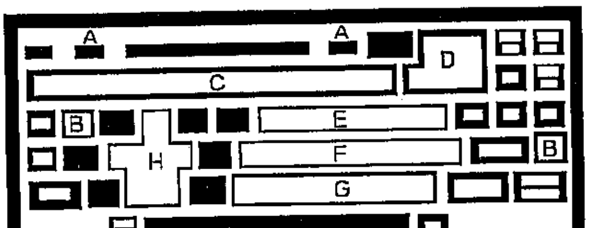


Figure 4–Keyboard layout example for the TRAC-system: (A) program management; (B) error management; (C) observation initiation; (D) trunk posture; (E) gross body posture; (F) activity; (G) direction of exertion/limbs; (H) environmental description.

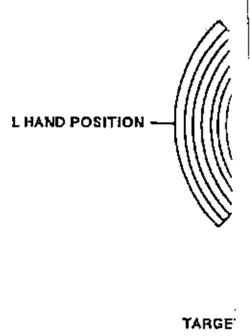
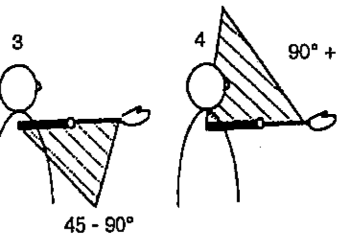


Figure 5–Weighted pol
PWSI method.

The time-sampled methods, O
techniques for whole body posture
agriculture. They are all computeri
most well known of the four and
Other time-sampled methods are
assessing seated activity and postur
Methods that can record postu
Forman, and *Stetson*. They are con
can be used for studying dynamic
videotaped. While the *Keyserling* sy
PEO and the *Forman* methods can
differs from the *Keyserling* system i
workstation (e.g., on a farm mach
analyzed instead of the shoulders
postures in sitting, lying, and stan
parlor). The *Stetson* method is ba
exertions observed during a work c
of risk factors on hand-intensive wo
The *AET*, *EWA*, *and PLIBEL*
sampling. These systems cover an
working postures constitute only on
assessment of agricultural work and
farm or between farms. They requi
analysis. Other task-sampling meth
RULA and *HAMA* focus on uppe
hand and wrist positions. The latter
agricultural work.
The *TRAC* and the *Observer*
applications. They can record most
time-sampled or in real time on a

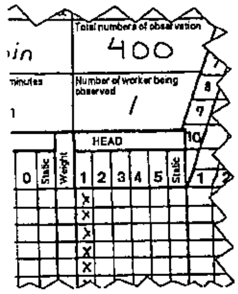


n, exemplified by the RULA method.

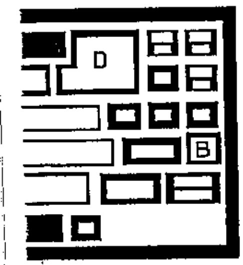
e *Forman* method and most of the
ıous scale (e.g., standing, sitting,
n.
r on special forms (fig. 3) or directly

put from the methods PWSI and

es or activities either time-sampled,



oding form.



the TRAC-system: (A)
;ement; (C) observation
ody posture; (F) activity;
ronmental description.

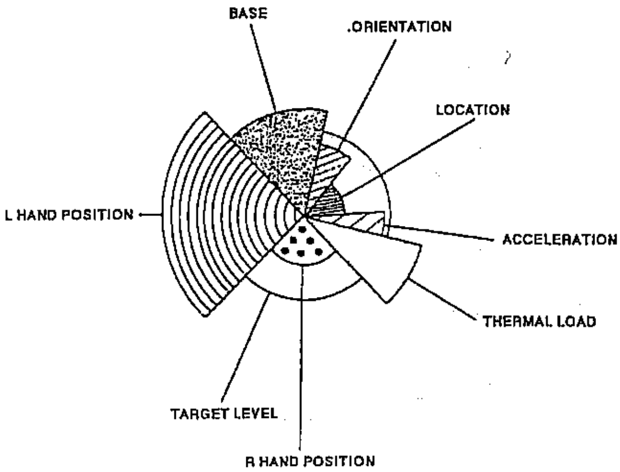


Figure 5–Weighted polar co-ordinate display. Output from the PWSI method.

The time-sampled methods, *OWAS, WOPALAS, TRAM,* and *ARBAN,* are useful techniques for whole body posture analysis and can be applied on all mobile work in agriculture. They are all computerized except for *TRAM.* The *OWAS* method is the most well known of the four and has also been most used in agricultural studies. Other time-sampled methods are *PWSI* and *Graf.* The *Graf* method is useful for assessing seated activity and postures, e.g., tractor driving.

Methods that can record postural data in real-time are *Keyserling, VIRA, PEO, Forman,* and *Stetson.* They are computerized (except for *Stetson*), video-based, and can be used for studying dynamic postures and activities in agriculture that can be videotaped. While the *Keyserling* system and *VIRA* focus on upper limb postures, the *PEO* and the *Forman* methods can analyze whole body postures. The *VIRA* method differs from the *Keyserling* system in that the worker is required to remain at a seated workstation (e.g., on a farm machine) and the neck and upper arm postures are analyzed instead of the shoulders and the trunk. The *Keyserling* system analyzes postures in sitting, lying, and standing positions (e.g., milking activities in a milk parlor). The *Stetson* method is based on counting the number and type of hand exertions observed during a work cycle. It can be used for quantitative descriptions of risk factors on hand-intensive works (e.g., milking and pot plant handling).

The *AET, EWA, and PLIBEL* are systems of work analysis based on task-sampling. These systems cover an ergonomic analysis of the workplace where the working postures constitute only one part. The methods can be used to get an overall assessment of agricultural work and enable a comparison of work conditions within a farm or between farms. They require both trained observers for data collections and analysis. Other task-sampling methods are *RULA, HAMA,* and the *Cube model.* The *RULA* and *HAMA* focus on upper limb postures, while the *Cube model* analyzes hand and wrist positions. The latter can be used for choosing suitable hand tools for agricultural work.

The *TRAC* and the *Observer* are two systems that are flexible in use and applications. They can record most of the activities and postures in agriculture, either time-sampled or in real time on a pocket computer. Some of the disadvantages of

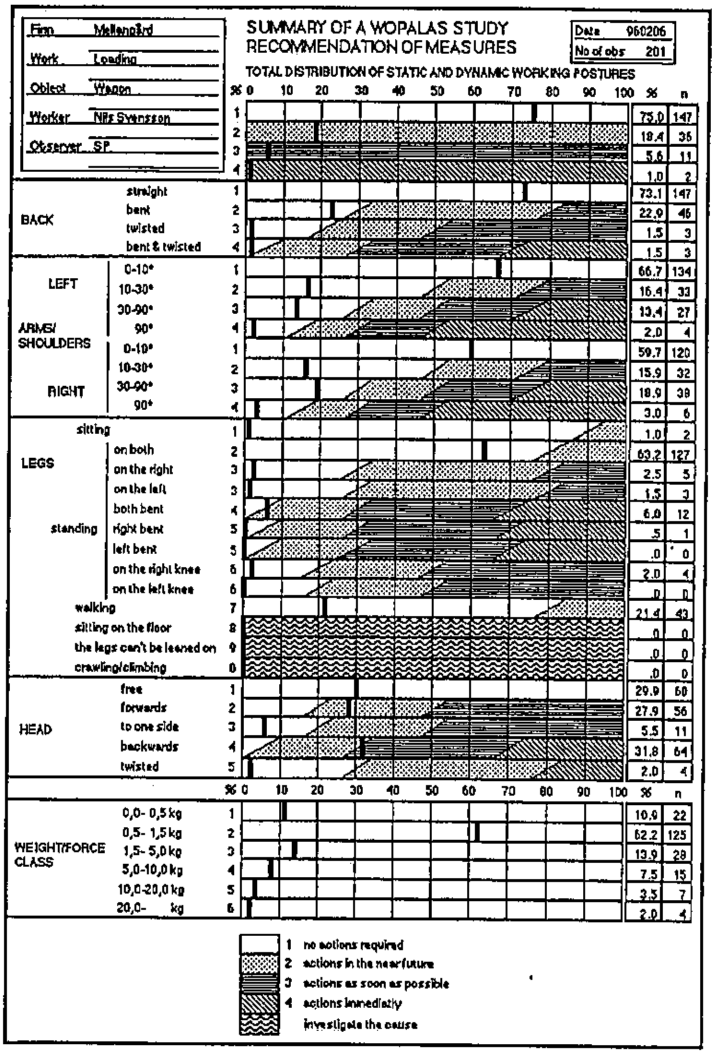


Figure 6–Summary of a WOPALAS study.

TRAC and the *Observer* are that they require trained observers for data collection and analysis and that no reference data are available.

Major advantages and disadvantages of the observational methods are listed in table 2.

Discussion

The existing techniques for measuring postures and physical work load can be categorized into direct measurements, observational methods, and self-report techniques.

Table 2. Advantages and di

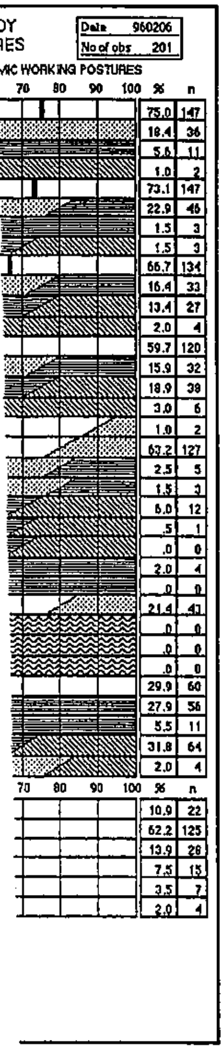
Method Name	Advan
OWAS	1,2,3,4
WOPALAS	1,2,3,4
TRAM	1,3,9
ARBAN	2,3,5,7
RULA	1,2,3,4.
Keyserling	1,2,7,1
PWSI	2,5,13,
VIRA	1,2,12,
PEO	2,3,7,1
HAMA	1,10
TRAC	3,7,16,1
Observer	3,16,17
Graf	2,3,10,1
Stetson	1,3,15
Cube model	3,4,10,1
Foreman	2,3,12,1.
AET	2,3,5,6,8
EWA	1,3,8
PLIBEL	1,3,7,8

Legend

Advantages

1 Easy to learn and use
2 Computerized
3 Portable
4 Limits for tolerance included
5 Reference data available
6 Used in agricultural studies
7 Tested for validity and reliability
8 Well documented
9 Checklist included
10 Rating scale included
11 Screening large number of workers quicl
12 Record postural data in reel-time
13 Easy to interpret the results
14 Acceleration, thermal load included
15 High reliability
16 Open computerized system
17 Flexible in its use and applications

The observational methods, the
this article, are contactless and indire
often only pen and paper as tools,
measurements. The observational m
therefore do not yield such accurate
Generally, the information obta
enough to get an overview of the wo
involved, such as postures and manua
Other risk factors to consider f
disorders, and where observational m
the psychosocial factors (e.g., general
and leisure-time activities) and the in
There is a need for research to clarify



ALAS study.

ned observers for data collection

servational methods are listed in

s and physical work load can be
ional methods, and self-report

Table 2. Advantages and disadvantages of the selected observational methods

Method Name	Advantages	Disadvantages
OWAS	1,2,3,4,5,6,7,8	1
WOPALAS	1,2,3,4,5,6	2
TRAM	1,3,9	1,2,3,4,5,6
ARBAN	2,3,5,7,8,10	3,5
RULA	1,2,3,4,7,8,11	3,6,7
Keyserling	1,2,7,12	3,5,6,8
PWSI	2,5,13,14	1,2,3,5
VIRA	1,2,12,15	3,5,6,9,10,11
PEO	2,3,7,12	3,5,6
HAMA	1,10	2,3,4,5,6,7
TRAC	3,7,16,17	3,5,6
Observer	3,16,17	3,5,6,12
Graf	2,3,10,15	3,5,6,9,11
Stetson	1,3,15	3,4,5,6,11,13
Cube model	3,4,10,13	1,3,4,6,11,13
Foreman	2,3,12,15	3,5,6,11
AET	2,3,5,6,8,15	3,5,11
EWA	1,3,8	2,3,4,5,6
PLIBEL	1,3,7,8	3,4,5,6

Legend

Advantages	Disadvantages
1 Easy to learn and use	1 Few posture classes
2 Computerized	2 Not or limited tested for reliability and validity
3 Portable	3 Trained observer required for data collection and/or analysis
4 Limits for tolerance included	4 Not computerized
5 Reference data available	5 No limits for tolerance included
6 Used in agricultural studies	6 No reference data available
7 Tested for validity and reliability	7 Restricted to upper limb postures
8 Well documented	8 Restricted to trunk and shoulder postures
9 Checklist included	9 Restricted to seated stationary work
10 Rating scale included	10 Restricted to head, shoulder and upper arm postures
11 Screening large number of workers quickly	11 Not or limited tested for validity
12 Record postural data in reel-time	12 Few studies on work posture analysis
13 Easy to interpret the results	13 Restricted to hand and wrist postures
14 Acceleration, thermal load included	
15 High reliability	
16 Open computerized system	
17 Flexible in its use and applications	

The observational methods, the group of techniques that have been the focus of this article, are contactless and indirect measurements. They are easier to use, require often only pen and paper as tools, and therefore are less expensive than the direct measurements. The observational methods depend on an analyst's judgement and therefore do not yield such accurate data as the direct methods.

Generally, the information obtained from the observational measurements is enough to get an overview of the work performed and the major physical risk factors involved, such as postures and manual handling.

Other risk factors to consider for developing work-related musculoskeletal disorders, and where observational methods are not suitable measurements, include the psychosocial factors (e.g., general well-being and quality of life, perceived stress, and leisure-time activities) and the individual factors (e.g., age, smoking habits, etc.). There is a need for research to clarify the relationship between physical exposure and musculoskeletal disorders (Kilbom, 1994) and the interaction between physical and psychosocial exposures (Östergren et al., 1995).

In most of the different observational methods, the rating criteria for awkward and harmful postures are based on the deviation from neutral positions or generally accepted recommendations. However, both the number of posture classes and the class limits differ for the methods. This indicates a lack of exact definitions of harmful postures and postural angles. Even if the biomechanical loads on the neck, the arms, and the back are highly dependent on the postural angles, more research is needed to clarify when a posture is harmful.

The OWAS, WOPALAS, RULA, and Cube model divide the analyzed data into levels indicating if the postures and work are acceptable or if actions for changes are required. These tolerance levels, even if they have not been validated, can be an aid for the observer to take further actions in the ergonomic work. Most of the other reviewed methods in this article are more detailed in recording postures and other risk factors which lead to time-consuming observations. They are very demanding on the part of the observers in learning the method, in classifying the observations, and interpreting the result. These methods seem to be more useful in ergonomic research under controlled conditions rather than for practical studies in the field.

The OWAS and WOPALAS systems are the observational methods most often used in agricultural studies. The data recording routines are the most time-consuming parts in the systems. A possible development would be to make the registration independent of manual routines. At our department, the Division of Work Science, Alnarp, Sweden, promising studies are being carried out on the direct registration of a person's movements and positions from videotape using image processing and object recognition.

In conclusion, most observational methods must be improved to be reliable and fully practical measurements in agricultural field studies. It seems particularly urgent to further develop methods similar to OWAS and RULA, since they, according to our judgement, are closest to meeting the major requirements of a good field method for agricultural purposes. The improvements that should be considered include the ease to learn and use and clear definitions and documentation of what constitutes harmful postures. The analysis of cause and effect relationships must be standardized as much as possible. The gains and losses of measuring during field conditions versus more controlled environments should be further evaluated. Since the ultimate goal is to prevent musculoskeletal symptoms, there is also a need for further research in teaching systems and methods that educate and train farmers and farm workers to adopt good working postures.

References

Aarås, A., R. H. Westgaard and E. Stranden. 1988. Postural angles as an indicator of postural load and muscular injury in occupational work situations. *Ergonomics* 31(6):915-933.

Ahonen, E., M. Venäläinen, U. Könönen and T. Klen. 1990. The physical strain of dairy farming. *Ergonomics* 33(12):1549-1555.

Ahonen, M., M. Launis and T. Kuorinka. 1989. *Ergonomic Workplace Analysis*. Helsinki, Finland: Institute of Occupational Health.

Andersson, G., F. Biering-Sørensen, L. Hermansen, B. Jonsson, K. Jørgensen, Å. Kilbom, I. Kuorinka and H. Vinterberg. 1985. Nordiska frågeformular för kartläggning av yrkesrelaterade muskuloskeletala besvär (The Nordic Questionnaires for the analysis of work related musculoskeletal symptoms; in Swedish). *Nordisk medicin* 99(2):54-55.

Arborelius, U. P. 1986. On assessmen
and EMG. Applications on should
thesis. Department of Anatomy, Ka

Atha, J. 1984. Current techniques for r

Axelsson, J. and J. Karltun. 1995. RUI
och skaderisker: Praktisk handledr
evaluating work postures and risks
LiTH-IKP-R, Universitetet i Linl
ergonomi, TräteknikCentrum, Arbe

Bao, S. 1995. Shoulder-neck expo
rationalization. PhD thesis. Divi
Technology, Luleå. *Arbete och Hälsa*
Sweden.

Beck, D. J. and D. B. Chaffin. 1992. A
prediction. In *Proc. Int. Conf. Co*
Tampere, Finland, 329-336. Amst
B.V.

Benesh, R. and J. Benesh. 1956. *An Int*
A. & C. Black.

Bhatnager, V., C. G. Drury and S. (
performance. *Human Factors* 27(2):1

Bobick, T. G. and J. R. Myers. 1995.
Agricultural Health and Safety Workpl
J. A. Dosman, K. M. Semchuk, S. A
CRC Press.

Borg, G. 1985. *An Introduction to Borg's*

Burdorf, A., G. Govaert and L. Elders.
manufacturing of prefabricated concr

Burdorf, A. and J. Laan. 1991. Compari
the back. *Scand. J. Work Environ. Hea*

Chen, J.-G., J. B. Peacock and R. E. Sc
work stress analysis. *Int. J. Indust. Erg*

Christensen, H., P. Vinzents, B. H. N
1992. Occupational exposures and
confinement buildings. *Int. J. Indust.*

Christmansson, M. 1994. The hama-m
movements and risk for work-relate
Congress of the Int. Ergonomics Assoc.
Ont., Canada: Human Factors Assoc.

Colombini, D., E. Occhipinti, G. Molten
Menoni. 1985. Posture analysis. *Ergon*

Conlan, T. M., J. A. Miles and W. E. Ste
harvesting. *Transactions of the ASAE* 3

Corlett, E. N. 1981. Pain, posture and p
27-42, eds. E. N. Corlett and J. Richar

Corlett, E. N., S. J. Madeley and I. M
recording working postures. *Ergonomic*

Corlett, E. N. and I. Manenica. 1980.
Appl. Ergonomics 11(1):716.

De, A. and R. Sen. 1992. A work measur
Int. J. Indust. Ergonomics 10(4):285-292

Douwes, M. 1991. Validity and reliabilit
observations. In *Design for Everyone*,
France: Taylor & Francis.

Ehlers, J. K., C. Connon, C. L. Themann,
hazards associated with farming. *AAOH*

ıe interaction between physical and

ods, the rating criteria for awkward
from neutral positions or generally
number of posture classes and the
ates a lack of exact definitions of
e biomechanical loads on the neck,
the postural angles, more research is

model divide the analyzed data into
eptable or if actions for changes are
e not been validated, can be an aid
rgonomic work. Most of the other
ed in recording postures and other
vations. They are very demanding
od, in classifying the observations,
ı to be more useful in ergonomic
or practical studies in the field.
observational methods most often
ng routines are the most time-
velopment would be to make the
our department, the Division of
are being carried out on the direct
ons from videotape using image

st be improved to be reliable and
udies. It seems particularly urgent
l RULA, since they, according to
quirements of a good field method
should be considered include the
ocumentation of what constitutes
elationships must be standardized
ing during field conditions versus
aluated. Since the ultimate goal is
o a need for further research in
ain farmers and farm workers to

ral angles as an indicator of postural
ns. *Ergonomics* 31(6):915-933.
1990. The physical strain of dairy

omic Workplace Analysis. Helsinki,

nsson, K. Jørgensen, Å. Kilbom, I.
igeformular för kartläggning av
Questionnaires for the analysis of
ordisk medicin 99(2):54-55.

Arborelius, U. P. 1986. On assessment of musculo-skeletal load with biomechanical models and EMG. Applications on shoulder during therapeutic exercise and standing work. PhD thesis. Department of Anatomy, Karolinska Institute, Stockholm.

Atha, J. 1984. Current techniques for measuring motion. *Appl. Ergonomics* 15(4):245-257.

Axelsson, J. and J. Karltun. 1995. RULA – en metod för egenutvärdering av arbetsställningar och skaderisker: Praktisk handledning och utbildningsmaterial (RULA – A method for evaluating work postures and risks of injury; in Swedish). Rapport 0281-5001, 1102-1071, LiTH-IKP-R, Universitetet i Linköping, Institutionen för yrkesmedicin och industriell ergonomi, TräteknikCentrum, Arbetsmiljöfonden, Linköping.

Bao, S. 1995. Shoulder-neck exposure from assembly work and the significance of rationalization. PhD thesis. Division of Industrial Ergonomics, Luleå University of Technology, Luleå. *Arbete och Hälsa* 1995: 17. National Institute for Working Life, Solna, Sweden.

Beck, D. J. and D. B. Chaffin. 1992. An evaluation of inverse kinematics models for posture prediction. In *Proc. Int. Conf. Computer-aided Ergonomics and Safety '92-CAES '92*, Tampere, Finland, 329-336. Amsterdam, The Netherlands: Elsevier Science Publishers B.V.

Benesh, R. and J. Benesh. 1956. *An Introduction to Benesh Dance Notation.* London, England: A. & C. Black.

Bhatnager, V., C. G. Drury and S. G. Schiro. 1985. Posture, postural discomfort, and performance. *Human Factors* 27(2):189-199.

Bobick, T. G. and J. R. Myers. 1995. Back injuries in agriculture: Occupations affected. In *Agricultural Health and Safety Workplace, Environment, Sustainability*, eds. H. H. McDuffie, J. A. Dosman, K. M. Semchuk, S. A. Olenchock and A. Senthilselvan. Boca Raton, Fla.: CRC Press.

Borg, G. 1985. *An Introduction to Borg's RPE-Scale.* New York, N.Y.: Movement Publications.

Burdorf, A., G. Govaert and L. Elders. 1991. Postural load and back pain of workers in the manufacturing of prefabricated concrete elements. *Ergonomics* 34(7):909-918.

Burdorf, A. and J. Laan. 1991. Comparison of methods for the assessment of postural load on the back. *Scand. J. Work Environ. Health* 17(6):425-429.

Chen, J.-G., J. B. Peacock and R. E. Schlegel. 1989. An observational technique for physical work stress analysis. *Int. J. Indust. Ergonomics* 3(3):167-176.

Christensen, H., P. Vinzents, B. H. Nielsen, L. Finsen, M. B. Pedersen and G. Sjögaard. 1992. Occupational exposures and health among Danish farmers working in swine confinement buildings. *Int. J. Indust. Ergonomics* 10(4):265-274.

Christmansson, M. 1994. The hama-method — A new method for analysis of upper limb movements and risk for work-related musculoskeletal disorders. In *Proc. 12th Triennial Congress of the Int. Ergonomics Assoc.* (IEA '94), Toronto, Canada, 173-175. Mississauga, Ont., Canada: Human Factors Assoc. of Canada.

Colombini, D., E. Occhipinti, G. Molteni, A. Grieco, A. Pedotti, S. Boccardi, C. Frigo and O. Menoni. 1985. Posture analysis. *Ergonomics* 28(1):275-284.

Conlan, T. M., J. A. Miles and W. E. Steinke. 1995. Static lower back stress analysis in citrus harvesting. *Transactions of the ASAE* 38(3):929-936.

Corlett, E. N. 1981. Pain, posture and performance. In *Stress, Work Design and Productivity*, 27-42, eds. E. N. Corlett and J. Richardson. London, England: Wiley.

Corlett, E. N., S. J. Madeley and I. Manenica. 1979. Posture targeting: A technique for recording working postures. *Ergonomics* 22(3):357-366.

Corlett, E. N. and I. Manenica. 1980. The effects and measurement of working postures. *Appl. Ergonomics* 11(1):716.

De, A. and R. Sen. 1992. A work measurement method for application in Indian agriculture. *Int. J. Indust. Ergonomics* 10(4):285-292.

Douwes, M. 1991. Validity and reliability of estimating body angles by direct and indirect observations. In *Design for Everyone*, 885-887, eds. Y. Quénnec and F. Daniellou. Paris, France: Taylor & Francis.

Ehlers, J. K., C. Connon, C. L. Themann, J. R. Myers and T. Ballard. 1993. Health and safety hazards associated with farming. *AAOHN J.* 41(9):414-421.

Engels, J. A., J. A. Landeweerd and Y. Kant. 1994. An OWAS-based analysis of nurses' working postures. *Ergonomics* 37(5):909-919.

Foreman, T. K., J. C. Davies and J. D. G. Troup. 1988. A posture and activity classification system using a microcomputer. *Int. J. Indust. Ergonomics* 2(2):285-289.

Foreman, T. K. and J. D. G. Troup. 1987. Diurnal variations in spinal loading and the effects on stature: A preliminary study of nursing activities. *Clinical Biomechanics* 2(1):48-54.

Fransson-Hall, C., R. Gloria, L. Karlqvist, Å. Kilbom, C. Wiktorin, J. Winkel and Stockholm Music I Study Group. 1995. A portable ergonomic observation method (PEO) computerized on-line recording of postures and manual handling. *Appl. Ergonomics* 26(2): 93-100.

Frings-Dresen, M. H. W., H. C. G. Kemper, A. R. A. Stassen, I. F. A. M. Crolla and A. M. T. Markslag. 1995a. The daily work load of refuse collectors working with three different collecting methods: A field study. *Ergonomics* 38(10):2045-2055.

Frings-Dresen, M. H. W., P. Van Leeuwen, A. Bouw and P. P. F. M. Kuljer. 1995b. Validity of posture registration based on visual observation at the workplace. In *Book of Abstracts: Premus '95—2nd Int. Scientific Conf. Prevention of Work-related Musculoskeletal Disorders*, 286-288, Montreal, Quebec, Canada. Montreal, Canada: IRSST.

Gellerstedt, S. 1993. Work and health in forest work — A multivariate study of cutters and machine operators. PhD thesis. Department of Operational Efficiency, Swedish University of Agricultural Sciences, Garpenberg.

Gil, H. J. C. and E. Tunes. 1989. Posture recording: A model for sitting posture. *Appl. Ergonomics* 20(1):53-57.

Graf, M., M. Guggenbuhl and H. Krueger. 1995. An assessment of seated activity and postures at five workplaces. *Int. J. Ind. Ergonomics* 15(2):81-90.

Grandjean, E. and W. Hünting. 1977. Ergonomics of posture — Review of various problems of standing and sitting posture. *Appl. Ergonomics* 8(3):135-140.

Gustafsson, B., P. Lundqvist and G. Lindgren. 1989. Climatic effects on the greenhouse worker. *Swedish J. Agric. Res.* 19(4):217-225.

Gustafsson, B., S. Pinzke and P-E. Isberg. 1994. Musculoskeletal symptoms in Swedish dairy farmers. *Swedish J. Agric. Res.* 24(4):177-188.

Hagberg, M. 1992. Exposure variables in ergonomic epidemiology. *Am. J. Indust. Medicine* 21(1):91-100.

Hagberg, M., B. Silverstein, R. Wells, M. J. Smith, H. W. Hendrick, P. Carayon and M. Pérusse. 1995. *Work Related Musculoskeletal Disorders (WMSDs): A Reference Book for Prevention*, eds. I. Kuorinka and L. Forcier. London, England: Taylor & Francis.

Harstela, P. 1987. Forestry in the Nordic countries, working postures—Overview of the problem. In Abstracts of the IXth Joint Int. Ergonomics Symp. "Working Postures in Agriculture and Forestry", 3-13, CIGR/IAAMRH/IUFRO, Kuopio, Finland.

Haslegrave, C. M. 1994. What do we mean by a "working posture"? *Ergonomics* 37(4): 781-799.

Hasselqvist, O., P. Söderström and A. Wiklund. 1962. *MTM:s grundrörelser* (The basic movements of the MTM; in Swedish), ed. S. MTM- gruppen. Uppsala, Sweden: Almqvist & Wiksell.

Havel, V. and M. Zimova. 1981. Physical load and fitness of women working in agriculture. *Pracov Lek* 33:265-268.

Hellsten, M. 1985. WOPALAS – en praktisk handledning för studier av arbetsställning och arbetsbelastning (WOPALAS – A practical guide for working postures and work load; in Swedish). PM 198509-06, Tekniska Högskolan (KTH), Byggergonomilaboratoriet, Stockholm.

Hellsten, M. and P. O. Axelsson. 1996. TEMO-WAGON: Development and Evaluation of a Multifunction Material-handling Machine (TEMO-VAGNEN: Utveckling och utvärdering av en Multifunktions Materialhanterings Maskin; in Swedish with English summary), ©MHAB, Falkenberg.

Hikspoors, G. J. J., C. Verspuij, B. van Wendel de Joode and A. Burdorf. 1995. The Observer, A general-purpose computer system for the collection and analysis of observational data: Outline and example of its use in ergonomics research. In *Book of Abstracts: Premus '95—*

2nd Int. Scientific Conf. Preventi
Montreal, Quebec, Canada. Montr
Hildebrandt, V. H. 1995. Musculosk
agriculture. *Ergonomics* 38(12):257
Holness, D. L. and J. R. Nethercott
Agricultural Health and Safety—
McDuffie, J. A. Dosman, K. M. S
Raton, Fla.: CRC Press Lewis Pub
Holzmann, P. 1982. ARBAN: A n
Ergonomics 13(2):82-86.
Holzmann, P. and M. Wangenhei
arbetsanalyser (ARBAN – A meth
1983: 3, Bygghälsans Forskningssti
Jensen, B.R., M. Pilegaard, B. Schiby
during agricultural work — An int
Int. Scientific Conf. Prevention of W
Quebec, Canada,. Montreal, Canad
Johansson, A. 1996. Evaluation of a
working postures and moveme
Engineering, Lund Institute of Tec
Kant, I., L. C. G.M. de Jong, M. van F
and dynamic work postures of op
63(6):423-428.
Kant, I., H. V. Notermans and P. J.
garages using the Ovako Working
workload reduction recommendatio
Karhu, O., R. Härkönen, P. Sorvali a
industry: Examples of OWAS appli
Karhu, O., P. Kansi and I. Kuorinka
practical method for analysis. *Appl.*
Karlqvist, L. 1995. Evaluation of ph
Licentiate thesis. Department of O
Arbete och Hälsa 1995:9. National In
Kember, P. A. 1976. The Benesh mov
Ergonomics 7(3):133-136.
Kemmlert, K. 1995. A method assig
PLIBEL. *Appl. Ergonomics* 26(3):19
Kemmlert, K. and Å. Kilbom. 1987.
factors which may have injurious ef
Occupational Accidents and Diseases, 4
Keyserling, W. M. 1986. Postural analy
Ergonomics 29(4):569-583.
Keyserling, W. M., L. Punnett and I
Identification and control of occupat
Kilbom, Å., J. Persson and B. Jonsson.
neck and shoulder — With special e
Ergonomics of Working Postures: M
Wilson and I. Manenica. London, E
Kilbom, Å. 1994. Assessment of physica
disorders — What information can
Work Environ. Health 20(special issu
Kilbom, A., D. Horst, K. Kemmlert
registrering av belastningar på rö
methods for registration of load and
English summary). *Arbete och Hälsa* 2

. An OWAS-based analysis of nurses'

38. A posture and activity classification
mics 2(2):285-289.
iations in spinal loading and the effects
. *Clinical Biomechanics* 2(1):48-54.
C. Wiktorin, J. Winkel and Stockholm
nomic observation method (PEO)
anual handling. *Appl. Ergonomics* 26(2):

Stassen, I. F. A. M. Crolla and A. M. T.
collectors working with three different
):2045-2055.
and P. P. F. M. Kuljer. 1995b. Validity of
at the workplace. In *Book of Abstracts:*
Work-related Musculoskeletal Disorders,
nada: IRSST.
— A multivariate study of cutters and
erational Efficiency, Swedish University

g: A model for sitting posture. *Appl.*

An assessment of seated activity and
(2):81-90.
posture — Review of various problems
):135-140.
. Climatic effects on the greenhouse

uloskeletal symptoms in Swedish dairy

epidemiology. *Am. J. Indust. Medicine*

I. W. Hendrick, P. Carayon and M.
ders (WMSDs): A Reference Book for
England: Taylor & Francis.
working postures—Overview of the
nomics Symp. "Working Postures in
UFRO, Kuopio, Finland.
orking posture"? *Ergonomics* 37(4):

2. *MTM:s grundrörelser* (The basic
gruppen. Uppsala, Sweden: Almqvist

ss of women working in agriculture.

ng för studier av arbetsställning och
working postures and work load; in
(TH), Byggergonomilaboratoriet,

N: Development and Evaluation of a
MO-VAGNEN: Utveckling och
Maskin; in Swedish with English

nd A. Burdorf. 1995. The Observer,
and analysis of observational data:
ı. In *Book of Abstracts: Premus '95—*

2nd Int. Scientific Conf. Prevention of Work-related Musculoskeletal Disorders, 568-570, Montreal, Quebec, Canada. Montreal, Canada: IRSST.

Hildebrandt, V. H. 1995. Musculoskeletal symptoms and workload in 12 branches of Dutch agriculture. *Ergonomics* 38(12):2576-2587.

Holness, D. L. and J. R. Nethercott. 1995. Acute and chronic trauma in hog farmers. In *Agricultural Health and Safety—Workplace, Environment, Sustainability.* eds. H. H. McDuffie, J. A. Dosman, K. M. Semchuk, S. A. Olenchock and A. Senthilselvan, Boca Raton, Fla.: CRC Press Lewis Publishers.

Holzmann, P. 1982. ARBAN: A new method for analysis of ergonomic effort. *Appl Ergonomics* 13(2):82-86.

Holzmann, P. and M. Wangenheim. 1983. ARBAN — en metod for ergonomiska arbetsanalyser (ARBAN – A method for ergonomic work analysis; in Swedish). Rapport 1983: 3, Bygghälsans Forskningsstiftelse, Stockholm.

Jensen, B.R., M. Pilegaard, B. Schibye, D. Ekner and V. Nielsen. 1995. Physical work load during agricultural work — An intervention study. In *Book of Abstracts: Premus '95 — 2nd Int. Scientific Conf. Prevention of Work-related Musculoskeletal Disorders,* 202-204, Montreal, Quebec, Canada,. Montreal, Canada: IRSST.

Johansson, A. 1996. Evaluation of a workplace redesign and of a method for measuring working postures and movements. Licentiate thesis. Department of Industrial Engineering, Lund Institute of Technology, Lund, Sweden.

Kant, I., L. C. G.M. de Jong, M. van Rijssen-Moll and P. J. A. Borm. 1992. A survey of static and dynamic work postures of operating room staff. *Int. Arch. Occup. Environ. Health* 63(6):423-428.

Kant, I., H. V. Notermans and P. J. A. Borm. 1990. Observations of working postures in garages using the Ovako Working Posture Analyzing System (OWAS) and consequent workload reduction recommendations. *Ergonomics* 33(2):209-220.

Karhu, O., R. Härkönen, P. Sorvali and Vepsäläinen. 1981. Observing working postures in industry: Examples of OWAS application. *Appl. Ergonomics* 12(1):13-17.

Karhu, O., P. Kansi and I. Kuorinka. 1977. Correcting working postures in industry: A practical method for analysis. *Appl. Ergonomics* 8(4):199-201.

Karlqvist, L. 1995. Evaluation of physical work load at video display unit workstations. Licentiate thesis. Department of Occupational Health, Karolinska Hospital, Stockholm. *Arbete och Hälsa* 1995:9. National Institute for Working Life, Solna, Sweden.

Kember, P. A. 1976. The Benesh movement notation used to study sitting behavior. *Appl. Ergonomics* 7(3):133-136.

Kemmlert, K. 1995. A method assigned for the identification of ergonomic hazards — PLIBEL. *Appl. Ergonomics* 26(3):199-211.

Kemmlert, K. and Å. Kilbom. 1987. Method for identification of musculoskeletal stress factors which may have injurious effects. In *Proc. XIth World Congress on the Prevention of Occupational Accidents and Diseases,* 401-404, Stockholm. Stockholm, Sweden: FFA.

Keyserling, W. M. 1986. Postural analysis of the trunk and shoulders in simulated real time. *Ergonomics* 29(4):569-583.

Keyserling, W. M., L. Punnett and L. J. M. Fine. 1988. Trunk posture and back pain: Identification and control of occupational risk factors. *Appl. Indust. Hygiene* 3(3):87-92.

Kilbom, Å., J. Persson and B. Jonsson. 1986a. Risk factors for work-related disorders of the neck and shoulder — With special emphasis on working postures and movements. In *The Ergonomics of Working Postures: Models, Methods, and Cases,* 44-53, eds. N. Corlett, J. Wilson and I. Manenica. London, England: Taylor & Francis.

Kilbom, Å. 1994. Assessment of physical exposure in relation to work-related musculoskeletal disorders — What information can be obtained from systematic observations? *Scand. J. Work Environ. Health* 20(special issue):3045.

Kilbom, A., D. Horst, K. Kemmlert and A. Richter. 1986b. Observationsmetoder för registrering av belastningar på rörelseapparaten — en litteraturstudie (Observation methods for registration of load and strain on the human body – a review; in Swedish with English summary). *Arbete och Hälsa* 21: 1-90.

Kivi, P. and M. Mattila. 1991. Analysis and improvement of work postures in the building industry: Application of the computerized OWAS method. *Appl. Ergonomics* 22(1):43-48.

Kuorinka, I., B. Jonsson, K. Jørgensen, Å. Kilbom, O. Sejersted and H. Vinterberg. 1990. *Arbetsrelaterade sjukdomar i rörelseorganen — förekomst, orsaker och förebyggande. En kunskaps- och problemöversikt* (in Swedish), ed. N. Lundgren. Vol. 6. Köpenhamn, Danmark: Nordiska Ministerrådet.

Kuorinka, I., B. Jonsson, Å. Kilbom, H. Vinterberg, F. Biering-Sörensen, G. Andersson and K. Jørgensen. 1987. Standardized Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl. Ergonomics* 18(3):233-237.

Laban, R. 1956. *Principles of Dance and Movement Notation*. London, England: MacDonald, Evans.

Landau, K. 1995. Description of JobExpert (expert system for occupational profiles) and ABBA (inspection of the work places and load analysis; in German), Universität Hohenheim, Fachgebiet Arbeitswissenschaft, Bad Urach.

Landau, K. and G. Wendt. 1995. Body postures involved in loading work — An investigation using the OWAS method. In *Book of Abstracts: Premus '95 — 2nd Int. Scientific Conf. Prevention of Work-related Musculoskeletal Disorders*, 262-264, Montreal, Quebec, Canada. Montreal, Canada: IRSST.

Landau, K. and J. Reus. 1979. Körperhaltungen be: Tätigkeiten in Industrie, Verwaltun, Landwirtschaft und Bergbau. International Archive of Occupational and Environmental Health 44:213-231.

Leskinen, T. and M. Tönnes. 1994. Utilization of a video-computer system for analyzing postural load — Evaluation of observation. In *Proc. 12th Triennial Congress of the Int. Ergonomics Assoc.* (IEA '94), Toronto, Canada, 383-385. Mississauga, Ontario, Canada: Human Factors Assoc. of Canada.

Liukkonen, P. 1989. What does sick leave cost? (vad kostar frånvaron?) Stockholm, Sweden: The Swedish Employers' Society (Svenska Arbetsgivareföreningen; in Swedish).

Long, A. F. 1992. A Computerized System for OWAS Field Collection and Analysis. In *Proc. Int. Conf. Computer-aided Ergonomics and Safety '92–CAES '92*, Tampere, Finland, 353-358. Amsterdam, The Netherlands: Elsevier Science Publishers B.V.

Lundqvist, P. 1988. Working Environment in Farm Buildings. Results of studies in livestock buildings and greenhouses. PhD thesis. Report 58, Department of Farm Buildings, Swedish University of Agricultural Sciences, Lund.

Lundqvist, P. 1990. WOPALAS — A practical method for ergonomical analysis and practical improvements — Examples from Swedish industry and agriculture. In *Advances in Industrial Ergonomics and Safety II*, 827-832, Montreal, Quebec, Canada. London, England: Taylor & Francis.

Lundqvist, P. 1995. A new type of poultry house: Ergonomical problems and accident risks. In *Agricultural Health and Safety—Workplace, Environment, Sustainability*. eds. H. H. McDuffie, J. A. Dosman, K. M. Semchuk, S. A. Olenchock and A. Senthilselvan. Boca Raton, Fla.: CRC Press, Lewis Publishers.

Lundqvist, P. and B. Gustafsson. 1992. Accidents and accident prevention in agriculture — A review of selected studies. *Int. J. Indust. Ergonomics* 10(4):311-319.

Lundqvist, P and S. Pinzke. 1996. Musculoskeletal disorders in horticultural workers. In *Proc. of the XIth Annual Int. Occupational Ergonomics and Safety Conf.*, Zurich, Switzerland, 433-438, 8-11 July 1996. Cincinnati, Ohio: Int. Society for Occupational Ergonomics and Safety.

Määttä, T. 1994. Analyzing working postures using "ERGOKAN"-method — An example of packing work at a bakery. In *Proc. 12th Triennial Congress Int. Ergonomics Assoc.* (IEA '94), Toronto, Canada, 351-353. Mississauga, Ontario, Canada: Human Factors Assoc. of Canada.

Mattila, M., W. Karwowski and M. Vilkki. 1993. Analysis of working postures in hammering tasks on building construction sites using the computerized OWAS method. *Appl. Ergonomics* 26(6):405-412.

Mattila, M., M. Vilkki and I. Tiilikainen. 1992. A computerized OWAS analysis of work postures in the papermill industry. In *Proc. of the International Conference on Computer-aided*

Ergonomics and Safety '92–CAES
Netherlands: Elsevier Science Publis

McAtamney, L. and E. N. Corlett. 19
work-related upper limb disorders. *A*

Milner, N. 1980. Methods to stu
Ergonomilaboratorium, Stockholm.

Mortimer, M., Å. Kilbom, G. Pernold
Vingård. 1994. Presentation and i
working postures. In *Proc. 12th T*
Toronto, Canada, 141-143. Missis
Canada.

Movement Techniques Limited. 19
Monitoring System. Loughborough
Limited.

Murphy, D. J. 1992. *Safety and Health*
Joseph, Mich.: ASAE.

Nag, P. K. and C. K. Pradhan. 1992.
Ergonomics 10(4):341-350.

National Board of Occupational Safety a
Diseases and Occupational Accidents 19

National Safety Council. 1990. *Accident*

Nevala-Puranen, N., M. Kallionpää and
milking. *Int. J. Indust. Ergonomics* 18(

Noldus Information Technology. 199
Wageningen, The Netherlands.

Nordin, M. 1982. Methods for studying
PhD thesis. Department of Orthopa
University of Gothenburg, Göteborg,

Ohlsson, K. 1995. Neck and upper liml
industrial tasks. PhD thesis. Departn
Lund University, Lund, Sweden.

Östergren, P.-O., I. Balogh, J. Ektor-And
Lindbladh, J. Ranstam, J. Winkel an
study — Design and preliminary resul

Oude Vrielink, H. H. E., E. van Dull
involvement in work-related musc
agricultural workers. In *Book of Abstra*
Work-related Musculoskeletal Disorders
Canada: IRSST.

Parton, K. 1990. Back injuries on farms:
Health Safety — Aust NZ 6(1):53-59.

Penttinen, J. 1987. Back pain and sciatic
Insurance Institution.

Persson, J. and Å. Kilbom. 1983. VIRA
analys av arbetsställningar och rörels
Registration and Analysis of working
summary). Undersökningsrapport, Na
Work Physiology Unit, Solna.

Pinzke, S. 1994. A computerized system f
Indust. Ergonomics 13(4):307-315.

Pinzke, S. and B. Gustafsson. 1995.
Musculoskeletal problems in Swedis
Belastningsbesvär hos svenska mjölkp
Rapport 95, Inst. för jordbrukets bios
Lund.

ent of work postures in the building
ethod. *Appl. Ergonomics* 22(1):43-48.
Sejersted and H. Vinterberg. 1990.
ikomst, orsaker och förebyggande. En
N. Lundgren. Vol. 6. Köpenhamn,

Biering-Sörensen, G. Andersson and
ires for the analysis of musculoskeletal

ation. London, England: MacDonald,

ystem for occupational profiles) and
l analysis; in German), Universität
rach.
d in loading work — An investigation
Premus '95 — 2nd Int. Scientific Conf.
262-264, Montreal, Quebec, Canada.

Tätigkeiten in Industrie, Verwaltun,
e of Occupational and Environmental

video-computer system for analyzing
roc. 12th Triennial Congress of the Int.
3-385. Mississauga, Ontario, Canada:

kostar frånvaron?) Stockholm, Sweden:
vareföreningen; in Swedish).
Field Collection and Analysis. In *Proc.*
-CAES '92, Tampere, Finland, 353-358.
blishers B.V.
Buildings. Results of studies in livestock
58, Department of Farm Buildings,

d for ergonomical analysis and practical
ustry and agriculture. In *Advances in*
Montreal, Quebec, Canada. London,

nomical problems and accident risks. In
vironment, Sustainability. eds. H. H.
Olenchock and A. Senthilselvan. Boca

accident prevention in agriculture — A
10(4):311-319.
sorders in horticultural workers. In *Proc.*
l Safety Conf., Zurich, Switzerland, 433-
iety for Occupational Ergonomics and

:RGOKAN"-method — An example of
Congress Int. Ergonomics Assoc. (IEA '94),
io, Canada: Human Factors Assoc. of

alysis of working postures in hammering
computerized OWAS method. *Appl.*

computerized OWAS analysis of work
nternational Conference on Computer-aided

Ergonomics and Safety '92-CAES '92, 365-372, Tampere, Finland. Amsterdam, The Netherlands: Elsevier Science Publishers B.V.

McAtamney, L. and E. N. Corlett. 1993. RULA: A survey method for the investigation of work-related upper limb disorders. *Appl. Ergonomics* 24(2):91-99.

Milner, N. 1980. Methods to study moving work posture. ASF, Dnr 790402, Ergonomilaboratorium, Stockholm.

Mortimer, M., Å. Kilbom, G. Pernold, K. Selin, E. Wigaeus-Hjelm, C. Wiktorin and E. Vingård. 1994. Presentation and inter-rater reliability of an observation method for working postures. In *Proc. 12th Triennial Congress Int. Ergonomics Assoc.* (IEA '94), Toronto, Canada, 141-143. Mississauga, Ontario, Canada: Human Factors Assoc. of Canada.

Movement Techniques Limited. 1987. *Technical Information of CODA-3 Movement Monitoring System*. Loughborough, Leicestershire, England: Movement Techniques Limited.

Murphy, D. J. 1992. *Safety and Health for Production Agriculture*, ed. P. DeVore-Hansen. St. Joseph, Mich.: ASAE.

Nag, P. K. and C. K. Pradhan. 1992. Ergonomics in the hoeing operation. *Int. J. Indust. Ergonomics* 10(4):341-350.

National Board of Occupational Safety and Health and Statistics Sweden. 1994. *Occupational Diseases and Occupational Accidents 1992*, SCB-Tryck, Örebro.

National Safety Council. 1990. *Accident Facts*. Chicago, Ill.

Nevala-Puranen, N., M. Kallionpää and K. Ojanen. 1996. Physical load and strain in parlor milking. *Int. J. Indust. Ergonomics* 18(4):277-282.

Noldus Information Technology. 1996. Product information of the Observer system. Wageningen, The Netherlands.

Nordin, M. 1982. Methods for studying work load with special reference to the lumbar spine. PhD thesis. Department of Orthopaedic Surgery I, Department of Orthopaedic Surgery, University of Gothenborg, Göteborg, Sweden.

Ohlsson, K. 1995. Neck and upper limb disorders in female workers performing repetitive industrial tasks. PhD thesis. Department of Occupational and Environmental Medicine, Lund University, Lund, Sweden.

Östergren, P.-O., I. Balogh, J. Ektor-Andersen, B. S. Hanson, A. Isacsson, S.-O. Isacsson, E. Lindbladh, J. Ranstam, J. Winkel and P. Örback. 1995. The Malmö shoulder and neck study — Design and preliminary results from the baseline investigations. (Unpublished)

Oude Vrielink, H. H. E., E. van Dulleman and J. H. van Dieen. 1995. Multiple factor involvement in work-related musculoskeletal complaints. A case study in female agricultural workers. In *Book of Abstracts: Premus '95—2nd Int. Scientific Conf. Prevention of Work-related Musculoskeletal Disorders*, 199-201, Montreal, Quebec, Canada. Montreal, Canada: IRSST.

Parton, K. 1990. Back injuries on farms: Regional variations in New South Wales. *J. Occup. Health Safety — Aust NZ* 6(1):53-59.

Penttinen, J. 1987. Back pain and sciatica in Finnish farmers. Helsinki, Finland: The Social Insurance Institution.

Persson, J. and Å. Kilbom. 1983. VIRA — en enkel videofilmteknik för registrering och analys av arbetsställningar och rörelser. (VIRA — a simple VIdeo film technique for Registration and Analysis of working postures and movements; in Swedish with English summary). Undersökningsrapport, National Board of Occupational Safety and Health, Work Physiology Unit, Solna.

Pinzke, S. 1994. A computerized system for analyzing working postures in agriculture. *Int. J. Indust. Ergonomics* 13(4):307-315.

Pinzke, S. and B. Gustafsson. 1995. Working environment in dairy barns. Part 3. Musculoskeletal problems in Swedish dairy farmers. (Arbetsmiljö i kostallar. Del 3. Belastningsbesvär hos svenska mjölkproducenter; in Swedish with English summary). Rapport 95, Inst. för jordbrukets biosystem och teknologi, Sveriges lantbruksuniversitet, Lund.

Pinzke, S. and M. Stål. 1990. Ergonomisk utvärdering av en avlastningsarm som hjälpmedel vid mjölkning av kor (Ergonomic evaluation of a load reducing device as an aid for milking cows; in Swedish). Intern rapport, Institutionen för lantbrukets byggnadsteknik, Sveriges lantbruksuniversitet, Lund.

Priel, V. Z. 1974. A numerical definition of posture. *Human Factors* 16(6):576-584.

Ridd, J. E., A. S. Nicholson and A. J. Montan. 1989. A portable microcomputer based system for "on site" activity and posture recording. In *Contemporary Ergonomics*, 366-371, ed. E. D. Megaw. London, England: Taylor & Francis.

Rohmert, W. 1985. AET — A new job-analysis method. *Ergonomics* 28(1):245-254.

Rohmert, W. and K. Landau. 1979. *AET — das Arbeitswissenschaftliche Erbunsverfahren zur Tätigkeitsanalyse* (in German). Bern, Switzerland: Huber.

Sakakibara, H., M. Miyao, T. Kondo, S. Yamada, T. Nakagawa and F. Kobayashi. 1987. Relation between overhead work and complaints of pear and apple orchard workers. *Ergonomics* 30(5):805-815.

Saldana, N., G. D. Herrin, T. J. Armstrong and A. Franzblau. 1994. A computerized method for assessment of musculoskeletal discomfort in the workforce: A tool for surveillance. *Ergonomics* 37(6):1097-1112.

Scott, G. B. and N. R. Lambe. 1996. Working practices in a perchery system, using the OVAKO Working posture Analyzing System (OWAS). *Appl. Ergonomics* 27(5):281-284.

Sinclair, M. A. 1990. Subjective assessment. In *Evaluation of Human Work: A Practical Ergonomics Methodology*, 58-88, eds. J. R. Wilson and E. N. Corlett. London, England: Taylor & Francis.

Sjöflot, L. 1987. Agriculture in the Nordic countries, working postures — Overview of the problems. In *Abstracts IXth Joint Int. Ergonomics Symp. "Working postures in agriculture and forestry"*, 1-2, CIGR/IAAMRH/IUFRO, Kuopio, Finland.

Sperling, L., S. Dahlman, L. Wikström and J. Öster. 1993. A cube model for classification of work with hand tools and formulation of functional requirements. *Appl. Ergonomics* 24(3):212-220.

Stetson, D. S., W. M. Keyserling, B. A. Silverstein and J. A. Leonard. 1991. Observational analysis of the hand and wrist; a pilot study. *Appl. Occup. Environ. Hyg.* 6(11):927-37.

Stoffert, G. 1985. Analyze und Einstufung von Körperhaltungen bei der Arbeit nach der OWAS-Methode (in German with English summary). *Z. Arb. wiss* 39(1):31-38.

Stoffert, G. and U. Timme. 1989. Körperhaltungen bei Handarbeiten am Boden: Bücken, Hocken, Knien. *Z. Arb. wiss.* 43(2):96-105 (in German with English summary).

Stål, M., U. Moritz, B. Gustafsson and B. Johnsson. 1996a. Milking is a high-risk job for young females. *Scand J Rehab Med* 28:95-104.

Stål, M., U. Moritz, B. Johnsson and S. Pinzke. 1996b. Natural course of musculoskeletal symptoms and clinical findings in upper extremities of female milkers. *Int. J. Occup. Environ. Health* (Submitted)

Stål, M. and S. Pinzke. 1991. Working environment in dairy barns — Musculoskeletal problems in Swedish milking parlour operators. Report 80. Lund, Sweden: Department of Farm Buildings, The Swedish University of Agricultural Sciences (in Swedish with English summary).

Thelin, A. 1980. Work and Health Among Farmers — A Study of 191 Farmers in Kronoberg County, Sweden. *Scandinavian J. Social Medicine* Supplementum 22.

Tomlinson, R. 1970. The assessment of work load in agricultural tasks. *J. Institute of Agric. Engineering* 25:18-29.

Tracy, M. F. and E. N. Corlett. 1991. Loads on the body during static tasks: Software incorporating the posture targeting method. *Appl. Ergonomics* 22(6):362-366.

Tuure, V.-M. 1992. Determination of physical stress in agricultural work. *Int. J. Indust. Ergonomics* 10(4):275-284.

Törner, M. 1991. Musculo-skeletal stress in fishery — Causes, effects and preventive measures. PhD thesis. Department of Orthopaedics, University of Gothenburg, Göteborg, Sweden.

U.S. Department of Labor. 1989. *Occupational Injuries and Illnesses in the US by Industries.* Bureau of Labor Statistics Bulletin 2379:3-6. Washington, D.C.: U.S. GPO.

van der Beek, A. J., L. C. van Gaalen
and activities of lorry drivers: A rel
pocket computer. *Appl. Ergonomics*
van der Schilden, M. 1989. The O
Horticulturae 237:129-136.
van Dieen, J. H. 1993. Functional
Netherlands: Vrije University.
van Dieen, J. H. and V. H. Hildebra
Report 233. Wageningen, The Net
van Wely, P. 1970. Design and disease.
Wangenheim, M. and B. Samuelso
Ergonomics 18(1):9-15.
Westgaard, R. H. and A. Aarås. 19
development of musculo-skeletal ill
Wiktorin, C., M. Mortimer, L. Ekenv
computer-aided observation metho
Health 21(6):440-449.
Winkel, J. and S. E. Mathiassen. 199
studies: Concepts, issues and operat
Zegers, D. 1987. The application of
systems in the Dutch agriculture.
postures in agriculture and forestry", 2
Zhou, C. and J. M. Roseman. 1994. Ag
farm operators in Alabama. *Am. J. I*

OWAS

One of the most widely used
posture analysis system (OWAS)
OWAS method is based on work-s
leg positions) different combination
postures for the whole body. The
three-class scale. The analysis produ
spent in the individual positions.
harmfulness of these postures is ap
urgency are: 1 normal posture, 2
postures, and 4 extremely harmful p
From the beginning, the OWA
performed on special forms. Sever
method have been developed, e.g., (
al., 1992; Määttä, 1994), and OWA
The OWAS method has been u
(Engels et al., 1994), garage work
(Stoffert and Timme, 1989), buildi
al., 1993), work in health care opera
(Mattila et al., 1992), loaders o
manufacturing work (Burdorf et al.,
agricultural studies, e.g., in egg p
(Nevala-Puranen et al., 1996; Zege
1988; van der Schilden, 1989).

ng av en avlastningsarm som hjälpmedel
oad reducing device as an aid for milking
för lantbrukets byggnadsteknik, Sveriges

Iuman Factors 16(6):576-584.
A portable microcomputer based system
temporary Ergonomics, 366-371, ed. E. D.

1od. *Ergonomics* 28(1):245-254.
beitswissenschaftliche Erbunsverfahren zur
Huber.
T. Nakagawa and F. Kobayashi. 1987.
1ts of pear and apple orchard workers.

ranzblau. 1994. A computerized method
the workforce: A tool for surveillance.

actices in a perchery system, using the
VAS). *Appl. Ergonomics* 27(5):281-284.
Evaluation of Human Work: A Practical
1 and E. N. Corlett. London, England:

s, working postures — Overview of the
Symp. "Working postures in agriculture and
, Finland.
1993. A cube model for classification of
:tional requirements. *Appl. Ergonomics*

and J. A. Leonard. 1991. Observational
Occup. Environ. Hyg. 6(11):927-37.
rperhaltungen bei der Arbeit nach der
ary). *Z. Arb. wiss* 39(1):31-38.
bei Handarbeiten am Boden: Bücken,
man with English summary).
. 1996a. Milking is a high-risk job for

96b. Natural course of musculoskeletal
nities of female milkers. *Int. J. Occup.*

nt in dairy barns — Musculoskeletal
port 80. Lund, Sweden: Department of
gricultural Sciences (in Swedish with

- A Study of 191 Farmers in Kronoberg
pplementum 22.
1 agricultural tasks. *J. Institute of Agric.*

1e body during static tasks: Software
rgonomics 22(6):362-366.
ss in agricultural work. *Int. J. Indust.*

ry — Causes, effects and preventive
, University of Gothenburg, Göteborg,

es and Illnesses in the US by Industries.
ington, D.C.: U.S. GPO.

van der Beek, A. J., L. C. van Gaalen and M. H. W. Frings-Dresen. 1992. Working postures and activities of lorry drivers: A reliability study of on-site observation and recording on a pocket computer. *Appl. Ergonomics* 23(5):331-336.

van der Schilden, M. 1989. The OWAS system for analyzing working postures. *Acta Horticulturae* 237:129-136.

van Dieen, J. H. 1993. Functional load of the low back. PhD thesis. Amsterdam, The Netherlands: Vrije University.

van Dieen, J. H. and V. H. Hildebrant. 1990. Load on the back in the agricultural sector. Report 233. Wageningen, The Netherlands: Institute of Agricultural Engineering.

van Wely, P. 1970. Design and disease. *Appl. Ergonomics* 1(5):262-269.

Wangenheim, M. and B. Samuelson. 1987. Automatic ergonomic work analysis. *Appl. Ergonomics* 18(1):9-15.

Westgaard, R. H. and A. Aarås. 1984. Postural muscle strain as a causal factor in the development of musculo-skeletal illnesses. *Appl. Ergonomics* 15(3):162-174.

Wiktorin, C., M. Mortimer, L. Ekenvall, Å. Kilbom and W. Hjelm. 1995. HARBO, A simple computer-aided observation method for recording work postures. *Scand. J. Work Environ. Health* 21(6):440-449.

Winkel, J. and S. E. Mathiassen. 1994. Assessment of physical work load in epidemiologic studies: Concepts, issues and operational considerations. *Ergonomics* 37(6):979-988.

Zegers, D. 1987. The application of the OWAS & NIOSH working posture analyzing systems in the Dutch agriculture. In *Abstracts IXth Joint Int. Ergonomics Symp. "Working postures in agriculture and forestry"*, 29-30, CIGR/IAAMRH/IUFRO, Kuopio, Finland.

Zhou, C. and J. M. Roseman. 1994. Agricultural injuries among a population-based sample of farm operators in Alabama. *Am. J. Indust. Medicine* 25(3):385-404.

Appendix

OWAS

One of the most widely used method of observation is the Ovako working posture analysis system (OWAS) (Karhu et al., 1981, 1977; Stoffert, 1985). The OWAS method is based on work-sampling from 84 (4 back positions, 3 arm, and 7 leg positions) different combinations and 5 head positions defined as typical working postures for the whole body. The use of strength (load/weight) is classified by a three-class scale. The analysis produces the frequency and relative proportion of time spent in the individual positions. A four-action category scale with respect to the harmfulness of these postures is applied in the method. The categories in order of urgency are: 1 normal posture, 2 slightly harmful posture, 3 distinctly harmful postures, and 4 extremely harmful postures.

From the beginning, the OWAS system was manual and the registration was performed on special forms. Several computerized systems based on the OWAS method have been developed, e.g., (Long, 1992), the ERGOKAN method (Kant et al., 1992; Määttä, 1994), and OWASCO/OWASAN (Leskinen and Tönnes, 1994).

The OWAS method has been used in many different occupations; e.g., nursing (Engels et al., 1994), garage work (Kant et al., 1990), handwork on the ground (Stoffert and Timme, 1989), building industry (Kivi and Mattila, 1991; Mattila et al., 1993), work in health care operating room (Kant et al., 1992), papermill industry (Mattila et al., 1992), loaders of aircraft (Landau and Wendt, 1995), and manufacturing work (Burdorf et al., 1991). OWAS has also been frequently used in agricultural studies, e.g., in egg production (Scott and Lambe, 1996), milking (Nevala-Puranen et al., 1996; Zegers, 1987), and in greenhouse work (Lundqvist, 1988; van der Schilden, 1989).

WOPALAS

The WOPALAS method (Working Posture Analyzing System) was developed by KTH (Royal Institute of Technology in Stockholm) (Hellsten, 1985). WOPALAS is more detailed than OWAS regarding registration of the different body parts and the load/weight classes. Accordingly, WOPALAS contains 4 back positions, 4 left arm positions, 4 right arm positions, 13 leg positions, 5 head positions and 6 load/weight classes. Besides postures and outer loads/weights, the system takes the influence of static work into account. WOPALAS has the same treatment classification as OWAS.

A manual OWAS or a WOPALAS study is performed by registering the working postures either directly at the working site or by video technique. The limb's positions, outer force, weight or load, as well as whether the working posture are static, are noted on special forms. The frequencies of the limb's positions are calculated at the end of the study. The frequencies are recalculated to percentages that are entered on pre-printed forms where the four treatment grades as described previously are displayed.

The WOPALAS method has been computerized (Pinzke, 1994). The program contains screen images for registering the different working postures with the computer's mouse or keyboard. The program also provides the possibility of entering working postures using bar codes. Each defined position (and whether it is static) of a particular limb has a four digit code. Likewise, weights and work codes are assigned codes that are entered into the computer. The program sums up the positions of each limb and weights/forces. Then percentages for each position are determined after correction for weights/forces. The number and percentages are entered as actual values. In addition, the action categories according to the WOPALAS system are indicated.

The WOPALAS system has been used in studies of agricultural and industrial workplaces and work operations, e.g., in farm buildings (milking cows, collecting eggs), slaughter house (slaughtering pigs, sorting meat), and grocery store (handling meat, cashier work) (Lundqvist, 1990), evaluation of a multifunction material handling machine (Hellsten and Axelsson, 1996), and design of checkout systems (Johansson, 1996).

TRAM

TRAM is a technique for recording and analyzing moving work postures (Milner, 1980). It is a pen and paper technique that consists of posture recording, load and posture severity assessment, and a checklist of workstation factors. The postures are representing codes from a series of basic postures (similar to the OWAS postures) and the potential body weight bearing parts of the body. The load and posture severity are also registered using a three-point scale. A checklist is included in the TRAM system representing the environment of the subjects at the work situation, together with factors such as lighting, noise and climate. The results of the posture observations and the load and posture severity are presented as histograms. By inspecting the histograms, a qualitative evaluation can be made and postural problems can be located.

ARBAN

ARBAN is a video-based method for analysis of ergonomic effort (Holzmann, 1982; Holzmann and Wangenheim, 1983; Milner, 1980). After recording the workplace situation on videotape, the postures, static muscle load, dynamic muscle

force, and vibration are coded and
to the effort as perceived in diffe
using computer facilities that cal
body and present the results as ti
The ARBAN system has mainly

RULA

The RULA method (Rapid U
of the loads on the musculoskele
forces they exert (McAtamney an
amount of a work cycle or where l
system, including the posture, the
arm, the wrist and twisted wrist,
four-coded action list similar to th

Keyserling-system

Keyserling and co-workers ha
trunk and shoulder (Keyserling,
videotape to record the jobs and
and posture data. The computer
for the trunk, 3 shoulder postures
which key is pressed (each of th
posture change. After registration
profile of time in each posture an
each respective joint. The postu
gives a more detailed description c

PWSI

An observational technique fo
(Chen et al., 1989). The techn
including body location, support b
acceleration, and thermal load. T
values from a four-graded scale.
computer resulting in an overall p
means high dynamic work stress
The system also provides a weigh
angles represent the component w

VIRA

VIRA is a video technique for
and postures (Kilbom et al., 198
developed to register movements a
for short-cycle, relatively rapid,
movements are registered using vi
the videofilm is shown on a TV
into a computer. Each separate po
ranges shown on the video film ha
registers time and which key is d
work-cycle time, time at rest, freq
each posture.

force, and vibration are coded and rated using the Borg's RPE scale (Borg, 1985) due to the effort as perceived in different parts of the body. The recordings are analyzed using computer facilities that calculate the ergonomic stress in different part of the body and present the results as time curves where heavy load situations can be read. The ARBAN system has mainly been used in analysis of building work.

RULA

The RULA method (Rapid Upper Limbs Assessment) provides a rapid assessment of the loads on the musculoskeletal system due to posture muscle function and the forces they exert (McAtamney and Corlett, 1993). The posture held for the greatest amount of a work cycle or where highest loads occur is selected and assessed. A coding system, including the posture, the muscle use and the forces for the upper and lower arm, the wrist and twisted wrist, the neck, trunk and the legs, is used to generate a four-coded action list similar to the one of the OWAS system.

Keyserling-system

Keyserling and co-workers have presented a system for postural analysis of the trunk and shoulder (Keyserling, 1986; Keyserling et al., 1988). The system uses a videotape to record the jobs and a personal computer for collecting recording time and posture data. The computer keyboard is used to enter the standard postures (9 for the trunk, 3 shoulder postures) as the videotape is played. The computer registers which key is pressed (each of the postures is assigned a key) and the time of the posture change. After registration is performed the computer can generate a posture profile of time in each posture and the number of times the posture was entered for each respective joint. The posture classification concept is similar to OWAS but gives a more detailed description of trunk and shoulder postures.

PWSI

An observational technique for physical work stress analysis has been described (Chen et al., 1989). The technique involves the process of activity sampling, including body location, support base, orientation, hand position, external work load, acceleration, and thermal load. The components are entered into a computer with values from a four-graded scale. The values are weighted and processed by the computer resulting in an overall power work stress index (PWSI). High PWSI value means high dynamic work stress and low PWSI might be high static work stress. The system also provides a weighted polar co-ordinate graph in which the sector angles represent the component weights and the radii represent the measured values.

VIRA

VIRA is a video technique for registration and analysis of working movements and postures (Kilbom et al., 1986a; Persson and Kilbom, 1983). VIRA has been developed to register movements and postures of the head, shoulder and upper arm for short-cycle, relatively rapid, repetitive seated assembly work. The working movements are registered using video cameras in a rear and side projection. While the videofilm is shown on a TV monitor the registration of the movements is fed into a computer. Each separate posture according to the positions in various angle ranges shown on the video film has a different key on the keyboard. The computer registers time and which key is depressed and after evaluation gives a list of, e.g., work-cycle time, time at rest, frequency of changes in postures, and the duration of each posture.

VIRA has been used in several studies of repetitive industrial work (e.g., Bao, 1995; Ohlsson, 1995). A method similar to VIRA is included in a computerized system for work analysis called Frequency and Load moment (Pinzke, 1994).

PEO

A portable ergonomic observational method (PEO) is used for recording postures and manual materials handling (Fransson-Hall et al., 1995). The observations are registered continuously on a computer in real-time at the worksite. Changes in posture and movements (arms, neck, trunk, kneeling/squatting) and manual handling activities (lifting, carrying, pushing, pulling) are registered. The computer program can calculate exposure estimates of a "typical" work week for a job with the registered exposure data combined with information on all work tasks included in the job obtained by interviews. The PEO method has been used in studies of materials handling in different jobs (e.g., Karlqvist, 1995).

A variant of PEO is the HARBO method (HAnds Relative to the Body) (Mortimer et al., 1994; Wiktorin et al., 1995) that observes the position of the hands and the duration of work tasks.

HAMA

The HAMA method (Hand-Arm-Movement-Analysis) was developed for analysis of upper limb movements and risk for work-related musculoskeletal disorders (Christmansson, 1994). The method is based on recording the type of basic motion [based on the Method-Time-Measurement (MTM) system (Hasselqvist et al., 1962)], type of grasp, position of the upper limb, external load and perceived exertion [the analyzed worker's rating using Borg's RPE-scale (Borg, 1985)]. The duration, frequency and working time for different motions and working postures can be obtained.

TRAC

The Robens Institute (University of Surrey, UK) developed an observational system that was first called ROTA (the Robens Occupation and Task Analysis system) and later Task Recording and Analysis on Computer (TRAC) (Ridd et al., 1989). The observations are performed directly at the workplace and recorded in real time on a pocket computer. The keys on the keyboard can be defined freely due to the variables and the categories within variables to be recorded at the workplace. The data from the pocket computer are transferred to a personal computer for analysis. Frequencies of activities and information on the sequence of activities and their duration can be provided. The TRAC system has been tested in different studies (e.g., Beck and Chaffin, 1992; Frings-Dresen et al., 1995a; van der Beek et al., 1992).

The Observer

The Observer is a software system for observing, coding and analyzing series of events and duration of observed events (Noldus Information Technology, 1996). The system is widely used in experimental psychology and zoology but is also suitable in the ergonomic field (Hikspoors et al., 1995). It permits measurement of activities, postures, movements, positions and other aspects of human or animal behavior. The events can be registered either directly into a PC or Macintosh computer or into a range of different hand-held computers. The system also supports event coding and analyzing of video tapes. The Observer system includes several sampling methods. Events, notes and comments are recorded by pressing appropriate keys when an

event occurs. The data can be anal
frequencies and duration, the se
occurrence of events can be obtaine

Graf's Method

A system for an assessment of s
on studies at five workplaces (Graf
this method consists of 68 differen
shoulder positions, 2 spine, 3 tru
manually or by bar-codes for aut
histograms showing the frequenci
tasks, frequency of kyphotic and tw
the frequency of the various th
calculated.

Stetson's Method

Stetson and co-workers have pre
hand and wrist (Stetson et al., 1991
later by observing a videotape, to fi
the total number of hand exertior
associated with high force or advers
be used for characterization of h
evaluations and exposure assessmen

The Cube Model

A cube model for classification
functional requirements is describe
cube model are demands of force, p
high demands, respectively. The cu
different combinations of demands.
situated in different subcubes. The
authors. An analysis includes the ha
and the user of the hand tool.

Foreman's System

A posture and activity classific
developed (Foreman et al., 1988). A
different postures and activities is e
observed activity or posture chang
frequency and the duration of the st
study of nursing activities (Foreman

AET

AET (Arbeitswissenschaftlishes
comprehensive system of work an
1979). The basic AET-system conta
working system, the task analys
development of the job demand ana
to AET (called H-AET) is divic
anthropometric data of the working

event occurs. The data can be analyzed in time-event tables and plots. Statistics on frequencies and duration, the sequential structure of the process, or the co-occurrence of events can be obtained.

Graf's Method

A system for an assessment of seated activity and postures was developed based on studies at five workplaces (Graf et al., 1995). The posture classification system in this method consists of 68 different positions (a selection of the combination of 2 shoulder positions, 2 spine, 3 trunk, and 6 leg positions). Data can be recorded manually or by bar-codes for automatic entry into a laptop computer. Different histograms showing the frequencies of various sitting positions during different tasks, frequency of kyphotic and twisted postures, frequency of position change and the frequency of the various thigh positions at different workplaces can be calculated.

Stetson's Method

Stetson and co-workers have presented a system for observational analysis of the hand and wrist (Stetson et al., 1991). An analyst has, either directly at the job site or later by observing a videotape, to fill in a data collection form with information on the total number of hand exertions per work cycle and the number of exertions associated with high force or adverse postures. The authors claim that the results can be used for characterization of high-risk jobs, pre and post-job intervention evaluations and exposure assessment for epidemiological research.

The Cube Model

A cube model for classification of work with hand tools and the formulation of functional requirements is described (Sperling et al., 1993). The dimensions of the cube model are demands of force, precision and time, divided into low, moderate and high demands, respectively. The cube model consists of 27 subcubes representing different combinations of demands. Tools of different shape and utilization will be situated in different subcubes. The limits for the dimensions are described by the authors. An analysis includes the hand tool, the manual task, the work organization, and the user of the hand tool.

Foreman's System

A posture and activity classification system similar to the VIRA method was developed (Foreman et al., 1988). A two-letter mnemonic activity code representing different postures and activities is entered on the computer keyboard each time the observed activity or posture changed. The system of analysis is able to show the frequency and the duration of the studied activities. The system has been tested in a study of nursing activities (Foreman and Troup, 1987).

AET

AET (Arbeitswissenschaftlishes Erhebungsverfahren zur Tätigkeitsanalyse) is a comprehensive system of work analysis (Rohmert, 1985; Rohmert and Landau, 1979). The basic AET-system contains 216 items that are divided in three parts, the working system, the task analysis and the analysis of demands. A further development of the job demand analysis part has been carried out. This supplement to AET (called H-AET) is divided in two parts, one containing analysis of anthropometric data of the working system and the other part containing analysis of both static and dynamic components of activity. The AET-method requires a trained analyst to perform both observations and interviews. The AET users can process the recorded data statistically as described in the handbook for the system that covers analysis of frequency, profile analysis, cluster and factor analyzes.

Computerized routines (JobExpert and ABBA) based on AET have been developed (Landau, 1995). These programs provide analysis of the workplace and loads involved and give a profile of the work. AET has been used for analysis of activities in farming and forestry (Landau and Reus, 1979).

EWA

The system for ergonomic workplace analysis (EWA) was developed in Finland (Ahonen et al., 1989). Observations and interviews are used to provide a description of the task and workplace. The workplace is analyzed according to the following 14 different items: worksite, physical activity, lifting, work postures and movements, accident risk, job content, job restrictiveness, communication and contacts, decision-making, repetitiveness of the work, attentiveness, lighting, thermal environment, and noise.

The analyst rates the various factors on a five-graded scale ranged from good to bad work conditions and arrangements. The ratings are written on special forms which together give a profile of the work task. A rating of 4 or 5 indicates that the work conditions could be harmful to the worker's health and therefore special measures are needed to change the work conditions or the work environment.

EWA has been used in several studies, e.g., in a study of women in the fish processing industry (Ohlsson, 1995).

PLIBEL

PLIBEL (Kemmlert and Kilbom, 1987) is a screening method for the identification of ergonomic hazards which may have injurious effects. It is a easy to use tool in the form of a checklist for workplace investigations. The checklist consists of questions on a register-chart concerning awkward working postures, tiresome work movements, poor design of tools or workplace and stressful environmental or organizational conditions. The questions are related to musculoskeletal stress factors on five body regions. PLIBEL has been tested for validity and reliability and been applied in several ergonomic studies and also for education (Kemmlert, 1995).

Characteristics
Work-related
Farm Op

L. Stall

Numerous studies have r
detailed information related t
relation to the risk of farm w
risk of injury associated with
male resident farm operators
related injuries were the numb
ratio 3.25, 95% confidence int
animals including beef, dairy,
interval 1.01, 21.25). Organo
previous 12 months were asso
when considered in a logistic r
related variables listed above.
exposure to the neurotoxic ca
confidence interval 0.59, 6.94)
analysis (odds ratio 1.47, 95% c

Keywords. Injuries, Pesticide

Farming is a hazardous oc
100,000 deaths and 387
Kentucky, relative risks of
a high of 1.9 on animal speci
(Stallones, 1990). Active surve
between 1984-1989 indicated 4
farm equipment, usually tractors
being caught in machinery (CD
animals as agents of injury amo
1990; Zhou et al., 1994; Brison et
Specific farm types which h
include dairy, forestry, and be

The authors are Lorann Stallones, Ph
Center), Thomas J. Keefe, PhD, Profess
University, Department of Environmental
Stallones, Director, Colorado Injury Con
Colorado State University, Fort Collins, C
mail: <lstallones@vines.colostate.edu>.

This work was conducted at the Color
Colorado State University and was suppor
National Institute of Occupational Safety ar