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Postural assessment in pen-and-paper-based observational methods and their associated health effects: a review

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Introduction. This review describes standardized ergonomics assessment based on pen-and-paper observational methods for assessing ergonomics risk factors. *Objective*. The three main objectives are to analyze published pen-and-paper observational methods, to extract and understand the risk levels of each method and to identify their associated health effects. *Methodology*. The authors searched scientific databases and the Internet for materials from 1970 to 2013 using the following keywords: ergo, posture, method, observational, postural angle, health effects, pain and diseases. Postural assessments of upper arms, lower arms, wrists, neck, back and legs in six pen-and-paper-based observational methods are highlighted, extracted in groups and linked with associated adverse health effects. *Results*. The literature reviewed showed strengths and limitations of published pen-and-paper-based observational methods in determining the work activities, risk levels and related postural angles to adverse health effects. This provided a better understanding of unsafe work postures and how to improve these postures. *Conclusion*. Many pen-and-paper-based observational methods have been developed. However, there are still many limitations of these methods. There is, therefore, a need to develop a new pen-and-paper-based observational method for assessing postural problems.

Keywords: posture; observational method; risk factors; health effects

1. Introduction

Posture is one of the most important factors that need to be considered in any postural analysis. Awkward, extreme and repetitive postures can increase the risk of musculoskeletal disorders (MSDs). Many researchers have studied ergonomics exposure measurement techniques in order to solve these problems.[1,2] Exposure measurement techniques can be divided into two types: indirect and direct techniques. The indirect technique consists of a self-reported questionnaire or a subjective evaluation, whereas the direct technique involves trained observers or video recordings. The direct technique can be used to measure ergonomics risk factors directly on a person who is at risk by using instruments such as electromyography, goniometry and an inclinometer.[3]

The direct measurement technique is considered a 'gold standard' in assessing biomechanical or physical exposures due to its validity and reliability characteristics.[4,5] However, limitations of its application are obvious where it has human involvement and it is equipment oriented.[6] On the other hand, the indirect measurement technique in an occupational setting is widely used for assessing biomechanical exposures.[7–10] This technique is used widely because it is cheap, user-friendly, applicable, repeatable in various conditions, does not interfere with workers' work and is an easy way to store and analyze data.[7,11,12]

Corlett et al. [13] mentioned that human movement is one of the most important factors that need to be considered in workload assessment. Most of the time, the whole body is involved during work. Methods to assess whole body posture are selected and discussed to understand the human body movement.[14] Dynamic and whole body posture assessment methods are then categorized into a pen-and-paper-based observational method due to its ability to handle postural data in real time and the avoidance of observer bias, as body movements can be recorded without the presence of an observer.[12]

In spite of the popularity and applicability of indirect measurement techniques as a method for conducting ergonomics assessment in the workplace, there have been very few studies that revealed the association between the developed postural assessment and its associated health effects. The present study was carried out to achieve the following three main objectives: to analyze the published pen-and-paper-based observational methods for assessing posture; to extract and understand the risk levels of each method; and to identify their associated health effects from published epidemiological studies and relate them to each risk level of postures.

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2. Methodology

English and Malay articles dated as far back as 1970 were compiled from PubMed, Science Direct and Google Scholar. The keywords used in the selection of the articles were ergo, posture, method, observational, postural angle, health effects, flexion, pain or discomfort, and diseases. In addition, a secondary search was also performed using references of retrieved articles to search for additional papers in conducting review and evaluations. Posture of the upper arms or shoulders, lower arms or elbows, wrists, neck, back or trunk and legs from six pen-and-paper-based observational methods were highlighted in this study. The postural assessments in each method were extracted and placed into groups. The postural angles were then linked with the gathered associated health effects.

3. Results

A total of 121 articles that assessed postural problems in work activities were found. However, after several intensive screening processes, only six articles regarding dynamic and whole body posture using the pen-and-paper-based observational methods were selected for further analysis. The selected methods are workplace ergonomic risk assessment (WERA),[15] quick exposure check (QEC),[16] rapid entire body assessment (REBA),[17] Ovako working posture assessment system (OWAS),[18] posture, activity; tools and handling (PATH) [19] and *Plan för Identifiering av. Belastningsfaktorer* (PLIBEL).[20] The authors will discuss in detail all six methods, the risk posture categorization and the associated health effects in the following paragraphs.

WERA is a tool developed by Rahman et al.[15] Its assessment provides a good indication of work-related musculoskeletal disorders (WMSDs) such as pain, ache or discomfort in the relevant body regions. It has a moderate reliability and has been proven easy to use.[21] The second method, QEC, is a tool developed at the Robens Centre for Health Ergonomics in the United Kingdom [22] and has been improvised several times.[22,23] The tool was tested in terms of its validity and reliability using both intra-observer and inter-observer methods. The QEC was found to have high sensitivity and reliability.[12] Thirdly, REBA by Hignett and McAtamney [17] was developed on the basis of the rapid upper limb assessment (RULA) system.[24] When using REBA, an observer has to select the activity to be assessed.[12] The application of REBA can be seen in the studies of Janowitz et al. [25] and Jones and Kumar.[26] The next method, OWAS, was developed in a steel company.[18] Mattila et al. [27] discovered that OWAS can assess perceived postural problems and discomforts well. OWAS is widely used and well documented [14] and many case studies of ergonomic applications have been reported using this assessment system.[27,28] The next method, PATH is a work sampling-based approach and was developed by Buchholz et al.[19] PATH is found to be reasonably valid and reliable in a preliminary study by Buchholz et al.[19] The sixth method, PLIBEL is a method assigned for identification of ergonomics hazards which consists of an observational checklist to identify ergonomics risk factors for MSDs. It was developed by Kemmlert.[20] This method involves assessments of posture, workplace and tools used. Each and every one of these six methods has their own scoring system and action levels which provide detection of the level of risk. All six methods suggest actions to be taken in conducting more detailed assessments.

Table 1 summarizes the selected pen-and-paper-based methods and the body regions assessed in the methods. It can be seen that only REBA covers all body regions (upper arms or shoulders, lower arms or elbows, wrists, back or trunk and legs). Meanwhile, WERA and QEC do not assess the lower arms or elbows and QEC does not assess legs. For OWAS, assessments of the wrists and neck are missing. For PATH and PLIBEL, the postural assessment of the wrists is not available.

The postures of body regions are categorized into risk levels. The categorization is done to make the assessment quantifiable. The following paragraphs discuss how each body region is ranked to set the level of risk for a certain posture.

The categorization of risk levels for upper arms or shoulders for the selected pen-and-paper-based observational methods is presented in Table 2. There are three levels of risk for categorizing the upper arm or shoulder posture in WERA, QEC, OWAS and PATH. Meanwhile, in OWAS the assessment is divided into four levels. For PLIBEL, a general checklist was adopted. OWAS and WERA ranked maximum exposure level at 45° (elbow joint) and REBA and PATH ranked shoulder abduction $>90°$ as the most hazardous posture. To identify the risk levels in each method properly, postures and their related health effects are needed (Table 3).

Table 1. Pen-and-paper-based dynamic observational method to assess posture and the body region.

	Body region					
Method	Upper arms/ shoulders	Lower arms/ elbows	Wrists	Neck	Back/ trunk	Legs
WERA	/	–	/	/	/	/
QEC	/	–	/	/	/	–
REBA	/	/	/	/	/	/
OWAS	/	/	–	–	/	/
PATH	/	–	–	/	/	/
PLIBEL	/	/	–	/	/	/

Note: / = can be evaluated using the method; – = cannot be evaluated using the method; WERA = workplace ergonomic risk assessment; QEC = quick exposure check; REBA = rapid entire body assessment; OWAS = Ovako working posture assessment system; PATH = posture, activity; tools and handling; PLIBEL = *Plan för Identifiering av. Belastningsfaktorer*.

Table 2. Upper arms/shoulders: posture and risk level.

Method	L1	L2	L3	L4	Additional information
WERA	Hand is at about waist level	Shoulders are moderately bent up ≤ 45°	Shoulders are extremely bent up > 45°	–	Considers repetition, force
QEC	At or below waist height?	At about chest height?	At or above shoulder height	–	–
REBA	20° (back–forward)	20 to 45° (back–forward)	45 to 90° (back–forward)	> 90°	Considers if shoulders are raised, upper arms are abducted, arms are supported or person is leaning – coupling
OWAS	Both below the elbow joint	One below the elbow joint	Both above the elbow joint	–	Upper and lower arms are combined
PATH	Neutral: both arms below shoulder height	One arm raised: one elbow above shoulder height	Two arms raised: both elbows above shoulder height	–	Upper and lower arms are combined
PLIBEL	Checklist: neck/ shoulders/upper back				

Note: L = level; WERA = workplace ergonomic risk assessment; QEC = quick exposure check; REBA = rapid entire body assessment; OWAS = Ovako working posture assessment system; PATH = posture, activity, tools and handling; PLIBEL = *Plan för Identifiering av. Belastningsfaktorer*.

Table 3. Upper arms/shoulders: description and associated health risk.

Posture	Health risk	Reference
Prolonged abduction of > 30°	Neck/shoulder pain	[29]
Work involving repeated or sustained flexion of the arm > 60°	Shoulder disorders	[30]
Prolonged elevation > 90°	Shoulder disorders	[31,32]
Shoulder flexion 120°	Muscle fatigue	[33]
Handling heavy loads or high force	Shoulder disorders	[34]

In the developmental stage of WERA, Rahman et al. [15] found that observers faced difficulties to define shoulder angular range in their reliability study. At first, Rahman et al. [15] decided to categorize shoulder risk into three levels: low (0 to 20° extension), medium (> 20 to 45°) and high (> 45°). Because of this, they finalized shoulder postural assessment using verbal description since this approach has been validated by David et al.[23] In addition, Li and Buckle [12] also claimed that practitioners prefer the use of descriptive words over specific postures quantified in degrees.

Previously, prolonged upper arm abduction > 30° was shown to have an association with neck and shoulder pain.[30] For the combination of shoulder posture and repetition, > 60° of upper arm flexion [29] and shoulder abduction at 90° and above [33,34] have proven to be associated with shoulder disorders. Shoulder abduction ≤ 120° should be avoided because it could impair muscle metabolism due to restricted muscle blood flow.[31]

The risk levels for lower arms are presented in Table 4. In OWAS and PATH, lower arm assessment is actually the same assessment used to assess upper arm or shoulder exposure. However, in WERA and QEC, wrist assessment is missing. In PLIBEL, there is a specific checklist for assessing lower arms. There are many studies on posture of the lower arms and the associated health risk as summarized in Table 5. It was found that working with lower arms

Table 4. Lower arms: posture and risk level.

Method	L1	L2	L3	Additional information
WERA, QEC	–	–	–	–
REBA	–	Flexion 60 to 100°	Flexion < 60° or > 100°	–
OWAS	Both below the elbow joint	One below the elbow joint	Both above the elbow joint	Upper and lower arms are combined
PATH	Neutral: both arms below shoulder height	One arm raised: one elbow above shoulder height	Two arms raised: both elbows above shoulder height	Upper and lower arms are combined
PLIBEL	Checklist: lower arms			

Note: L = Level; WERA = workplace ergonomic risk assessment; QEC = quick exposure check; REBA = rapid entire body assessment; OWAS = Ovako working posture assessment system; PATH = posture; activity, tools and handling; PLIBEL = *Plan för Identifiering av. Belastningsfaktorer*.

Table 5. Lower arms: description and associated health risk.

Posture	Health risk	Reference
Forearms working at shoulder height (females)	Muscle fatigue	[36]
Arms above shoulder level	Shoulder pain	[11,32]
Elbows above shoulder height > 10% of total work time	Shoulder disorders	[35]
45° arm elevation 5 to 10% of the observation time	No indication of health risk	[37]

or elbows above shoulder height is associated with muscle fatigue or shoulder pain.[11,35–37] This association can be seen in the classification of REBA where the most severe posture of the lower arms is when the arm is flexed > 100° and in PATH when both arms are raised above shoulder height. Referring to Table 4, the lowest risk level for lower arms is the location below elbow joint [18] and this was found to corroborate with Westgaard's [37] findings.

In postural analysis in WERA, the risk for wrists is divided into three levels which are neutral, moderately bent up or down and extremely bent up or down as shown in Table 6. The assessment has considered repetition of body movements. This is the same in the assessment for upper arms or shoulders in WERA. For wrist posture, Rahman et al. [15] also found that observers faced difficulties in defining the wrist angular range in their reliability study. Because of this, Rahman et al. [15] finalized wrist postural assessment using descriptive terms to represent those angles, since this approach has been validated.[23] For QEC, the risk levels for wrists are quite simple and basic whereby linguistic descriptors such as 'almost a straight wrist' or 'with a deviated or bent wrist' were used. This application was also problematic in estimating a specific angular value in the early QEC development.[23] In REBA, the assessment is only concerned with two conditions objectively (≥ 15° flexion) but additional scores will be given if the wrist posture is bent or twisted.

For wrist posture and its association with health effects (Table 7), flexion and extension activity in unsafe conditions is harmful to the wrist area.[38–41] A simulation study to determine the load on the forearm during typing activities discovered that wrist extension to 30° may lead to MSDs of upper extremities.[42] There is also strong evidence that the combination of awkward wrist posture, force, repetition and duration [29,43] and the combination of awkward wrist posture, repetition and force [43] are associated with MSDs. Armstrong et al. [43] found that the prevalence of carpal tunnel syndrome has increased from 0.6% to 5.1% from low-force or low-repetitive jobs to high-force/high-repetitive jobs. Weight handling was also found to be a significant risk factor of WMSDs for the upper arm and shoulder area.[29] In addition, force specifically in weight handling has been accounted for in QEC, combined with the assessment of wrists.

Table 8 summarizes posture for the neck and its risk levels. In the early development of QEC and WERA, observers found it difficult to estimate a specific neck angle. Therefore, instead of using an angular range, David et al. [23] and Rahman et al. [15] used descriptive terms to represent the level of the neck risk factor. On the WERA sheet, however, an illustration to portray their descriptive terms for each risk level is provided. The observers will, therefore, have better understanding to conduct assessment. Specifically for neck assessment, besides posture

Table 7. Wrists: description and associated health risk.

Posture	Health risk	Reference
Flexed or hyperextended wrists	Wrist and arm pain	[33]
Flexion and extension activity	Muscle disorders	[38–41]
Wrist extension 30°	Muscle disorders	[42]
Combination of awkward posture, force, repetition and duration	Wrist disorders	[29,43]
Combination of awkward posture, repetition and force	Carpal tunnel syndrome and repetitive strain injury	[44]
High force/high repetitive/vibration	Carpal tunnel syndrome	[43]
Heavy loads or high force	WMSDs	[29]
Low levels of wrist exposure (movement rates up to 10 times/min)	WMSDs	[45]

Note: WMSD = work-related musculoskeletal disorder.

Table 6. Wrists: posture and risk level.

Method	L1	L2	L3	Additional information
WERA	Neutral posture	Moderately bent up/down	Extremely bent up/down	Considers repetition
QEC	Almost straight wrist	Deviated or bent wrist	–	–
REBA	15° flexion	> 15°	–	Considers wrist is bent or twisted
OWAS, PATH, PLIBEL	–	–	–	–

Note: L = level; WERA = workplace ergonomic risk assessment; QEC = quick exposure check; REBA = rapid entire body assessment; OWAS = Ovako working posture assessment system; PATH = posture, activity, tools and handling; PLIBEL = *Plan för Identifiering av. Belastningsfaktorer*.

Table 8. Neck: posture and risk level.

Method	L1	L2	L3	Additional information
WERA	Neutral or little bent forward (0 to 10°)	Moderately bent forward (10 to 20°)	Extremely bent forward/bent back (> 20°)	Considers repetition
QEC	Not bent or twisted	Occasionally bent or twisted	Continuously bent or twisted	Considers duration and visual demand
REBA	0 to 20° flexion	> 20° flexion/extension	–	Considers twisting or side flexed
OWAS	–	–	–	–
PATH	Lateral bending < 30° or twisting < 45°	lateral bending > 30° or twisting > 45°	–	–
PLIBEL	Checklist: neck/shoulders/upper back			

Note: L = level; WERA = workplace ergonomic risk assessment; QEC = quick exposure check; REBA = rapid entire body assessment; OWAS = Ovako working posture assessment system; PATH = posture, activity, tools and handling; PLIBEL = *Plan för Identifiering av. Belastningsfaktorer*.

itself, repetition can be assessed in WERA, and exposure duration and visual demand can be measured using QEC.

Based on the literature, WERA and REBA ranked neck flexion of > 20° as the most severe posture for the neck.

Table 9. Neck: description and associated health risk.

Posture	Health risk	Reference
Head/neck extension	Neck pain	[53]
Flexion 20 to 45°	Mild neck flexion	[46]
	Neck pain	[47,48]
Flexion > 45°	Severe neck pain	[46]
	Neck pain	[49]
Twisting and/or lateral bending > 20°	Increased occurrence of neck and shoulder symptoms	[50]
Task duration	WMSDs	[29,46,51,52]

Note: WMSD = work-related musculoskeletal disorder.

As presented in Table 9, Keyserling et al. [46] ranked neck flexion of > 45° as severe, and neck flexion of 20 to 45° is ranked as mild. However, studies by Huiting et al. [47] and Kilbom et al. [48] found that 20 to 40° of neck flexion is associated with neck pain. In fact, neck flexion of > 45° would cause pain after only 15 min of exposure.[49] In PATH, flexion > 30° or neck twisting > 45° is the most hazardous posture and movement. Meanwhile Tola et al. [50] found that neck twisting and/or lateral bending of > 20° increased the occurrence of MSDs. For neck and trunk posture, duration of exposure is very important to consider in the ergonomics assessment methods.[29,46,51,52]

Risk levels for trunk posture are presented in Table 10. WERA and REBA have the same classification of risk levels for the trunk, but WERA additionally considers repetition and REBA considers trunk posture of > 60° forward and whether the trunk is twisted or side bent. In

Table 10. Trunk: posture and risk level.

Method	L1	L2	L3	L4	L5	Additional information
WERA	Neutral = 0°	Moderate = 0 to 20° forward	Extreme = 20 to 60° forward	–	–	Considers repetition and force
QEC	Almost neutral	Moderately flexed or twisted or side bent	Excessively flexed or twisted or side bent	–	–	–
REBA	0°	0 to 20° (back– forward)	20 to 60° (back–forward)	> 60°	–	Considers twist and side bending
OWAS	Upright posture	Leaning forward	Flexuous	Leaning forward and flexuous	–	–
PATH	Flexion, lateral bend and twist < 20°	Flexion: 20 to 45°	Flexion > 45°	Flexion < 20° and lateral bend/twist > 20°	Forward flexion and twisting > 20°	–
PLIBEL	Checklist: upper part of back, lower part of back					

Note: L = level; WERA = workplace ergonomic risk assessment; QEC = quick exposure check; REBA = rapid entire body assessment; OWAS = Ovako working posture assessment system; PATH = posture, activity, tools and handling; PLIBEL = *Plan för Identifiering av. Belastningsfaktorer*.

WERA, however, the classification of the trunk posture combines verbal description and a simple postural angle. Li and Buckle [12] also suggested that practitioners prefer the use of descriptive words over specific postures quantified in degrees, which can also be found in QEC and OWAS. Meanwhile, the risk level of the trunk in PATH is quite detailed (neutral = forward flexion, lateral bending and twisting < 20°; moderate = flexion > 20 to 45°; severe = forward flexion > 45°, forward flexion < 20° and lateral bending or twisting > 20°, forward flexion and twisting > 20°).

Table 11 shows that many researchers have linked trunk flexion with MSDs.[51,54–56] In dynamic physical work, trunk twisted or bent postures were found to be related to the neck and shoulder symptoms when compared with office work.[50] When the movement of the trunk is considered, fast trunk flexion or extension is shown to be associated with low back disorders [55,56] and sustained neck or trunk twisting was also found to be risky to the neck and shoulders.[33] Bovenzi et al. [60] found that, while driving, trunk bending of 20 to 40° and at the same time the back being bent forward or twisted is significantly associated with low back pain (LBP). Trunk flexion > 20° for one-third of work time was also found to be harmful to the back [46,51] and Bovenzi et al. [60] predicted that trunk flexion of 40° forward causes LBP.

Keyserling et al. [46] developed a checklist for assessing ergonomic risk factors. In their study, trunk forward flexion > 45° was considered severe bending. This condition was also considered as discomfort,[58] biomechanical pressure on muscle and tendon [59] and associated with low back disorder when combined with unbalanced postures.[55] For trunk posture, it is very important to consider the duration of exposure in the assessment.[29,46,51,52] Rahman et al. [15] combined the assessment of trunk with load handled in WERA. This approach is considerably great, whereby to consider force in the assessment of the trunk is also vital.[29]

The classification of leg posture in pen-and-paper-based methods can be seen in Table 12. Basically, WERA and REBA have applied the same risk classification (neutral, moderate bending and extreme bending), except that in the third level of risk classification of WERA sitting with feet not touching the floor can also be assessed and ranked. Meanwhile, OWAS applied verbal descriptions totally but the risk of working with one leg bent, kneeling and walking was also included. For details of risk classification of legs, PATH might be preferred. In PATH, factors such as sitting on the ground, crawling and legs not supporting the body (worker using a body harness) can be assessed whereas these important factors cannot be found in other pen-and-paper-based observational methods.

Chung et al. [62] conducted an experiment to develop leg posture classification based on a discomfort rating. They classified leg posture 30 to 60° as mild flexion, and leg posture > 60° as severe flexion. From this, it can be said that WERA and REBA are in agreement. Squatting is a very uncomfortable condition,[62] because it affects compression of the plantar nerves.[62] However, squatting was defined by Keyserling et al. [46] as the angle between the thigh and calf < 150° which is missing in WERA, OWAS and REBA assessments. Squatting assessment can be found in PATH, where it is described as knee flexion > 90°. Kneeling in leg risk classification is very important.[62] Chung et al. [62] defined kneeling as one or both knees touching the ground. This posture also increases the risk of pain or injury at the knee.[62] However, kneeling can only be assessed using OWAS and PATH. A summary of leg posture and its associated health risks is presented in Table 13.

Chung et al. [62] performed a good study on leg posture classification based on consistent objective experimental data, and they believed that more precise results can be obtained by implementing this leg posture classification. Chung et al. [62] classified leg posture into six categories: standing, knee-flexed, squatting, sitting, kneeling and on foot. For each category, there are significant subcategories. The discomfort rating for each risk factor is

Table 11. Trunk: description and associated health risk.

Posture	Health risk	Reference
Bent 20 to 40° + back twisted	LBP	[60]
Flex/twist/lateral bend	Neck and shoulder symptoms	[50]
Sustained twist neck/trunk	Neck and shoulder pain	[33]
Fast flexion/extension	Low back disorders	[55,56]
Trunk flexion > 20° for one-third of work time	Low back disorders	[46,51]
Trunk bent forward > 40°	Predicted for LBP	[60]
Trunk > 45° forward flexion	Severe bending	[46]
	Increased discomfort	[58]
	Increased biomechanical loads	[59]
	Low back disorder when combined with asymmetric postures	[55]
Static or cyclic spine flexion for a 30-min period	Ligament creep and an attendant dysfunction of the back muscles for a period of up to 24 h	[52]
Sitting and back support	Reduce the stress on the lumbar spine	[61]
Handling heavy loads or high force applications	WMSDs	[29]
Task duration	WMSDs	[29,46,51,52]

Note: LBP = low back pain; WMSD = work-related musculoskeletal disorder.

Table 12. Legs: posture and risk level.

Method	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
WERA	Neutral posture	Legs moderately bent (30 to 60°)	Legs extremely bent forward (> 60°) or sitting feet do not touch floor	–	–	–	–	–	–	–
QEC	–	–	–	–	–	–	–	–	–	–
REBA	Straight	Bent 30 to 60°	Bent > 60°	–	–	–	–	–	–	–
OWAS	Sitting	Standing: legs upright	Standing: one leg upright	Standing: legs bent	Standing: one leg bent	Kneeling	Walking	–	–	–
PATH	Flexion < 35°	One foot not supported	Bending: at least one knee flexion > 35°	Squatting: knee flexion > 90°	Walking	Kneeling	Sitting on a chair	Sitting on the ground	Crawling	Legs do not support body
PLIBEL	Checklist: feet, knees and hips									

Note: L = level; WERA = workplace ergonomic risk assessment; QEC = quick exposure check; REBA = rapid entire body assessment; OWAS = Ovako working posture assessment system; PATH = posture, activity, tools and handling; PLIBEL = *Plan för Identifiering av. Belastningsfaktorer.*

Table 13. Legs: description and associated health risk.

Posture	Health risk	Reference
Prolonged standing	Intervertebral and vertebral end-plate compression	[63]
	LBP	[64]
	Pain in the low back, hips, legs, knees, ankles and feet	[65]
Standing (tiptoe)	Uncomfortable	[62]
Excessive walking	Intervertebral and vertebral end-plate compression	[63]
Knee flexion angle < 30°	Safe	[66]
Knee flexion angle 30 to 60°	Mild knee flexion, uncomfortable	[62]
Knee flexion angle > 60°	Severe knee flexion, very uncomfortable	[62]
Squatting	Uncomfortable	[62]
	Numbness and pain	[67]
Kneeling	Pain, injury and numbness in the leg regions	[62]

Note: LBP = low back pain.

presented by verbal descriptions so that the rating can be easily understood and interpreted.[62]

4. Discussions

To date, many literature reviews have been published, e.g., a literature review by Denis et al. [69] which focused on simple assessment methods for assessing MSDs. The selected methods comprised postural assessment, force exerted and time duration. However, the comparison only focused on how to define the input data and the required procedure and also on how each selected method is different in each evaluation step.

Another review paper was published on indentifying and performing a systematic comparison of observational assessment methods.[14] In addition, critical analysis was performed with respect to the selected methods. A few suggestions were proposed such as objective and data sampling requirements to facilitate the decision-making process. As for a general screening purpose, one can use a simple, short and quick method. Meanwhile, for the identified problematic work tasks, it is more appropriate to use an evaluation method that can provide numerical output. Besides, it is also important to ensure that each observer is well trained and able to use the methods competently so that methodological errors can be reduced.

There is also a review paper based on an analysis of 12 assessment methods which classified posture into three categories: macro-postural, micro-postural and postural work activities.[9] This study is based on a similar approach from past review papers in determining body posture and postural movement reference angles.[69,70] In addition, the study seeks additional information from review articles published based on the existing observational methods found in the literature to provide basic understanding of these methods.[12,71]

With respect to past published articles on observational variables based on different methods, it can be concluded in general that the risk factors identified were quite similar. However, when focus is given to body posture only, each method cannot be directly compared because they are not using uniform body angles.

This study begins with identifying assessment methods that can be applied to evaluate whole body posture. Next, the study selects and carefully studies the methods that meet the required criteria. In each method, the risk levels for measuring whole body posture were classified and presented in a tabular format. From the risk level categorization, each factor is taken into consideration as guidelines for the selection process for epidemiological study to find the relationship between risk factors for body posture and their effects on health. From the risk level classification, each factor is taken into consideration in the selection process guidelines to publish an epidemiology study and find the relationship between the risk factors for body posture and its effects on health.

Work posture evaluation is quite straightforward because human posture can be simply expressed in terms of joint angles. The angular deviation of a body segment from neutral posture is estimated by observing a worker's actual work activity. A postural classification scheme is usually used. However, the challenge now is to have a valid and standardized method, especially standardization on how each posture for each limb is scaled in order to determine the exposure levels. For the selected pen-and-paper-based observational methods in the assessment of ergonomics risk factors, especially posture, the variation of risk levels to define the severity of each posture is obvious. The verbal descriptions for postural classification and each classification of posture represented by angular deviation of a body segment had an impact in the assessment process. If the posture of the body segment is not well measured, misclassification of risk level is bound to happen. In this study, six pen-and-paper-based observational methods to assess whole body posture were reviewed. Each posture classification to indicate the risk level in the selected methods was carefully cross-checked with the associated health risk. Specifically for upper arm or shoulder assessment, REBA and WERA have their own strengths. The detailed assessment of REBA which takes into consideration other factors (shoulder raised and coupling) is outstanding. Rahman et al. [15] also did the same thing, whereby they have included repetition in assessing upper arm and shoulder posture because this approach is supported by other researchers.[29] Other factors such as force, e.g., in weight handling, is also a significant risk factor of WMSDs for the upper arm and shoulder area.[29] But specifically for the upper arm or shoulder posture, there are no selected methods that have considered force in their assessment. The combination of upper arms or shoulders and lower arms such as in OWAS and PATH to represent the risk of upper extremities is not advisable. This is because both upper and lower arms pose different risks in work activities in the lower arm assessment; therefore it is important to clearly differentiate between hand, forearm and elbow to avoid misclassification.

5. Conclusion

Presently, there are many pen-and-paper-based observational methods that were developed to assess work posture. Observational assessment methods can be used as a reliable tool in conducting ergonomic risk assessment because it has been shown that there is a linkage between body part movement and the related health effects. However, the literature review conducted posits that the available published methods still have their shortcomings and limitations. For example, some of the methods are not able to assess lower arms, and do not include exposure duration and force measurement during postural assessment.

Evidence from past epidemiological studies showed that it is important to assess the lower arms in order to avoid MSDs. In addition, the factor of right or dominant arm versus left or non-dominant arm while performing work tasks need to be considered. Depending on which limb is actively used, the workload is definitely not symmetrically distributed between the two sides. Because of this fact, it is important to develop a method which can measure the left and right limbs separately. Unfortunately, none of the six selected methods took this into consideration. However, enough evidence was provided to consider observation data as potentially reliable. The findings from this literature review may assist researchers and practitioners to understand better the unsafe work postures and correct them to ensure employees are safe while performing their work.

Disclosure statement

No potential conflict of interest was reported by the authors.

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