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Observation Procedures Characterizing Occupational Physical Activities: Critical Review

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The first objective of this paper is to compare the observation procedures proposed to characterize physical work. The second objective is to examine the following 3 methodological issues: reliability, observer training, and internal validity. Seventy-two papers were reviewed, 38 of which proposed a new or modified observation grid. The observation variables identified were broken down into 7 categories as follows: posture, exertion, load handled, work environment, use of feet, use of hands, and activities or tasks performed. The review revealed the variability of existing procedures. The examination of methodological issues showed that observation data can be reliable and can present an adequate internal validity. However, little information about the conditions necessary to achieve good reliability was available.

observation procedures physical work reliability validity observer training

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1. INTRODUCTION

Collecting observation data is a common practice in a number of disciplines. In ergonomics, the data first used in work analysis (Ombredane & Faverge, 1955) to characterize modus operandi and operators' strategies is obtained through observable events such as eye movements and direction, gestures, sequence of operations, management of incidents, communications, and so forth (Amalberti, de Montmollin, & Theureau, 1991; de Montmollin, 1984; Leplat, 1993). It may even be said that the use of observation procedures—which are mainly uninstrumented—constitutes the key difference between Human Factors and Ergonomics methodologies. Variables were often defined a posteriori directly in the field. The definition of concepts rather than the process of observation itself was the focus of attention, whereas the reliability or internal validity of the observations received little attention. From the 1970s on, a multitude of observation grids were designed to characterize or spot check deficient work conditions in order to set action priorities (e.g., Régie Nationale des usines Renault, 1983; AET [Arbeitswissenschaftliches Erhebungsverfahren zur Tätigkeitsanalyse], Rohmert & Landau, 1983). Observation variables were therefore defined a priori—the targeted user often being an untrained ergonomist. In past years, the recognition of musculoskeletal lesions as a major occupational health problem led to the design of several new grids to characterize physical demand and identify risk conditions. In these cases, understanding the modus operandi or strategies is usually not an issue. In addition, thanks to the influence of epidemiology, assessment of exposure became a major issue. Punnett and Keyserling's work (1987) in the garment industry represents one of the very first efforts to assess exposure through observation procedures. However, as shown in the Burdorf (1992a) review of risk factor assessment, questionnaires are still used far more often than observation procedures, which are receiving more attention as research tool. Furthermore, a number of grids are now computerized and proposed as practical tools for assessing work environments. This raises several basic questions: Is there actually a clear and rational consensus on the characterization of physical work activities procedures? What is the expected quality of data? What conditions are required to achieve a good observation performance?

The first objective of this paper is to compare the observation procedures proposed to characterize physical work. The second is to examine the following three specific methodological issues: reliability, training of observers, and internal validity. The paper's general purpose is to pinpoint areas of consensus about the choice of observation variables and identify general guidelines for the development and use of an observation method.

2. METHODOLOGY

2.1. Papers Reviewed

Seventy-two articles dealing wholly or partially with the observation of physical work involving general body work, such as in handling or construction work, published between 1975 and 1997 in eight peer-reviewed journals were reviewed *(Human Factors, Le Travail humain, International Journal of Industrial Ergonomics, Scandinavian Journal of Work, Environment and Health, Journal of Human Ergology, Ergonomics, Applied Ergonomics,* and *Journal of Occupational and Environmental Medicine;* see Appendix). Papers focusing on sitting posture and upper limb work were excluded. Thirty-eight of these papers proposed a new or modified grid, whereas 27 applied a previously established grid. Seven papers discussed methodological issues relating to observation.

The first part of this review is limited to the 38 grids proposed. Of these, 23 were designed to assess exposure within the framework of an epidemiological study or to document a sector; four, to benchmark specific risk factors (e.g., exertion above a certain value or intensity), circumstances or events viewed as risky (e.g., sliding surfaces); and 11, to document the work activities performed and the modus operandi or strategies, without specifically assessing exposure or risks.

2.2. Observation Classification

The observation variables were divided into the following seven categories: posture, exertion, characteristics of object handled, work environment, use of feet, use of hands, task or activities performed. The variable "object handled" could refer to a piece of equipment, an object, or a container. "Work environment" mainly included variables referring to the work context or the presence of unfavorable conditions (e.g., spatial restriction, use of vibrating tools, thermal environment). "Use of feet" included variables dealing with the position of the feet, supporting base or displacements. "Use of hands" referred to observations describing the contact between the hand and the object or the spatial hand position. The "task or activity" category encompassed observations on the work content or the breakdown of the activity. Those grids that grouped together several observation variables (e.g., exertion combined with the application conditions) were broken down for classification purposes.

The seven observation categories were subsequently subdivided into 38 more homogeneous subcategories (posture variables excluded). The variables proposed were either discrete (e.g., nature of exertion applied) or continuous (e.g., back flexion). In the first instance, a series of descriptors could be proposed, as well as a simple presence or absence notation. In this paper, the term descriptors refers to the word or phrases used to describe a discrete variable, whereas the term class reflects the numerical value divisions proposed for continuous variables. Reference values proposed for defining the descriptors and the breakdown of class values were reviewed.

2.3. Methodological Information Reviewed

Information dealing with the observation protocol was reviewed for the 72 papers covered. With respect to training procedures, information on training modalities, such as the duration of the training, the teaching material used, training assessment, and trainer qualifications, was collected. Details on inter- or intra-observer reliability tests and the internal validity of the observations were also noted. In addition, information about the observation process itself, such as the definition of observation criteria or benchmarks, was compiled.

3. RESULTS

3.1. Overview of the Grids

Almost all the grids proposed the observation of postural elements (*n* = 36), whereas the majority included exertion (*n* = 28), load handled (*n* = 21), and tasks or activities conducted {*n* = 19; see Table 1). The observation of elements relating to the other three categories—the use of feet, the use of hands, and the environment—were covered by about one third of the grids. Twelve proposed observations covered at least five or more of these seven observation categories. As can be seen from Table 2, 26 of the 38 variable subcategories (postural variables excluded) were retained by less than 15% of the 38 grids reviewed; only two variables (the nature of the exertion and the weight) were retained by more than 10 grids.

TABLE 1. The 38 Newly Proposed Grids: Main Purpose[a], Type of Work Targeted, and Observation Categories Used

Studies	Work/Sector	Observation Category						
		Posture	Exertion	Object Handled	Environment	Use of Feet	Use of Hands	Task/Activity
A. Exposure assessment ($n = 23$)								
1. Karhu, Kansi, & Kuorinka, 1977	All	✓	✓	✓		✓	✓	
2. Saari & Wickström, 1978	Concrete reinforcement	✓	✓	✓	✓			✓
3. Corlett, Madeley, & Manenica, 1979	All	✓						✓
4. Damlund, Goth, & Munk, 1986	Semi-skilled construction	✓	✓	✓	✓			✓
5. Keyserling, 1986	Automobile	✓						
6. Magnusson & Ötengren, 1987	Butchers	✓						✓
7. Chen, Peacock, & Schlegel, 1989	All	✓			✓	✓	✓	
8. Keyserling, 1990	All	✓						
9. Louhevaara, Hakola, & Ollila, 1990	Manual sorting	✓	✓					✓
10. Malchaire & Rezk-Kallah, 1991	Bricklayers	✓	✓					
11. van der Beek, van Gaalen, & Frings-Dresen 1992	Lorry drivers	✓	✓	✓		✓		
12. Johansson et al., 1993	Truck assembly	✓		✓				
13. McAtammey & Corlett, 1993	Garment-making, VDU operators	✓	✓	✓		✓		
14. Pinzke, 1994	Agriculture	✓	✓	✓		✓		
15. Christensen, Pedersen, & Sjogaard, 1995	Wood/furniture	✓	✓	✓	✓			
16. Fransson-Hall, Gloria, Kilbom, & Winkel, 1995	All	✓	✓		✓		✓	
17. Frings-Dresen et al., 1995	Refuse collectors	✓	✓	✓	✓			✓
18. Grant & Habes, 1995	Grocery cashiers	✓					✓	
19. Thomas, van Baar, & van der Stee, 1995	Baggage handlers	✓			✓			
20. van der Beek & Frings-Dresen, 1995	Lorry drivers	✓	✓	✓	✓			✓
21. Wiktorin, Mortimer, Ekenvall, Kilbom, & Hjelm, 1995	All		✓	✓			✓	

TABLE 1. (*continued*) The 38 Newly Proposed Grids: Main Purpose[a], Type of Work Targeted, and Observation Categories Used

Studies	Work/Sector	Observation Category: Posture	Exertion	Object Handled	Environment	Use of Feet	Use of Hands	Task/Activity
22. Buchholz, Paquet, Punnett, Lee, & Moir, 1996	Construction	✓		✓	✓	✓	✓	✓
23. Wickström, Laine, Pentti, Hyytiäinen, & Salminen, 1996	Industrial work	✓	✓	✓				✓
B. Risk assessment ($n = 4$)								
24. Takala & Kukkonen, 1987	Nurses	✓	✓	✓	✓			✓
25. Harber, Billet, Shimozaki, & Vojtecky, 1988	Nurses	✓	✓	✓	✓			✓
26. Schierhout, Myers, & Bridger, 1993	Manufacturing	✓	✓	✓	✓			
27. Winn, Biersner, & Morrissey, 1996	Miners	✓	✓				✓	
C. Work assessment ($n = 11$)								
28. Drury, Law, & Pawenski, 1982	MMH		✓	✓	✓		✓	✓
29. Lortie, 1986	Orderlies	✓	✓		✓			✓
30. Stålhammer, Leskinen, Kuorinka, Gautreau, & Troup, 1986	Baggage handlers	✓	✓					✓
31. Harber, Shimozaki, Gardner, Billet, Vojtecky, & Kanim, 1987	Nurses	✓	✓	✓				
32. Foreman, Davies, & Troup, 1988	All	✓					✓	✓
33. Ryan, 1989	Supermarket	✓	✓					✓
34. St-Vincent, Tellier, & Lortie, 1989	Orderlies	✓	✓			✓		✓
35. Harber et al., 1992	Cashiers	✓	✓	✓			✓	
36. Kuorinka, Lortie, & Gautreau, 1994	MMH warehouse	✓	✓	✓		✓	✓	
37. Baril-Gingras & Lortie, 1995	Handlers	✓	✓	✓		✓	✓	✓
38. Authier, Lortie, & Gagnon, 1995	Handlers	✓	✓			✓	✓	✓
	Total	36	28	21	14	10	13	19

Notes, a—In some cases, parts of the proposed grid have different purpose than the main one identified; MMH—manual material handling.

TABLE 2. Observation Variables Proposed (Except Posture)

Categories and Subcategories	Examples	References[a]
Exertion ($n = 26$)		
A. Nature of exertion ($n = 18$)	push, pull, lift, carry; dynamic, static	2, 4, 9, 11, 15, 16, 17, 20, 21, 26, 27, 28, 30, 31, 33, 34, 35, 37
B. Intensity classes ($n = 4$)	slight force; heavy effort; frequent lifting	4, 10, 13, 27
C. Object displacement or trajectory ($n = 3$)	tilt of the object; sliding, pivoting	28, 37, 38
D. Use of the body ($n = 2$)	arms, back, legs action; lifting motion	4, 34
E. Plane/axis/direction ($n = 5$)	sagittal, asymetric; vertical, horizontal	28, 29, 31, 34, 37
F. Spatial context ($n = 11$)		
• Height of grips and deposits ($n = 9$)	above shoulder; below waist; below knee	15, 16, 25, 26, 28, 29, 31, 36, 37
• Body–load distance ($n = 6$)	close (<50 cm), far (>50 cm)	4, 15, 23, 26, 28, 36
G. External support/load reduction ($n = 2$)	limb on the bed; leaning on one hand	23, 24
Object handled ($n = 23$)		
A. Weight ($n = 17$)		2, 4, 10, 11, 12, 13, 14, 15, 16, 20, 21, 22, 23, 26, 27, 28, 36
B. Typology ($n = 5$)	small box, bags, street litter	17, 20, 31, 35, 37
C. Characteristic ($n = 8$)		
• Handle/grip ($n = 2$)	hands symmetrical; handles positions	28, 37
• Format ($n = 4$)	irregular, cylindrical	4, 28, 36, 37
• Patient ($n = 3$)	patient activation; fighting patient	24, 25, 31
• Content ($n = 1$)	loose content	28
• Quality ($n = 2$)	unhandy material, rigidity	15, 37
Work environment ($n = 14$)		
A. Equipment and aids used ($n = 5$)	list of tools	4, 22, 24, 25, 29
B. Unfavorable conditions or events ($n = 10$)		
• Space limitation ($n = 5$)	space between the furnishing; obstacles	17, 20, 24, 25, 28
• Unexpected strain/loads ($n = 2$)	stumbling; sliding	4, 15
• Incidents ($n = 2$)	extra events, sorting errors	16, 19
• Other unfavorable conditions ($n = 4$)	slippery footing; type of work surface	2, 4, 15, 25

TABLE 2. (*continued*) Observation Variables Proposed (Except Posture)

Categories and Subcategories	Examples	References[a]
C. Physical agents ($n = 4$)		
• Temperature ($n = 3$)	temperature extremes; thermal load	4, 7, 26
• Vibration ($n = 3$)	shocks; whole body vibration	2, 7, 26
Use of feet ($n = 10$)		
A. Foot position ($n = 4$)		
• Spacing ($n = 1$)	close, somewhat apart, far apart	34
• Angulation ($n = 1$)	parallel, at angle	34
• Disposition ($n = 1$)	feet side by side, one behind	36
• Distance versus platform/cart ($n = 1$)	0–16, 16–32, 32–48, 48–64 cm	38
• Feet versus axis of movement ($n = 1$)	feet not or along the axis of movement	37
B. Foot support ($n = 7$)		
• Base of support ($n = 5$)	standing on the left leg; number of foot support	1, 11, 14, 22, 38
• Weight distribution ($n = 1$)	weight evenly distributed over both feet	13
C. Foot displacement ($n = 1$)	5–10, 10–50, >50 m	7
Use of hands ($n = 13$)		
A. Contact with object ($n = 7$)		
• Position on object ($n = 4$)	symmetrical, asymmetrical	28, 36, 37, 38
• Number of hands/object ($n = 2$)	1 object/2 hands, 1 object/1 hand	18, 28
• Grip type ($n = 3$)	power grip, precision grip	18, 32, 35
B. Spatial position ($n = 7$)		
• With reference to worker ($n = 6$)	hand above shoulder level	1, 16, 21, 22, 27, 32
• Region in front of the body ($n = 1$)	in box, edge of box, outside of box	7
Task and activity ($n = 19$)		
A. Identification ($n = 4$)	emptying concrete from the bucket	4, 6, 23, 25
B. Breakdown ($n = 15$)		
• Task ($n = 9$)	assembling tasks	2, 3, 9, 17, 20, 22, 29, 32, 33
• Spatiotemporal ($n = 7$)	pre-grips, pick up, move/carry, put down	22, 24, 28, 30, 34, 37, 38

Notes. a—see Appendix.

Exertion (n = 26). The nature of the exertion was the most frequent observation proposed (*n* = 18), the three most common descriptors being to lift (*n* = 13), to push (*n* = 12), and to pull (*n* =11), followed by the spatial context (*n* = 11; mainly the rising and lowering heights and the horizontal distance between the load and the subject). The observation of other elements such as the importance of the exertion, its direction or orientation, the purpose of the exertion (e.g., to roll, slide, or pivot), or the use of external support were marginally suggested. Very few grids proposed reference values to set borders between descriptors (e.g., 50 cm as a limit between near and far). In the best case, four grids proposed a value to define static exertion (30 **s** in three cases vs. 1 min).

Object **handled (*n* = 23).** Three subcategories were identified: the weight (*n* = 17); the different characteristics of the object, such as the presence or lack of handles (*n* = 8); and the type of load (*n* = 5). A minimal value from which to assess the exposure was proposed in five cases, ranging from 1 to 5 kg. Nine grids proposed a breakdown into three or more classes, eight of which suggested different cut-off values. The three references values proposed to define a descriptor were found to be different (e.g., the values proposed for heavy lifting or effort or large force varied from 10 to 22.7 kg).

Work environment (n = **14).** The most frequent observation variable proposed dealt with presence or non-presence of unfavorable conditions or events, although the proposals varied greatly (e.g., spatial restriction, presence of obstacles, sliding surfaces, unexpected loads).

Use of feet (n = **10).** The position of the feet, the foot support, or the foot displacement are the three possible types of observation proposed. The proposals are as variable as previously noted. The single observation that was retained more than once was the use of one or two feet support when applying an effort (*n* = 5). Except for one instance, no grid retained both the observation of the foot positioning and support.

Use **of hands (*n* = 13).** Two basic proposals were identified: the observation of the contact between the object and the hand and the hand spatial position (generally in reference to the worker). Neither proposal was ever retained simultaneously.

Task and activity (n = **19).** The following descriptive variables—or concepts—were identified: task, activity, action, function, and operation. Identical descriptors were found to be classified under different variables. For example, carrying, lifting, push/pull were classified as a task, an activity as well as an action. Two main observation strategies were identified. In the first, attention is focused on the tasks and the observation is organized around descriptors presenting different ways to divide the tasks and different levels of accuracy. For instance, in the Saari and Wickström (1978) grid, the structure erection work is broken down into several phases or large task categories (e.g., steel rod preparation phase, assembling tasks), whereas in the Damlund, Goth, and Munk (1986) grid in the same sector the work is observed across three levels, moving from the more general to the more specific (work tasks, work function, and work operation). In the second strategy identified, the division is spatiotemporal. Work activities were broken down in order to determine the exact moment or locus for recording observation. For example, in the Drury, Law, and Pawenski (1982) grid, box handling is divided into three phases (start, during, stop) and five steps (pre-grip, pick up, move/carry, put down, adjust).

3.2. Posture (n = 36)

The breakdown of classes was reviewed. As shown in Table 3, no dominant proposals were identified, whatever the articulation targeted. For instance, 18 different proposals were identified from the 32 grids dealing with sagittal flexion. Out of the 11 grids proposing a two-class breakdown, seven were different. Out of 10 grids proposing shoulder and neck sagittal flexion classes, six and seven different proposals were recorded respectively. In respect to knee flexion, the ratio is seven out of 11. This variability was also observed with elements more rarely observed or presenting a narrower range. For instance, six grids retained the back extension, with three different breakdowns. The relationship between the number of classes retained and the breakdown was also examined: More classes corresponded mainly to a greater total amplitude rather than smaller class breakdowns.

As several experimental studies documented combinations of articular deviations, we examined this aspect. In fact, about 50% of the time, the back or neck rotation and the shoulder abduction were observed in combination with the back or neck lateral or sagittal flexion or the shoulder flexion. However, it is not clear whether the aim was to observe the combination itself or whether the choice related to observational difficulties.

When two classes are proposed, it may be assumed that the cut-off value represents a threshold value from which a postural deviation is considered to be significant. No clear consensus could be identified. Four grids proposed three different reference values to determine the relevance of recording a postural events (10 s as a minimal duration for a postural

TABLE 3. Posture Observation: Postural Deviation and Angular Breakdown Range for Each Class Used

	Number of				Angular Breakdown Range			
Posture	**Classes**	**Studies**	**Proposals**	**Y/N[a]**	**1st class**	**2nd class**	**3rd class**	**4th class**
Back ($n = 33$)								
Sagittal flexion (32)[b]	2	11	7	5	15°–60°	>15°, >45°		
	3	15	8		0°–30°	10°–90°	>45°, >90°	
	4	6	3		6°–45°	15°–90°	45°–135°	>75°–>135°
Extension (6)	2	6	3	3	<5°, <–20°	>5°, >–20°		
Lateral flexion (5)	2	5	2	4	<45°	45°–90°		
Rotation/torsion (14)	2	14	3	12	<20°, <45°	>20°, >45°		
Sagittal flexion and rotation (7)	2	7	3	3	<10°, <20°	>20°, 10°–90°		
Lateral flexion/rotation (8)	2	6	3	3	<20°, <30°	>20°, >30°		
	3	1	1		<15°	15°–45°	>45°	
	4	1	1		<15°	15°–45°	45°–75°	>75°
Shoulder ($n = 15$)								
Sagittal flexion (10)	2	5	2		<45°, <60°	>45°, >60°		
	3	2	2		<30°, <45°	30°–90°	>90°	
	4	3	2		10°–45°	10°–90°	45°–135°	>90°, >135°
Extension (3)	2	2	2		<–20°,<–30°	>–20°, >–30°		
	4	1	1		<45°	45°–90°	90°–135°	>135°
Flexion and abduction (4)	2	2	2	1	<60°	>60°		
	3	2	1		<45°	45°–90°	>90°	
Abduction/adduction (3)	2	2	2		<60°	>60°		
	4	1	1	1	<45°	45°–90°	90°–135°	>135°
External rotation (1)	2	1	1	1				
Elevation (2)	2	2	1	2				
Neck ($n = 10$)								
Sagittal flexion (10)	2	6	3	4	<30°, <20°	>30°, >20°		
	3	3	3		10°–20°	10°–45°	>20°, >45°	
	4	1	1		<45°	45°–90°	90°–135°	>135°
Extension (4)	2	4	2	3	<–20°	>–20°		
Lateral flexion (5)	2	5	3	3	<30°, <45°	>30°, 45°–90°		
Rotation (6)	2	6	2	4	<45°	>45°		
Sagittal flexion and rotation (1)	2	1	1		<20°	>20°		
Lateral flexion/rotation (1)	3	1	1		<15°	15°–45°	>45°	
Knee ($n = 11$)								
Sagittal flexion (11)	2	8	4	3	<15°–50°	>15°–50°		
	3	2	2		<10°, <30°	10°–80°	>45°, >80°	
	4	1	1		<45°	45°–90°	90°–135°	>135°

Notes. a—Yes/No notation, b—number of studies.

deviation, a frequency of 4 per minute or a time proportion of 50% as minimum for repetition). Finally, about half (*n* = 19) proposed global posture descriptors, primarily: kneeling, standing, walking, squatting.

3.3. Methodological Data

Observation reliability. Forty-four percent provided reliability data (new or modified grid: n = 21; edited grid: *n* = 8; see Table 4). The agreement percentage (Po: *n* = 15) was by far the most widely used ratio in assessing reliability, followed by calculation of the kappa coefficient (K: n = 6), which is considered more valuable as it discounts the proportional agreement that is expected by chance (Burdorf, Derksen, Naaktgeboren, & Van Riel, 1992; van der Beek, van Gaalen, & Frings-Dresen, 1992). As demonstrated by data published by several authors, a high Po might be associated with a low K, depending on the rarity of the events observed (e.g., leg support: Po = 91.2 vs. K = .24 [van der Beek et al., 1992]; distance from body to external weight: Po = 77 vs. K.26 [Wickström, Laine, Pentti, Hyytiäinen, & Salminen, 1996]). Kilbom (1994) explains kappa's limits (e.g., inapplicable to continuous data). We reviewed which threshold could be considered acceptable for both statistics (n = 7). Three thresholds are suggested for Po, 80% (Buchholz, Paquet, Punnett, Lee, & Moir, 1996), 85% (Engels, Landeweerd, & Kant, 1994a; Engels et al., 1994b) and 90% (Authier, Lortie, & Gagnon, 1995; Baril-Gingras & Lortie, 1995), whereas .5 (van der Beek et al., 1992; Fransson-Hall, Gloria, Kilbom, & Winkel, 1995) and .6 (de Looze, Toussaint, Ensink, & Mangnus, 1994) are suggested for kappa. Three other tests were also marginally used: the correlation coefficient {*n* = 4), the Kendal coefficient of concordance (*n* = 1), and the Wilcoxon signed ranks test (n = 1).

As can be seen in Table 5, the Po obtained for the different variables was quite variable—ranging from excellent (>90%) to fairly low (56%). Whereas the agreement computed for the back flexion was usually around 75%, it could be over 90%. In general, when both inter- and intra-observers were checked, the intra-observer reliability coefficient appeared to be slightly better. If there was a bias, it was a consistent one. The impact of the task was also reviewed. Analysis of data published by the seven studies presenting reliability data for a same element observed for different tasks indicated that the task has a major impact on reproducibility coefficients (e.g., Po for sagittal trunk flexion task 1: 61%, task 2: 82%; arm flexion task 1: 78%, task 2: 99%).

TABLE 4. Reliability: Protocol[a], Element Tested, and Main Results

Reference	Participants Intra	Participants Inter	Jobs Used	Material Used	Variable Tested	Sample Size[b]	Test	Main Results
1	2	2	—	L	14	36240 observations; 52 tasks	Po	Inter: 93 (74–99); Intra: 86 (70–100)
3	10	—	5	L, V	6	60 postures	r	.79–.88
4		nm	—	L	12	—		Most marked difference: duration of inclined posture
5	1	5	2	L, V	3	75 s	—	Intra: high for trunk, less consistent for shoulder Inter: moderate for left shoulder, less for trunk/right shoulder
11	—	2	—	L	7	—	Po; κ	79–97; .24–.89
13	—	120	4	L	9	—	—	High consistency
15	nm	nm	—	L	6	—	—	Said to be satisfactory
16	5	5	4	L	4	—	W	.67–.90
17	—	—	—	—	—	—	κ	—
18	nm	nm	—	L	7	45–90 min/cashiers	r	Postures: .77–.99, grasp type: .40
20	—	—	—	—	—	—	κ	—
21	—	2	5	V	5	≈356 min	r	.99 and 1.00
22	1	1	2	L, V	15, 17	—	Po	Intra: 65–97; Inter: 29–99
23	2	2	—	V	5	719 pictures	Po; κ	Intra: 84–95, .55–.93; Inter: 56–94, .24–.92
24	1	—	—	—	11	15 to 36 observations	r	.41–.97
32	2	2	—	V	6	—	Po	Intra: 74–100; Inter: 61–97
33	—	nm	—	L	14	—	—	Reported very similar results
34	2	2	—	L	11	44 sequences	Po	Intra: 91 (81–97); Inter: 89 (73–93)
35	nm	nm	—	L	4	10 × 20 min	—	Intra: no temporal drift in the coding Inter: good, except lumbar flexion
37	nm	nm	—	L	36	—	Po	Over 90
38	—	—	—	—	—	—	Po	—

TABLE 4. (*continued*) Reliability: Protocol[a], Element Tested, and Main Results

Reference	Participants Intra	Participants Inter	Jobs Used	Material Used	Variable Tested	Sample Size[b]	Test	Main Results
44	—	—	—	—	—	—	κ	—
48	—	2	—	L	14	—	*Po*	Variability was 4% with respect to final %
49	—	2	—	V	14	—	*Po*	85–94
55	—	2	—	V	14	593 postures	*Po*	97–100
56	—	2	—	L	14	90 observations	*Po*	87–95
58	—	2	—	L	14	200 observations	*Po*	Appeared to be over 97
62	—	2	—	—	14	—		—
65	—	2	—	L	14	540 observations (3 hrs)	*Po*	Almost 90 for all postures except "body weight on one leg"
66	—	5	10	L	4	10–30 min/job	—	Perfect agreement (5 experts): 30% of the scores Consensus agreement (≥3 experts): 88% of the scores
69	—	nm	—	L	5	—	*Po*; κ	76 to 97; .66–.86

Notes. nm—not mentioned, L—live, V—video, *Po*—percentage agreement, *r*—correlation coefficient, κ—kappa coefficient, *W*—Kendal coefficient of concordance; a—see Table 6 for details of training and practice session, b—as reported.

TABLE 5. Observation Reliability: Results Obtained for Different Observation Variables

Observation Variables	Test	Reliability Intra	Reliability Inter	Reference
Standing				
Y/N[a]	r	.83	—	3
Y/N: frequency; duration	Po	92, 87; 93, 92	87; 88	32
Back sagittal flexion				
<5° | 6–30° | 31–60° | 61–90° | >90°	Po; κ	86; .81	81; .73	23
<15° | 15–45° | 45–75° | >75°	Po; κ	—	79–85; .61–.72	11
<15° | 15–45° | 45–75° | >75°	Po; κ	—	76; .68	69
<45° | 45–90° | 90–135° | >135°	r	.75	—	3
<20° | 20–45° | >45°	Po	73	61, 82[b]	22
<20° | 20–45° | >45°	—	raw data	raw data	5
>20°	r	.77	.74	18
>60°	r	.91	—	24
>15°: frequency; duration	Po	98, 99; 90, 93	91; 94	32
>30°	r	.41	—	24
Hands>knee: frequency; duration	Po	92, 75; 88, 76	90; 61	32
Back rotation/lateral flexion				
Y/N	r	.97	—	24
Y/N	Po; κ	—	94–96; .48–.59	11
Y/N	Po; κ	84; .60	56; .24	23
>20°	—	raw data	raw data	5
Shoulder flexion/abduction				
<45° | 45–90 | >90°	—	raw data	raw data	5
<60° | >60°	Po; κ	—	90–93; .51–.65	11
<60° | >60°	Po; κ	—	90; .79	69
>60°	r	.83	.89	18
Elbow versus shoulder height	Po	97	78, 99[b]	22

Notes. Po—percentage agreement, r—correlation coefficient, κ—kappa coefficient; a—Yes/No notation, b—two different jobs.

Impact of observer training. A single study had been designed to examine this question specifically. Furthermore, few studies tested the same variables; different tasks were used, and the level of grid complexity varied. Nevertheless, some trends were noted.

Of the 29 papers mentioning this issue, 13 provided some information on training modalities and nine specified the duration of the training or practice. None of the studies using a published grid provided data on observer training. The training could range from one hour to several days. Additional practice sessions could last up to one month. The distinction between each format was not always easy to determine and longer training

TABLE 6. Observation Reliability: Impact of the Training Versus Practice of the Observers

Observation variables		Training	Practice	Test	Reliability: Intra	Reliability: Inter	Reference
Standing							
Y/N		1 hr	—	*r*	.83	—	3
Y/N	frequency	1 session	90 hrs	*Po*	87 vs. 92	87	32
	duration				92 vs. 93	88	
Back sagittal flexion							
<15° I 15–45° I 45–75° I >75°		4 days	4 × 1/2 day[a]	*Po*; κ	—	79 vs. 83; .61 vs. .69	11
<15 I 15–45° I 45–75° I >75°		—	1 week	*Po*; κ	—	76; .68	69
<45° I 45–90° I 90–135° I 135°		1 hr	—	*r*	.75	—	3
<20° I 20–45° I >45°		2 hrs	20 hrs	—	raw data	raw data	5
<20° I 20–45° I >45°		30 hrs	—	*Po*	73	61, 82[b]	22
<15°	frequency	1 session	90 hrs	*Po*	99.5 vs. 98	91	32
	duration				93 vs. 90	94	
Hands>knee	frequency	1 session	90 hrs		75 vs. 92	90	32
	duration			*Po*	76 vs. 88	61	
Back rotation/lateral flexion							
Y/N		4 days	4 × 1/2 day[a]	*Po*; κ	—	95 vs. 94; .49 vs. .48	11
>20°		2 hrs	20 hrs	—	raw data	raw data	5
Shoulder flexion/abduction							
<45° I 45–90° I >90°		2 hrs	20 hrs	—	raw data	raw data	5
<60° I >60°		4 days	4 × 1/2 day[a]	*Po*; κ		90 vs. 93; .51 vs. .53	11
<60° I >60°		—	1 week	*Po*; κ	—	90; .79	69
Elbow vs. shoulder height		30 hrs	—	*Po*	97	78, 99[b]	22
Miscellaneous							
4 postures; 5 activities:	frequency	—	10 vs. 100 hrs	*W*	—	.75 vs. .67	16
	duration	—			—	.76 vs. .89	

Notes. *Po*—percentage agreement, *r*—correlation coefficient, κ—kappa coefficient, *W*—Kendal coefficient of concordance; a—observation criteria were modified between the two sessions, b—two different jobs.

periods probably included practice sessions. In general, more extensive training or practice sessions were linked to the use of more complex grids. As shown in Table 6, no substantial benefits were noted in relation to practice sessions over training sessions or longer training sessions. For example, in the case of the saggital flexion, the reliability appeared to be about the same for both after one hour and after a few days of training (Corlett, Madeley, & Manenica, 1979; van der Beek et al., 1992). van der Beek et al. (1992) reported a small yet consistent (up to 6%) improvement between the sessions. However, this improvement was attributed to better criteria definitions. Experienced and inexperienced observers showed about the same level of reliability (Fransson-Hall et al., 1995). Nonetheless, goals other than improving the reliability itself, such as improving skills (better recording speed, improving memory), reducing of the effect of tiredness, and so forth, were pursued while planning longer training or practice periods.

In point of fact, results tend to show that attention paid to the definition of observation criteria or to the training method (e.g., use of visual supports) has more impact on the reliability than the length of training. Overall, trained observers were shown to be able to efficiently manage complex grids and achieve reliability coefficients superior to 90% (Karhu, Kansi, & Kuorinka, 1977; Keyserling, 1986; St-Vincent, Tellier, & Lortie, 1989).

Internal validity. Eleven studies provided such data, essentially on postural variables (mainly saggital flexion). Observations were compared with a direct measurement from a picture or a video tape, or from the participant (inclinometer/goniometer or optoelectronic recording). Two elements were checked: the frequency or proportion attributed to the different classes and the accuracy of the observation. As different class breakdowns **and** different methods were used, the results cannot be directly collated. As previously indicated, a broad range of results was obtained (see Table 7). However, it was noted that observation internal validity could be excellent. For example, van der Beek et al. (1992) reported a correlation coefficient of .98 and a mean absolute error below 5° for a sagittal flexion breakdown in four classes. The only other study documenting observer accuracy capacity showed less impressive results, with an average error of 9° for the shoulder flexion (Genaidy, Simmons, Guo, & Hidalgo, 1993).

The reliability and validity for both frequency and duration were also assessed in three studies (Buchholz et al., 1996; Fransson-Hall et al., 1995; Karlqvist, Winkel, & Wiktorin, 1994). Results show that when the frequency

TABLE 7. Internal Validity: Element Tested, Reference Used, and Main Results

Postures (*n*)[a]	Reference Used	Sample Size	Main Results	Reference
Angular accuracy				
Trunk flexion: <15°, 15–45°, 45–75°, >75°	Optoelectronic VICON	25 pictures 2 observers	*r* = .98; Mean of absolute error <5° for both observations	11
Shoulder flexion: <60°, 61–120°, 121–180°	Goniometer	18 observations (30s/observations) 20 observers	Slightly overestimated for 1–60; Slightly under-estimated for the 2 others; Average absolute error of 9.2°	68
Frequency/duration				
Postures (10)	Frame-by-frame method	1 observer	*r* = .65–.82 for head and trunk; *r* = .01–.49 for arm and leg	3
Postures (7)	Frame-by-frame method	75 s; 1 observer	Good, except for mild flexion, twisted/bent	5
Postures (3), MMH	Video analysis and goniometer	20 observations 5 observers	Best agreement: "right hand>shoulder"; Trunk flexion overestimated; Duration of neck flexion vastly overestimated; In general, frequency underestimated	16
Hands>shoulder or<knuckle level	Arm position analyser	374 min (69 participants) 5 observers	*r* = .69–.97	21
Trunk postures (5)	Frame-by-frame method	2 hrs; 1 observer	Most marked difference for neutral (21%) and moderate flexion (24%)	22
Trunk flexion: 20–60°, >60°	Trunk flexion analyser	58, 45, 31, and 41 min 1 observer	Modest trunk flexion (20–60°) underestimated	42
Trunk bending: >20°	Inclinometer	180 observations/worker 30 workers	Sedentary work *r* = .62, Dynamic work: *r* = .57; Large differences (>20%) found at individual level	67
Postures (4), load	Optoelectronic VICON	21 min; 2 observers	Poor for torso flexion (κ = .38), arms (κ = .43), and legs (κ = .46), load handled (κ = .50); Acceptable for gross body posture (κ = .79)	69
Postures (4), actions (4)	Optoelectronic Selspot II and video	10 min/task 1 observer	High agreement: duration and frequency of clearly identifiable sustained postures and actions; Lowest agreement: postures of the neck	71

Notes. *r*—correlation coefficient, κ—kappa coefficient; MMH—manual material handling, a—number of postures tested.

of an event is under-evaluated, its duration may instead be over-evaluated because the two different events are considered as only one.

In general, little information could be gathered on the observation problems, apart from some comments about difficulties related to using two-dimenssional video supports in observing dynamic work.

4. DISCUSSION

4.1. Observation Proposals

The observation proposals were considerably more varied than expected. About 60% of the papers reviewed presented their own observation grid. Except for posture, few observation variables were retained by a majority of grids. In the case of the posture, observations were seldom defined in the same way: the number of classes, breakdown, and reference values varied and the choices were rarely explained. There is an urgent need to define clearly formulated and supported observation procedures, at least for frequently used observation variables.

Despite this variability, the scope of the proposals nevertheless appears to be narrow. For example, the purpose of the majority of the grids was to assess exposure or to benchmark musculoskeletal risks. However, several elements documented or suspected in the literature as risk factors were missing or rarely retained. Some examples of these are eccentric contraction (e.g., Armstrong, Warren, & Warren, 1991; Edwards, 1988), balance problems (e.g., Manning, Ayers, Jones, Bruce, & Cohen, 1988; Oddsson, 1990), asymmetry (e.g., Adams, 1980; Gunzburg, Hutton, & Fraser, 1991; Shirazi-Adl, 1989), temporal loading frameworks (e.g., Hägg, Öster, & Byström, 1997), statism (e.g., Van Dieën & Oude Vrielink, 1994; Winkel & Westgaard, 1996), space restrictions (e.g., Drury, 1985a; Kumar, Mital, Garand, & Persad, 1993), presence of obstacles, sudden exertions (e.g., Lavender et al., 1989), presence of hard-to-control material (e.g., Imbeau, Montpetit, Desjardins, Riel, & James, 1998). Difficulties encountered in clearly linking posture and exertions with musculoskeletal problems are therefore not surprising. The experimental research results seem to be only partially integrated in field studies.

The review also indicates a lack of consensus for defining an exposure threshold for risk assessment or intervention level, which seems to reflect the lack of operational data on which a decision could be based. This is hardly surprising as several biomechanical and physiological studies lead to controversial results or conclusions regarding the importance or relevance of certain risk factors. For example, there is no clear consensus regarding torsion (e.g., Adams & Hutton, 1981; Goel et al., 1986; Schultz et al., 1982), lumbar extension (e.g., Adams & Hutton, 1983; Burton, Tillotson, & Boocock, 1994; Jackson, 1992) or acceleration of the load (e.g., Bush-Joseph, Schipplein, Andersson, & Andriacchi, 1988; Delisle & Gagnon, 1995; McGill & Norman, 1985). Some studies even point out the advantages of adopting so-called risk (e.g., Adams, 1996; Manas & Mirka, 1989; Gravel, Gagnon, Plamondon, & Desjardins, 1992).

Several studies were intended to characterize modus operandi or strategies. In these cases, it was often hard to establish a link between the observations proposed and scientific literature. For instance, the supports and the position of the feet at the time of the effort were observed in many studies. The position of the feet is effectively recognized as having an impact on the lumbar constraint (e.g., Anderson & Chaffin, 1986; Delisle, Gagnon, & Desjardins, 1998). However, it is very difficult to identify experimental studies that would help interpret these observation data, which reflects what people are really doing. In this case, experimental research appears to have difficulty integrating field research data. In general, this points up important problems inherent in linking experimental and field data research.

4.2. Methodological Issues

This review shows that a good reliability level can be achieved—as concluded by Kilbom (1994) from her review of 19 grids—as well as adequate internal validity. Nevertheless, reliability is not an automatically transmittable result. It was striking to see how observer training procedures or reliability control tests were rarely mentioned in studies using an edited grid.

The review reveals that there is insufficient data to answer the following basic questions about good observer performance: What training process should be put in place? How experienced should the observer be? What problems can be expected? What are the observer's limits? Nevertheless, it does demonstrate that training has an important impact on reliability, although few basic rules or guidance about training modalities or duration could be identified. In fact, most proposed grids provided no guidelines about the training procedures to be followed by subsequent users. Attention is currently being focused on computerizing grids to facilitate data treatment and to expand their use in industry. It may be time to be more concerned about the subsequent quality of data.

Perhaps we are too easily assuming that experienced observers are competent observers. This premise should be reconsidered. For instance, it has been shown, through the studies on "time and motion" speed assessment that observers needed periodic retraining (Barnes, 1950). Fransson-Hall et al. (1995) found that post-trained new observers could perform as well as experienced ones. They also noted that extending practice sessions seemed to have little effect on observation reliability per se, without discarding other potential positive impacts such as on recording speed, memory, or skilfulness in the use of recording equipment. On the whole, it is clear that the quality of the training rather than its duration or practice sessions is the key issue.

The problems encountered by both users and designers of the observation grids were rarely mentioned. Few indications were provided about the difficulties encountered by the observers. It is reasonable to assume that the low reliability coefficient reported in some cases resulted more from a definition problem than from limited observational capability. The definition of observation constitutes a key issue that is rarely discussed. Without accurate observation criteria, a grid can not be used with reliability. Unfortunately, there is usually no space in edited papers to present these criteria.

Finally, this review shows that the characteristics of the tasks observed have a major impact on observer performance. For example, the more a task presents a high proportion of elements at the borderline between two classes, the higher the risk of misclassification. As observers seem to display specific trends, misclassification may be important when only one observer is used. Strategies to assess the material difficulty need to be developed. As studies show that observers are quite good at assessing an angle, they probably know when they are in the border zone. This skill could be taken advantage of.

5. CONCLUSION

The review shows an actual lack of consensus about the observation procedures. Few choices in the breakdown of variables were motivated. In spite of the variability of the proposals, several aspects the literature defines as relevant were scarcely, or not at all, covered by the grids. There is still much to be developed. However, enough evidence was provided to consider observation data as potentially reliable. Nonetheless, the large range of reliability results obtained indicate the importance of the training procedures adopted and of the accuracy of the observation criteria, for which very few guidelines exist. Methodological issues relating to the development and use of observation methods need to be more thoroughly addressed in the future.

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