

Case Study on the Assessment Effort of the Key Indicator Method for Awkward Body Postures (KIM-ABP)

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Abstract

This case study deals with the derivation of a necessary and sufficient analysis period for the practical application of the Key Indicator Method Awkward Body Posture (KIM-ABP). For the case study involving the de-icing of aircraft in open baskets, we chose a sample with an extreme working position for the deicers, involving continuous forced postures of the legs and torso (Sample A). This is therefore an extremely one-sided posture that workers must maintain for several hours per shift with very few opportunities to rest. It should therefore be expected that KIM-ABP would produce reliable results even with short observation times. To verify the KIM-ABP results, we used EAS as an alternative method (Sample B). Our working hypotheses for this case study are therefore: H1: With KIM-ABP, valid results for the risk areas are achieved after an observation period of 15 minutes. We speak of validity when the ergonomic assessment of forced postures is representative of the strain situation over an entire de-icing season. H2: If the 15-minute analysis period is divided into three randomly selected 5-minute observations, we expect the interquartile range (IQR) of all analysis results for Sample A to be small. Based on experience, we set IQR_{max} to 50. The influencing factors of the worker (e.g., height, gender), the technical and ergonomic design of the basket, the weather, the time of the day, the volume of traffic, the aircraft type, and the work organization all may have an impact on the KIM results. Since our case study focuses on the procedural economics of KIM-ABP compared to EAS, we kept these influencing factors constant through the study design. Both assessment methods used the same population. Likewise, there is no analyst bias, as a single, experienced analyst evaluated both methods. The problem of calculating values of central tendency and dispersion for classifications on an ordinal scale is addressed. Since the same analyst was used for sample A and sample B, learning effects can be ruled out. The IQR_{max} -criterion (H2) is violated in five

of 13 analyses of Sample A. The standard deviations of KIM-ABP were 64.85 for sample A and 16.26 for sample B. The median absolute deviation (MAD) was 55.4 for sample A and 9.9 for sample B. This means that 15-minute KIM-observations per workstation are not sufficient to yield reliable results in relation to the more refined EAS values in our case study. Similarly, both the macro KIM-ABP method and the more refined EAS method do not allow for a conclusive clarification of the influences of the worker, workplace design, weather, etc, particularly for short observation times.

Keywords

Key Indicator Method Awkward Body Posture (KIM-ABP), Ergonomic Activity Sampling (EAS), Deicing, Necessary Observation Time

1. Introduction

1.1. Scope of Study

The KIM-ABP method was applied to a database of the activities of de-icing personnel (11 males, 2 females) in open baskets at Montreal airport. 13 video files were at our disposal, each with three camera shots (person from the side, person from behind, long shot of trucks plus airplane). Each video lasted between 60 and 90 minutes (with two slightly shorter exceptions). On the one hand, subjective classifications of KIM-ABP were made on the basis of 3 randomly selected 5-minute intervals. With a sample size of 39 observations (13×3) the total observation time added up to 195 minutes. In contrast, with the alternative method EAS, a total of 1404 codings were created from 1073 minutes of video time. KIM-ABP values were calculated from the EAS codings.

1.2. Analysis of Postures at Work

This case study deals with forced body postures and their analysis and evaluation using the Key Indicator Method Awkward Body Posture (KIM-ABP).

There are numerous analyses and evaluation methods for postures at work in the literature and in practical implementation. Representing the multitude of sources, we will mention just a few recent synoptic publications:

Comparative analyses of OWAS, RULA, OCRA, and REBA are widely used, as discussed, for example, by [1].

There are numerous studies on the use of video-based data for posture analysis and ergonomic assessment. Automated or AI-supported derivations of ergonomic risk analyses from video recordings are available (e.g. [2]). Furthermore, [3] compare observation methods with the analysis of video recordings. [4]-[6], for example, focus specifically on video-based analysis methods and their test-statistical evaluation. [7] investigate the error probabilities of observation methods for analyzing musculoskeletal strain.

Older publications, e.g., by [8] and [9] analyze spinal strain in particular and illustrate that changing body posture and back support are crucial for preventing disc damage. In his dissertation, [10] examines the physiological effects of different body postures.

Review articles report the following complaints and illnesses in workers who are forced to maintain the same posture for long periods of time (e.g.: [11]-[13]):

- Back problems due to overstraining of muscles and ligaments;
- Chronic back pain;
- Restricted movement;
- Pain syndromes in the neck area and radiating to the shoulder region;
- Degenerative diseases of the shoulder;
- Varicose veins in the legs.

It should be noted that this list of synoptic studies is by no means exhaustive.

Important prevention topics include the ergonomic assessment of forced postures, the promotion of dynamic workplaces, and targeted risk assessment using key indicator methods and biomechanical analyses.

However, we have not found any source that deals with the systematic comparison of KIM-ABP with video studies.

1.3. Awkward Body Postures

The type of strain known as “forced posture” or “awkward body posture” is characterized by strenuous postures, often at the extremes of the musculoskeletal system’s range of motion, which are dictated by the work process and are maintained for long periods of time/continuously (static) ([14]: p. 520). Forced body postures lead to strain on the affected and adjacent regions of the entire musculoskeletal system due to constant static postural forces on the muscles and local internal biomechanical forces and pressure loads. Each of these areas is closely related to the following in terms of function ([15]: p. 12):

- the back to the lumbar spine region, but also to the thoracic spine region and the extensor muscles, which are used to straighten the body, when performing postural work;
- the shoulder region with the upper arm, the strain on which depends on the position of the arm, as well as with the neck and throat and their muscles;
- the leg region, especially with the knee joints, but also with the feet and hips.

Compensatory movements cannot be performed, or can only be performed inadequately, when working in forced postures. A break in the forced posture occurs when an unfavorable posture can be interrupted by a relaxed posture such as standing upright or sitting in a variable position in combination with relaxed hanging or resting arms. Even postures that appear “neutral” at first glance can become forced postures if compensatory movements are not possible over longer periods of time.

The level of strain per working day in the case of forced physical postures depends primarily on the cumulative duration of the static postures, *i.e.*, the total

duration of uninterrupted postures during the working day, and the type of forced posture (e.g., standing, kneeling, sitting) in conjunction with the posture angle of the upper body (e.g., bending forward) and arms (e.g., overhead work). In addition, there are unfavorable working conditions such as additional twisting and lateral bending of the upper body, tilting or twisting of the head, lack of support for the upper body, restricted movement, limited stability, as well as wetness, cold, and drafts. As with all other types of physical strain, the distribution of strain over the working day is important ([14]: p. 520).

Changing tasks during the work shift can result in both recovery effects and additional fatigue effects.

For our comparative study of workplace observation and video analysis, we chose aircraft de-icing as a forced posture involving a one-sided static standing load: workers stand in a compact size open basket (approximately $l = 0.9$ m, $w = 1.2$ m) for most of their shift and perform dynamic actions using their hand-arm system. The forced postures are only interrupted by waiting times in the truck cab. In addition, there is a demanding superposition of stress from the physical environmental influences. Added to this is psychological stress due to the high level of responsibility for the subsequent safety of the de-iced aircraft.

1.4. Work Tasks during Deicing

Deicing aircraft on the ground, part of an ultra-safe high-risk industry's life-cycle [16], is a crucial and mandatory maintenance service in preparing for flight to prevent deterioration of the aircraft's aerodynamic properties and crashes: "Clean Aircraft Concept" [16] [17]. To this end, several technicians and deicing trucks must coordinate their activities in day and evening shifts under severe time constraints and communication challenges, which have led in the past to OHS accidents [17]-[22]. The time constraints are dictated by the airport's scheduled departures [20]. The composition of the teams—and thus their respective experience—varies [23] [24]. Quality control in the area of aircraft deicing is carried out under cold and wind-chill thermal stress, in situations where noise and vibrations are also present [23]-[25].

Deicing takes place in closed and open baskets that are moved vertically and horizontally into position over the aircraft. The aircraft deicing work system is described in detail in [25] and [26]. Control work may be required on the snow-cleared ground near the running aircraft engines, especially in the case of tail engine aircraft types [17] [26] [27]. In deicing bays, there is also vehicle traffic as well as basket-plane collision risks [17] [23] [24] [28].

After deicing is complete, deicers must perform a tactile/haptic and visual quality check of the deicing [29] [30]. Even today, detecting clear ice is very difficult, especially when it is dark and the wings are wet. No satisfactory technical solution has yet been found to prevent the danger of clear ice [27].

The deicing quality check consists of detecting icing conditions under different lighting and light conditions (natural during the day, artificial at night) on low-

contrast surfaces, with glare risks in the daytime [17]. There must be no contact between the equipment (basket, spray guns, etc.) and the aircraft, so a safe distance must be maintained between the deicing equipment and the aircraft [31]. Visual inspections could not be further investigated in our previous work [27]; using eye trackers in harsh climatic conditions or cameras when deicers' faces are covered is a technical challenge.

1.5. Possible Consequences of Forced Postures during Aircraft Deicing

Deicing involves prolonged and sustained standing positions [24] [32] manipulating a 3 to 4 kg tool often beyond the reach zones for short and medium periods [32]. Standing can lead to torso torsion (sometimes up to 25°) and bending (sometimes sagittal up to 90°, sometimes lateral up to 25°) as well as strenuous head positions (sagittal and lateral flexions as well as rotations) [24] [32]. Workers have to perform tasks, arms fully extended or forearms flexed sometimes up to 60°, sometimes above their shoulders. These arm positions vary significantly throughout the entire shift [18] while the position of the legs and torso remains largely stationary. The waiting times in the truck refer to sitting positions [25]. The strain pattern does not change throughout the entire winter season. A more in-depth analysis of spraying deicing fluids under the airplane wings is needed [24].

Deicing technicians working in open baskets feel more tired than technicians working in closed baskets [26] [33]-[35], which has impacts on their physical health [36]. Fatiguing activities were therefore investigated through work analysis, working heart rate data analysis and posture/movements/action force analysis [25] [37] [38] as well as work-related energy turnover studies [24]. Results show that spraying anti-icing and deicing fluids, performing ground control (tactile and visual), entering and moving the basket and truck are strenuous tasks [23] [25]. Stress superposition is the main cause and work breaks are not sufficient for recovery [23].

2. KIM-ABP Key Indicator Method

2.1. Key Indicator Methods—Overview

The Key Indicator Methods (KIM) of the German Bundesanstalt (BAuA) are standardized procedures for the ergonomic assessment of working conditions, in particular for the assessment of physical strain in manual activities. They are recommended by the Federal Institute for Occupational Safety and Health (BAuA) and are available in different versions for different types of workloads [39]-[41].

The development of the BAuA's key indicator methods (LMM) began in the context of the implementation of EU Directive 90/269/EEC of 1990. Starting in 2015, preliminary drafts of the revised and expanded key indicator methods were extensively tested and evaluated in companies. The current, comprehensive, and revised six key indicator methods were finally published by the BAuA in October 2019 [42]. [42] present the development history and validation concept of the key

indicator methods.

The KIMs are used for the practical analysis of stress factors such as lifting/carrying, pulling/pushing, forced body postures, repetitive activities, and whole-body forces. They help specialists, psychologists, company doctors, and engineers to systematically identify stressful activities and derive measures for the prevention of occupational ergonomic risks. Each key indicator method consists of several key indicators (individual factors), for which points are awarded. The total number of points determines the risk of strain and provides information for ergonomic improvements.

The following **Figure 1** provides an overview of the various key indicator methods.

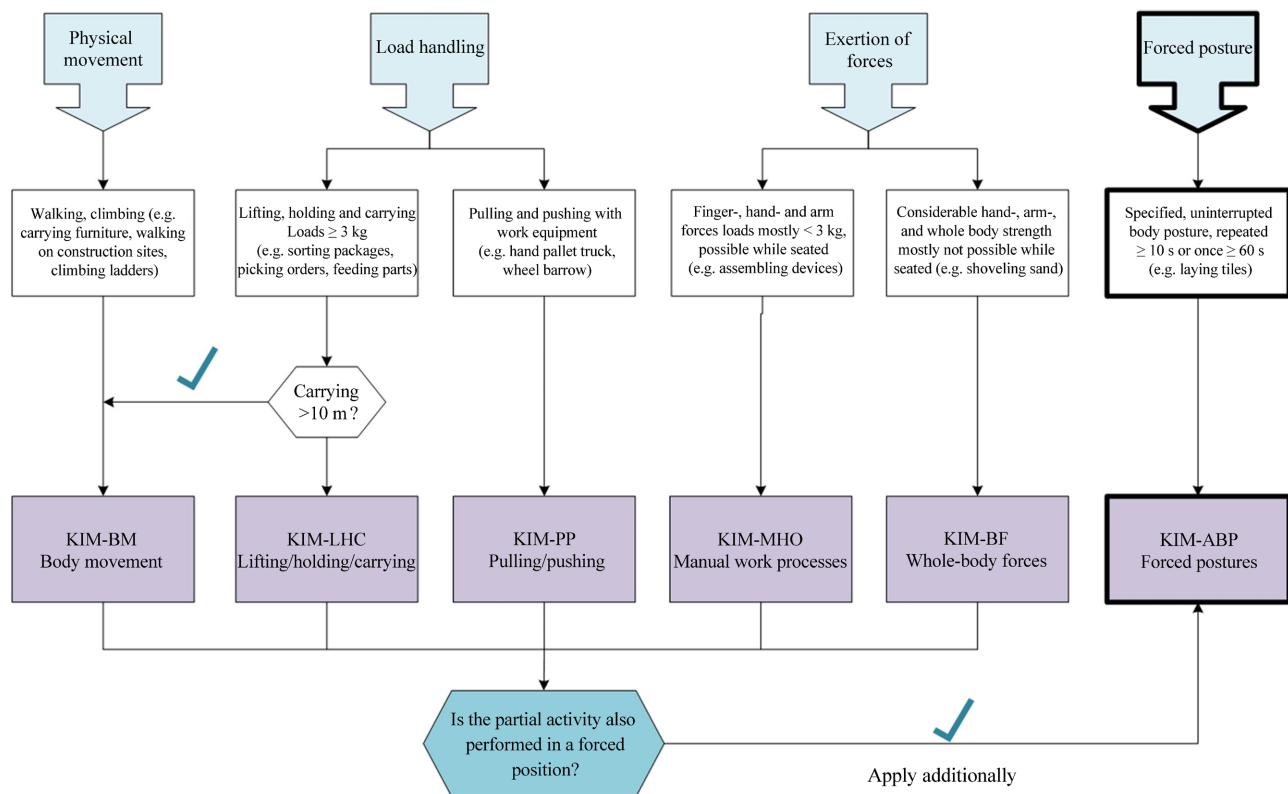


Figure 1. Guide to the key indicator methods (adapted from [15]).

2.2. Scale Level of the Key Indicator Methods

As practice-oriented screening methods, key indicator methods are based on ordinal scales, e.g., with the levels good/limited/unfavorable in the extended key indicator method for manual lifting, holding, and carrying. The levels cannot be assumed to be equidistant in any case, so arithmetic treatment of the classifications—*i.e.*, the assumption of a metric scale level can lead to misjudgments (see, for example [43]).

In the key indicator method for forced body postures [44], however, equidistance of the levels can be assumed both for the time weighting (step 1) and for the time proportions of the back, shoulder, and leg loads (step 2). However, this does

not apply to the execution conditions (step 3). The points are assigned equidistantly for steps 1 and 2, but not for step 3.

2.3. Quality Criteria for the KIM-ABP Key Indicator Method

Statistical analyses of KIM-ABP were conducted several times and the results published [41] [44] [45].

[45] determined objectivity and reliability in two workshops (with and without repeated measurements). Thirteen and fourteen sample activities were rated by 21 and five workshop participants, respectively. Intraclass correlation coefficients (ICC) were determined (Table 1):

Table 1. Objectivity and inter-rater reliability (adapted from [45]).

	Objectivity (ICC)	Inter-rater reliability (ICC)
Workshop 1	0.87	0.85
Workshop 2	0.91	0.93

According to [44] the objectivity and reliability of KIM-ABP are excellent.

However, the validity studies by [15] ([45]: p. 29) and other publications point to shortcomings (test rating “mostly good”):

- Unclear definition: not every uncomfortable posture is a forced posture; deviations from neutral postures and constraints imposed by the work process are decisive, which is often misjudged.
- Incorrect time weighting: rough estimates instead of measured data lead to systematic misjudgments; good knowledge and measurements are expressly required.
- Incorrect task breakdown: KIM evaluates partial activities; heterogeneous sections in an evaluation produce mixed values that are meaningless.
- Mixed loads: simultaneous loads are hidden in a key indicator method, although separate procedures are necessary.
- Observer variance: without forms/instructions, scale assessments are inconsistent; the boundaries of the risk areas are indicative, not precise.

However, our study is less concerned with objectivity, reliability, and criterion validity, and instead focuses solely on the statistical-testing criterion of procedural economy, particularly the question of how long an observation should last before the KIM-ABP classification can be made to achieve valid results.

There are very different, and in some cases only qualitative, recommendations regarding the necessary duration of observation on site [15]:

“The key indicator method consists of screening procedures that should be applied after gaining a good understanding of the specific work situation; a fixed observation time is not specified.” The developers of the key indicator methods cite the following as a guideline for the observation period: “Depending on the cycle and variance, a few cycles can take approximately 30 to 60 minutes” [14].

In practice, a short video time sample over representative cycles has proven effective until the proportions of the postures in the back, shoulders, upper arms, knees, and legs for the partial activity can be reliably determined. A brief, targeted observation (*often just a few minutes*) is usually sufficient for clearly structured, repetitive activities (e.g. [15] [46]).

The following time requirements are empirical values from practitioners that cannot be justified from a scientific point of view:

- For retail, 30 to 60 minutes are recommended [45].
- Observation times of 60 to 120 minutes per sub-activity are typical for the construction industry. One or more observation days are recommended for activities involving a wide range of variations on the construction site [45].

3. Methods

3.1. Working Hypothesis

In our case study, we set ourselves a challenging goal: Can reliable KIM-ABP ratings be made with 15 minutes of observation time?

Our working hypotheses for this case study are therefore:

H1: With KIM-ABP, valid results for the risk areas are achieved after an observation period of 15 minutes. The term “valid results” can encompass several dimensions, such as correct application of the procedure, content validity, usefulness, absence of bias, reliability, and statistical significance. In this case study, we focus primarily on the correct application of the procedure, content validity, and the efficiency of the procedure’s application. We had to forego statistical significance tests comparing KIM-ABP and EAS due to the small sample size ($n = 13$ video files).

H2: If the 15-minute analysis period is divided into three randomly selected 5-minute observations, we expect the interquartile range (IQR) of all analysis results for Sample A to be small. Based on experience [32], we set IQR_{max} to 50.

The influencing factors of the worker (e.g., height, gender), the technical and ergonomic design of the basket, the weather, the time of the day, the volume of traffic, the aircraft type, and the work organization all may have an impact on the KIM results. Since our case study focuses on the procedural economics of KIM-ABP compared to EAS, we kept these influencing factors constant through the study design. Both assessment methods used the same population. Likewise, there is no analyst bias, as one single, experienced analyst evaluated both methods.

Method for testing these working hypotheses:

We applied KIM-ABP to the activities and work design situations based on 13 video recordings (Sample A). The recordings covered the de-icing processes over a period of 4 months (December 22nd 2016 to April 18th 2017). The working methods of the workers are filmed on video for 55 to 90 minutes. Two videos were slightly shorter.

We then calculated the KIM-ABP scores using an alternative method, the EAS (Sample B, s. section 4).

The disadvantage of our study is that it is a case study with only one analyst (an ergonomist with 40 years of professional experience in work analysis), meaning that it is not possible to make generalizable statements about reliability and validity based on this study.

3.2. Assessment of the Analysis Effort Required by KIM-ABP

3.2.1. Activity-Sampling with EAS

To assess the observation and analysis effort required by KIM-ABP, we used an activity sampling method as an alternative method [24] [47]. Extensive data sets [17] [32] are available for forced body postures, which we consider suitable for testing the analytical effort of KIM-ABP. This means that we compare the activity sampling results of the EAS (sample B) with the subjective observation evaluations using KIM-ABP (sample A). At EAS, we performed posture analysis using the multi-moment technique. This is a work study method that has been tried and tested for more than a hundred years, validated and accepted by the collective parties [48] [49]. The principle is illustrated in the following time band diagram (Figure 2).

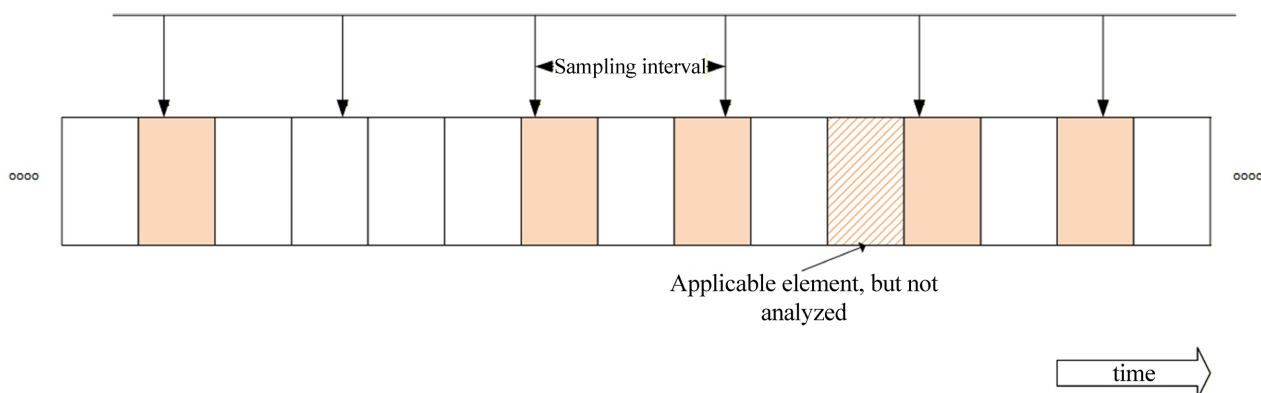


Figure 2. Time band diagram.

The multi-moment observations should be statistically random. In the past, complex, statistically validated tour plans were designed for this purpose. Today, this is often dispensed with, assuming that the large number of observations—despite a fixed “snapshot window” of, for example, 10 seconds (here)—ensures statistical randomness. The work processes highlighted in brown in Figure 2 are recorded during the tour, but the work process shown in hatched lines would be missed by the analyst. However, this is irrelevant due to the “large number” principle of observations.

The multi-moment technique is ideal for analyzing work processes, postures and movements, the use of force, load handling, etc., especially when based on photo and video documentation. It is also more precise than a classic time study, as it usually covers a large observation period (ch. 3.2).

In industry, multi-moment studies are often conducted over two weeks, possibly over three shifts [48].

We conducted $N = 1404$ observations using EAS, with the total analysis time amounting to 1073 min. Postures were recorded at 10-second intervals.

It is not always easy to distinguish video-based between static postures and dynamic body movements. The time range of 4 to 10 seconds is often given as the temporal boundary between “static” and “dynamic.” However, this distinction is not possible with the time-based technique of activity sampling. We therefore always interpreted the observed posture as “static.” When de-icing, the posture up to the shoulders is often static in any case, while the movement of the arms and hands can be dynamic.

3.2.2. Video Analysis with KIM-ABP—Method and Test Material

We had 13 video files at our disposal, each with three camera shots (person from the side, person from behind, long shot of trucks plus airplane). Each video lasted between 55 and 90 minutes (with two slightly shorter exceptions).

We conducted our video analysis as if an observer were to appear at the workplace three times at random intervals and remain there for five minutes to code KIM-ABP. This amounts to a total of 15 minutes of observation time per workplace. Waiting times in trucks are not the focus of this study (forced postures during *de-icing*) and were therefore not included in our analyses. According to the recommendations for use in sections 2.2 and 2.3, 15 minutes would be the lower limit of the observation period (see also [14]). We only performed additional analyses (7 in total, 35 minutes) on one video (O7) to obtain further results on point value dispersion using an example.

However, if all the KIM-ABP analyses we performed are combined in one file, the observation and analysis time amounts to 195 minutes.

We used an interactive PDF form for the analysis [14].

When entering the KIM data, we assumed a working time of 6 hours for all videos. The remaining working time (2 hours) was spent on preparatory work, getting dressed, walking to the truck, etc. The active shift duration is therefore 6 hours, during which employees work at the airfield and are exposed to various environmental factors. This 6-hour baseline is the same for all participants in our study. This means that the active shift duration does not affect KIM-ABP or EAS comparisons between participants.

The start time of each (sample A) observation was determined using a random number generator. To generate uniformly distributed pseudorandom numbers in the interval, the `RAND()` function implemented in spreadsheet programs was used, which by default returns a uniformly distributed random number:

$$\text{Start time} = \text{RAND}() * (\text{Video length} - 0) + 0$$

To avoid start times that are too close together or identical, duplicates were discarded and `RAND` was reapplied.

Table 2 provides an overview of the working conditions and workers for each video.

Further details on the test subjects can be found in [37]. The participation of the workers in our study was voluntary. Test subject O12 withdrew from participation, which is why O12 is missing from **Table 2**. The aircraft models featured in our study are listed in [18].

Table 2. Conditions for video recordings.

Video (recorded time interval)	Test subject	Cloudiness	Wind speed	Temperature
O1 (05:37 - 07:13)	male	clear	30 km/h	-15.5°C
O2 (15:58 - 17:13)	male	light snowfall	9 - 26 km/h	between -5°C and 0°C
O3 (17:54 - 18:58)	male	clear or cloudy	19 - 37 km/h	between -5°C and -2°C
O4 (19:48 - 20:46)	female	light snowfall	20 km/h	0.6°C
O5 (07:11 - 07:56)	male	light snowfall	9 - 26 km/h	between -5°C and 0°C
O6 (05:16 - 06:51)	female	clear	12 km/h	1.4°C
O7 (06:29 - 07:52)	male	light snowfall	9 - 26 km/h	between -5°C and 0°C
O8 (07:02 - 08:18)	male	light snowfall	9 - 26 km/h	between -5°C and 0°C
O9 (07:13 - 08:06)	male	clear or cloudy	19 - 37 km/h	between -5°C and -2°C
O10 (06:51 - 08:00)	male	clear or cloudy	19 - 37 km/h	between -5°C and -2°C
O11 (07:05 - 08:25)	male	cloudy	27 km/h	-10.1°C
O13 (13:42 - 14:18)	male	cloudy	35 - 40 km/h	between -7°C and -8°C
O14 (14:32 - 17:36)	male	clear or cloudy	19 - 37 km/h	between -5°C and -2°C

Although KIM-ABP also allows interpolation for time shares, we did not use this in our study. Since KIM is a screening tool, there is a risk of creating false accuracy with temporal interpolation and overloading the tool (see section 2.3).

Similarly, the algorithms of the extended key indicator methods for workload changes between forced postures, lifting, holding, carrying, pulling, and pushing, etc. [50] were not used either, as the load bottleneck “forced posture” is clear in deicing activities and we wanted to focus on the ergonomic cost/benefit analysis of KIM-ABP.

3.2.3. Problem Definition and Methodological Rationale

The authors aim to compare the procedural metrics KIM-ABP and EAS. Both methods measure the same target variable, “forced body posture,” using samples drawn simultaneously from the same population (13 video files). Possible target variables for the methodological evaluation are:

- Processing time per case (e.g., min/video or min/subject);
- Total effort per project (e.g., number of analysts, qualification level);

- Error susceptibility of the two methods (e.g., rework rate).

Based on this, we define the following as the target variables for our study:

- Error susceptibility during short observation periods;
- Variation in the assessed forced postures.

The contextual factors influencing body posture (see **Table 2**) are confounding variables for the research questions “Which method is more economical?” or “To what extent can observation durations be minimized?” and are kept constant by the study design. Differences in the economic indicators when analyzing with KIM-ABP or EAS are therefore attributable to the method and not to the population. The influencing factors in **Table 2** are thus controlled conditions that are irrelevant for the method comparison as long as they are equally distributed across both methods. Therefore, it is important that both samples originate from the same population.

The “true” postural constraint cannot be identified using this method comparison. This would require a reference method (“gold standard”), e.g., 3D motion capture. A statement is only possible in the following form:

- Method A exhibits greater variability than Method B;
- Method A exhibits higher internal consistency or stability;
- Observation times $t < t_{min}$ lead to greater variability in results.

Thus, our study focuses on methodological economy and reliability.

3.2.4. No Significance Tests between Samples A and B

With very small sample sizes ($n = 13$) and less-than-ideal sampling conditions (ordinal scale, paired special population), the statistical power of many statistical methods is so low that significance tests provide only limited value and can easily be misleading. We therefore rely on a qualitative comparison—location parameters, distribution, and trends (ch. 4.1 - 4.2).

As an exception to this limitation, we used the bootstrap method to attempt to expand the basis for assessment beyond the existing sample size (ch. 4.3).

4. Results

4.1. Procedure for KIM-ABP Coding

We refer to the form in [41]. **Figure 3** shows an excerpt from the coding as an example. The procedure is the same for samples A and samples B.

KIM-assessment is a mixed-scale approach: KIM-ABP uses ordinal-scale input variables, each of which is coded with a point value. These point values are aggregated into a total score. This does not automatically result in a metric total score, as the intervals between the point levels are not equidistant. The assignment to risk classes is also at the ordinal scale level. Nevertheless, statistical evaluations are frequently performed at the metric scale level in ergonomics. We address this situation below by providing alternative calculations at both the ordinal scale level and the metric scale level.

KIM for assessing and designing physical workloads with respect to Awkward Body Postures (KIM-ABP)

Workplace/sub-activity	Excerpt from O14, classified as EAS		
Duration of the working day	8	Evaluator:	
Duration of the sub-activity	6	Date:	

1st step: Determination of time rating points

Total duration of this sub-activity per working day (up tohours)	Up to 1	2	3	4	5	6	7	8	9	10
Time rating points	1	2	3	4	5	6 ✓	7	8	9	10

2nd step: Determination of the rating points for other indicators

A	Loads on the back – body posture when working without or with low force exertion		Amount of time as part of the sub-activity	Points
	1	Upright back posture in standing, squatting,.....	34 %	2.7
	2	Torso being moderately inclined forward (> 20°- 60°).....	29 %	8.6

3rd step: Evaluation and assessment

		A Back	B Shoulder/upper arms	C Knees/legs	Highest risk score (total risk)
	Total of risk scores in key indicators	14.6	1.9	5.1	
	Unfavorable working conditions	5.0	3.0	3.0	
	Further working conditions +	3.0	3.0	1.0	
Time rating points 6 x	Total of all indicator rating points +	22.6	7.9	9.1	
	Risk scores of body postures	135.6	47.4	54.6	135.6

Figure 3. Excerpt from KIM-ABP-coding (source of the form: [44]).**4.2. Results Overview**

Table 3 provides an overview of the scores achieved with KIM-ABP. Part A of the table shows the scores based on subjective assessment after three five-minutes observation periods (= Samples A). Part B of the table contains the assessment based on the EAS (= Samples B, alternative method) evaluation.

We use the arithmetic mean for the ordinal scale of the KIM-ABP with caution, but due to the equidistance of the time scale levels, we consider this approach to be acceptable (for now). In statistics, MAD stands for mean absolute deviation and is a measure of dispersion that indicates how much the values of a sample deviate on average from the selected median. However, with small samples—as is the case here—the MAD is only of limited significance. In section 4.2, we will instead discuss sample expansion.

Table 3. Results overview.

Samples A										Samples B		
Video-No.	KIM-ABP-scores (subjective assessment based on a random 5-minute observation)							Arithmetic mean	Median	Median absolute deviation (MAD)	Interquartil range	KIM classification based on EAS evaluation (in total n = 1404 observations in 1073 min)
	Analysis number											
	1	2	3	4	5	6	7					
O1	48	48	72					56.0	48	0	12	117.0
O2	258	240	222					240.0	240	18	18	142.8
O3	162	148	168					159.3	162	6	10	148.2
O4	156	138	192					162.0	156	18	27	123.6
O5	120	204	84					136.0	120	36	60	174.0
O6	108	114	84					102.0	108	6	15	112.8
O7	168	180	270	96	162	210	96	168.9	168	12	51	132.0
O8	120	84	168					124.0	120	36	42	129.6
O9	108	168	72					116.0	108	36	48	117.0
O10	72	72	162					102.0	72	0	45	122.4
O11	270	48	102					140.0	102	54	111	126.6
O13	96	192	72					120.0	96	24	60	131.4
O14	66	126	270					154.0	126	60	102	135.6

The interquartile range (IQR) can be used as a measure of dispersion for ordinal-scale data, similar to the standard deviation for metric-scale data. However, there are no established thresholds as with the coefficient of variation, since the interquartile range depends on the range of values on the scale. Based on the authors' experience with five-level ordinal-scale ergonomic assessment procedures [32], we expect that the interquartile range (IQR) in multiple analyses of the same workstation (*ceteris paribus*) should be below 50. This criterion is violated in five of 13 analyses of Sample A (penultimate column in **Table 3**).

Figure 4 points out the large spans of the individual video observations and also the spans within a video.

The scatter plot shows, first of all, that the EAS values (Sample B, blue crosses) fall within the KIM-ABP (Sample A, coloured dots) range. In some cases, slightly higher EAS values are observed; in others, the differences fall within the range of variation observed in repeat measurements.

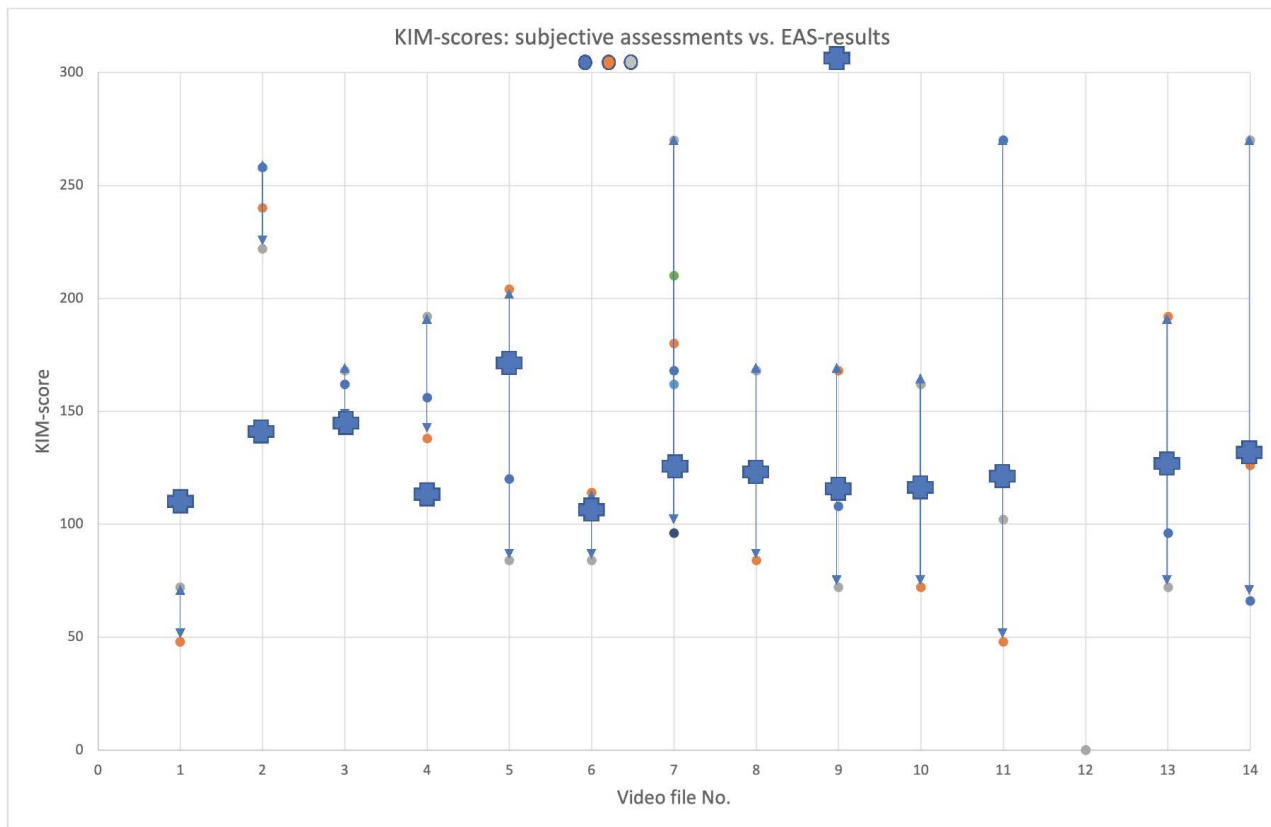


Figure 4. Wide range of KIM scores according to subjective assessments (colored dots) compared to KIM calculation based on EAS (blue crosses).

As the figure shows, the absolute values of the KIM-ABP scores (colored dots) vary greatly. The score ranges of the five-minutes observations are sometimes very large.

The standard deviations clearly illustrate the difference between the subjective, relatively short-term assessment of KIM-ABP (sample A) and the long-term observation based on a large number of surveys (sample B, blue crosses): in the first case, the standard deviation is 64.85, while in the second case it is only 16.26 (**Table 4**) A small standard deviation means: The values are close to the mean, the dispersion is low, and the mean describes the data well. A large standard deviation means: The values are widely distributed across the value range, there are large differences between the observations, and the mean is therefore less “representative.” For the deicing case study, this means that a few brief observations are in no way sufficient to classify the strain caused by forced body postures.

Table 4. Comparison of dispersion measures of KIM-ABP-scores.

Statistical parameter	Samples A	Samples B
	Subjective short-term assessment (n = 13 × 3 × 5 min)	EAS-based long-term observation (10-second-intervals in videos lasting between 60 and 90 minutes)
Standard deviation	64.85	16.26
Median absolute deviation (MAD)	55.4	9.9

As already explained, the limitations in calculating the standard deviation for ordinal scaled characteristics must be taken into account. The mean absolute deviation from the median is a measure of dispersion that is appropriate for the ordinal scale level. It is 55.4 for subjective short-term observation, but 9.9 for EAS-based evaluation.

The 95% confidence interval for the median of sample A can be calculated in various ways. We have opted for the bootstrapping method (ch. 4.3).

For sample B, the 95% confidence interval for the arithmetic mean of this sample (with standard error SE) is

$$\bar{x} \pm t \cdot SE \approx 132.5 \pm 2.18 \cdot 4.5 \approx 132.5 \pm 9.1$$

With 95% confidence, the true mean value in the population lies between the lower limit of 123.4 and the upper limit of 141.6.

4.3. Bootstrap Method for Small Samples

Is it possible to make a reliable statement based on 13 × 3 KIM-ABP scores of sample A?

Using the bootstrap method [51], we can perform resampling, which allows us to estimate uncertainty even with small samples. However, it should be noted that the bootstrapping method estimates confidence intervals too optimistically (*i.e.*, too narrowly) for small samples.

For the current KIM-scores, we performed a “draw and replace” procedure, in our case 1000 times. This allows the scores from a small sample to provide a more stable statement regarding the central tendency and dispersion when compared with the EAS results (Table 5).

Table 5. Bootstrapping results for sample A (n = 1000).

KIM-ABP-scores	O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O13	O14
Arithmetic mean	55.94	239.34	158.94	162.26	140.00	101.72	208.58	123.74	116.12	104.49	147.91	121.97	151.28
Median	48	240	162	156	120	108	180	120	108	72	102	96	126
MAD	0	18	6	18	36	6	12	36	36	0	54	24	60
97.5% percentile	72	258	168	192	204	114	270	168	168	162	270	192	270
2.5% percentile	48	222	148	138	84	84	168	84	72	72	48	72	66

For sample A, the 95% confidence interval of the median of the Bootstrap-sample ($n=1000$) A is

$$ME \approx [84; 168].$$

The confidence interval is therefore significantly larger for sample A than for sample B.

5. Discussion

5.1. Application Experiences

5.1.1. Unfavorable Selection of the Observation Interval

The challenge we set ourselves of only 15 minutes of observation time does not allow for reliable conclusions to be drawn about forced body postures. Even if the 15-minute observation period is split into randomly selected time points, the results are highly scattered and deviate significantly from the results of an alternative procedure (sample B).

- When traffic is light, the worker often finds themselves waiting in the truck. In the worst-case scenario, the analysis intervals could all fall within the waiting period, resulting in a completely inaccurate picture of reality (the first two observations intervals of O1).
- An unfavorable choice of observation interval can also lead to serious misstatements, as example O1 (third interval) shows: Shortly before the end of the observation interval the test subject returns from the truck cab (sitting until then), to the basket—physical activity after a long wait in the truck would actually be positive from an ergonomic point of view. However, this causes the KIM-ABP score to increase from 48 to 72 points—higher postural strain.

[41] demonstrate and recommend that short video recordings even when taken repeatedly across workers at different times on different days may not be effective for identifying peak exposures if they do not occur frequently...if...reliable quantitative estimates of ergonomics risk factors are needed...careful consideration must be given to the exposure assessment strategy that is used...Highly variable exposures will require more video recordings.

The factors discussed in **Table 2** naturally also affect the awkward postures. As already explained in Chapter 3.2.3, there are too many variables to take them into account in the methodological comparison between KIM-ABP and EAS. We will therefore discuss them only in qualitative terms below.

5.1.2. Traffic Volume

Traffic volume is strongly influenced by the shift schedule (morning or evening shift) and by the respective observation intervals within the shift. High traffic volume (e.g., 7:30 to 9:30 in the morning shift) means that the time spent in the truck is virtually zero. This means that there is hardly any sitting (e.g., O5, O6...O11).

The type of aircraft to be deiced also has a strong influence on body posture. Small aircraft models (propeller or below B737) require the operator to lean for-

ward significantly to ensure proper deicing. In addition, some aircraft models require the basket to be lowered and a check walkaround of the aircraft to be performed. In such cases, the static requirements for KIM-ABP are no longer met.

5.1.3. Weather

In extreme weather conditions, the supervisor may grant an additional break to warm up in the truck cabin. However, this is only possible if alternative, manned deicing vehicles are available to compensate.

As with all physically demanding activities in extreme weather conditions, workers experience fatigue during their shift. This also affects their posture. For example, the worker sprays large areas of the wings (“sprinkling”), largely in an upright position, to limit strenuous and tiring bending or twisting postures. This large-area “sprinkling” does not comply with work regulations, but is occasionally observed.

This raises the question of how KIM-ABP deals with fatigue-related changes in body posture.

5.1.4. Workplace Design

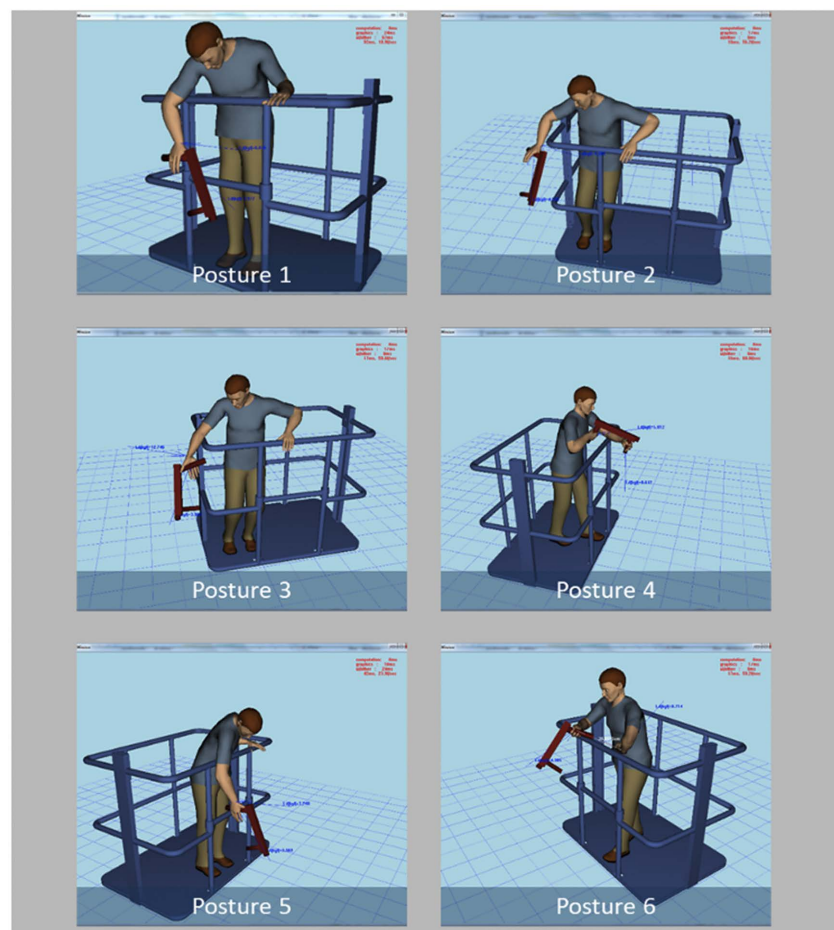


Figure 5. Critical representative postures (JACK 7.1) 2016–2017 field study—open basket without control panel, receptacles for the two deicing guns and others, railing height 1 m [52].

The design of the basket has a significant influence on the body posture of workers. There is a conflict here between preventing workers from falling by installing high railings (mandatory and height defined by European or North American standards) and the difficulty of working with railings when deicing aircrafts (**Figure 5**).

5.1.5. Influence of Workers

Figure 6 shows how strongly the data relating to the worker and the respective work task can influence the KIM-ABP result. A small woman has to bend forward and twist significantly to deice a low, small-format propeller aircraft (subject O6).



Figure 6. Forward and twisted leaning by a “small woman” worker and the de-icing of a small aircraft.

5.2. Conclusion and Outlook beyond Our Case Study

Short observation periods carry a high risk of incorrect KIM-ABP assessments. Activity sampling over longer observation periods reduces this risk. In any case, assessments based on a single tour of the facility are unacceptable, as they carry the risk of recording random or one-off events in the KIM-ABP assessment. Even a longer observation period during a shift does not protect against misjudgments. It therefore seems sensible to consider all possible factors influencing posture before KIM-ABP observation and classification. The BAuA initial screening for preliminary risk assessment can help with this ([15]: pp. 18-19).

However, the initial screening requires knowledge of the expected body postures even before the actual KIM studies. It would be worth checking whether the observation repertoire necessary for the reliability of the results—the observation frequencies and time intervals—could be better estimated based on the work tasks to be performed. The authors recommend an initial screening based on the types and frequencies of work tasks. This information is usually available in the company’s organizational data bases.

Regarding the “unfavorable working conditions” on the second page of the

KIM-ABP coding sheet, we suggest revising the frequency classifications, as they are very rough. In the case of trunk twisting, “frequently” and “constantly” should not be in the same category. When classifying head tilt, “occasional or constant” should also not be in the same category.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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