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Partly visible periods in posture observation from video: Prevalence and effect on summary estimates of postures in the job

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ABSTRACT

This paper investigated the extent to which observers rated clearly visible postures on video differently from partly visible postures, and whether visibility affected full-shift posture summaries. Trunk and upper arm postures were observed from 10,413 video frames representing 80 shifts of baggage handling; observers reported postures as fully or only partly visible. Postures were summarized for each shift into several standard metrics using all available data, only fully visible frames, or only partly visible frames. 78% of trunk and 70% of upper arm postural observations were inferred. When based on all data, mean and 90th percentile trunk postures were 1.8° and 5.6° lower, respectively, than when based only on fully visible situations. For the arm; differences in mean and 90th percentile were 0.7° and 8.2°. Daily posture summaries were significantly influenced by whether partly visible postures are included or not.

1. Introduction

Observation has been called “probably the most often used approach to evaluate physical workload”, and there are many different observation protocols available for use in realistic working conditions, on real workers performing real work tasks within the real industrial context (Takala et al., 2010). For example, observations may be made based in real time using a paper-based (Village et al., 2009) or computer aided system, on running video (Liv et al., 2012), on video still images, or using a multi-camera system. Posture values may be recorded into broad categories (McAtamney and Nigel Corlett, 1993; Callaghan et al., 2004), or narrow ones that can be treated as continuous variables (Bao et al., 2007; Trask et al., 2013). However, one challenge that field-based observation protocols have in common is that the view of the observed worker is not always clear, as the workplace setting does not always make for ideal observation conditions, i.e. an unobstructed, sagittal view of the relevant body part (See Fig. 1). In addition to skew introduced by oblique viewing angles or far distance, the body segments in question may be obstructed by equipment, other workers, or the worker's own body segments (Sutherland et al., 2007). Situations when postures are only partly or not at all visible may arise for instance when workers are in machinery-operation cabs; under conditions of heavy rain, fog, or dust; when the observer has inadequate safety training or security clearance to enter a worksite; and when workers are occupying a small space that would not accommodate the observer (Trask et al., 2007).

Past studies have quantified the potential errors in observation introduced by: oblique camera angles (Sutherland et al., 2007, 2008; Qu et al., 2012); expert vs. novice observers (Weir et al., 2007; Andrews et al., 2008); the size of body parts and range of motion (Bao et al., 2009); and category resolution and ability of observers to identify detailed categories (Weir et al., 2007; Andrews et al., 2008; Lowe, 2004). These aspects are important for understanding how to arrive at the best possible validity and efficiency when assessing postures by observation. However, questions remain regarding the degree of inference and estimation involved in typical work posture observation under realistic working conditions. Although some estimation and inference are required by the nature of any workplace observation, studies rarely report the degree to which postures are assumed or approximated when they are only partly visible; for example, situations where evidence from other body parts or inference based on the task are still at hand to guide the observer. Even validation studies that

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Fig. 1. Examples of partly visible body positions where the posture must be inferred: a) the arm is hidden behind the body; b) the bag is obscuring the right arm and much of the trunk; c) the narrow-angle frame does not show the hips. In these cases, given the context, position of other body parts, and the load in the hand, postures may be inferred.

describe the observation protocol and training practices in depth rarely describe the procedure for posture estimation in such cases (Village et al., 2009; Paquet et al., 2005). If estimation of partly visible postures is required for significant parts of the total observation period, and if postures differ between fully and partly visible periods, including the approximations (or not) may substantially influence the overall summary results on postures in the job.

Thus, there is a need to determine the extent to which periods with partly visible postures influence daily exposure summary statistics. If overall results are influenced by whether partly visible periods are included or not, the ergonomist faces the trade-off between increasing the amount and completeness of data by including such periods, and taking the risk of posture estimates in partly visible periods being less correct than those in fully visible periods. Using video data collected from aircraft baggage handlers, this paper addresses two questions: 1) how often are observers required to approximate postures during dynamic work due to the worker being only partly visible?; and 2) to what extent do estimates of overall summary variables of postures in the job differ depending on whether such approximations are included or not? We hypothesize that partly visible postures are commonplace in video-based observation, which in turn influence summary exposure estimates.

2. Methods

2.1. Study population and sampling

Prior publications describe in detail the methods for data collection (Trask et al., 2012) and data processing (Trask et al., 2013). Briefly, twenty-seven randomly-selected full- or part-time baggage handlers from a single employer at a large Swedish airport were recruited to the study. Workers who consented were video-recorded with a single camera for at least 4 h during their regular work activities. In this context, where workers move throughout the worksite, dual-cameras were not feasible for shift-long exposure assessment. Also, as this was a field-based study, we were not able to control lighting conditions, camera angle, and whether parts of the body were occluded. Video-recordings were collected both indoors and outdoors during the winter months of January and February, during a variety of weather conditions including: snow, sun, wind, and clouds. Day, afternoon, and night shift were included, resulting in recordings with indoor light, daylight, dusk, and darkness. Thus, these measurements represent conditions in *real-world* observations of productive work. Three measurement days were successfully collected from all but 1 worker who could not complete a third due to injury, resulting in data being available from 80 different shifts. All participants gave informed consent and all methods were approved by the Regional Ethical Review Board in Uppsala, Sweden.

2.2. Observation data collection and processing

Participating workers' regular work tasks were video recorded using a single camera by following them throughout the airport during for the first or second half of their work shifts. These recordings were subsequently analyzed by four (4) trained observers using a customized software program, ViSPA (Video Sampling Posture Analysis), similar to that described by Bao et al. (2007, 2009). Observers were university students; all received a 35-h structured training program following training suggestions laid out by Bao et al. (2009). This included training in the posture definitions and recording protocols, practice watching trunk and shoulder postures, instruction and practice using the ViSPA software, group discussions on complex scenarios, and feedback on performance. Observers had access to senior researchers throughout the analysis process and were encouraged to ask questions and clarification whenever needed (Trask et al., 2013). Worksite still frames were selected at 55-s intervals, yielding up to 252 unique frames per half-shift. Each workshift was divided into four parts, with each observer assessing one randomly-assigned part (Trask et al., 2013). Observers coded posture with 1-degree resolution relative to gravity for the trunk ($-180°$ extension to $+180°$ flexion) and upper arm ($0°$ to $+180°$) at a self-selected pace. Observers also coded trunk twisting and lateral flexion as binary variables; angles judged to be greater than $20°$ were recorded as ‘twisted’ or ‘laterally bent.’ Additionally, the amount of time between displaying a still frame and the observer submitting the posture rating was recorded automatically by the registration software.

For each frame, the degree of visibility was evaluated by the observers for each body part: left arm, right arm, and trunk; in one of the categories: clearly visible, partly visible (inferred postures as shown in Fig. 1), or completely undistinguishable. Thus, this data set provides an opportunity to analyze the difference between daily exposure summaries based on observations where the body parts were fully visible and no inferences were made, vs. summaries based on all available ratings, irrespective of posture visibility.

2.3. Statistical analysis

Daily exposure summaries were generated for both trunk flexion/extension and right upper arm inclination, including: mean angle, 90th percentile angle, and percent of work time spent in