Workload Assessment in Field Using the Ambulatory CUELA System

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Abstract. Ambulatory assessment of physical workloads in field is necessary to investigate the risk of work-related musculoskeletal disorders (MSD). Since more than ten years the BGIA is developing and using the motion and force capture system CUELA (computer-assisted recording and long-term analysis of musculoskeletal load), which is designed for whole-shift recordings and analysis of work-related postural and mechanical loads in ergonomic field analysis. This article gives an overview of the actual state of development and some applications of the system.

Keywords: ambulatory workload assessment, inertial tracking device, motion capturing, CUELA, ergonomic field analysis.

1 Introduction

At many workplaces, musculoskeletal workloads due to manual material handling, awkward postures or repetitive movements can be commonly observed. Observational methods are commonly known for workload assessment in field. The problem with these methods is that the description of risk factors (e. g. postural workloads) is too broad to provide accurate information for an appropriate assessment [18]. Therefore, direct measurements should be preferred for more accurate and less time-consuming workload data acquisition and assessment. There are several measurement systems for assessment of postural workloads of a specific body part, e.g. assessment of trunk postures at work [20, 21]. The BGIA (Institute for Occupational Health and Safety of the German Social Accident Insurance) is developing and using a measuring system known as CUELA (computer-assisted recording and long-term analysis of musculoskeletal load) for assessment of postural and kinetic workloads of several body parts (upper and lower extremities, trunk and head). CUELA allows for a quantification of musculoskeletal workloads even in complex work processes. In a second step a check of the effectiveness of already initiated measures is possible to improve the ergonomics of the work process.

2 Method

The CUELA system consists of accelerometers, gyroscopes and potentiometers, which can directly be attached to the worker's clothes, and a small portable

V.G. Duffy (Ed.): Digital Human Modeling, HCII 2009, LNCS 5620, pp. 221–226, 2009.

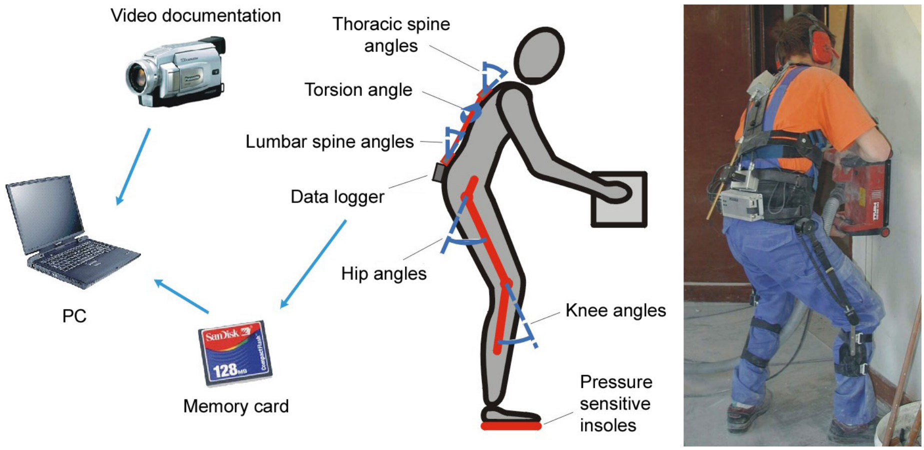

Fig. 1. Setup of the CUELA system (basic version)

data-logger (sampling rate 50 Hz, 168 channels). The basic CUELA system enables a motion capturing of the trunk (3D) and of the lower extremities in the sagittal plane [5, 6] (see figure 1). An extension of the CUELA system also provides a 3D motion recording of the upper limb (shoulder blade, shoulder joint, elbow, forearm and wrist), the inclination of the pelvis and the head [7, 14]. As the system run on a miniature battery, CUELA is specifically designed for field analysis at mobile workplaces.

The synchronous registration of ground reaction forces is realized using foot pressure sensitive insoles. Each insole consists of 24 piezo-resistive hydro cells. From the ground reaction forces, it is possible by using a biomechanical model to detect the handled load weights even during dynamic movement [5].

The measuring system, which can be fitted at the workplace in about 20 minutes, weighs approximately 3 kg. It can be adjusted to body size and height. Employees wearing the system can go about their work in the usual way.

The measurements are additionally documented on video. By synchronizing the video recording with the measured data, it is possible to match the load readings with the actual work situation. Immediately after measurement the data can be placed into a developed CUELA software and displayed (see figure 2). Using this software it is possible to display body postures at any given point with the aid of a 3-dimensional computer-animated figure and a time-dependent graph of the measured data. At the same time, the associated work situation is automatically illustrated in the video sequence.

After measurement it is possible to mark any actions or situations to highlight certain work activities and have them evaluated. The CUELA software automatically issues a series of statistical evaluations to give a quick impression of the quantified risk factors. Body angles and postures are analyzed with reference to the literature and some relevant standards:

- Extreme body angle positions, asymmetrical posture patterns (assessed in accordance with ISO and European standards and literature e. g. [4])
- Static postures (assessed in accordance with European standards)
- Repetitive movements (assessed in accordance with RULA [19, 14], OCRA [1, 14] and other literature [23, 17]

For each measurement, it is possible to have an OWAS (Ovako Working Posture Analysing System [16]) ergonomic analysis carried out. The software automatically identifies work postures classified in accordance with OWAS in connection with the handled weights and evaluates them statistically. As a result, the user receives a list of priorities that distinguishes between four risk classes (action category/class of measures).

For the biomechanical assessment of manual load handling and to estimate the associated load on the spine, the measured data can be entered as input data into biomechanical human models [5]. Apart from the measured body/joint movements and forces, the model also requires the subject's data, e.g. body height, length of limbs and body weight, as input variables. From this, force and torque vectors are calculated at the model's joints. For estimation of the loading on the lumbar spine, an interface to the biomechanical model “The Dortmunder” [15] exists.

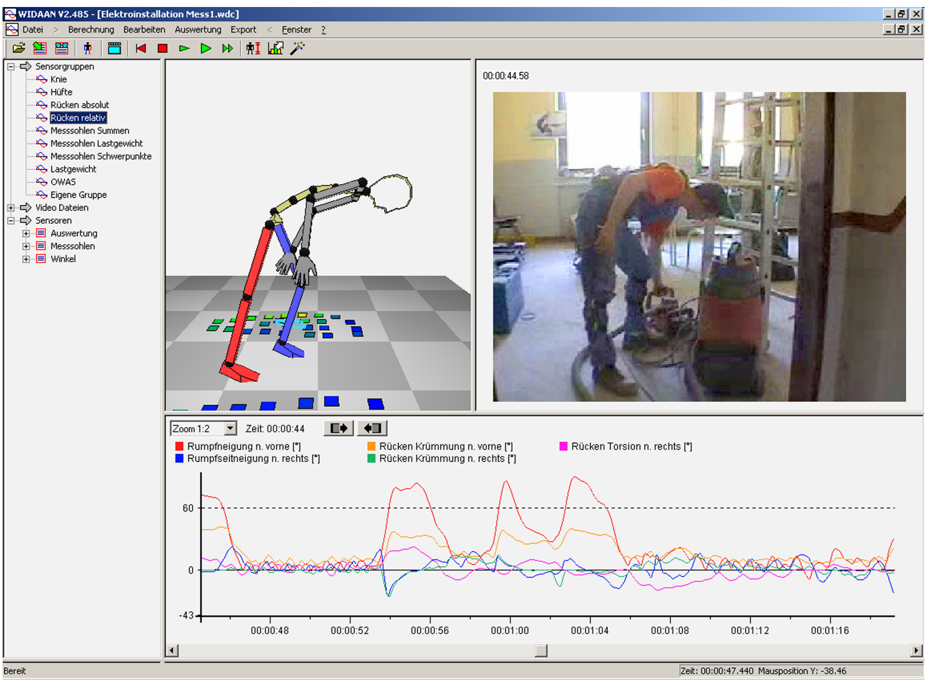

Fig. 2. Data visualization and assessment with the CUELA software, including video, 3D puppet and time graphs

CUELA enables also a synchronous application and data acquisition with other physical and physiological measurement devices: 3D force handles, e. g. [10], force gloves, ECG, EMG [11] and whole body vibration [13].

An interface of the CUELA software to a BGIA database allows for collecting workload data from occupational practice for evaluating workplaces and developing suitable preventive measures [3].

3 Results

The effective CUELA method has been successfully employed in the last years in reducing health risks at numerous workplaces in a variety of industries (including the building industry, the retail trade, the energy industry, electrical industry, metalworking industry, chemical industry, textile and leather industry and nursing). Both in consultations with the companies themselves and in research projects, targeted measures have been initiated to prevent excessive loading of the musculoskeletal system at the workplace. The quantification of the loading situation before and after ergonomic modifications facilitates a precise control of the effectiveness of such preventive measures. The findings from the measurements have in several cases been converted into simple instructions with practical tips for the persons concerned.

Some examples for projects including the application of CUELA are listed in the following:

- ergonomic intervention study at sewing workplaces [7]
- assessment of pushing and pulling of trolleys aboard aircrafts [10, 12]
- redesign of crane operator workplaces [3]
- whole shift postural workload assessment in different nursing workplaces [9]
- assessment of physical activity at workplaces [24]
- combined assessment of posture and whole body vibration [13]
- comparative assessment of dynamic office chairs [8]

Currently the hardware of the CUELA system is updated by replacing the analog motion sensors with digital 3D inertial sensor packages [22].

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