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Predicting real-world ergonomic measurements by simulation in a virtual environment

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ABSTRACT

Virtual reality techniques have been increasingly used for ergonomic applications. However, it is always important to know whether the results obtained in a virtual environment (VE) are representative of a real environment (RE) ones. This paper presents our preliminary experimental results on the relationship between ergonomic measurements in VE and RE for some typical "drilling" tasks. The same tasks were carried out by thirty male manufacturing factory workers in both VE and RE. Five evaluation indices – three objective (elbow angle, maximum force capacity reduction, and task completion time) and two subjective (BPD – Body Part Discomfort and RPE – Rated Perceived Exertion) – were used to evaluate the similarities between VE and RE for the selected "drilling" tasks. Four of these indices (all except elbow angle) were significantly higher ($p < 0.05$) in VE than in RE, which indicates that subjects experienced more discomfort and grew fatigued more quickly in VE. However, linear correlations (Pearson's *rho*: 0.635–0.807) between VE and RE were found for two of the five indices (BPD and maximum force capacity reduction).

Relevance to industry: Using digital mock-ups and virtual reality simulations, industrial work activities can be evaluated to identify potential ergonomic problems during an early design stage, which reduces design time and costs, increases quality and improves customer satisfaction. A validated linear relationship can provide a reference for work design in virtual reality.

1. Introduction

Musculoskeletal disorder (MSD) is a serious occupational health problem facing manual material handling workers which affects a significant proportion of the workforce. In 2001, the National Research Council and the Institute of Medicine reported that MSD represented 40% of compensated injuries at cost of 45–54 billion US dollars per year in the United States (National Research Council and Institute of Medicine, 2001). In the European Union, 40 million workers suffer from MSD, and the financial loss caused by MSD has been estimated at between 0.2% and 5% of GDP (Buckle and Devereux, 1999). Therefore, many researchers are focusing on analyzing potential MSD exposures and preventing MSD in work design (Ma et al., 2009a).

MSD is believed to be closely related to posture, physical overexertion, duration and frequency of physical effort, discomfort, and physical fatigue (Pheasant, 1999). In order to reduce MSD risks, many methods have been developed to investigate ergonomic design problems. These methods can be mainly classified into subjective and objective evaluation methods (Li and Buckle, 1999). Borg's scale, which is also called the Rated Perceived Exertion (RPE) method, is a subjective tool that has been used to evaluate the effort of subjects in a variety of research; it has been validated as consistent with several physiological variables (e.g., heart rate) (Garcin et al., 1998; Kim et al., 2004). Another well-known subjective method, Body Part Discomfort (BPD), was developed to evaluate the intensity of discomfort felt by subjects (Corlett and Bishop, 1976; Lowe, 2004; Yuan and Kuo, 2006; Lin et al., 2010). Some posture-based observational methods have been developed to objectively assess physical exposures. The Ovako Working Posture Analysis System (OWAS) was designed to facilitate the evaluation of the overall human body (Scott and Lambe, 1996). The posture targeting method (Corlett et al., 1979) and Rapid Entire Body Assessment (REBA) (Hignett and McAtamney, 2000) were also designed to evaluate total body postures, while Rapid Upper Limb Assessment (RULA) was specially designed to evaluate upper

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