A fatigue failure-based ergonomics assessment tool for low back disorders: The Low Back Cumulative Trauma Index (LBCTI)

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1. Introduction

Low back disorders (LBD) have been estimated to be one of the most common and costly Musculoskeletal Disorders (MSD) facing industry (Marras et al., 1999). LBDs are a huge cost burden to society, with an average cost estimated to be over $30,000 per case. Recently it has been demonstrated that using the fatigue failure theory can provide a method to assess MSD risk involving variable loading patterns (Gallagher an Heberger, 2013). The purpose of this paper is to describe the development of a tool to assess low back disorder risk using fatigue failure theory as a basis – the Low Back Cumulative Trauma Index (LBCTI).

2. Method

The tool described here has been developed in accordance with several dictates of fatigue failure theory. First, the impact of repetition on LBD risk will vary exponentially with respect to the loading on the spine. Second, that the relationship above is predicated upon the ultimate strength of the spine of an individual. And thirdly, fatigue failure techniques of assessing cumulative loading can be used to develop a “daily dose” of loading that may be positively correlated with the risk of LBDs.

Use of the tool requires collection of demographic data of the individual performing the task and direct observation and analysis of tasks performed by the individual. The questionnaire includes questions about gender, age, height, weight, and overall work satisfaction. Gender, age, height, and weight are used to derive an estimate of the ultimate strength of the individual’s spine using data from data provided by Jäger and Luttmann (1991).

Estimate of spinal loading (i.e., L4/L5 compressive force) in the performance of work tasks are obtained using the 3-Dimensional Static Strength Prediction Program (3DSSPP, University of Michigan Board of Regents). The amount of damage resulting for a correlating percentage of ultimate compressive strength measured by data extracted using Weibull analysis from studies conducted by Brinckmann et al. (1988) and Gallagher (Gallagher et. al., 2007).

A user-friendly interface was developed in Excel software to input data specific to the worker and task as shown in Figure 1. The tool is designed to evaluate a lifting task using the worst posture experienced during a lifting task (i.e., greatest trunk flexion or load moment). Age and gender inputs from the user are used to lookup the ultimate strength of the lumbar spine by using an index and match function. Body segment angles and the percentile of the worker are used to lookup the L4/L5 compressive strength resulting from the task. The tool is setup to calculate the percentage of ultimate strength by dividing the compressive strength obtained from the 3DSSPP data by the estimated ultimate compressive strength. Another lookup function is used to match the percentage of ultimate strength to the amount of damage estimated to be experienced per cycle based on the Weibull analysis referenced earlier.

3. Results

Figure 1 shows an example of an assessment of a task using the LBCTI. The task involves a 41-year-old worker of average anthropometry who is performing a lifting task of a 35-pound load involving trunk flexion of 45 degrees, no trunk rotation, an upper arm angle of 60 degrees and elbow angle of 30 degrees (both from the horizontal). As can be seen in Figure 1, the estimated L4/L5 compression is 788.44 pounds. Estimates of the expected cycles to failure at this level of loading are provided (based on the Weibull analysis estimates of cadaveric tests), along with the expected damage per cycle. Cumulative estimates of damage per shift are also provided. While
the current analysis shows just a single task, analyses can be done with multiple tasks involving various loads and frequencies, and cumulative loading estimates can be calculated using fatigue failure techniques.

4. Discussion

The purpose of the LBCTI was to have the means to incorporate a fatigue failure model in estimating the risk of manual material handling tasks on low back disorders. Previous ergonomic assessment tools were constructed using only biomechanical, physiological, or psychological criterion and did not factor in the concept of fatigue failure. The previous tools have tended to focus on single load exposures and treat force and repetition as independent MSD risk factors. As mentioned previously, using the fatigue failure theory can provide a method to assess low back MSDs utilizing variable loading patterns and thus lead to greater identification of high MSD related tasks and help to individualize risk assessment based on personal factors. With the model we have developed, we can vary the load exposures with different anthropometric inputs over different cycle/shift durations. It is hoped that this tool can be used to: 1) develop better assessments of LBD risk based on cumulative loading, 2) develop more effective job rotations schemes to reduce injury risk, and 3) assist to develop more productive rest / healing periods.

References


Figure 1 – Tool results from the scenario described above.