from several viewpoints so that representative postures could be defined for each of the actions that the production option mix required. The duration for each action was obtained from the industrial engineering standard line balance assessment data.

Each of the tools and parts that the operators worked with were weighed using a digital force gauge, (DFI500, Chatillon, Raleigh, NC, USA). Forces acting on the hands were considered to be zero for activities that involved minimal hand forces (e.g., joining connectors). Support forces acting on the operators, such as an operator leaning on an elbow while joining a connector, were also assumed to be zero.

2.3. Software

2.3.1. General overview: The custom software utilized in this study was developed to: (1) estimate the moment of force and reaction forces for the major body joints (in particular the lumbar spine), for all of the actions required in performing a job, and (2) to predict the probability of a low back pain report being associated with that job. The core components of the software are a biomechanical model (described in 2.3.2.) and a database of peak and cumulative (dose/response) curves for spinal loading. The software requires inputs as described in 2.3.3. that are collected in the field so that biomechanical estimates may be made of the magnitude of the peak and cumulative spinal loading parameters. These values are used in conjunction with the database to generate the software outputs described in 2.3.4. which are the predictions of the probability of a low back pain report being associated with that job.

2.3.2. Biomechanical model: To estimate the moment of force and reaction forces for the major body joints a quasi-static, two dimensional, fifteen-link segment biomechanical model was used in the software. This model has been described in detail in earlier publications (Andrews et al. 1997, Norman et al. 1998). The model allows analysis of postures that are asymmetrical in the sagittal plane and/or involve asymmetrical hand forces. Reaction forces and moments are calculated by beginning at the wrist of each arm and then proceeding to the elbow, shoulder, seventh cervical vertebrae and down to L4/L5. A single extensor muscle equivalent with a 6 cm moment arm at L4/L5 is used in the calculation of the joint compression and shear forces.

2.3.3. Model inputs: In the field it is necessary to collect specific parameters related to the job and the worker in order to permit estimates of the sizes of both peak and cumulative spinal loading risk factors to be made. The duration, or shift length, of the job to be assessed, excluding rest and meal breaks, must be known. The job must then be divided into its discrete tasks. Each task may consist of single or multiple action(s). For each action a representative posture for the trunk, arms and legs is recorded (e.g. using photographs, video or an observational check list). Also, the magnitude and direction of any forces acting on each hand must be documented for each action. In order to quantify cumulative loading it is necessary to know the total amount of time per shift for which each action is performed. If this value is not known then the duration and number of repetitions of each action performed per shift should be recorded.