- Reliability
  - Increase use and confidence in workstation.
  - Support quality and scheduling.
- Durability
  - Design to withstand expected factors related to users' expected lifespan.
  - Design with consideration of application environment.

6.5.1 Designing to Fit the Moving Body

Humans are dynamic and function better over extended periods when allowed to vary posture, loading, and work position. The workplace should be designed to accommodate a range of motions that are expected of the operator for task performance. One way to accomplish this is to select the extremes of body positions that are expected and design for the motions between these ranges.

Traditionally, there are three work postures or combinations of these postures including lying down, sitting, and standing. However, there are other positions, for example, kneeling on one or both knees, squatting, and stooping. In order to measure the effects of work postures, both independent and dependent variables need to be considered. Independent variables relate to body movements, postures, and change measurement variables, such as rate of change, range of change, and maximum displacement. Dependent variables fall within a range of disciplines including physiological, for example, oxygen consumption, heart rate, blood pressure, and electromyogram; medical, such as musculoskeletal disorders (MSDs) and cumulative trauma disorders (CTDs); biomechanical, for instance spine disc pressure, x-rays, CAT scans, and force calculations from models; engineering, for example, productivity, forces, and pressures on seat, backrest or floor; and psychophysical, including subjective measures, such as interviews and surveys (Kroemer et al., 1994). Subjective measures consist primarily of subjective pain or discomfort ratings. Subjective measures have been highly correlated with many physiological measures, such as heart rate and psychological rating of perceived exertion. However, these measures are highly dependent on how well the survey is administered and the results can be quite accurate.

Biomechanics is a useful tool to evaluate dynamic task performance, as the field studies the human body in movement. These types of evaluations are used extensively in occupational analysis and to enhance the performance of athletes, particularly in elite athletics such as the Olympics. Biomechanical analysis can include the use of modeling tools video analysis, and mathematical models to predict the loading and impact of a work environment on an operator, indirect and direct measurement tools to assess capabilities in specific postures, or task activities throughout task performance.

6.5.2 Designing for the Standing Operator

Standing is usually used as a working posture if sitting is not possible, because the operator must exert large forces with the hands, the work area requires mobility, or the operator has to cover a large work area. Standing in one place should

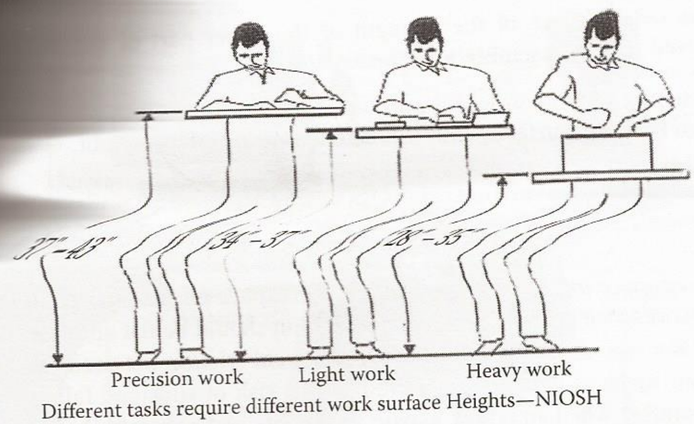

FIGURE 6.2 Standing workstation design dimensions.

be imposed for a limited time period. Forcing someone to stand because the work area is placed high above the floor or outside the sitting reach areas is not a good justification.

The working height is critically important in the design of workplaces, and this height depends on the activity and the size of the object handled such as hand tools (Figure 6.2). The main reference point is the elbow height of the worker, because generally the strongest hand forces and the most useful mobility are between the elbow and hip heights. If the working height is too high, the shoulders must be frequently lifted, causing discomfort and painful cramps in both the neck and shoulders. Working heights at or above shoulder height can also contribute to shoulder tendonitis or other cumulative trauma disorder (CTDs) of the shoulder. Likewise, if work is placed too low, the back must be constantly bent leading to temporary or potentially long-term discomfort, pain, or injury.

The average elbow height (distance from floor to underside of elbow when it is bent at right angles with the upper arm vertical) is almost 1070 mm for men and 1000 mm for women both in North America and Europe. The generally recommended working height for hand work, while standing, is between 50 and 100 mm below the elbow level. The following text lists three recommended height guidelines when performing certain types of standing work (Kroemer and Grandjean, 1997):

- Delicate work or fine manipulation (i.e., drawing)
  - Support the elbows to minimize loading on the back.
  - Design to support viewing requirements.
  - Design for work surfaces 50–100 mm above the elbow height.
- Manual work (i.e., light assembly)
  - Allow space for equipment, hand tools, materials, and containers.
  - Design for work surfaces 100–150 mm below the elbow height.
- Exertion of extensive manual effort or constant use of weight (i.e., heavy assembly or woodworking)

- When constant use of the strength of the upper part of the body is involved (heavy assembly work or woodworking), the working surface needs to be lower.
- Provide forearm and wrist support when possible.
- Design for work surfaces 150–400 mm below the elbow height.

Table 6.1 provides more detailed dimensions for designing standing workstations for men and women.

Sufficient room for the feet of the operator must also be provided, including toe and knee space in a standing workplace. This space allows the worker to move closer to the workspace. The floor at the workstation should be flat and free of obstacles to reduce the risk of tripping. Likewise, sufficient friction between the soles of shoes and floor surfaces is necessary to reduce the risk of slips and falls. Finally, to promote comfort when standing, elastic floor mats and soft soles have been useful for reducing foot, leg, and back discomfort.

To manage the static loading that results from standing workstations, employers will sometimes provide stand seats or semi-seats. These semi-seats should provide a level of support between standing and sitting without interfering with the task performance. Due to variability within a task, this type of seating is often useful for certain job activities without impacting overall task performance. However, it is important to remember to not fully take the weight off the legs using these seats, as they tend to be higher than traditional seating and oftentimes workers cannot fully reach the floor and thus can lead to ischemia (occlusion of blood flow in the legs). Possible disadvantages that come with these seats include stability issues, restriction of the range of motion, and discomfort due to ischemia in the lower limbs.

6.5.3 Designing for the Sitting Operator

Sitting down is a much less strenuous working posture than standing. Stabilizing the body while sitting down is easier because fewer muscles need to be contracted and the body benefits from the support of the chair. Sitting allows better control of hand movements, but the seated postures mean the capacity for force exertion with the hands is reduced. Sitting individuals can operate controls with their feet; however, the amount of force that can be applied is considerably less than when standing. When designing a workstation for a sitting operator, it is important to consider the free space required by the legs and feet for movement in all directions. Also, the seat should be designed so that the sitting posture can be changed frequently. An adjustable chair that meets ergonomic design criteria should be considered. An overview of the dimensions of interest for seated workers is shown in Figure 6.3.

Humans are not biomechanically adapted for long-term static postures, whether it is standing or sitting. Therefore, sitting for extended periods of time can lead to lower back pain and foot swelling. Changing postures throughout the shift will reduce continued compression of the spinal column, as well as muscle fatigue. The preferred working area is right in front of the body at about elbow height, with the upper arms hanging. Visual requirements should also be considered when determining