International Handbook of Occupational Therapy Interventions

Chapter 15
The Design of Artisans' Hand Tools: Users' Perceived Comfort and Discomfort

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Using the new masonry trowel, the bricklayer was not suffering from pain anymore during his work.

Abstract Is artisans' comfort in using hand tools a necessity or a luxury? Ergonomically well-designed hand tools, which provide comfort to the user, decrease the risk of occupational health problems and increase the job performance. Therefore, it is not a luxury, but rather a necessity that hand tools be designed with a focus on comfort, and that artisans make themselves informed about the use of ergonomically well-designed hand tools.

Keywords Artisans • Comfort • Complaints • Discomfort • Hand tools • Performance

Background

A hand tool is a device for doing a particular job. It can be freely manipulated and is held by a person. Hand tools, such as hammers, pliers, scalpels, and knives, are used very frequently by many people in daily life and in their work.

The use of hand tools is very often accompanied by discomfort. Feelings of discomfort can reduce job satisfaction and cause musculoskeletal problems in the long term. Therefore, it is important that people work with well-designed hand tools. Occupational therapists (OTs) and ergonomics consultants should be able to recognize well-designed hand tools in order to advise their clients.

Method

Candidates for the Intervention

Candidates for interventions are professional groups that work with hand tools for long periods of time during the day, such as surgeons, carpenters, assembly workers, hairdressers, cooks, and gardeners.

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Epidemiology

Although the relationship between hand tool design and musculoskeletal disorders was directly obtained from the study of Tichauer (1978, cited in Chaffin et al. (1999), other studies have indicated poor hand tool design as a risk factor of musculoskeletal disorders (Chaffin et al., 1999; Mital and Kilbom, 1992). Moreover, some studies show that less discomfort was experienced by using appropriately designed hand tools (Chang et al., 1999; Dempsey et al., 2002; Kilbom et al., 1993). This is important, as discomfort can lead to musculoskeletal problems in the long term (Hamberg-van Reenen et al., 2008).

Risk Factors for Occupational Hand and Arm Injuries

Besides the risk on injuries due to accidents, other risk factors can cause discomfort and physical complaints:

- Awkward postures and movements of hands, wrists, and arms
- High-force exertions (working with the tool on material) or low static force supply (holding a tool above shoulder height)
- Highly repetitive movements or force exertions
- High precision requirements (e.g., use of dental instruments)
- Vibrations and high impact
- Local friction or pressure on the skin of the hand

The risk of physical complaints increases the more times a day workers are exposed to the physical load and as the frequency of use rises. Appropriate hand tool design can contribute to a reduction of the risk factors such as awkward postures or high-force exertions. However, the tasks that have to be performed and the context in which a hand tool is used also affect the way it is used, the risk of physical complaints, and the feelings of discomfort and comfort. For example, in pruning a grapevine using pruning shears, the shears can be very well designed, but the wrist position and body posture are mostly determined by the direction and the height of the branches that have to be cut.

Results

Hand Tool Evaluation Studies

Studies in a laboratory setting as well is in the field are conducted in order to compare different kinds of hand tools with the risk factors for musculoskeletal disorders. Objective as well as subjective measurements are used to determine the risk factors of using hand tools.

Objective measurements are used to measure body postures, force exertion, and pressure on the hand. Several objective measurements can be used:

- Awkward postures and movements of wrist and forearm can be measured by (electro-)goniometrics (Fig. 15.1).
- Force exertion can be measured directly:
  - In the hand–tool interface by a glove with force sensors
  - By built-in force sensors in the handgrip (McGorry, 2001).
- Force exertion can be measured indirectly:
  - Measuring the external reaction forces on the tool and calculating the wrist load moment value
  - Measuring electromyography (EMG) especially during static force exertions (Fig. 15.2) (Hoozemans and van Dieën, 2003).
- Pressure distribution on the hand surface can be recorded using a hand mat with pressure sensors (Fig. 15.3).

Subjective measurements (e.g., questionnaires) are valuable in measuring discomfort or comfort in using hand tools. The most common subjective method to assess

Fig. 15.1 Electrogoniometrics.

Fig. 15.2 Electromyograph measurements.

discomfort is using a body map or a detailed hand map (Fig. 15.4) (Corlett and Bishop, 1976). For each region, the feelings of discomfort are rated on a scale from no discomfort to extreme discomfort.

The workers' perception of comfort in using hand tools is assessed with the Comfort Questionnaire for Hand Tools (CQH) (Kuijt-Evers et al., 2007). This questionnaire uses phrases, such as "fits the hand," "causes pressure," "nice-feeling handgrip") that describe the needs of artisans regarding comfort in using hand tools. The CQH can be used for several purposes:

- Investigate the most important comfort aspects for a specific type of hand tool
- Find starting points for hand tool design improvement
- Compare the comfort of different kinds of the same type of hand tool

Clinical Application

Hand tool evaluations and design studies lead to design guidelines. Some general guidelines for hand tool design are as follows:

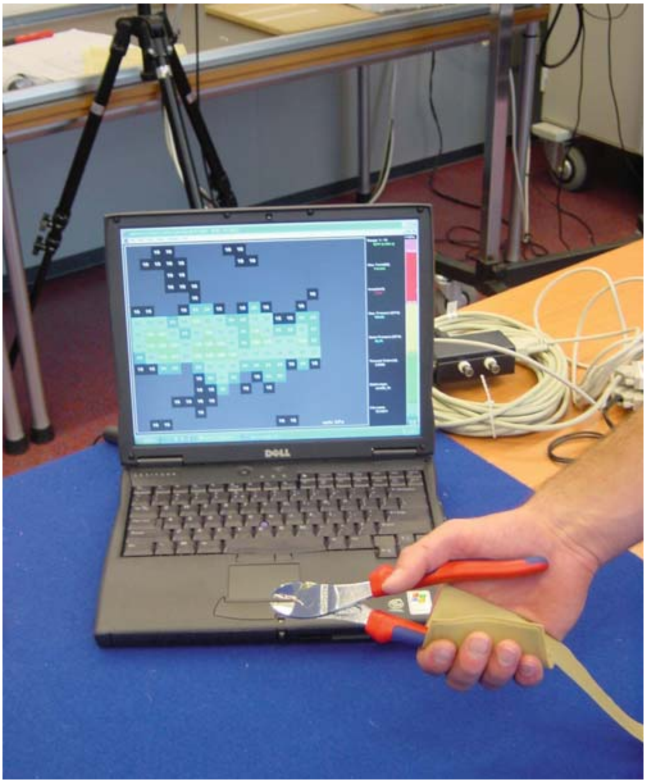

Fig. 15.3 Pressure distribution measurement.

Criteria for Optimal Design of Hand Tools

Handgrip Length

The optimum handgrip length depends of the type of grip that is used. When a power grip is used (such as for a masonry trowel), the handgrip length should be longer than the size of the user's hand to avoid points of excessive pressure on the palm (Aptel et al., 2002). To arrive at this dimension, the handbreadth at the metacarpal phalange is often used (Das et al., 2005). In the literature, lengths of 110 to 135 mm are recommended depending on the population and glove use.

Handgrip Diameter

In the literature, different handgrip diameters for use in a power grip are recommended, ranging from 30 to 50 mm. From an ergonomics viewpoint, it is apparent that one size of handgrip will not accommodate or satisfy the entire working population, male and female. Therefore, ergonomists recommend small, medium, and

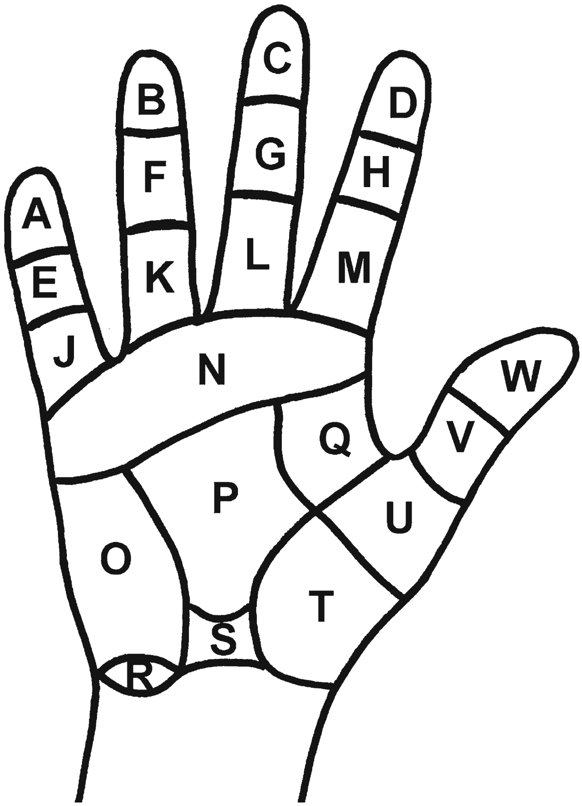

Fig. 15.4 Hand map. Drawing by L.F.M. Kuijt-Evers. Published in Kuijt-Evers L,F,M., Comfort in Using Hand Tools; Theory, Design and Evaluation. 2006. TNO Kwaliteit van Leven, Hoofddorp, proefschrift. Published with permission.

large handgrip diameters of 30, 35, and 40 mm, respectively (Das et al. 2005; Kuijt-Evers and Eikhout, 2006).

Handgrip Shape

The dimensions of the handgrip cross section should vary over the length of the handgrip, as this (1) reduces the movement of the tool forward and backward, (2) accommodates the shape of the hand, (3) permits greater force to be exerted along the tool axis due to a better bearing surface, and (4) acts as a shield if placed at the front (Konz, 1995).

A rectangular or an oval cross section allows tactile orientation of the tool. However, if the handgrip is used in different orientations (e.g., it is rotated in the hand during use), a circular cross section is preferred, to avoid pressure on the hands.

Furthermore, the handgrip should have a smooth surface, without (sharp) edges or finger holes. The connection between two parts (e.g., soft and hard material) should be smooth, as should the shape of the handgrip.

Handgrip Material

The handgrip material is important in regard to surface friction properties and the ability to grasp and manipulate the tool. Frictional characteristics vary with the pressure exerted by the hand, the smoothness and porosity of the surface, and the type of contamination (sweat increases the coefficient of friction, and oil reduces it) (Bobjer et al., 1993; Bucholz et al., 1988).

Rubber, compressible plastic, or wood are better handgrip materials than are hard plastic or metal. Compressive materials tend to dampen vibration and allow better distribution of pressure, reducing feelings of fatigue and hand tenderness (Fellows and Freivalds, 1991).

Balance and Mass of the Tool

The tool weight should be balanced around the grip axis to minimize the wrist load moment value. The maximal acceptable mass of the tool depends on the task, the direction of force exertion, the frequency of use, and the total task duration during a day. Sometimes the mass of a tool supports the task, as the gravity force is in the same direction as the force exertion of the user, such as drilling a hole in vertical direction or using a circular saw. In other situations, the optimal tool weight is about 1 kg with a maximum of 1.5 kg for one-hand use. When tools are used with two hands, the maximum recommended weight is 3 kg.

Work Side of the Tool

The work side of the tool (e.g., the blade of the saw) is especially important. It determines the functionality of the tool. A study on handsaws showed that if the functionality of the handsaw is lacking (due to a blunt saw blade or a too flexible blade), the performance is reduced 50%, the carpenters works less accurately, and the discomfort level increases.

Users' Perceived Comfort of Using Hand Tools

As comfort is a personal experience and a reaction to the environment, a product can never be comfortable in and of itself. It becomes comfortable (or not) in its use (Vink et al., 2005). Comfort is affected by the interaction between the user, the hand tool, and the task in an environment. Figure 15.5 illustrates these interactions.

Tool–Task Interaction

The primary goal of using a hand tool is to perform a task, for example, to cut a wooden beam or to fix elements together. The interaction between the task and the

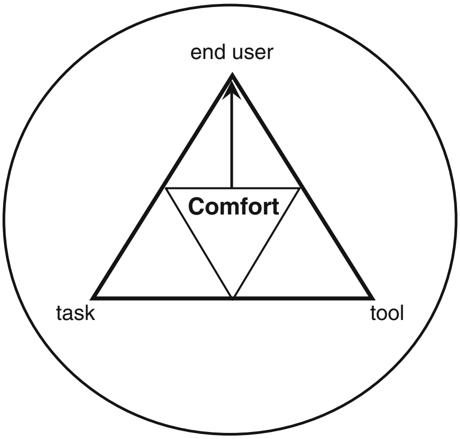

Fig. 15.5 Illustration of the interactions between the user, the hand tool, and the task, as illustrated by the triangle within the environment (illustrated by the large circle). Drawing by L.F.M. Kuijt-Evers. Publiced: Kuijt-Evers, L.F.M. Comfort in Using Hand Tools; Theory, Design and Evaluation. 2006. TNO Kwaliteit van Leven, Hoofddorp, proefschrift. Published with permission.

hand tool is mostly determined by the work side of the tool. This part of the tool is also the part that is very important for the functionality of the tool. If the end-user cannot fulfill the task in an appropriate way, due to the hand tool, then the hand tool can never be comfortable to work with. The functionality of the tool is one of the most important factors in comfort in using hand tools. It is the basis of good hand tool design and an integral part of the task–tool–user triad.

Interaction Between User and Tool

The physical interaction between the hand tool and the hand, along with functionality, is the most important predictor of comfort in using hand tools. For designers, it is important to know how the physical interaction can be optimized by proper handgrip design, and it is important for OTs to recognize good or bad handgrip designs. Adverse body effects (or the absence of adverse body effects) are the second important predictor of comfort in using hand tools, which include numbness and lack of tactile feeling in the hand, inflamed skin of the hand, and pressure on the hand.

Interaction Between User and Task

The way in which the hand-tool user performs his task is related to his experience. There are differences in comfort experience between professionals and layman. This may be explained by the fact that professionals very often have preferences for a particular type of tool and have better physical capabilities to perform the job. Feelings of discomfort will be less if the user is better trained for the job.

Hand Tool–Specific Comfort Factors

We described how the interaction among the tool, the task, and the user in the environment affects the feeling of comfort. To optimize comfort, one should know the factors that determine comfort in using hand tools. These factors include the task intensity (movement frequency and force exertion) and the force direction (perpendicular or parallel to the handgrip surface) (Kuijt-Evers et al., 2007). The flow chart in Fig. 15.6 shows which aspects should be taken into account, depending on the task characteristics.

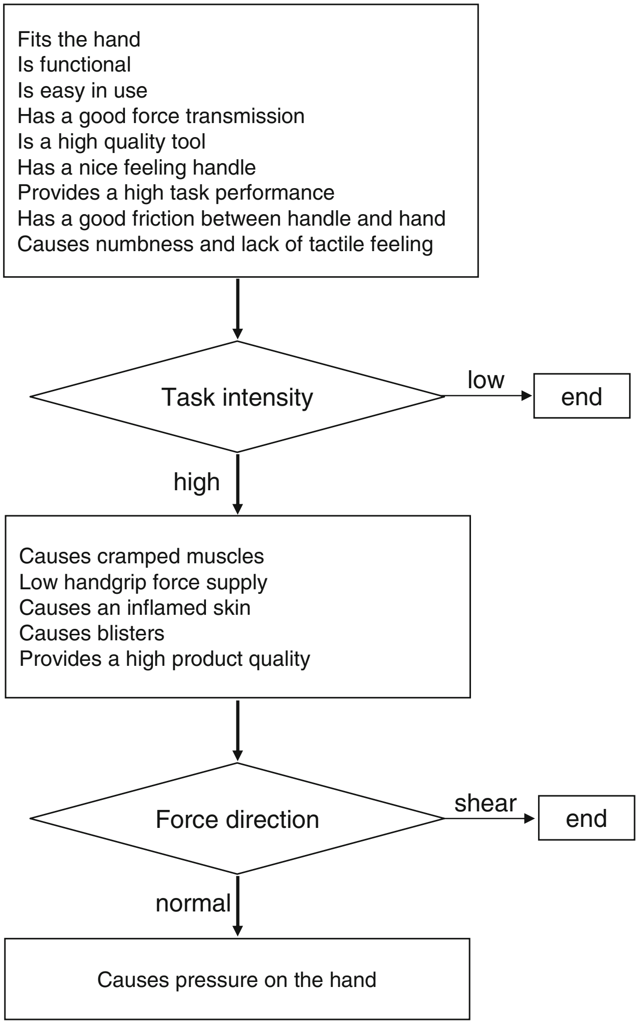

Fig. 15.6 Flow chart to support designers and researchers to focus on the appropriate comfort descriptors in hand tool design. Drawing by L.F.M. Kuijt-Evers. Publiced: Kuijt-Evers, L.F.M. Comfort in Using Hand Tools; Theory, Design and Evaluation. 2006. TNO Kwaliteit van Leven, Hoofddorp, proefschrift. Published with permission.

To recap, the main factors related to comfort in using hand tools are the functionality of the tool, the physical interaction with the tool, and the adverse body effects (on the skin and on soft tissues). The importance of the comfort factors differs among different kinds of hand tools (as shown by the flow chart) (Fig. 15.6).

Discussion

For OTs, it is important to recommend to their clients well-designed tools that avoid discomfort, as discomfort can lead to musculoskeletal disorders in the long term. Furthermore, the occurrence of discomfort can result in productivity loss and days on sick leave. On the other hand, a well-designed hand tool in itself cannot prevent discomfort (or provide comfort). The feelings of comfort and discomfort and the physical load also depend on the task that is performed, the capacities of the user, and the environment in which the task is performed. Therefore, it is not sufficient to look at the tool out of context; rather, all tool–task–user interactions in the working environment should always be taken into account.

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