Avoiding Injury While Using Tools: Good Tool Design

By Tamara Mitchell

Whether you are a professional working in the trades or you are a weekend warrior improving your abode or garden, there is a high level of risk for Cumulative Trauma Disorder (CTD) if the injury threshold is crossed. Injuries occur when people use poorly designed tools, when they don't use the proper tools for the job, when they use tools improperly, when they ignore fatigue, or when they underestimate the time required for a big project.

In many cases, projects can keep you mentally and physically sound. We do not want to discourage anybody from tackling an interesting and challenging project. We want you to be aware of things to consider when working.

Injury prevention involves a complex interaction between users and their tools. It involves buying well-designed tools, choosing the right tool for the job, using the tool in a way that avoids strain on your body, and planning the job so that you avoid fatigue and overuse. The good news is that in most cases CTD is easily avoided.

Before you start working

Before we discuss tool design and usage, please take a moment to raise your awareness about when you are experiencing a problem. Our goal in this article is to *prevent* repetitive strain injuries, but maybe you are already starting to experience one or more of the following symptoms?[1]

- Tingling
- Swelling in the joints
- Decreased ability to move
- Decreased grip strength
- Pain from movement, pressure, or exposure to cold or vibration
- Continual muscle fatigue
- Sore muscles
- Numbness
- Change in the skin color of your hand or fingertips

These symptoms usually don't appear right away. They can crop up during a particularly intense project or weekend of doing a big job, or they can take weeks, months, or years. We ask you to listen to your body while you are working and to pay attention to how tools feel when you use them. When something starts to hurt or causes you fatigue, tingling, or numbness, it is an indication that something needs to change. It may mean that you need to take more breaks, share the job with someone else, or break the job up into smaller pieces so you don't wear your body out. It may also mean that your tool isn't designed well for you, you are working in an awkward posture, you aren't using the best tool for the job, you are having to use too much force, or experiencing tool vibration that is causing muscle or nerve damage.[1]

This article covers:

- tool design factors
- choosing a good tool for the current job
- planning the task to best avoid injury

Tool design

Developing a single standard for hand tool design is challenging due to the size differences of tool users, so product development continues to evolve.[2] No hand tool is perfect for every job or every user, but there are some universal design standards which apply to everyone. [2]

A good tool is one that[1]

- Fits the job you are doing
- Fits the work space available and can be used in a comfortable work position
- Reduces the force you need to hold the tool or to use it and reduces exposure to vibration
- Fits your hand

A good tool feels like an extension of the body.

To avoid injury while using tools, the following goals need to be met.[2] The best tool will:

- Decrease the force or grip strength and avoid contact pressure
- Decrease repetitive motion.
- Decrease awkward body postures or wrist positions.
- Decrease vibration transmitted to the hand, wrist, arm, etc.
- Doesn't produce damaging and stressful amounts of noise during operation

When it comes to power tools, unfortunately even today manufacturers tend to focus more on horsepower and battery run time than on ergonomic design and comfort of the user.[3] Users often develop work-arounds for poorly designed tools, for instance they may grip the tool by the motor housing rather than the handle if the tool is awkward to hold.[3] A review of major power tool manufacturers websites found very little mention of tool design, comfort, ease of use, reduced vibration, or noise reduction, so even though ergonomics may be used as a marketing buzzword, it appears that little is actually being done to make tools less damaging to use. We did find quite a bit of information on Makita's UK website regarding safe noise and vibration levels, but the US version of their website is devoid of this helpful information.[4]

Force or grip strength

There are several factors that affect the amount of force and grip strength needed when using a tool:

- the type of handles and grips
- how the tool is maintained
- the balance and weight of the tool.

1. *Handles and grips*

The most important consideration is to avoid tools that are difficult to use or hold. There are some general rules, but the only way to find out if something fits you is to hold it in your hand. You cannot do this by looking at pictures of tools on the internet. We suggest that you go to a couple of tool or hardware stores where you can try the products. If you want to shop for better deals online after you have found a tool you like, make sure you note the exact model number and manufacturer so you purchase the exact same tool. If you are on a budget, it is possible to find good used tools at garage sales and thrift stores, but make sure the tool is in good condition and is not worn out. Some tools, like old screwdrivers with comfortable wood handles may have better design than today's molded plastic handles. In most cases

power tools are not a bargain if they have been used hard and not cared for or if they use the heavy old Ni-Cad batteries. Don't buy tools just because they are inexpensive. Be critical and use your judgement or they won't be a bargain when you find they work poorly, cause frustration and strain, wear out quickly, and then you must spend money on a new tool to replace it!

In general, tools with **longer handles** require less force.[2,5] A hand tool with a longer handle allows the user to generate more leverage with a smaller force at a greater distance. A handle should extend across the entire breadth of the palm to avoid the end of the handle digging into the palm. [6] This is an example of contact pressure, where part of a tool or a particular position causes sustained pressure in one location on the body.

The preferred length is 4-6 inches depending on the size of your hand, although it may need to be longer if the user is wearing gloves. [1,6]

		
Short handles dig into the palm causing contact stress.	Handle is long enough to extend across the whole palm.	Handle is long enough to prevent digging into the palm.

Illustrations courtesy of Reference 1

Tools such as pliers and wrenches with slightly **wider handles** distribute grip force and contact stress over a larger surface, thus reducing the required grip strength.[2]

Photo courtesy of hisco.com

Generally, **larger diameter handles** allow more surface for grasping and spreads the forces to a maximum area of the hand to reduce stress, however the handle must be the right size for the hand.[2,7] For example, a screwdriver with a thicker handle has increased torque which reduces the overall required force.[2] But if the handle is too thick, it will cause greater strain for someone with smaller hands [2] There is a widespread recommendation that grip diameter should be determined by making the "okay" sign using the thumb and index finger, then measure the diameter of the "O" formed by the thumb and index finger[2]. A custom toolmaker tried this and found that the grip is definitely too large using this rule.[7] As with many things, it is probably best to simply hold the tool in the positions you will be using it. If your hand fits comfortably around it without having to spread too far open or wrap your fingers around something too small, you will be able to feel that less strain is needed to use it. The custom toolmaker found that a handle with at least 8 sides or more is likely to be the most comfortable to hold.[7] A handle with facets

Illustration courtesy of http://www.choosehandsafety.org/choosing-hand-tools/hand-size

has the advantage of giving some frame of reference as to the angle it is being held, as well as giving some advantage in overall safety and keeping tools from rolling.[2,7]	

Textured handles reduce slippage, but handles should NOT be contoured or ridged for the fingers.[8] Finger contours do not tend to fit all hands, so are often located in the wrong place for many users making the handle difficult and uncomfortable to hold. And handles with flutes or ridges down the length of the handle, often found on screwdrivers, are generally not recommended.[9] Interestingly, screwdrivers with smaller heads often have smaller handles which makes little sense. Unless you are using a pinch grip (such as with small screwdrivers for mending glasses), your hand size should determine the size of the handle, not the head of the tool itself.[9]

Tools with **straight** handles are good for tasks where the force is exerted perpendicular to the straightened forearm and wrist.[6,10]

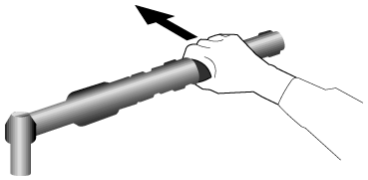
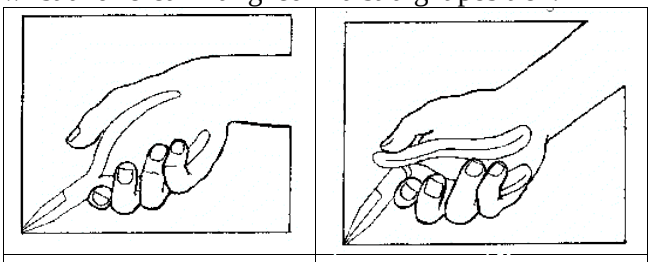


Illustration courtesy of Reference 10

Bent handles are effective when most tasks are performed in the same plane and height as the arm and hand.[6] The general rule pertains, however, where the most important thing is to use a tool that keeps your wrist and forearm aligned in a straight position.



BAD	**GOOD**
Bent wrist, straight tool	Straight wrist bent tool

Illustration courtesy Reference 11

For most tasks, avoid tools that require finger or pinch grip. A **power grip** allows the operator to align the fingers so they work together to maximize hand strength.[6] The occasional exception is during precision work when a pinch grip allows better finger control for minute manipulations with the tool.[6]

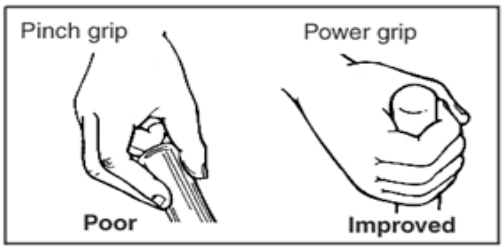


Illustration courtesy of Reference 12

A tool designed with a **pistol grip** may require less gripping force than an in-line tool handle.[2] Pistol grips are preferred when the force is exerted in a straight line in the same direction as the straightened forearm and wrist, especially when the force must be applied horizontally.[6] If the wrist is not straight, however, pistol grips put more force on the wrist and forearm.

Cushion grips with texture provide better tool comfort and slip resistance, so the user doesn't need to grip the tool hard.[2,6] Compressible materials on grips are better than metal or hard plastic.[5] Handles made of plastics or compound rubbers are recommended for applications involving electricity or temperature extremes that get conducted to the hand through the metal. [6] In general, the handle material should be a poor conductor of electricity, temperature, should be non-porous to avoid absorbing oils or other liquids, should be strong enough not to chip or crack.[9]

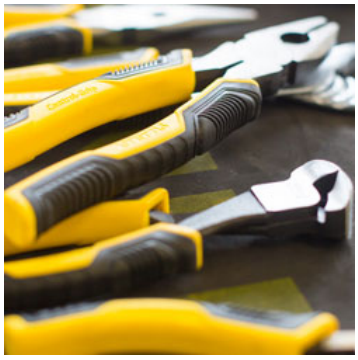


Photo courtesy of Stanley Tools
https://www.stanleytools.co.uk/

A variety of materials can be used to customize tool handles and grips.[2] These materials include foam wraps and plastic dips. Get creative, but do not waste time trying to salvage cheap tools.

		
Stromberg Carlson FP-1002-R Foam Grip Wrap Available on Amazon.com	**BV brand EVA foam handlebar tape** Available on Amazon.com	**Performix Brand Plasti Dip** Available on Amazon.com

Triggers and switches. When possible, select tools with **switches** that allow use of all four fingers to operate.[5] It is advised that triggers should be at least 1 inch in length to allow more than one finger to activate them, reducing force and strain on one finger.[6] In reality, a lot of power tools have switches and triggers only intended for use with the index finger such as drills and circular saws. Miter saws often have triggers that accommodate multiple fingers. Do not buy or use a tool that uses a thumb trigger.[6] The switch location and style is very important for power tools. When shopping, make sure the grips are comfortable, they are the right size for your hand, and the triggers are in a location that is natural for your fingers.

Gloves need to fit properly and there are many materials to choose from for specific applications.[5] Tight gloves put pressure on the hands; loose gloves require more grip force to hold tools.[5] Gloves can affect dexterity and the ability to grip.[5]

In fact, gloves are not appropriate for all jobs. When using power equipment like table saws or band saws, gloves are actually a hazard because they can get caught in the blade and drag your hand into the saw blade. Use gloves when you are sure your hands will be free of anything that can catch them and draw your hand into moving machine parts.

Some people have a minor or severe, life-threatening allergic reaction to latex. Although only about 1% of the population is allergic to latex, people with this allergy should use gloves made of alternative materials.[13]

All-Spec provides a useful chart for determining appropriate materials for various applications on their website: http://www.all-spec.com/glove-comparison-chart. Note that in some instances, such as handling small, delicate parts, finger cots are available to avoid the need to wear gloves. Some gloves are not that comfortable to wear in hot or damp environments because they do not breathe causing moisture buildup inside the gloves.

- Vinyl, latex, and nitrile gloves offer great manual dexterity, electrostatic discharge protection, and protection from non-hazardous liquids and bacteria as well as protection of hands from wear and tear, cuts, and abrasions.[14]
- Cotton gloves protect hands against snags and abrasions and can offer some warmth if they are kept dry. They can be lightweight or heavy enough to protect hands from hot objects.[14]
- Neoprene gloves protect against chemical burns, corrosion, abrasions, and cuts.[14]
- Leather gloves protect hands from splinters and prevent blisters when handling tools and rough materials.
- Knit work gloves with latex or nitrile palms and fingers are breathable, offer moderate dexterity, slip resistance, and protection from splinters and some chemicals. Many of these are sold as gardening gloves, but they work well in many applications.

2. *Tool maintenance*

Worn out or poorly maintained tools require more force, such as worn drill bits and saw blades.[2] Proper power tool maintenance may reduce vibration.[2,6,15] Splintering, chipped, or broken handles, loose parts or parts that don't work correctly can affect the way you hold and use a tool and it can require more strain on a frequent basis to adjust or operate the tool.[16]

3. *Tool balance and weight*

The weight of the tool and distribution of the load within the tool affects the way the user holds the tool.[6, 9] It is best to limit the weight of the tool to 2.5 to 3 pounds for tools operated with one hand.[6, 10] Precision tools should weigh less than 1 pound.[6] If a tool weighs more, it should be designed for two-handed operation.

A well-balanced tool can sometimes make it feel lighter. A well-balanced tool is easier for the user to hold, fits the hand better, feels more natural, allows for good control, and avoids tiring of muscles.[3,9] An unbalanced tool is unstable when held in the work position and/or causes muscle fatigue by requiring the user to compensate for such problems as off-balance weighting or fighting against forces generated when using the tool. For instance, a drill that is front-heavy will require more effort in the wrist and forearm to hold in position.[10]

Advances in electronics and tool materials affect tool weight:[3]

1) Lithium Ion (Li-Ion) batteries are now standard for cordless tools. This type of battery weighs less than the NiCd batteries, has a much longer run time, and is much smaller. Therefore, the tool is more compact and easier to use.

2) Housings made with plastic/fiberglass compounds or magnesium reduce overall weight.[3]

Repetitive motion

Certain tool design elements help reduce repetitive motion.

1. Avoid tools that require repetitive motions and bending or twisting of the wrist. The greater the force exerted and the more the hand must twist to use it, the greater the risk of injury. [6] When possible, replace hand tools that require frequent and repetitive force with power tools.
2. Power tools increase efficiency as well. However, in some cases, switching to power tools may cause other risks such as vibration.[2] It is important to consider all options when selecting a tool.
3. Use hand tools that have adjustable spring-loaded returns, such as pliers and scissors.[2]
4. Look for other innovations that can reduce repetitive motions, such as saw blades that cut faster.[2]
5. Use proper operating methods to eliminate unnecessary force and repetition. For example, make pilot holes for drilling. [2]
6. If a task has sufficient clearance, use tools with gears or a ratcheting mechanism.[2]

Awkward body postures or wrist positions

A lot of awkward postures and wrist positions aren't a problem with the tool design, but with the actual selection or usage of a tool which will be discussed in the second section of this article. Clearly the grips and handles should fit the users hand and switches should fall perfectly at the fingertips so that contorting the hand, reaching the fingers, or twisting the wrist is not required. Cord location is another consideration that is often overlooked. Cords can get in the way during use and they not only pose a safety hazard they can be a source of awkward postures, frustration, and excessive force.[17]

Vibration

Vibration may be the largest concern with power tools.[2, 5] Exposure to large amounts of vibration in a localized area, such as the hand, increases the risk of chronic disorders of the muscles, nerves, tendons, joints and bone.[2,18] White finger syndrome and hand-arm vibration syndrome (HAVS) are caused by tool vibration. These start out with mild tingling, progresses to blanching of one or more fingertips with increasing frequency and interference in ability to work, to finger ulceration or gangrene in extreme cases.[8] HAVS is an advanced condition where the entire hand or arm may be affected by repeated and constant use of tools that cause vibration.[19] Some equipment such as tractors and heavy machinery generate whole-body vibration which can damage the body and cause fatigue, but this is beyond the scope of this article which focuses on tools.

In addition to the physical damage done by vibration or as a response to vibration with protective muscle contractions, vibrations of different speeds resonate in various parts of the body causing unseen stress and damage.[8] Everything in the human body has a natural frequency and the closer a tool vibrates to that frequency, the more that vibration resonates in that body part.[8]

The amount of vibration transmitted by a power tool can be influenced by the tool's weight, design, and various attachments.[2] Poor design is often responsible for unnecessary vibration.[15]

The goal is to create as much distance as possible between the tool vibration and the user.[6] Tool covers and anti-vibration gloves can help achieve this distance, although their effectiveness varies.[2,6] It is best to choose tools well-designed with vibration damping built into the tool rather than trying to reduce vibration with gloves.

Power tools designed with anti-vibration materials or anti-vibration mounts/handles have had limited success in reducing the amount of transmitted vibration.[2]

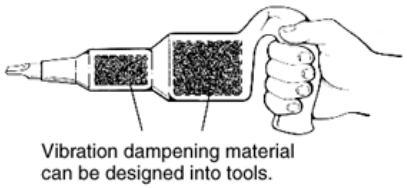


Illustration courtesy of Reference 12

If you must use vibrating power tools for prolonged periods of time, try to redesign the process, redistribute the work, or use some kind of external support to handle the power tool.[2] Do not grip the tool tightly, allow the tool or machine to do the work, alternate the use of vibrating and non-vibrating tools, restrict the number of hours using vibrating tools, and take 10-15 minute breaks every single hour.[OSAH_Wood] Chainsaws produce a lot of vibration and they are often used in cold, damp environments which pose high risk of HAVS.[18]

Other hand tools such as hammers certainly can transmit a lot of shock and vibration to the hand, wrist and arm. Stanley has designed the FatMax line to reduce strain and shock to the hands and arms, improving grip material, handle shapes, spring-loaded operations, and vibration damping.

High Velocity Hammer with improved grip and vibration damping
Photo courtesy StanleyTools.com

Noise

Some power tools produce sound levels that are higher than acceptable (85 dBA for 8-hour day).[17] Try to seek out tools that conform to noise level standards and use ear plugs to avoid hearing damage. Hearing loss may be the result of prolonged exposure to excessive noise or to a single loud event. The best way to eliminate excess noise is to stop it at the source or at least isolate it, then limit the amount of time people are exposed to the noise, and protect their hearing with protection devices.[20]

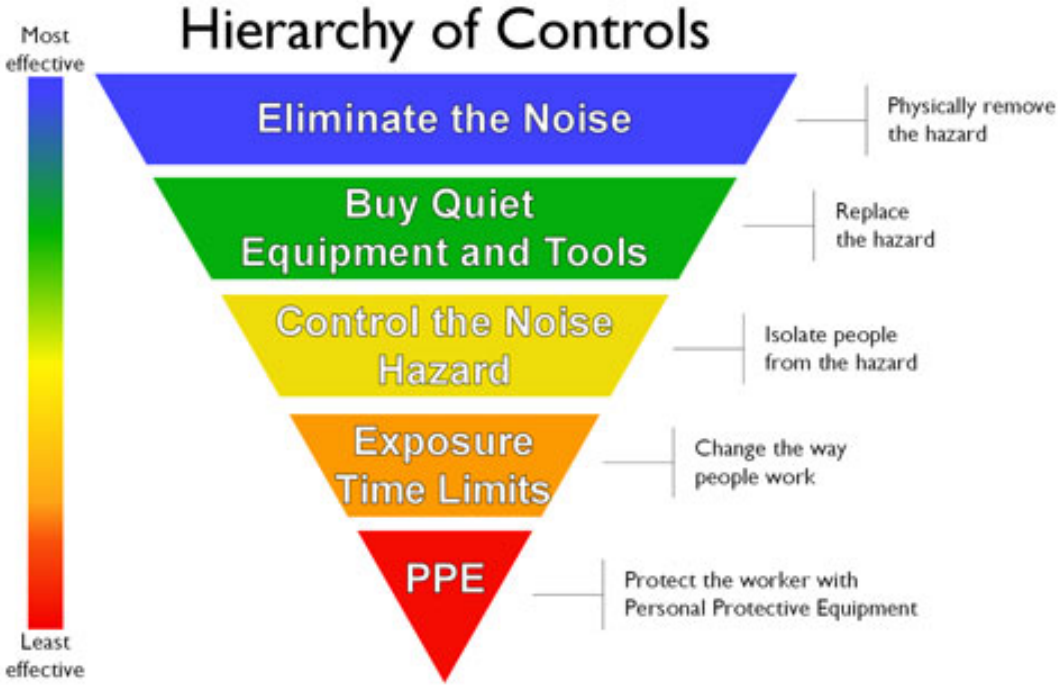


Illustration courtesy of Reference 20

Stop it at the Source: Identify and reduce the source of the noise. This can be done by maintaining all motors and moving parts to ensure that they are balanced, lubricated, and not producing excessive noise due to worn parts or friction.[21] Reduce the speed of operation of equipment to the minimum needed to produce the quantity and quality required.[21] Move power equipment out of buildings that reflect, echo, or amplify noise.[21] Equipment should be firmly seated on solid floor or other solid surface that doesn't move or vibrate and use rubber footings, springs, or other damping suspension.[21] Apply vibration/noise damping materials to all resonating surfaces using sound absorbent hoods when appropriate.[21]

Divert and isolate: Segregate noisy operations so that as few people as possible are exposed to the noise.[21] Enclose noisy equipment in absorbent housing or try to divert the noise in a harmless direction rather than toward people.[21]	
	Protect hearing: Hearing protection should be worn diligently by anyone using noisy equipment.[21] This is a last line of defense against hearing loss due to repeated exposure to noise and it requires ongoing commitment to be in the habit of using hearing protection. It is effective, especially when the previous two measures have been carried out and reduced noise levels as much as possible.

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