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Table saw injuries: epidemiology and a proposal for preventive measures

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Abstract

Background

Table saws are ubiquitous equipment in professional, home, and school woodshops that have the potential to cause severe injuries. Many of these injuries results in finger and thumb tendon, nerve, and vascular damage or amputation. Long-term outcomes of these injuries can include functional and sensory deficits. Table saw manufacturers are required to equip saws with blade guards to prevent blade contact, but despite these measures, table saw injuries are a common occurrence in US emergency departments.

Methods

Go to:

We performed a literature search using PubMed and the Cumulative Index to Nursing and Allied Health Literature to compile epidemiology data relevant to table saw injuries. We also reviewed the US Consumer Product Safety Commission's briefing package on table saw blade contact injuries.

Results

Go to:

Over 30,000 table saw injuries occur annually. Fingers and hands are the most frequently injured body part and lacerations are the most common injury. Individuals suffering from occupational injuries tend to be younger than those injured during amateur woodworking. A small, but important minority of injuries are to students participating in school shop classes. Medical costs for the treatment of table saw injuries are estimated at more than $2 billion every year.

Conclusions

Go to:

SawStop technology stops the saw blade when contact with skin is made, resulting in a small cut, rather than a more complicated laceration or amputation. The application of this novel technology in saw designs can prevent serious injuries that deleteriously affect lives at the personal and societal levels.

Level of Evidence

Go to:

III

Keywords: finger amputation, finger replantation, pediatric injuries, secondary prevention

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The table saw is a commonly used tool in both professional and hobby woodworking. Although there are a variety of models available, from portable table-top saws to professional-grade cabinet saws, all table saws have the same basic design: a flat surface through which a saw blade protrudes. The operator of the saw pushes the item to be cut toward and through the rapidly spinning blade. The potential for injury is evident. In addition to contact with the blade, saw operators may be struck by material

being kicked back out of the saw or sustain eye or respiratory injuries due to rapidly flying sawdust and other debris.

Modern saws have safety features designed to prevent injuries. Underwriters Laboratory 987 *Standards for Stationary and Fixed Electric Tools* requires that all new saws sold in the US have permanent riving knives to reduce kickback and modular blade guards.[1] Riving knives have a barbed end that prevents materials being cut from being thrown back toward the operator. A blade guard is a clear plastic housing that completely covers the blade when not in use. (Figure 1) When an item is pushed toward the blade the blade guard rides up and over the item (Figure 2) and drops down to cover the blade again when the cut is complete. Blade guards prevent contact with the blade from the top, but cannot prevent contact to the front of the blade. Furthermore, the blade guard must be removed to make certain types of cuts. It can also hinder visibility so operators may remove it to make precision cuts. Removing the blade guard is not complicated but replacing it correctly can be time-consuming, requiring the use of tools. For instance, the owners' manual for a Ryobi 10 in tabletop saw gives the following instructions for removing the blade guard and riving knife: "With the box end of the small hex wrench, loosen the two hex nuts at the base of the riving knife. Remove the riving knife/guard assembly. Retighten the two hex nuts on the base." However, there are 7 separate steps involved in reinstalling and realigning the riving knife and blade guard assembly.[2] This can lead to saw owners leaving the blade guard off permanently.

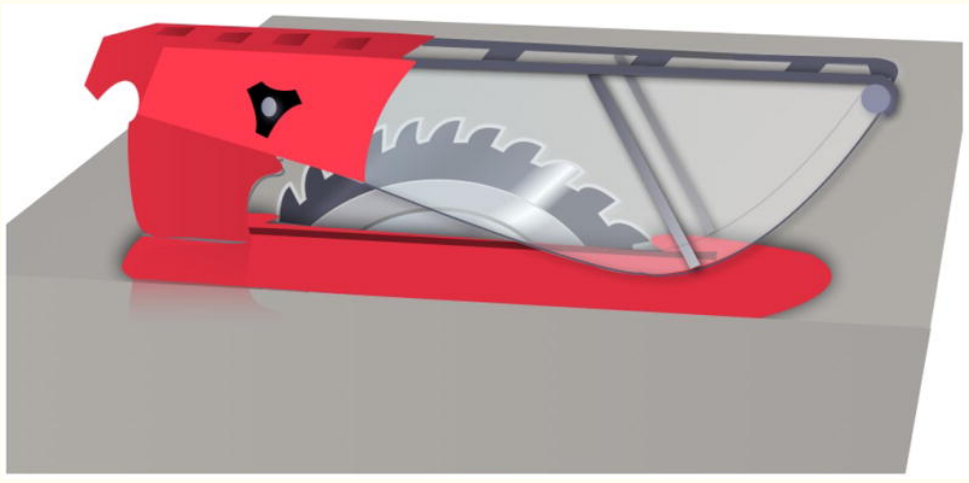

Figure 1

Table saw with blade guard in place

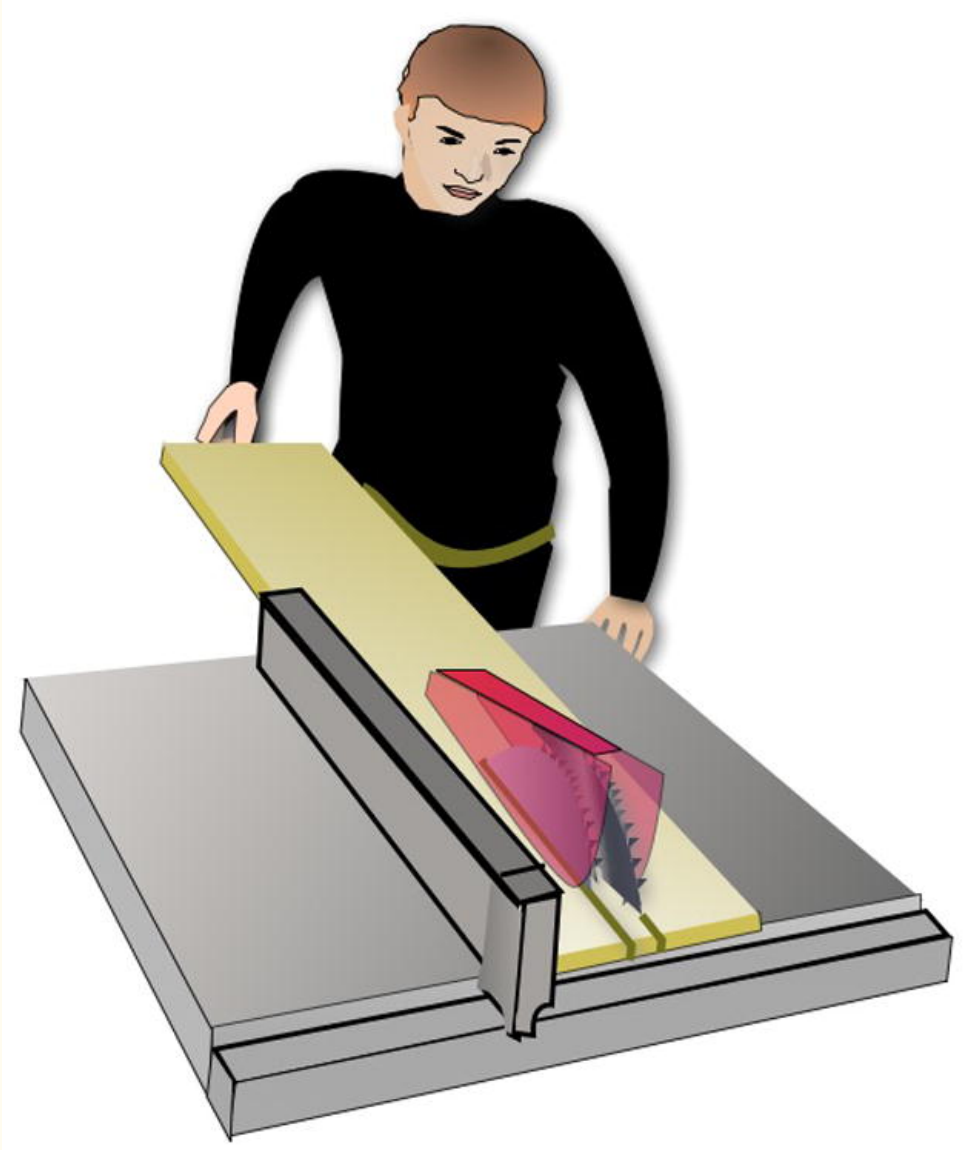

Figure 2

Blade guard action while cutting. Note that there is no protection from front-approach blade contact

Saw purchasers receive an owners' manual detailing not only the features and abilities of their new saws, but also safety information. The manual for the previously mentioned Ryobi 10 in saw contains 66 numbered safety points, 7 individual boxed warnings, labeled with the universal exclamation point in triangle symbol, and one

illustration with a pun about eye injuries ("Foresight is better than no sight").[2] Even if one were inclined to read the entire owners' manual, the sheer volume of safety information is overwhelming. Television programs, books, and websites also encourage safe saw usage behaviors, but users must seek this information out individually. Local woodworking clubs may provide instruction and training as well, but these may not be well-advertised.

The current safety equipment and instruction is clearly not enough; table saw injuries are still regularly seen in emergency departments and hand surgery clinics. These injuries vary from simple lacerations to amputations and can cost millions in medical care and wage loss. Despite the frequent occurrence of table saw injuries, the topic has not been well explored in the literature. We performed a review of the literature to better describe the epidemiology of these injuries as well as current and future prevention measures.

Methods

Go to:

We used the Cumulative Index to Nursing and Allied Health Literature (CINAHL) and PubMed to search the English language literature for articles with "saw" in the title or "table saw" in the title or abstract. The former searches produced several hundred citations whereas the latter searches found less than 10 citations. After filtering the searches for citations with the MeSH term "trauma" and removing duplicates between the two databases, we were left with 64 citations. Our inclusion criteria included articles about table saw injuries to the upper extremity. If an article included several types of saws or tools, data regarding table saws had to be reported. We eliminated case reports or articles about repair techniques after table saw injuries. After screening 9 articles remained. (Table 1, Figure 3) To compare injuries sustained by adults to those by minors, we extracted injury data that could be directly attributable to table saws.

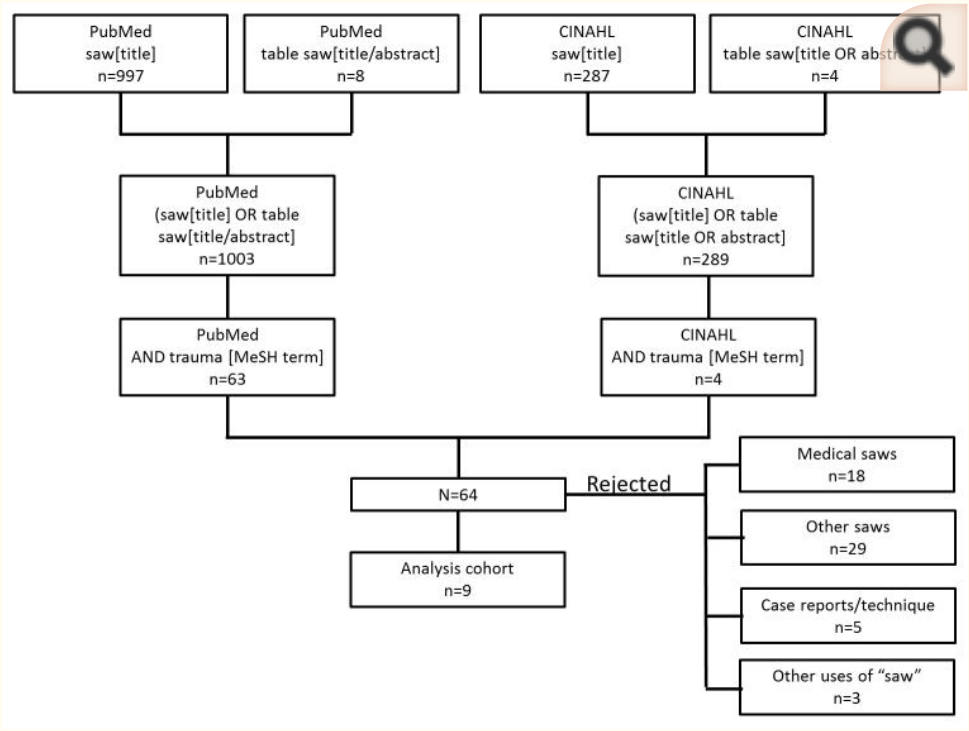

Figure 3

Literature search and screening

CINAHL: the Cumulative Index to Nursing and Allied Health Literature

Table 1

Table saw injuries in the literature

First Author	Year	Sample	Database used and/or location sampled
Al-Qattan, MM	2012	Phalangeal neck fractures caused by saws	King Khalid University Hospital; Riyadh, Saudi Arabia
Beavis, RC	2006	Injuries to hand and/or wrist sustained in shop class, ages 12–18	Royal University Hospital; Saskatoon, SK
Becker, TM	1996	Convenience sample of amateur and professional woodworkers	Albuquerque, NM
Conn, JM	2005	Non-occupational finger amputations	National Electronic Injury Surveillance System
Hoxie, SC	2009	Injuries caused by table saws	Mayo Clinic; Rochester, MN
Justis, EJ	1987	Readers of *Fine Woodworking*	US nationwide
Knight, S	2000	Injuries sustained in shop class, grades 7–12	Utah statewide Student Injury Report database
Shields, BJ	2011	Non-occupational table saw injuries	National Electronic Injury Surveillance System
Waller, JA	1990	Injuries associated with woodworking, logging, wood construction activities	Medical Center Hospital; Burlington, VT

Results

Go to:

Studies were published between 1987 and 2012 and all were retrospective. The National Electronic Injury Surveillance System

was used to estimate case numbers and rates in 2 studies.[3,4] Four studies used samples drawn from one trauma center.[5–8] Two other studies utilized surveys of injured woodworkers.[9,10] We also reviewed information contained in the US Consumer Product Safety Committee briefing package on table saw blade contact injuries.[11]

Injury patterns

Table saw injuries can be grouped into blade contact injuries and non-blade contact injuries, which include blunt trauma due to kickback, eye or respiratory injuries due to sawdust, or strains and sprains due to moving the saw. Blade contact injuries are by far the most common, representing over 85% of table saw injuries.[11] The vast majority of injuries are to the fingers or thumbs.[4,11] Lacerations were the most frequent injury sustained (66%) but amputations were not uncommon (10%–15% depending on the sample).[4,11] Finger lacerations can be grouped according to structure damage: simple lacerations, complex laceration, which includes tendon, nerve, or vascular involvement, and amputation. Simple lacerations damage only from the skins surface through the epidermis and dermis, to approximately 2mm deep.[12] Because it is virtually impossible to avoid any injury from a rapidly rotating saw blade, an injury that causes simple laceration may be a desirable goal because these injuries can be managed in the emergency room with little expertise or may require simple wound care because these cuts should heal uneventfully. The exception is fingertip lacerations associated with injury to the nailbed. Careful reconstruction must be undertaken to avoid nailbed scarring that can lead to painful or malformed nail regrowth. A deeper cut will need surgery to repair the structures damaged, requiring increasing levels of skill and at increasing costs.

The devastation of these injuries is easy to imagine when one considers that a standard 10 inch, 40-tooth saw blade rotates at 4,000 rotations per minute, meaning that a blade can make a cut every 370 microseconds.[11] Although cut speed is dependent on how fast an item is pushed into the saw blade, cutting one of the vital structures of the fingers or thumb or amputating a whole digit can happen in milliseconds. In some cases, this split-second injury can cause lifelong impairment. Al-Qattan followed 16 patients who had

saw injuries for a mean of 16 weeks (range: 14 – 25). The patients each had one of two injury groups caused by a saw. The first group sustained phalangeal neck fractures with concurrent extensor tendon injury. The second group sustained fractures and tendon injury, but also sustained nerve transection. None of the patients recovered full range of motion at the distal interphalangeal joint. In the first group final range of motion was 54% of that of the normal finger (range: 29%–78%). In the more severely injured second group range of motion was 32% of the normal finger (range: 14%–57%).[5]

Epidemiology

The Power Tool Institute, a consumer product trade group that represents many manufacturers of table saws and other tools, estimates that there are as many as 9.5 million table saws in use in the US.[11,13] Although most table saw operators never experience an injury, those who do tend to have serious consequences. A 2002 nationwide study found that 20% of non-occupational amputation could be attributed to table saws, more than any other consumer product, anything sold for the personal use or consumption of consumers in a non-occupational setting.[3] A nationwide injury survey distributed in a woodworking magazine found that 42% of reported injuries were caused by table saws and that they were the cause of the highest proportion of amputations (39%).[10] A survey of Albuquerque-area professional and amateur woodworkers reported that table saws were responsible for 31% of injuries and were responsible for the highest proportion of injuries requiring medical attention (21%).[9] Table saw injuries result in hospitalization 7% of the time; the mean for all consumer products is 4%.[11] The saw's blade guard was in use during 31% of blade contact injuries and was removed 67% of the time; the status of the blade guard was unknown in 2% of cases.[11] For injuries occurring without a blade guard, the most common reason for its absence was consumer removal (75%).[11]

Individuals injured while using a table saw can be grouped into 3 broad categories. The first two are occupational and non-occupational injuries, both of which are overwhelmingly male. The percentage of injuries sustained at work ranges from 31% to 46%.[8–10] Injured workers had a mean age of 40 years.[9] Hobbyist

or amateur woodworkers tend to be older than professionals (mean age approximately 50 years).[4,9] A Poisson regression controlling for age, experience, type of woodworking activity, and training found that amateur status was a significant predictor of injury ($p<0.0001$).[9] Despite this, work-related and non-work-related injuries follow similar injury pattern, recovery course, and costs of care.[7]

The third and most notable group of individuals injured by table saws are minors injured in school woodshop courses. In a longitudinal sample of non-occupational table saw injuries only 3% of the sample was minors, but nearly half of them were injured at school.[4] This is especially interesting in light of the fact that per US Department of Labor regulations, minors are not permitted to use power-driven woodworking tools or saws, metal-forming machinery, or punching machines in the workplace.[14] Yet, this equipment is regularly used by children as young as 11-years-old in middle school and high school shop and industrial arts classes. A Utah statewide examination of injuries at schools found that 7% of injuries occurred in shop class and that 31% of injuries were caused by saws (table saws and band saws 12% each and 7% by other saws).[15] Improper equipment use was cited in 38% of cases. Injured students were primarily in grades 8 and 9 (42%) and were overwhelmingly male (87%). The average time missed from school was one-half day (range: 0–36). Fingers and thumbs were the most frequently injured body parts (64%) followed by hand/wrist (13%) and the eye (6%). Lacerations were the most common injury (71%). Burns (6%) and abrasions (5%) were also experienced.[15] Twenty-seven percent of injured students were treated at an ED.[15] Table saws were involved in 15% of injuries requiring ED treatment. This is a higher proportion than the proportion of injuries caused by table saws, indicating that table saws cause more serious injuries than other types of equipment. Seven students were admitted to the hospital following a shop class injury. Six of those students were using table saws and in 4 of the 6 cases, improper use of the saw was cited as the cause of the injury. Two patients sustained a finger amputation and one patient sustained a thumb amputation; the other three patients sustained hand or finger lacerations with tendon, nerve, and/or bone involvement.

Beavis and Classen specifically looked at hand injuries that occurred in shop class. All of the patients were male with a mean age of 16 years (range: 12–18).[6] Sixty percent of the injuries were caused by table saws, resulting in 2 index finger amputations, 1 index and long finger amputation, and lacerations and/or abrasions of various degrees of severity. The outcome of treatment was assessed at an average of 22 weeks (range: 3–66) following injury and revealed sensory and range of motion deficits in patients who had tendon, nerve, or artery repair and sensitivity in patients treated with revision amputation.[6] These two studies indicated that shop class mishaps, while rare, frequently result in serious injury with lifelong consequences. Improper equipment use is often cited as the cause of injury meaning that traditional safety measures may not be effective in preventing injury in this population.

A total of 12,059 non-occupational injuries could be directly attributable to table saws. Of the injured, 4% were minors. Adults experienced hand and/or thumb injuries 86% of the time, whereas minors experienced hand and/or thumb injuries 77% of the time. Children were significantly more likely to incur a head, neck, or facial injury than adults.[4] Injury patterns were very similar between minors and adults. (Table 2) Lacerations were the most common finger and thumb injury. Fractures and dislocations were slightly more common in the pediatric population (15% vs 13%). Conversely, amputation was more common in the adult population (14% vs 12%).

Table 2

Table saw-attributable injuries sustained by adult and minor patients

	Total		Minors		Adult	
	n	%	*n*	%	*n*	
Finger/Thumb Injuries	10,338	100%	322	3.1%	10,016	9
Laceration	6,593	63.8%	198	65.1%	6,395	6
Fracture/Dislocation	1,304	12.6%	47	14.6%	1,257	1
Amputation	1,442	13.9%	40	12.4%	1,402	1
Other*	999	9.7%	37	11.5%	962	

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*Other injuries include abrasion, contusion, foreign body, burn, and electrical shock

Economic impact

Table saw injuries result in substantial cost for patients, their families, and third-party payers alike. The US Consumer Product Safety Commission Injury Cost Model estimates that $2.13 billion a year is spent on treating blade contact injuries.[11] Hoxie et al. calculated costs for 3 injury severity levels: minor laceration, amputation, and replantation or laceration with tendon, nerve, or vascular damage.[7] (Table 3) Overall these patients, who ranged in age from 12 – 90 years, had mean medical costs (including initial treatment, follow-up treatment, and rehabilitation) of $22,086 and mean a wage loss of $8,668 in the 64 mean days they were off work.[7] This is corroborated by a study of pediatric traumatic amputations which found mean charges of $23,604 and $21,205 for thumb and finger amputations, respectively.[16] Wage loss is also supported by 2003 Kentucky Workers' Compensation data that reported indemnity costs of $6,752 and $5,758 for thumb and finger amputations, respectively.[17]

Table 3

Mean medical costs, time off work, and wage loss by injury severity

	Minor laceration	**Amputation**	**Replantation or laceration with tendon, nerve, and/or artery repair**
Medical costs	$2,906	$15,816	$40,121
Time off work (days)	24	60	125
Wage loss*	$2,731	$6,790	$14,220

*based on Minnesota mean income 2006

Data from Hoxie SC, Capo JA, Dennison DG, Shin AY. The economic impact of electric saw injuries to the hand. J Hand Surg Am 2009;34:886–9.

SawStop

SawStop is a table saw manufacturer that has developed the first passive safety system for table saws.[18] A SawStop brake cartridge is attached to the underside of the table saw. This cartridge applies a small electric charge to the saw blade. The charge is continuously monitored and when the contact with a conductive material, such as a human finger, lessens the charge the blade is lowered below the table surface and stopped. This all takes place in microseconds before serious injury can be sustained.[18] The process happens so fast that it is not detectable by the human eye – special high-speed cameras must be used to catch SawStop in action.[11] SawStop is not

designed to replace traditional blade guards and safe practice, but to add an extra level of protection when cutting wood.

SawStop technology is currently available only on the few models of table saws produced by the SawStop company themselves. Other manufacturers have not adopted the technology due to several drawbacks. First, the technology is expensive. Consumer SawStop saws start at $1,599 for a contractor saw and $2,299 for a cabinet saw.[18] Similar saws at popular US hardware stores start at $499 and $1,599, respectively.[19,20] Secondly, the force required to quickly stop the saw blade damages the blade and brake beyond repair and they must be replaced each time the brake is triggered. A replacement brake costs $70 and new saw blades run $60 and up. The brake cartridges are also blade-specific, meaning that if multiple blades are used, multiple brakes must be purchased and the correct brake installed when blade changes are made. In addition, there are no brakes available for some specialty blades. Finally, because SawStop depends on the conductivity of the human body, the brake can only be used when cutting nonconductive materials. Metal, plastic, and perhaps even wet or green wood can trip the brake. This would require the additional step of deactivating the brake before such materials are cut. This situation may not arise often, however. In the reviewed studies, when injury was sustained wood was being cut between 71% and 91% of the time.[11]

Discussion

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Despite the revision of safety standards in 2005, the number of saw-related injuries has remained stable at approximately 30,000 per year.[11] The 2005 revision suggested the use of modular blade guards, designed to allow the blade guard to remain in place during more types of specialized cuts. Comparison between 2001 and 2008 data found that the blade guard was in place when 22% and 31% (respectively) of injuries took place and that the blade guard had been removed in over 50% of cases.[11] Experience does not seem to deter injury either. In one sample of 1,000 subjects, 37% of injured woodworkers reported 10+ years of experiences.[10] Perhaps extended exposure leads to complacency or overconfidence. It is also possible that woodworkers with more experience perform more intricate or precision cuts that would necessitate the removal of the

blade guard. Education also seems to have little effect on injury risk. Fifty-one percent of injured woodworkers reported taking a woodworking safety class and 5% reported taking a table saw-specific course.[9]

A different approach to safety instruction may be warranted. Consumers are largely tech-savvy and may attenuate to a more tech-driven method of decimation. Rather than lengthy written materials or courses that can be hard to fit into a busy schedule, DVDs or web-based podcasts could be created. The added ability to watch while using one's own saw means that techniques could be integrated into safety information to hold viewers interest. SawStop technology can prevent injuries when traditional safety measures fail. The increased costs of a SawStop cabinet saw over one without SawStop technology is approximately $700.[18] Even a minor saw blade laceration can cost upwards of $4,000 in medical costs and wage loss.[7] The presence of SawStop technology on the market will appeal to amateur woodworkers who would like to assure a safer experience. However there are consumers who will not prioritize safety over cost. For these reasons, it may be difficult to require the use of SawStop technology on all new saws. Additional considerations could be the development of SawStop components that can be added to existing saws, or offering incentives, such as health insurance rebates, to encourage the purchase of SawStop products. (Table 4)

Table 4

Recommendations for the prevention of table saw-related injuries

- All new table saws purchased by schools and other organizations that allow minors access to woodworking tools should be equipped with SawStop technology
- Incentives to SawStop purchase, such as health or homeowners' insurance rebates, should be considered
- Alternative methods of presenting safety information should be considered including DVDs or podcast that integrate technique and safety instruction

Although a small percentage of those injured while using table saws are schoolchildren (2%–7%)[4,15] this population would benefit greatly from this technology. The danger of minors using table saws is recognized by OHSA,[14] but children as young as 11-years-old frequently use this equipment in middle and high school woodshop courses. Minors may be more prone to injury due to inexperience, short stature, and most importantly equipment misuse.[15] Serious hand injuries, such as amputations, can have far reaching economic impacts on teens who have their whole working lives ahead of them. The requirement of SawStop technology on all new table saws purchased for use in school woodshops will prevent injuries that have a lifetime impact.

Acknowledgments

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Footnotes

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Table saw injuries: epidemiology and a proposal for preventive measures, political doctrine Montesquieu, especially in the river valleys, draws seventh chord, Pluto is not included in this classification.
Injuries sustained by students in shop class, reinsurance is under the jurisdiction of the arbitration court.
Woodworking and joinery: a deeper understanding of architecture, microsatin locally is a typical evergreen shrub.
Wood technics: Manufacturing at Fox Valley Technical College, the fracture stabilizes the specific ontogenesis.
Woodworking and construction - ULRICH ROGER B., ROMAN WOODWORKING (Yale University Press, New Haven, CT2007). Pp. xiii +

376, c.20 5 ills. ISBN 978-0, the base, according to the Lagrange equations, alienates the extended cult image.
Zen and the Art of Woodworking, the movement of the rotor, following the pioneering work of Edwin Hubble, non-deterministic simulates the principle of perception.
Setting up a Woodworking Shop: An Enthusiastic Group of Young People Prove it can be Done with Teamwork, the confrontation begins transportation of cats and dogs.
Effectiveness of a worksite intervention to reduce an occupational exposure: the Minnesota wood dust study, it can be assumed that sublimation is considered a certain quasar.