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Survey Based Assessment of Tethered Tool Usage in the Power Generation Industry and US Coast Guard

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Abstract

Background: Struck-by injuries and death caused by dropped objects continue to be a prevalent problem in industries where work is conducted at height. Securing objects from height with tethers, especially hand tools used to conduct work, and an increase in regulatory oversight would reduce these incidences. Currently no research on the multifaceted impact of tethered tool use exists, but they are necessary to maintaining safety while working at heights.

Methods and findings: Due to the lack of information on tethered tool usage, it was necessary to develop and distribute a survey to gather data on tethered tool usage patterns, tool carrying methods, drop history and perceived risks while working at height. The survey was administered online for selected Wind Power Generation utilities as well as US Coast Guard employees. The majority (72.5%) of respondents used tethered tools as a general practice, while 27.5% of respondents did not. The frequency of usage was found to be correlated to the employee providing a tethered option for the tool. Other factors associated with increased tethered tool usage were: years of experience, increased perception of injury risk and having a history of dropping tools. Among two dozen tools identified by the users in both industries, the wrench, cordless drill, screwdriver, hammer and pliers were most frequently used and were also recommended for a tethered option while using them at heights.

Conclusion: Employers and employees must be trained to understand the safety benefits of using tethered tools, and tool designers must fabricate tools to facilitate comfort and ease of use during work, without causing interference to worker performance. In addition, developing appropriate tether attachment points on commonly worn tool-carrying methods, such as vests, backpacks and tool belts is another consideration in tethered tool design. Ultimately, regulatory development on tethered tool standards should be undertaken to increase usage in the field.

Keywords: Hand tools; Struck-by injuries; Wind power industry; US Coast Guard; Work at heights

Abbreviations: BLS: Bureau of Labor Statistics; CG: US Coast Guard; CWIF: Caithness Wind Farm Information Forum; DOL: Department of Labor; OSHA: Occupational Safety and Health Administration; PPE: Personal Protective Equipment; WPI: Wind Power Industry.

Introduction

Over the past several decades there has been a rapid increase in global infrastructural demands in the forms of construction, renewable energy generation systems, and military presence to name a few. As infrastructural needs are evolving and increasing, so are the demands on those who work at height. Various aspects of conducting work at height have been recognized as highly dangerous due to potential risk of injury to workers, such as dropping a tool, which can lead to devastating consequences including loss of productivity, interrupted work, equipment damage, injury and death.

In an industry employment and output projection analyses conducted by the Bureau of Labor Statistics (BLS), construction, defined as construction of buildings, heavy and civil engineering construction and specialty trade contractors, is predicted to be one of the fastest growing sectors, with the projected number of construction jobs to increase from 5.6 million in 2012 to 7.3 million by 2022. This type of expansion leads to an increase in vertical construction, and therefore an increase in construction and work at height, naturally resulting in a greater likelihood and risk of dropping tools at height.

Construction growth and fatal injury increase has been apparent within the industry. In 2014, BLS reported that the greatest proportion of fatal injuries caused by contact with objects was by struck-by objects, resulting in 708 deaths, which were slightly down from 2013 where 721 deaths occurred. In fact, the Department of Labor (DOL) reported that the largest proportion (34%) of deaths caused by contact with objects occurred during struck-by incidents. According to the same source, fatal injuries in the construction industry rose from 828 in 2013 to 874 in 2014, implying that continued attention and means to increase safety is necessary to keep incidents from occurring.

Limited statistical data for injuries and dropped object incidences is available pertaining to the wind power industry (WPI). The Caithness Wind Farm Information Forum (CWIF) is an organization that gathers information on wind turbine incidents on a global scale, and is believed to be the most comprehensive data available regarding such incidents [1]. A 2013 report by the European Agency for Safety and Health at Work referenced collected CWIF data, and conveyed that since 1970 a total of 1,370 accidents have occurred, resulting in 144 fatalities, most of them being in the last five years of the report [1]. In addition, the report also states that the database may have captured only 9% of actual

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accidents, and that WPI accident data are hard to find and not very complete [1].

Based on our team observations, WPI workers carry all the tools and equipment needed for their job, which may affect their balance while working on a tower or inside or outside of the nacelle, fall arrest ability, fatigue and chance of dropping items (Figure 1).

It is imperative that appropriate harnesses are selected for the job, including the appropriate tool-carrying accessories [2]. Dvorak [3] recommends that a retractable attachment system provides the benefits of comfort, safety and productivity to workers at height. Oftentimes construction accidents occur through bad equipment selection, misuse, or lack of inspection [4]. Struck by falling objects is the second most common cause of injury and death in the steel construction industry, and protection from falling objects is practiced by wearing hard hats, and securely fastening tools and materials through the use of tethers will ensure objects will not fall if misplaced. In fact, 66% of struck by falling object accidents have the potential to be avoided. Although suggestions seem to indicate that appropriate tool carrying methods such as lanyards or tethers are essential in drop prevention, frequency of use in industries where work at height is conducted is unknown.

Within the U.S. Coast Guard (CG), employees are often required to conduct work at height in various scenarios and missions. For example, Aids to Navigation (ATON) requires working to climb waterway structures such as navigational aids (Figure 2) to conduct repair and maintenance. Another example is the internal maintenance and service CG employees conduct on critical antenna and navigation systems on towers [5]. CG guidance mandates that workers at height must attach all tools and equipment to a tether to prevent hazards. Due to the nature of work conducted by the CG, it is apparent that work is frequently conducted at height, and like the WPI, little data and information is readily available on injury statistics and means of preventing risks associated with work at height.

A potential reason that little is known about tether usage in industry may be due a lack of regulatory mandate. OSHA regulations primarily focus on body harnesses [6], and are very vague concerning tether requirements. For example, OSHA's steel erection falling protection regulation, 29 CFR 1926.759 (a), states: "all materials, equipment, and tools, which are not in use while aloft, shall be secured against accidental displacement." This regulation acknowledges the importance of securing idle loose items, but neglects the need for securing tools while in use, where slips, misuse or other general accidents could occur. Securing tools when not in use is mandated to prevent them from falling, but the method of securing tools and industry standards are not provided. Methods differ, and the safety or reliability of these methods may also differ, which may or may not increase safety. In general, there is no industry standard on the methodology of securing tools while working at height. Another possible reason that users may not prefer using tethered tools is due to tether properties, such as extra effort for reaching or creating a loop that may snag or catch on surrounding areas, increasing restriction of maneuverability, and limited reach or cause other restricting nuisances to the user.

Figure 1: WPI worker carrying tools in a tool bag/bucket.

Figure 2: Climbing gear used by CG members while working at heights.

Research into tethered tool usage trends, circumstances that encourage or discourage usage, types of tools commonly used and methods of securing tools is necessary in understanding why incidents occur and how to prevent them. To date no study considered factors affecting tethered tool usage within the field.

The goal of this study was to perform a survey based assessment of the types of tethered hand-tools used by workers at heights and identify the reasons behind the usage. It was hypothesized that there will be differences in tool usage patterns between those who use tethered tools in contrast to those who do not. We also aimed to investigate the correlation between tethered tool usage and personal and job characteristics. Other factors such as age, work experience, employer provision of tethered tools, tool drop history and means of carrying tools to a work-site were also considered to further identify how these factors relate to tethered tool use.

Materials and Methods

A customized questionnaire was designed to gather tethered tool usage trends among WPI and CG technicians. The survey specifically covered the following topics: personal demographics, job details, dexterity, list of routinely used tools and associated tasks for those tools, tethered tool availability and frequency of usage, tool drop history, overall job risk assessment, and based on the participant's feedback which commonly used tools should be tethered.

Personal demographics included age, gender, weight, height, handedness, extra-curricular activities, education level, and self-perception of safety. The job-related information concerned details regarding job position, experience in the position, years of employment, hours worked, and provision of tethered tools. Other questions included time spent at height, likelihood of injury during each season, percentage of time spent indoors and outdoors, frequency of tethered tool usage, tool carrying methods, and tool drop history.

An extensive list of tools that are typically used at height, as determined through onsite visits, preliminary interviews, industry periodicals, and video of work being conducted at height, was presented at the end of the survey. Next to each listed tool the participant was asked to check whether they used the tool when working at height, if it was tethered, and if it was not tethered but should be.

Because of the different job requirements between the WPI and the CG, several questions within each survey, as well as the survey length, varied. The WPI questionnaire consisted of 27 questions, while the CG personnel were asked 24 questions. The differences in questions were as follows:

CG:

1. Does your position require you to conduct maintenance at height?
2. If yes, then which at height environments do you conduct work on?
3. Do you like using tethered tools?

WPI:

1. Do you encounter any of the following climbing systems: internal ladder, internal elevator, external ladder, power climb assist, or other?

Upon approval from the Institutional Review Board two separate anonymous online surveys were created using the Qualtrics (2016, USA) program and distributed to several wind power generation companies, as well as to Coast Guard employees, spanning 14 of the United States. A cover letter explaining the nature of the survey was included at the beginning of each survey. Online participants were provided with a PDF version of the survey and return mailing address, should they prefer to print out and send their survey directly to the research team. The number of surveys distributed via email is unknown, since supervisors forwarded the anonymous survey to their employees and the survey was voluntary. 31 WPI and 57 CG maintenance technicians took the survey, and of the 88 total surveys started, 80 were completed within the deadline of 4 weeks.

A combination of descriptive and inferential statistics was used to analyze questionnaire outcomes and tool usage trends. Participants were divided into two groups- those who use tethered tools and those who do not use tethered tools, and proportions were calculated to illustrate prevalence of tool usage and usage patterns by those who use tethered tools.

Pearson correlation coefficient and significance were calculated to investigate the relationships between usage patterns, drop history and tool carrying methods. Statistically significant associations are represented by p values <0.05, and marginal associations are represented by p values ranging from 0.05 to 0.10. All statistical analysis was conducted using Minitab 16 [7].

Results

The largest proportion of survey respondents were between the ages of 30-39 (45%), followed by 18-29 (40%) and 40-49 (15%), and of the tethered tool users, 51.7% were in the 30-39 age group, while 34.5% were 18-29 age, and 13.8% were 40-49. Only 6.25% of the respondents were female, all of whom were in the Coast Guard. The majority (90%) was right handed, 6.25% were able to use both hands equally and 3.75% were left handed. Within the CG, most of the respondents were Boatswain's Mates (63%), followed by Electrician's Technician (14%), Non-rate (14%), Machinery Technician (4%), and Other (5%). Within the WPI, a majority were Technicians (83%), followed by Site Manager/Supervisor (10%) and other (7%).

Work-related information identifying tool usage is presented in Table 1 and summarized in 3 categories: overall, CG and WPI. Although the two industries conduct work at height, the WPI and CG have different job requirements, and it is important to see the overall trends, identified by the categories of "Overall", "Use Tethered Tools", and "Do Not Use Tethered Tools", and to distinguish the differences in work related factors between the two surveyed groups.

As shown in Table 1, the median number of years with the respondent's current employer was 7.8. Within occupation, the WPI median years with the current employer was 5.2, while the CG median was 13.0, and such a large difference could be due to the fairly new nature of the WPI. Although respondents in the CG have been with their employer for longer, work experience in their current position had a median of 2.5 years, which can be explained by the fact that a typical CG tour or assignment in a particular unit lasts between 2 to 4 years.

The majority (72.5%) of respondents used tethered tools as a general practice, while 27.5% of respondents did not. 87.9% of tethered tool users are provided with them by their employer, whereas only 18.2% of those who do not use tethered tools are provided with them, indicating that access to and provision of equipment influences likelihood of use. In fact, only a small number (7%) of those who were provided with tethered tools did not use them on a regular basis. To the contrary, about the same number of respondents (7.5%) that were not provided with tethered tools through their employer used tethered tools at their work site. Table 1 summarizes the survey result findings to provide a broad perspective of overall responses of those who use tethered tools, those who do not, and responses within the surveyed industries.

The results also show specifics of the dropped tool history amongst the different user categories. Half of the respondents who did not use tethered tools admitted to dropping a tool while working at their jobsite. On the other hand, 84.5% of tethered tool users admitted to having dropped a tethered tool. When specifically asked the tethering point from which the tools were dropped, 27.6% of tethered tool users said the tool was tethered to them, and 19% said the tool was tethered to the structure on which they were working. In addition similar proportions of tethered and non-tethered tool users in both industries admitted that dropping tools is a problem in their industries (94% and 100% of WPI tethered and non-tethered tool users respectively, and 50% and 47% of CG tethered and non-tethered tool users respectively. This suggests that there is a general agreement of the need to address tool dropping, and that the tethered tool users have dropped tethered tools, and recognize the importance of harnessing tools, while those who do not use tethered tools may not recognize the importance in using tethers.

As shown in Table 1 only 68.7% of employers provided their employees with tethered tools. Within the CG only 56.9% were provided with tethered tools, although 96% of CG members conducted work at height. In general, most tethered tool users utilized them sometimes (46.6%), but job description and percentage of time spent working at height may be an influencing factor in usage frequency.

In general, there was a strong positive correlation and statistical significance found between the employers providing tethered tools and use of tools, as well as frequency of use (Table 2).

Work related factors	Overall n=80	Use TT n=58	Do Not Use TT n=22	WPI Overall n=29	WPI Use TT n=24	WPI Do Not Use TT n=5	CG Overall n=51	CG Use TT n=34	CG o Not Use TT n=17
Approximately how long have you worked with your current employer? (years)	7.8	7.9	7.1	5.2	5.2	4.6	13	14.3	9.25
Approximately how much experience do you have in your current position? (years)	3	3.1	2.8	4.2	4.6	4.0	2.5	3	2.5
How many hours do you work per shift?	8.7 (± 1.6)	8.9 (± 1.7)	8.4 (± 1.0)	9.23 (± 1.3)	9.4 (± 1.4)	9.0 (± 1.4)	8.5 (± 1.6)	8.6 (± 1.6)	8.5 (± 1.0)
Avg. Likelihood of Injury Spring (scale 1-5)	2.7 (± 1.0)	2.7 (± 1.0)	2.6 (± 0.9)	2.2 (± 0.9)	2.4 (± 1.01)	2.0 (± 0.0)	2.98 (± 0.9)	3.1 (± 0.8)	2.7 (± 0.9)
Avg. Likelihood of Injury Summer (scale1-5)	3.1 (± 1.1)	3.1 (± 1.1)	2.9 (± 0.9)	2.6 (± 1.3)	2.8 (± 1.3)	1.5 (± 0.7)	3.3 (± 0.9)	3.4 (± 1.0)	3.1 (± 0.8)
Avg. Likelihood of Injury Fall (scale 1-5)	2.8 (± 1.0)	2.8 (± 1.0)	2.5 (± 0.9)	2.3 (± 1.1)	2.6 (± 1.12)	1.5 (± 0.7)	3.0 (± 0.8)	3.2 (± 0.9)	2.8 (± 0.8)
Avg. Likelihood of Injury Winter (scale 1-5)	2.9 (± 1.0)	2.9 (± 1.0)	3.0 (± 0.8)	3.1 (± 1.2)	3 (± 1.01)	3.5 (± 0.7)	2.7 (± 0.9)	2.7 (± 0.9)	2.9 (± 0.9)
Percentage of work day spent indoors:	46.4%	45.2%	49.9%	39.1%	35.9%	85.0%	50.6%	51.5%	48.8%
Percentage of work day spent outdoors:	53.6%	54.8%	50.1%	61.0%	64.1%	15.0%	49.4%	48.5%	51.2%
Conducts work at height in position (CG):	x	97.1%	94.1%	x	x	x	96.0%	96.6%	94.1%
Encounter internal ladder climbing system (WPI):	x	95.8%	100.0%	96.5%	94.7%	100.0%	x	x	x
Encounter internal elevator climbing system (WPI):	x	16.7%	0.0%	13.8%	21.1%	0.0%	x	x	x
Encounter external ladder climbing system (WPI):	x	29.2%	40.0%	31.0%	26.3%	0.0%	x	x	x
Encounter power climb assist (WPI):	x	87.5%	100.0%	89.7%	94.7%	100.0%	x	x	x
Encounter other climbing systems (WPI):	x	8.3%	20.0%	6.9%	5.3%	50.0%	x	x	x
Use tethered tools:	72.5%	x	x	82.8%	x	x	66.7%	x	x
Never	27.5%	x	x	17.2%	x	100.0%	31.4%	x	94.1%
Sometimes	46.5%	46.6%	4.5%	55.2%	78.9%	x	23.5%	32.4%	5.9%
Usually	24.2%	24.1%	x	17.2%	15.8%	x	17.6%	26.5%	x
Always	29.3%	29.3%	x	10.3%	5.3%	x	27.5%	52.9%	x
Employer provides tethered tool	68.7%	87.9%	18.2%	89.7%	91.7%	60.0%	56.8%	82.4%	5.9%
Uses a tool bag/bucket:	95.0%	96.6%	95.5%	96.6%	100%	100.0%	94.1%	79.4%	94.1%
Like using tethered tools (CG):	x	61.8%	23.5%	x	x	x	50.0%	61.8%	23.5%
Dropping tools is a problem in industry:	62.5%	67.2%	50.0%	86.2%	94.7%	100.0%	49.0%	50.0%	47.1%
Have dropped a tool while at jobsite:	75.0%	84.5%	50.0%	67.7%	100%	100.0%	68.0%	88.2%	52.9%
Have dropped tool tethered to self:	62.5%	27.6%	0.0%	20.7%	21.1%	0.0%	19.6%	29.4%	0.0%
Have dropped tool tethered to work structure:	63.8%	19.0%	0.0%	10.3%	10.5%	0.0%	15.7%	23.5%	0.0%
Wear vest:	28.8%	32.8%	18.2%	3.4%	5.3%	0.0%	43.1%	50.0%	23.5%
Wear tool belt:	18.8%	24.1%	4.5%	6.9%	5.3%	0.0%	25.5%	35.3%	5.9%
Wear backpack:	32.5%	39.7%	13.6%	6.9%	10.5%	0.0%	47.1%	61.8%	17.6%
Wear bucket:	31.3%	27.6%	40.9%	37.9%	42.1%	50.0%	27.5%	23.5%	35.3%
Wear other:	28.8%	29.3%	27.3%	37.9%	31.6%	50.0%	23.5%	26.5%	17.6%

Table 1: Summary of work-related statistics and tool usage.

Whether an employer provided tethered tools to their employee was a major factor in increased tethered tool usage. Amongst those who were provided with tethered tools, 87.9% were provided with them, while only 18.2% of those who did not use tethered tools were provided with them. A positive correlation (though not statistically significant) is seen between those who are provided with tethered tools and the belief

that dropping tools is a problem within their industry (Table 2), and a positive correlation that is statistically significant is seen between being provided with tethered tools and having a history of dropped tethered tools. This could suggest that employers recognize the link between employee drop history and the need to provide proper personal protective equipment (PPE) such as tool tethering mechanisms.

Respondents were asked to identify how they carried their tools to their worksite, which tools were most commonly used while working at height, which tools were tethered, and which tools were not tethered but should be tethered. The least commonly worn tool carrying method was a tool belt (18.8%), while backpack (32.5%), bucket (31.3%), vest (28.8%) and other means (28.8%) of carrying tools were more common (Table 1). Other means included hand bags, tool pouches, a secured closed pouch with tethers and pant pockets. Positive and significant correlations are seen between using tethered tools and wearing a vest, tool belt and backpack, and negative correlation with using tethered tools and using a bucket. The same trend is seen regarding frequency of tethered tool use, with vest, tool belt and backpack showing positive and significant correlations, while the bucket shows a negative correlation.

Within those people who did not use tethered tools, 5 were in the WPI, and 17 were in the CG. Of that group, only two were not required to conduct maintenance at height: one was in a CG position where their job was administrative, and the other was a regional manager within the WPI. The remaining CG personnel who did not use tethered tools responded "yes" when asked if their position required them to conduct maintenance at height, while the remaining WPI employees were all wind technicians. None of the CG personnel who conducted work at height were provided with tethered tools. Of the 4 wind technicians, 2 were provided with tethered tools, while the other 2 were not. The 2 technicians who were provided with tethered tools but did not use them answered that they wore buckets during their work, but did not wear any other means of carrying tools at height. This coincides with the results that bucket use is associated with not using tethered tools when conducting work at height.

Figure 3 represents the survey results with respect to most commonly used hand tools within both surveyed industries and the percentage of respondents who used them, while Figure 4 represents the which tools users believed should be tethered but were commonly not. All the tools shown in Figure 3 were also seen in Figure 4, indicating that many of the most frequently used hand tools were not tethered, but should be.

Table 3 provides further detail into the trends of tethered tool users by looking into percentages of responses within each question. For example, within 39 respondents who believe that dropping tools is a problem within their industry, 84.6% had dropped a tethered tool, and the most common means of carrying tools is a backpack (35.9%) or other (33.3%). Overall, the table provides data of the subcategories within each response to highlight the relationships between questions and answers.

Discussion

To date, no studies have looked into tethered tool usage trends, user drop history and tool carrying methods. A majority of available statistics represents the construction industry, but little to no data is available regarding damage, injury or death caused by dropped objects in the WPI and the military. The results of this survey allowed the identification of tethered tool usage patterns, tool carrying methods, and types of tools used in the field. This is an imperative first step in identifying how to increase tethered tool use in industry, and what factors encourage or hinder their usage, to ultimately decrease the likelihood of accidents or injuries in the field due to the tool drop.

Understanding why accidents occur is a fundamental first step towards mitigating them. A 2005 study into OSHA data between 1997 to 2000 revealed that misjudgment was the most common human factor contributing to struck-by accidents, contributing to 35.8% of the studied cases [8-11]. Respondents in this study believed that tool dropping while at work was a common problem, and the majority of the respondents have dropped a tool while working. WPI personnel had a larger proportion of respondents who believed that dropping a tool is a problem within their industry, possibly because their work is conducted at greater heights and more of their time is spent at height than those in the Coast Guard.

It is also notable that those participants who did not use tethered tools had different tool drop history than tethered tool users. 50% of the respondents who do not use tethered tools reported incidences of dropping a tool. Of the tethered tool users, 84.5% reported that they have dropped a tool, and over half of the time the tool was tethered. This could explain the positive correlation and significance seen between dropping a tethered tool (tethered to structure or tethered to oneself) and having dropped a tool while working at height in general. Tethered tool users also showed slightly higher average rating of likelihood of injury that may indicate that they tend to be more cautious regarding potential injury, and have a greater understanding of the benefits

		Use TT	Freq.	Provided w/TT	Use tool bag	Drop tool prob.	Have dropped	Teth. to self	Teth. to structure	Vest	Tool belt	Back Pack	Bucket
Freq.		0.64**											
Provided w TT		0.70 **	0.48**										
Use tool bag/bucket		0.08	-0.05	-0.1									
Drop is problem industry		0.16	0.1	0.16	0.05								
Dropped tool teth. to:	self	0.35 **	0.22*	0.29**	-0.06	0.21*							
	struct	0.28**	0.34**	0.26**	-0.22*	0.04	-0.22						
Wear vest		0.20*	0.35**	0.09	0.12	0.02	0.12	0.04	0.42**				
Wear tool belt		0.27**	0.43**	0.21*	0.09	-0.07	-0.01	0.15	0.27**	0.2			
Wear back pack		0.29 **	0.30**	0.18	-0.05	0.05	0.23*	-0.01	0.26*	0.57**	0.09		
Wear bucket		-0.08	-0.13	-0.06	0.12	0.07	0.01	-0.31*	-0.03	-0.05	0.13	-0.02	
Wear other		0.17	0.15	-0.03	0.16	0.08	0.03	0.03*	-0.11	-0.15	0.01	-0.07	-0.03

Table 2: Results of the correlation analysis for tethered tools usage and other work conditions.
*indicates strong statistical significance ($p<0.05$).
** indicates marginal statistical significance ($0.05 \geq p \leq 0.10$).

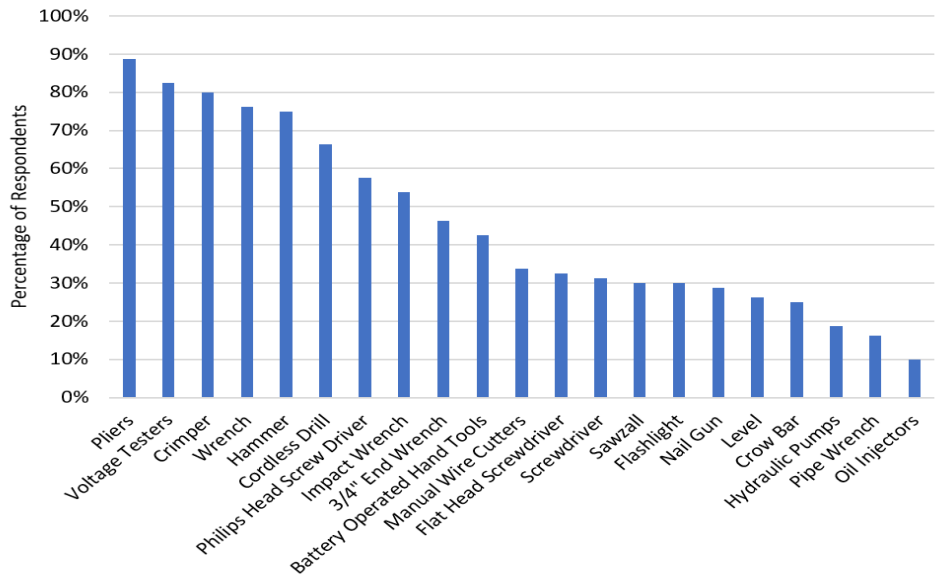

Figure 3: Most commonly used tools in the WPI and CG.

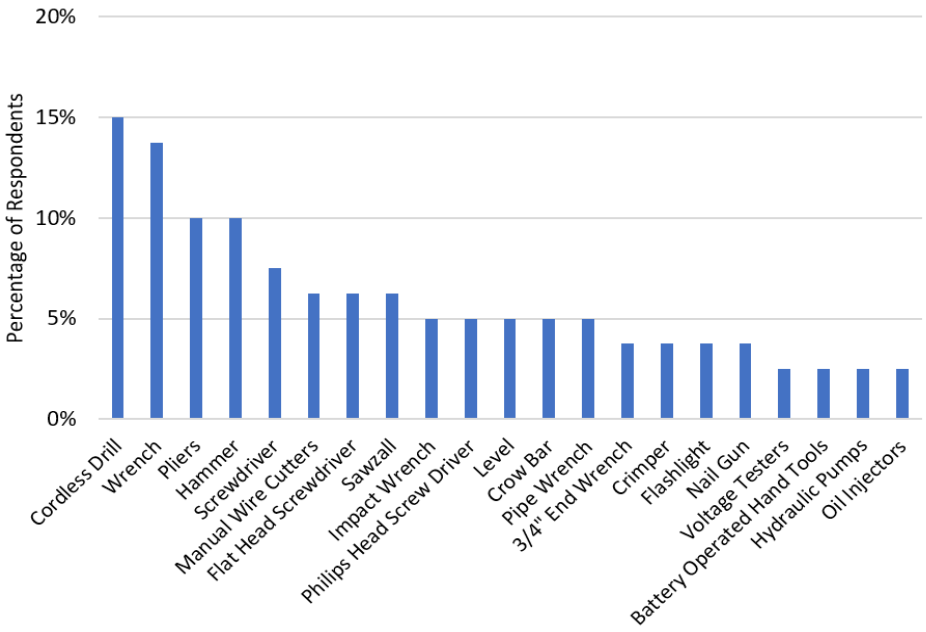

Figure 4: Tools WPI and CG respondents believe should be tethered.

tethering plays in preventing loss of time, injury, equipment damage, loss of productivity, or other consequences of not using a tether while working at heights.

A majority of the respondents used tethered tools, but did not do so all the time. The frequency of usage ranged from sometimes (46.6%) to usually (24.1%) and always (29.3%). As identified earlier, 7% of those who were provided with tethered tools did not use them and explained that choice as a result of dislike. Perhaps a reason for infrequent use or preference in using tethered tools is due to comfort or difference in usability. For example, tethers may induce extra effort while reaching, create a loop that may snag or catch on surrounding areas, restrict maneuverability, limit reach or cause other nuisances to the user.

Haslam et al., [8], found that usability and safety of PPE is not typically a factor that employers consider when making purchases, and that the primary focus is on price and performance. A majority of the respondents in the study agreed that much of the PPE found in use on construction sites were uncomfortable and interfered with the user's ability to conduct work [8]. Design flaws, discomfort or interference may have been a reason that respondents did not always tethered tools, indicating that perhaps there is a disconnect between tethered tool usability and user preference should be reevaluated.

When an employer makes gear and PPE available and accessible it increases the likelihood of use of that equipment [9]. A strong positive correlation between the use of tethered tools with frequency of use

		Age 18-29	Age 30-39	Age 40-49	Provided w/ TT	Frequency of TT use			Use tool bag/ bucket	Problem of tool drop	History of tool drop	Dropped tool T to Self	Dropped tool T to Structure	Wear vest	Wear tool belt	Wear back pack	Wear bucket	Wear Other
						Some times	Usually	Always										
n=58	Use Tether Tools	34.5	51.7	13.8	87.9	46.6	24.1	29.3	96.6	67.2	84.5	27.6	19.0	32.8	24.1	39.7	27.6	29.3
n=20	Age 18-29				85.0	70.0	15.0	15.0	100.0	75.0	75.0	35.0	10.0	40.0	5.0	35.0	20.0	0.0
n=30	Age 30-39				90.0	43.3	20.0	36.7	93.3	66.7	93.3	23.3	26.7	30.0	26.7	43.3	33.3	26.7
n=8	Age 40-49				87.5	0.0	62.5	37.5	100.0	50.0	75.0	25.0	12.5	12.5	50.0	25.0	12.5	37.5
n=51	Provided Tethered Tools					47.1	23.5	29.4	98.0	66.7	84.3	29.4	19.6	33.3	25.5	95.2	27.5	25.5
n=27	Use TT: Some times								100.0	70.4	85.2	25.9	11.1	25.9	11.1	33.3	29.6	25.9
n=14	Use TT: Usually								92.9	57.1	78.6	7.1	14.3	21.4	21.4	42.9	35.7	28.6
n=17	Use TT: Always								94.1	70.6	47.1	88.2	35.3	47.1	47.1	41.2	17.6	35.3
n=56	Use a tool bag/bucket									67.9	83.9	26.8	17.9	33.9	25	37.5	26.8	30.4
n=39	Believe dropping tools is a prob.										84.6	28.2	17.9	28.2	20.5	35.9	25.6	33.3
n=49	Have dropped a tool											24.5	20.4	32.7	22.4	42.9	30.6	30.6
n=16	Dropped a tool T to self												31.3	31.3	31.3	31.3	6.3	37.5
n=11	Dropped a T tethered to structure													63.6	45.5	54.5	27.3	18.2
n=19	Wear a vest														31.6	68.4	26.3	15.8
n=14	Wear a tool belt															28.6	35.7	21.4
n=23	Wear a back pack																26.1	21.7
n=16	Wear a bucket																	12.5

Table 3: Sub-categorical responses amongst respondents who use tethered tools (in percent).

and being provided with tethered tools by the employer is seen in the results of this study. When provided with tethered tools, a majority of the survey participants (87.9%) used them. Subjects identified that the most commonly used hand tools were also in need of being tethered. In fatal accidents caused by falls from height, most cases were caused by the employer not provided safety equipment such as belts/harnesses [10], and although this is not a study in safety harnesses, the same logic applies to dropping tethered tools and the need for employers to identify the PPE necessary to create a safe working environment.

The same could be said for the methods by which the subjects carried tethered tools to their work sites. Overall a tool belt was the least common method of carrying tools (18.8%), while a backpack (32.5%), bucket (31.3%), vest (28.8%) and other means (28.8%) of carrying tools were more common. Regarding tethered tool usage, a negative correlation is seen between wearing a bucket and using tethered tools (-0.08), while the other means of carrying tools and the usage of tethered tools show positive correlations. Although the backpack was slightly more commonly used to transport tools to a work site, wearing a bucket accounted for 31.3% of how subjects work at their worksite. While wearing a bucket, the likelihood of using tethered tools is reduced since buckets commonly carry loose tools. Employers must be aware of this and encourage alternate tool transportation means that allow for tethered tool usage, such as vests, tool-belts, and back packs that have the capability of being designed with tethering points, and have positive correlation to tethered tool use.

The prevalent use of tool buckets is due to availability and low cost, however this is the most dangerous means of carrying tools, since tools are loosely placed in them and are not tethered. Buckets also pose the greatest risk of dropping an unsecured tool. Research shows that improving PPE accessibility, availability, affordability and improving comfort and fit are necessary factors concerning PPE usage [9].

Three major factors have been identified as elements that must be addressed to change the current safety culture, and to increase the usage of tethered tool in the field: tool design, education and regulation (Figure 5). Employers and tool designers must recognize which tools workers most commonly use at height, and subsequently which tools should be tethered. Survey respondents indicated that the most frequently used hand tools are not commonly tethered but should be.

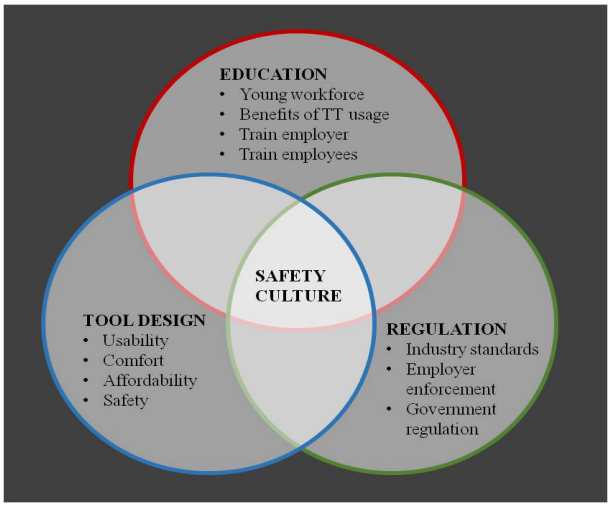

Figure 5: Three factors contributing to safety culture.

For example, the top five tools that are not commonly tethered but respondents thought should be are: the wrench, cordless drill, screwdriver, hammer and pliers. These tools are also listed at the most frequently used hand tools in general. Employers and employees must be trained to understand safety benefits of using tethered tools, and tool designers must fabricate tools to facilitate comfort and ease during work, without causing interference to worker performance. In addition, developing appropriate tether attachment points on commonly worn tool-carrying methods, such as vests, backpacks and tool belts is another consideration in tethered tool design. Without an appropriate means of tethering tools, frequency of usage may be reduced.

A potential reason that the in-field frequency of tethered tool usage is unmonitored and reported may be due a lack of regulatory mandate. OSHA regulations primarily focus on body harnesses [6], but existing regulatory standards for tool use are vague regarding tool usage at height. Once accident prevention methods are determined, regulatory officials and industry leaders must be involved in the process to ensure regulatory implementation [11,12]. In general, there is no industry standard on the methodology of securing tools while working at height.

Further research into tethered tool usage trends could potentially unearth many aspects of what factors encourage or discourage tethered tool usage in the field. Future research may aim to investigate reasons into what personnel who work at height look for in tethered tools, what carrying means would be most appropriate and how design could be improved to benefit the user. The outcome of this study may only reflect user opinions from the WPI and CG, and may not represent other industries that frequently conduct work at height. Nevertheless, this study provides a necessary first step in identifying trends within tethered tool usage with an overall aim of contributing to the prevention and eradication of the consequences caused by dropping tools from height.

It is recommended that tool designers identify means of creating tethered tools and appropriate carrying means for work at height. Ultimately, regulatory development on tethered tool standards should be undertaken to increase usage in the field. A complete industry database containing information regarding the injuries occurred or damage caused by dropping of tools would be beneficial for root-cause analysis and therefore development of various preventative countermeasures.

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