DEVELOPING BEST PRACTICES FOR WRENCHING IN VARIABLE WORK ENVIRONMENTS

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Ergonomists are often challenged to train workers to use "best practices". Textbook techniques that work in one situation are not however always applicable in other work environments. Ergonomists and safety professionals who promote techniques such as 'bend your knees", when the loads or workstations do not accommodate this method, run the risk of losing credibility, and thereby rendering their training ineffective. Companies who are pursuing engineering controls often have a legitimate need to provide training for workers as an interim measure, to ensure that workers are using optimum biomechanics for tasks with high force and awkward posture requirements. An example of this type of work is gas meter installation and service work, where wrenching tasks may involve high forces in constrained, awkward postures and variable work environments. This case study reviews how best practices for utility services workers were identified and substantiated, and how training was developed and delivered with the goal of developing effective wrenching techniques. The training course was developed as a train-the-trainer, using internal company safety resources to facilitate the hands-on training with affected employees across the company.

KEYWORDS: wrenching, hands-on training, technique

1. INTRODUCTION

Following a change in gas meter-set design at this natural gas utility there were reports of increased fatigue and musculoskeletal discomfort by the Utility Service Representatives (USRs) who are responsible for changing these meters. An ergonomics assessment was conducted to identify hazards and potential improvements, and the need for additional engineering controls was identified. During the assessment, it became clear that variability in fitting height, orientation and installation tightness, as well as environmental obstructions, create a highly variable work environment and introduce musculoskeletal disorder (MSD) hazards (Lee et al., 2014). Observations found that not all USRs used the same techniques, that different techniques were used depending on the variables at that work site, and that some techniques appeared to have a protective effect. For example, some USRs were small females who were capable of tasks which the biomechanical assessment models predicted were not possible. The company reviewed existing MSD prevention training and determined that it did not address these specific hazards and techniques effectively. It was decided that, in addition to implementing additional engineering controls, enhanced training was needed to communicate effective techniques for wrenching in this variable work environment.

The goals of the proposed training were to provide information on validated, effective, wrenching practices, and to help guide employees with developing skills in applying these techniques in the field. It was determined that a hands-on practical program was required, considering both adult education principles, and the intended audience of skilled tradespeople who are more accustomed to outdoor physical work than being in a classroom. The proposed format would provide a demonstration of each new skill, and a hands-on exercise designed to allow participants to practice the skill and get immediate tactile feedback on the efficacy of the technique.

This paper outlines the method used to collect and validate effective wrenching practices in this environment, the techniques used in the development of the facilitated hands-on training, and the implementation of the training itself by internal company resources. The training format introduced some challenges and obstacles during deployment, which will be discussed later.

2. METHOD

At the request of the company, the consulting ergonomists proposed an outline for the development of the wrenching training, and the following steps were then carried out:

- Ergonomists reviewed existing technical training (MSD prevention, wrenching, meter exchange ergonomics), spent time at the training facility to discuss the potential for hands-on training, and met with a focus group of USRs to identify concerns, ideas, etc.
- Ergonomists compiled a list of best practice ideas from previous reports and projects, research, and discussions with company resources. The list of “best practices” reflected the current understanding of the methods that are biomechanically sound and would reduce exposure to MSD hazards.
- Company safety resources (Environmental Health and Safety Coordinators - EHSCs) reviewed the best practice list and provided feedback.
- Ergonomists collected data with USRs in the field, photographing and describing the best practices.

- Ergonomists completed biomechanical analyses using University of Michigan 3D Static Strength Prediction Program to substantiate if and why these observed methods are preferable.
- Each best practice was described, step by step, and the technical biomechanical analysis results were used to compare and validate the technique. Results for each practice were compiled in a one-page summary document.
- Company EHSCs reviewed these best practice summaries and provided feedback.
- Ergonomists drafted a 90-minute training session that includes practical applications. The biomechanical analysis results were used in the development of the training modules and associated practical exercises.
- Ergonomists ran a pilot session with key company EHCSs for feedback and revised the session.
- Ergonomist ran the 90-minute session for a group of USRs for feedback.
- The session was finalized, with instructor notes.
- Ergonomist ran a train-the-trainer program for EHSCs, who would roll the training out for all USRs in multiple locations across a wide geography.

Training techniques were developed in order to facilitate practical exercises and allow participants to more effectively gauge the force applied in each of the exercises. A training fixture was designed for the hands-on exercises, and customized pipe wrench head torque wrenches were fabricated. Skill reinforcement would be through feedback and completing ratings of perceived exertion scales after each practical exercise.

The company requested that modules should follow the “SCAT” principle – Simplify, Consolidate, Automate and Translate Technical. The request was to simplify the information in the training and reduce the technical language as well as minimize the anatomy, biomechanics, and injury components.

3. DATA ANALYSIS

During the initial data collection and research, ergonomists identified almost 20 best practices. These practices were identified through research (e.g. McGill, 2002), and by interview and observation of experienced USRs.

The initial list was reviewed by the key stakeholders, in an effort to identify the most effective and useful practices to include in the training. Some concepts were consolidated into one practice; for example, “prepare the work site” included both preparing the environment, and preparing the body to work. A total of 11 “Best Practices” were accepted for inclusion into the training:

1. **Prepare** the work site and pre-stretch
2. **Pre-contrac**t abdominals and **test** the load
3. Adopt a stable **stance**
4. Use the **strongest** muscle group
5. Select the **appropriate wrench**
6. Apply force **gradually**
7. **Direct** the force
8. **Re-direct** (divert) the force
9. Keep wrench ends **close**
10. Apply only the **necessary** force
11. Use appropriate equipment to **pre-assemble** components when possible

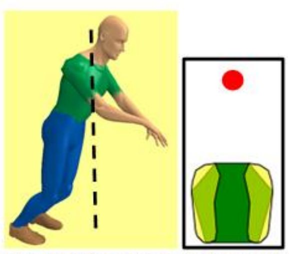
Practices specifically associated with wrenching technique were validated using biomechanical modeling software (Michigan 3D Static Strength Prediction Program) and where applicable the technique was compared biomechanically to the common or less effective alternative technique. For example, the effect of wrenching with a wide and stable stance was contrasted with using an unstable or narrow stance.

A Best Practice Summary was developed for each effective practice. These summaries contained the validation that the practice offered a biomechanical advantage and provided information needed for effective knowledge and skill transfer. For each identified best practice, the summary included photographs and descriptions of the “common practice” and “best practice”, and the researched rationale or biomechanical analysis to substantiate the practice. It also offered training suggestions. Figure 1, below, shows the best practice summary that was used to substantiate best practice #3, “Adopt a stable stance”.

Unstable stance

USRs are required to work in various environments, on various surfaces and around objects. The stance is the foundation of force transfer and if compromised, force transfer and balance is decreased. Working around customer objects (flower pots, toys) was observed.

A narrow stance provides a very small base of support (shown in green). When the body’s center of gravity (red dot) passes outside this footprint, the USR becomes unstable and the risk of falling increases. This is often seen when leaning into or pulling on a wrench with one’s body weight. If the fitting should happen to loosen unexpectedly, then the USR risks falling.



The USR can increase the size of his/her “footprint” by widening his/her stance. If the USR’s center of gravity should again, happen to travel outside this “foot print” while leaning to wrench (shown), the risk of falling increases.

Wide and stable stance

The USR should clear the work space of any customer objects that could pose a hazard or hinder foot placement.

The USR should adopt a wide and staggered stance while evenly distributing his/her body weight between the feet. This stance increases the USR’s base of support. The larger area allows for more body movement and weight shifting with the center of gravity still falling within the supported ‘footprint’. This decreases the risk of falls.

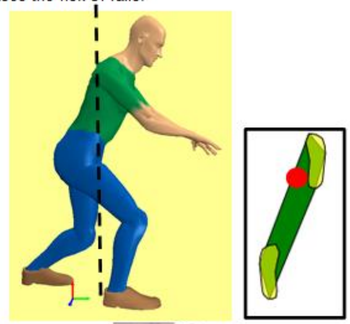


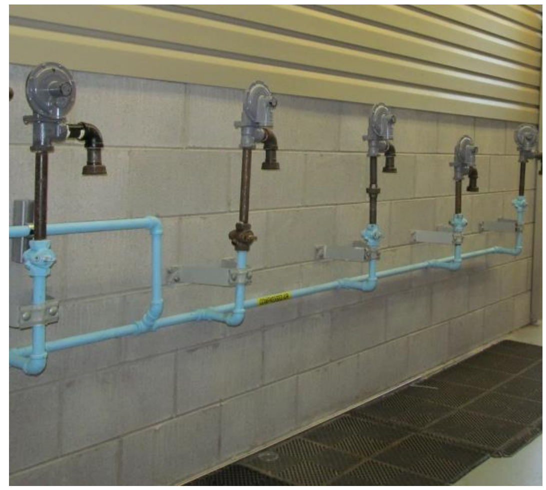
Figure 1: Best practice summary for “Adopt a Stable Stance”

Once the best practices were proven by the ergonomists and the summaries reviewed and accepted by the key stakeholders, the ergonomist developed a training outline. The outline included the lecture content, demonstration, application (activity to be performed by the trainees), and feedback to be provided.

4. RESULTS

In order to allow participants to fully understand the techniques that we were training, custom-made pipe wrench head torque wrenches were purchased. These torque wrenches were used throughout the training to provide direct feedback to participants on the technique. With the wrench set to a specific torque and participants instructed not to exceed that force, they completed exercises with each of the specific practices. This allowed participants to directly compare the perceived exertion with different techniques with a consistent and known actual force.

A training fixture (pictured left) was constructed at the company training center. The pilot sessions and train-the-trainer used this fixture, and it is now used during core training for all new hire USRs. This fixture was challenging to build because of the need for stability with multiple different fitting orientations and heights.



The combination of the fixture and custom wrenches allowed participants to practice wrenching at various heights between knee and shoulder height, and in several different directions (up/down, push/pull, sideways). Fittings were tightened and loosened, using both the participants' own pipe wrenches and the customized torque wrench.

The training slide show included photographs to assist with each "hands on" activity, and each participant received a manual in which to record his/her results. The training was completed in a lab setting, such that short lectures were interspersed with hands-on activities, discussion, and feedback. The last activity in the course required participants to consider which of the best practices would be practical under a few complex situations (e.g. a meter that was obstructed by a deck).

Many of the best practices involved positioning the wrenches, and the body, to allow optimal strength. During the activities for each of these best practices, participants were expected to apply only the amount of force *required* to cause the torque wrench to "click". The customized torque wrenches allowed a direct comparison of perceived efforts, when comparing a common practice to an 'effective practice'. For each practice, participants were asked to use a 10-point rating scale to compare the two techniques or positions. By comparing these ratings, participants were able to understand that the practice offered an advantage; the "best practice" consistently generated lower effort ratings.

The customized torque wrench was also effective in providing tactile feedback so that participants were able to learn what the *appropriate* amount of force "felt" like. With the torque wrench set at the amount of force that was *required* to tighten the fitting, participants received audible feedback when the torque was reached. This knowledge and understanding is important in reducing overtightening of fittings, which not only increases risk to the USR performing the work, but also much later when another USR is required to loosen the fitting.

The initial pilot session took 2.5 hours instead of the 90 minutes that we originally planned. It had been anticipated that during the pilot unnecessary material would be identified and purged to yield a shorter session. Instead, a decision was made to keep all of the content and extend the training duration because all of the material and exercises were perceived as important.

Once revisions were completed after the pilot, a train-the-trainer session was conducted with the Environmental Health and Safety Coordinators (EHSCs) to train them to deliver the program with USRs in multiple locations. The EHSCs were brought to the training facility for a full day. The ergonomist first taught the program to the EHSCs as if they were USRs. Basic adult learning principles were discussed, although most of the EHSCs already had experience with facilitating other safety training. The course was broken down into modules, and each EHSC was assigned one module to prepare. S/he reviewed the instructor manual and developed his/her own notes or anecdotes for presentation. Then the program was run again, with each EHSC presenting one section, followed by self-evaluation, group discussion, and feedback from the ergonomist.

When the training program was rolled out by the EHSCs to all existing USRs the training fixture needed to be portable so that sessions could be conducted in multiple locations away from the main company training facility. A portable design was developed, incorporating two ‘fixtures’ mounted to reinforced plywood and a stable base with lockable casters. This was replicated as needed by the EHSC trainers so that sufficient numbers were available to complete the training. These fixtures were transported by the EHSC between locations as needed. These units were relatively heavy and cumbersome, creating some logistical challenges with transportation between training locations, as well as a requirement for assistance to set up the training facility. Regardless, the feedback was that the fixture coupled with the torque wrenches was critical to the success of the program.

5. DISCUSSION

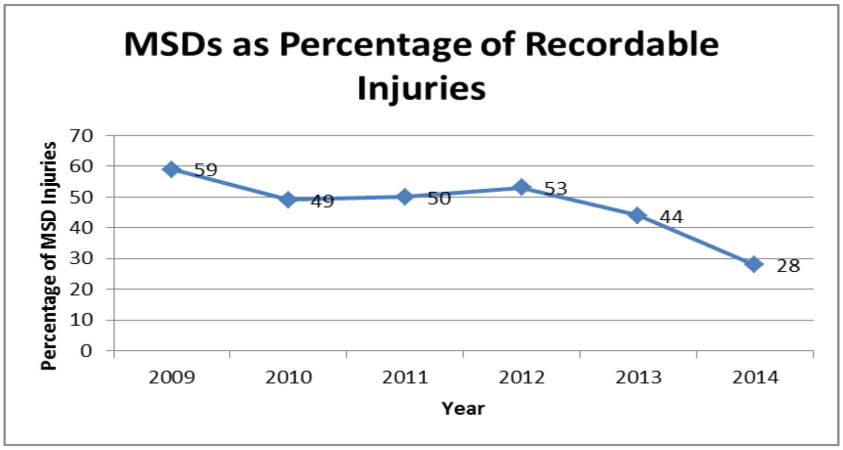
In addition to the discussion during the pilot sessions and train-the-trainer, formal course evaluation forms were also completed following the train-the-trainer. Average scores (on an increasing scale of satisfaction from 1 to 10) were 8.6 out of 10 for course content criteria, 8.9 out of 10 for course materials and 9.1 out of 10 for instruction. The feedback on the use of the training fixture and tools was positive. Opportunities for improvements were identified, and corrections made.

From the preliminary sessions, the feedback from USRs was that it was ideal to work at the techniques in a practical setting, rather than reviewing ergonomic concepts at a computer. Having the “feel” of the tools and the techniques was important to them and provided a better perspective on proper body positioning, leverage, stretching techniques etc.

The initial roll out of the training with all existing USRs was positive. Despite the challenges with transporting and setting up the training fixtures in field locations, over four hundred employees received this training within a short time period. Feedback from employees was positive, with many offering anecdotes and discussing other applications of the effective practices. In particular, the use of the torque wrench to allow direct comparison of perceived exertion between the different techniques was highly effective, as was the use of the torque wrenches to provide tactile and quantitative feedback on how ‘tight’ is tight enough.

As an ongoing requirement, the Practical Ergonomics training is now provided to all USRs during their initial training at the technical training center. It is practical and engages new employees to identify and use effective practices from the beginning.

The company saw a reduction in employee recordable injury frequency in 2014. The Recordable Injury Frequency (# of Recordable injuries X 200,000 hours / Employee hours worked) in 2013 was 2.44, and this dropped to 1.44 in 2014. Overall, sprains, strains, and tear injury types trended downwards in 2014 (28% of all personal injuries) from 2013 (44% of all personal injuries). This translates as a significant reduction in both overall and MSD injuries with the company. It should be noted that other safety and ergonomic related initiatives and controls were implemented during the same time period, so the direct impact of this training initiative cannot be quantified.



The company is in the process of implementing additional engineering and administrative controls for this work, and various options for sustained reinforcement of the identified effective practices are being reviewed.

6. CONCLUSION

The training shared 11 effective practices from research and field observations. These techniques were validated and verified through biomechanical analysis where applicable. The training used combined lecture and practical exercises, using tactile feedback from the customized torque wrenches and ratings of perceived exertion to provide immediate information to the participants regarding the efficacy of the technique. This proved to be an effective knowledge transfer and exchange technique for this group of experienced employees. Application of effective wrenching techniques consistently through the large group of employees is thought to have contributed to sixteen percent decrease in frequency of MSD injuries in the year following implementation of the training.

7. REFERENCES

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