GUIDED BRAINSTORMING

A Method for Solving Ergonomic Issues

By Tony Brace and Jim Nusser

MUSCULOSKELETAL DISORDERS (MSDs) such as sprains and strains, muscle fatigue, ligament strains, disc injuries of the low back and tendon inflammation continue to be a significant problem in industry. These injuries have an adverse impact on business through lost work time, increased absenteeism, increased workers' compensation costs, reduced employee morale, reduced and poorer quality productivity (CDC, 2020; NIOSH, 2014; NRC & IOM, 2001).

Guidance on how to solve musculoskeletal problems in the workplace typically includes developing and implementing programs that comprise issues such as top management support, employee involvement, problem identification, risk quantification and a process to implement controls (Burgess-Limerick, 2018; Chengalur et al., 2004; Lyon et al., 2013; OSHA, 2012). While these elements are crucial to the ergonomics process, little guidance exists for safety practitioners in the problem-solving process and identifying specific solutions (e.g., a product, a new method) to fit within unique business process elements.

With respect to developing countermeasures, the universally held aim is to follow the hierarchy of controls by first engineering the hazards out of the process followed by administrative controls, then by work practice techniques or PPE (Brauer, 2016; Hagan et al., 2015; Haight, 2012). These controls are usually talked about in broader terms or referred to when discussing a specific case study of how someone solved a problem. When it comes to developing solutions or countermeasures to solve for those risk factors, the literature has few methods a practitioner can use or follow to arrive at the best possible solution that could be tested.

KEY TAKEAWAYS

- **After identifying an ergonomic risk, it can be challenging for OSH professionals to generate solutions because little guidance is available on how to arrive at ideas for specific ergonomic solutions.**
- **This article presents a methodology and tool that can be used to generate innovative solutions for ergonomic risks. A structured brainstorming session can improve the quantity and quality of potential ergonomic solutions.**

PAVLO STAVNICHUK/ISTOCK/GETTY IMAGES PLUS

While brainstorming can be effective and is a common approach for generating ergonomic solutions, it can be challenging for OSH professionals and ergonomic team members to generate a wide variety of quality ergonomic solutions during a brainstorm session. Structured methods for solving problems and creating innovative ideas have been proposed, such as the theory of inventive problem solving (TRIZ; Ilevbare, 2013) and SCAMPER (substitute, combine, adapt, modify, put-to-another-use, eliminate and reverse; Howard et al., 2009). Both methods aim to provide novel inspiration to increase the number of potential effective ergonomic solutions when compared to traditional brainstorming methods (Duran-Nova et al., 2019; Kalemba et al., 2017). Alongside traditional brainstorming, TRIZ is more intricate, technical and time consuming, and can be difficult to teach to nonengineers (Howard et al., 2009; Ilevbare et al., 2013; Kalemba et al., 2017; Lin et al., 2017). A downside of SCAMPER is its breadth, as TRIZ focuses the search to areas likely to be productive (Butlewski, 2013).

The EIG Solution

A simplified method to help OSH practitioners quickly develop unique solutions to unique problems is proposed in Figure 1 (p. 37). The authors propose a structured methodology for generating ergonomic solutions and a tool called the ergonomic idea generation (EIG) tool to guide the process that is easy to use and is designed to address specific ergonomic issues.

When discussing industrial hygiene controls, there are three pathways to controlling a hazard: 1. control the contaminant or hazard at the source (e.g., containment, local ventilation); 2. control the hazard along the pathway between the source and the person (e.g., dilution ventilation); and 3. control the hazard at the person (e.g., earplugs, respirators; Anna, 2011). Applying the same thought to control for ergonomic hazards, the authors propose that there are seven different pathways to control a musculoskeletal risk: process, object, workspace, tools, human, movement and exposure time factors (i.e., frequency

and duration). A change in any one or more of these areas can lower musculoskeletal risk factors that lead to injury. A guided brainstorming method using the EIG tool can help OSH practitioners step through a process of brainstorming ways that changes in each of these seven areas could affect the musculoskeletal risk, and the OSH practitioner can quickly generate ideas that could have significant impacts. Use of the EIG tool can be broken down into three key steps: prework, brainstorming and validation.

Step 1: Prework

Prework involves ensuring that the conditions are set up so that the right problem is being solved with the involvement of key stakeholders.

The "Right" Problem

Prior to generating solutions, make sure an ergonomic team has selected the "right" problem. The quantitative tools to evaluate risk can be used to assess multiple tasks throughout an organization. The use of quantitative risk assessment can help ensure that an organization spends limited resources on the tasks with the highest risks as opposed to tasks with vocal workers or managers desiring changes (Rostykus et al., 2016).

The "Right" People

A team approach when addressing complex issues is important because the OSH professional cannot be sufficiently knowledgeable about all the processes in an organization to understand potential barriers to ergonomic solutions (Burgess-Limerick, 2018). Effective ergonomic teams often include line workers, supervisors, maintenance staff and engineers. Having a maintenance staff member on the team can be particularly helpful so they understand the reason behind any work orders submitted, which increases the chance the work will fix the issue.

It is important to have the right stakeholders as part of the team. The authors met with a motor coach manufacturer that modified its chassis design so that wiring harnesses could be installed in a few minutes instead of taking more than an hour. The organization saved hundreds of dollars per coach by having the worker perform other value-added production work while the change also avoided significant force and awkward postures for the worker. Unfortunately, the service staff were not represented when the solution was created and implemented. When a wire harness developed a fault during use, the new solution made it much more difficult for the service staff to access the correct wire in the harness. By making a minor modification in the design of the chassis, the organization could have realized the time savings and risk-reduction benefit in production while also avoiding creating a significant downstream servicing issue. This solution could have been implemented with the original change had someone from the service staff been involved in the team.

Step 2: Brainstorming

Set Ground Rules

After training the team members on ergonomic risk factors and clearly defining which task the organization is working to address, brainstorming can be an effective process for generating ideas for solutions. Effective brainstorming groups strive for several qualities:

- Avoid judging ideas during the idea generation phase.
- Aim for quantity of ideas.
- To encourage staff to generate many ideas, number the ideas.
- Building on or combining ideas is encouraged.
- Use a facilitator to capture ideas visually for group brainstorming. As energy on one train of thought decreases, the facilitator can move to another.
- Assemble a diverse group and encourage participation of all members (Burgess-Limerick, 2018; Lin & Wu, 2016; Ritter & Mostert, 2018).

Prior to brainstorming as a group, it can be beneficial to encourage individuals to brainstorm on their own. Allowing for individual brainstorming prior to group brainstorming allows individuals to explore a "train of thought" without being distracted by group discussion, also called cognitive interference (Ritter & Mostert, 2018). It may also encourage individuals to take additional ownership in solving the problem. Allowing individuals time to brainstorm a problem alone before conducting group brainstorming resulted in more useful ideas than either just individual brainstorming or only group brainstorming (Ritter & Mostert, 2018).

In both individual brainstorming and group brainstorming, the proposed methodology can help participants create new solutions by forcing the consideration of various valid approaches for solving ergonomic issues. In the authors' experience, groups using the traditional, unstructured brainstorming approach often spend too much time focusing on the human (e.g., considering training options and technique) and the tools (e.g., PPE). The use of a traditional, unstructured brainstorming session frequently does not spend enough time considering how the overall process can be changed or how the workstation could be modified.

Guided Brainstorming Method

The authors encourage OSH practitioners and ergonomic team members to use the EIG tool presented in Figure 1. The tool is structured around the seven control pathways noted: Process, object, workspace, tools, human, movement and exposure time factors (i.e., frequency and duration). The tool provides focus areas that can be considered for modification for each control pathway and describes how the modification might be made. For example, an ergonomics team can consider changing the process to reduce the risk. The team can evaluate whether changing the order of steps would impact the risk and whether changing the upstream process could positively impact the job being assessed.

Consider the following example in which changing the order of steps was beneficial. In the manufacture of refrigerators, instead of assembling part of the ice maker inside of the unit (a location that required an awkward worker posture), one author and the ergonomics team had the workers first build the ice maker on a workbench, then install the completed unit.

As an example of changing the upstream process, the authors worked with an ergonomics team to successfully address an issue around assembling wooden chairs. At the time of the assessment, the firm had employees using rubber mallets to strike the chair frame to get the chair to fit together securely without gaps. In evaluating the process, it was discovered that the tool being used to drill the holes in the chair rail was slightly out of tolerance. When the size of the drilled hole was increased to the proper dimension, the chair went together without the use of a mallet, which saved time and eliminated a forceful exertion.

Team members need not discuss every aspect in each section of the EIG tool, but considering each of the seven cat-

FIGURE 1

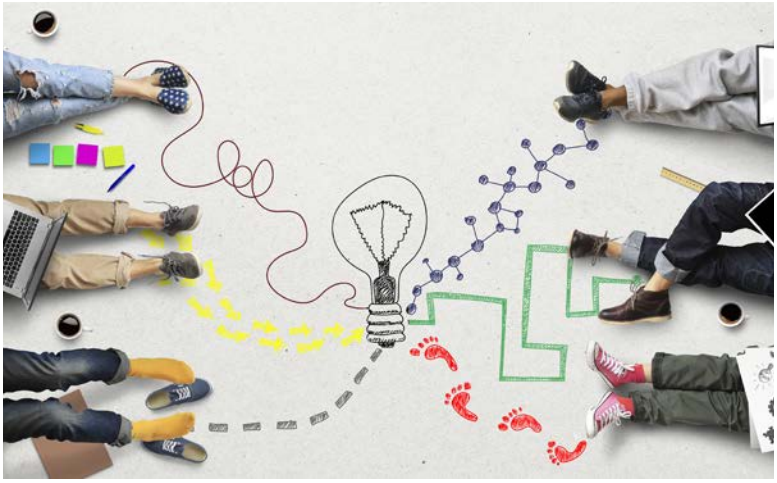
ERGONOMIC IDEA GENERATION TOOL

A change in any one or more of the seven areas outlined below can lower musculoskeletal risk factors that lead to injury. After identifying a job's risk factors for musculoskeletal disorders, use the tool as a brainstorming guide to rethinking the task.

Concept	Task	Improvement
Process	Change the order of steps	Instead of building from A+B+C+D+E+F, consider building C+D+E+F first, then adding this to A+B. For example, consider building a preassembly that attaches to the final assembly rather than building everything in the final assembly.
	Change the upstream process	Consider changing a preceding step to eliminate or reduce risks in a downstream task.
	Eliminate or remove wasted steps	Consider eliminating steps in the process if they do not add value. For example, if an item is picked up and moved twice, consider whether the process can be changed so it is only moved once.
	Substitute	Consider substituting a different material in the process to reduce risk. For example, lightweight plastic may be used in place of metal.
	Move substeps to another part of the process	Consider changing who performs specific substeps. For example, in a production line, consider moving a step to the upstream or downstream task.
	Job rotation	Consider job rotation so tasks with a similar risk factor are not done back-to-back.
Object	Improve coupling	Consider adding handles for moving or holding items. Consider placing amorphous-shaped items in a container with handles. Consider changing to a power grip instead of a pinch grip.
	Increase weight	Consider increasing object weight so it is too heavy for manual lifting, so staff will need to use manual material equipment.
	Reduce weight	Consider reducing the weight of the object, such as purchasing raw materials in a smaller container.
	Secure object	Consider securing the object to reduce the force a worker needs to apply to hold it in place, such as with a clamp or jig.
	Reposition closer	Consider moving the item closer to the worker.
	Balancer	Consider a tool balancer, pneumatic balancer or zero-G system for reducing force.
Workspace	Shorten reach distance	Consider ideas to bring the work or stored parts closer to the worker.
	Lower or raise workstation surface	Consider raising or lowering workstation so the upper arms are neutral with elbows at the side when the work is performed.
	Eliminate twists	Consider modifying the space so the person does not need to reach to the side or turn to the back, such as when accessing tools or materials.
	Improve headroom	Evaluate whether crouching or kneeling can be eliminated. Consider whether headroom can be improved.
	Store on carts	Consider storing items on carts if objects need to move.
	Racking placement	Consider storing heavy items in a middle shelf, lighter items on the bottom and lightest on the top. Consider placing frequently used items in the middle.
Tools	Low-vibration power tool	Consider switching to a low-vibration tool.
	Change orientation of handles	Consider whether a pistol-grip tool or an in-line tool would allow a more neutral wrist and elbow posture. Consider extending or lengthening the handles on the tool.
	Power tool vs. hand tool	Consider switching to a power tool. In some cases, consider switching from a power tool to a hand tool.
	Automate or semi-automate	Evaluate whether an automated machine or semiautomated machine can help.
	Preventive maintenance	Establish a preventive maintenance program or evaluate current program for adequacy. Some tools require considerably more force when the cutting edge is dull and other tools generate more vibration.
	PPE	Antivibration gloves, antivibration coatings, knee pads
Human	Isolate the employee	Consider isolating the employee from the hazard, such as a dampening seat to reduce whole body vibration, or an exoskeleton for reducing force.
	Team lift or handle	Consider whether a two-person lift is feasible and would reduce risk.
	Techniques	Consider whether there is a better technique to perform the job, such as improved body mechanics. For example, sometimes a small group of workers has discovered an easier way to perform a task.
	Training	Consider training options (Note: This should never be the first choice in any solution decision).
Movement	Vertical lift and lower	Consider a hoist or fixture to lift or lower (Note: Ensure that one lift fixture can do 100 jobs rather than 100 jobs each with one fixture). Consider a vacuum system.
	Lateral hoist placement	Use a hoist that can make a lateral placement.
	Raise object from bottom	Use scissor lifts to raise objects up where they can be slid to another surface or worked on, mounted from underneath (e.g., transmission jack).
	Motorized vs. manual movement	Consider using a motorized way of transporting material, such as a cart tugger instead of manually pushing a cart.
	Slide vs. lift	Consider whether an object can slide instead of being lifted. Use a low coefficient of friction material (Note: Workers can push or pull more weight than they can lift).
	Cart design	Consider using large caster wheels and carts with vertical handholds.
	Push vs. pull	Pushing is generally better than pulling.
	Change applied force from horizontal to vertical	It is easier for workers to apply force in a horizontal direction than a vertical.
	Change applied force from lateral to forward horizontal	It is more difficult to reach across the body when applying force than fore/aft movement.
	Change applied force from axial to rotational	Consider changing the direction of force from a straight line to rotational. For example, in some cases using torque and a lever arm will make a task easier.
Time, duration, frequency	Shorten the duration of the risk factor	Consider changes that would allow the task to be completed quicker. It may reduce time spent applying force or in awkward postures.
	Shorten the frequency of the risk factor	Consider reducing the frequency of the task. For example, instead of something happening once every 3 minutes, is there a way to change it so it occurs once every 5 or 10 minutes instead?

Note. Adapted from "Brainstorming Solutions for Ergonomic Issues," by SAIF, 2020. Used with permission. The original can be downloaded at https://bit.ly/3cizg93.

Using a structured guided brainstorming approach to ergonomic solution generation can yield more ideas and a wider range of options regarding where and how to implement controls, allowing organizations to solve ergonomic issues more effectively.



egory areas will likely yield better solutions. Asking "what" and "how" questions can be helpful. For example, instead of asking "can we change the order of steps?" which could be answered with a "yes" or a "no," the authors encourage the ergonomics team to ask, "what might it look like if we were to change the order of steps?" and "how could building a subassembly and attaching it to a final assembly reduce the risk?" Encourage participants to build on ideas.

The first time the tool is used with an ergonomics team, ensure that participants can visualize a concrete example for each individual item listed in the seven categories. As a group, this can be accomplished by starting at the top (i.e., process: change the order of steps) and asking the group to share an example, then continuing until the last item (i.e., time, duration and frequency: Shorten the duration of the task) has been discussed. With more experienced teams and a business culture in which asking questions is encouraged, it may be quicker to ask participants to review the form and identify items on the list for which they cannot think of a practical example.

Step 3: Validation

As with traditional brainstorming, the authors recommend that participants avoid evaluating ideas during the structured brainstorming until the process is complete. Judging ideas prematurely can reduce creativity and discourage participants from generating more ideas (Lin & Wu, 2016).

Hierarchy of Controls

Not all types of solutions have the potential to yield the most effective result. Whenever possible, engineering solutions should be selected that eliminate the risk (Lyon et al., 2013). While many of the questions in Figure 1 (p. 37) will point to engineering controls or controls that will eliminate the hazard, the tool includes questions that may yield administrative and PPE controls, which are less effective. In some cases, it may not be feasible to design out the problem, and administrative or PPE interventions can yield some risk reduction to staff. In other cases, administrative controls and PPE may serve as interim solutions in the event that significant time is required to implement a more effective control, possibly because the desired engineering solution will take time to design, manufacture and install. In evaluating the generated ideas, staff will often need to conduct cost-benefit analyses and return-on-investment calculations to select the most feasible and effective option as well as to convince decision-makers (Lyon et al., 2013).

Occasionally, ergonomic teams will create an innovative solution that fails to address the primary risk factors with the original task. When possible, reassess the task while considering the proposed changes using quantitative risk assessment tools prior to the implementation of the solution. This is especially important when the cost of implementing the solution is high in time, money or both. It is also beneficial to reevaluate the job after the solution is implemented to verify that the exposure to the MSD risk was reduced to an acceptable level (Rostykus et al., 2016).

Mock-Up Ideas

While the aforementioned methods can generate excellent ideas, the authors have observed that complex solutions occasionally fail to be implemented as initially designed. When feasible, creating a mock-up of the solution can save time and money, and yield a more refined idea. Cardboard, PVC pipe and duct tape can be used to create mock-ups of modified workstations. In a semiconductor plant, the width of a new tool designed to allow staff to work on a wafer was changed from the original design after creating a cardboard version and noting the difficulty in moving the height-adjustable cart into the space to position the part. In creating a new method for cutting bagels, a cardboard mock-up helped staff recognize that the tool as initially designed lacked effective handholds. In both cases, the cardboard mock-up saved money and resulted in a better final solution.

Application

The authors believe it is not always necessary to spend the time and resources conducting group brainstorming sessions when solving ergonomic issues. A safety professional may effectively implement a solution without group brainstorming when the solution is easily identifiable, low cost and readily available "off the shelf." For example, using a scissor lift cart or height-adjustable pallet turntable to reduce repetitive bending in a pallet loading task is a well-used industry solution that is low cost. In addition, group brainstorming is less beneficial when there are specific ergonomic design specifications and guidelines. One author once had a conveyor on a manufacturing line lowered by 8 in. to better comply with good ergonomic guidelines.

The use of the group brainstorming process is most helpful with complex issues, especially when a solution may impact downstream processes or require significant capital investment

DORIAN2013/ISTOCK/GETTY IMAGES PLUS

to implement. The authors believe utilizing a group brainstorm process that involves key stakeholder representatives can improve employee buy-in and decrease the chance that a solution will create unforeseen new problems.

Case Study

To demonstrate how the tool works, consider the following example of an assessment of a wooden panel assembly process. The process required employees to lift a 20-lb, 24 x 24 in. wooden panel onto a worktable, then insert a thin wooden strip on the four edges of the panel. The employees would grab a length of the wooden strip, apply some glue along the seam of the panel, then gently tap the wooden strip into a groove in the side of the panel. The work surface was high enough that all employees were working with their arms lifted above their shoulders for more than 60% of the cycle time through an 8-hour shift.

The authors began working through the EIG tool and asking questions about the different factors that could potentially be changed. Working through the seven categories on the EIG tool and asking questions about how or what things would look like if any of the parameters in the seven categories were changed, three of the seven categories yielded viable solution ideas.

- Process: Changing the order of steps or changing the upstream process were not feasible. It was determined that it would not be possible to add the wooden strips to the panel earlier in the process or at a different part of the sequence. Job rotation was discussed as a possible solution.
- Workspace: When considering the workstation height, exploring options to raise or lower the workspace led to a simple idea of modifying the workstation by adding small, padded J-hooks attached to the table legs about 2-ft lower than the workstation height at 24 in. from the ground. This concept would allow employees to place the edge of the panel on the two hooks at the lower height, which would lower the panel and allow the work to be done with the shoulders at an optimal height. Building on the idea further, it was determined that the J-hooks could have some level of inexpensive adjustability by drilling holes at regular 0.5-in. intervals going up the table legs that would allow users to modify the optimal height for their shift at their workstation.
- Tools: When evaluating the tooling aspect, rather than use a small hammer to tap the strips in, a pneumatic palm hammer was suggested that would provide better arm position and reduce the arm repetition of using a hammer.

Conclusion

Using a structured guided brainstorming approach to ergonomic solution generation can yield more ideas and a wider range of options regarding where and how to implement controls, allowing organizations to solve ergonomic issues more effectively. This can yield cost-effective changes that enhance operator performance, decrease risk of injuries, promote a healthy workforce and increase employee morale. **PSJ**

References

Anna, D.H. (2011). *The occupational environment: Its evaluation, control and management*. American Industrial Hygiene Association.

Brauer, R.L. (2016). *Safety and health for engineers* (3rd ed.). Wiley.

Burgess-Limerick, R. (2018). Participatory ergonomics: Evidence and implementation lessons. *Applied Ergonomics, 68*, 289-293. https://doi.org/10.1016/j.apergo.2017.12.009

Butlewski, M. (2013). Heuristic methods aiding ergonomic design. In C. Stephanidis & M. Antona (Eds.), *Universal access in human-computer interaction. Design methods, tools and interaction techniques for inclusion* (pp. 13-20). Springer. https://doi.org/10.1007/978-3-642-39188-0_2

CDC. (2020). Work-related musculoskeletal disorders and ergonomics. www.cdc.gov/workplacehealthpromotion/health-strategies/musculoskeletal-disorders/index.html

Chengalur, S.N., Rodgers, S.H. & Bernard, T.E. (Eds.). (2004). *Kodak's ergonomic design for people at work*. Wiley.

Duran-Novoa, R., Lozoya-Santos, J., Ramírez-Mendoza, R., Torres-Benoni, F. & Vargas-Martínez, A. (2019). Influence of the method used in the generation of valid engineering concepts. *International Journal on Interactive Design and Manufacturing, 13*(3), 1073-1088. https://doi.org/10.1007/s12008-019-00577-4

Hagan, P.E., Montgomery, J.F. & O'Reilly, J.T. (Eds.). (2015). *Accident prevention manual for business and industry: Engineering and technology*. National Safety Council.

Haight, J.M. (2012). *The safety professionals handbook: Technical applications*. ASSP.

Howard, T.J., Culley, S.J. & Dekoninck, E.A. (2009). Stimulating creativity: A more practical alternative to TRIZ. In M. Norell Bergendahl, M. Grimheden, L. Leifer, P. Skogstad & U. Lindemann (Eds.), *DS 58-5: Proceedings of ICED 09, the 17th International Conference on Engineering Design: Vol. 5. Design Methods and Tools (pt. 1), Palo Alto, CA, USA, 24.-27.08.2009* (pp. 205-216).

Ilevbare, I.M., Probert, D. & Phaal, R. (2013). A review of TRIZ, and its benefits and challenges in practice. *Technovation, 33*(2-3), 30-37.

Kalemba, A., Dewicka, A. & Zywert, A. (2017). The application of TRIZ and SCAMPER as innovative solutions methods to ergonomic problem solving. In P.M. Arezes, J.S. Baptista, M.P. Barroso, P. Carniero, P. Cordeiro, N. Costa, R.B. Melo, A.S. Miguel & G. Perestrelo (Eds.), *Occupational Safety and Hygiene V: Selected papers from the International Symposium on Occupational Safety and Hygiene (SHO 2017), April 10-11, 2017, Guimarães, Portugal* (p. 473). CRC Press.

Lin, S.Y. & Wu, C.T. (2016). Application of TRIZ inventive principles to innovate recycling machine. *Advances in Mechanical Engineering, 8*(5). https://doi.org/10.1177/1687814016647303

Lin, Y.J., Hsieh, W.L. & Pai, T.Y. (2017). The combination of SCAMPER and TRIZ for a more effective idea-generation method. *International Journal of Kansei Information, 8*(1), 19-27.

Lyon, B.K., Popov, G. & Hanes, K. (2013, Dec.). Improving ergo IQ: A practical risk assessment model. *Professional Safety, 58*(12), 26-34.

National Research Council (NRC) & Institute of Medicine (IOM). (2001). *Musculoskeletal disorders and the workplace: Low back and upper extremities*. National Academy Press. www.nap.edu/read/10032/chapter/1

NIOSH. (2014). Worker health chartbook 2004 (Publication No. 2004-146). www.cdc.gov/niosh/docs/2004-146/default.html

OSHA. (2012). Solutions for the prevention of musculoskeletal injuries in foundries (Publication No. 3465-08 2012). www.osha.gov/sites/default/files/publications/osha3465.pdf

Ritter, S.M. & Mostert, N.M. (2018). How to facilitate a brainstorming session: The effect of idea generation techniques and of group brainstorm after individual brainstorm. *Creative Industries Journal, 11*(3), 263-277. https://doi.org/10.1080/17510694.2018.1523662

Rostykus, W.G., Ip, W. & Dustin, J.A. (2016, Dec.). Managing ergonomics: Applying ISO 45001 as a model. *Professional Safety, 61*(12), 34-42.

SAIF Corp. (2020). Brainstorming solutions for ergonomic issues. https://bit.ly/3cizg93

Tony Brace, M.S., CPE, CIH, is an ergonomist for SAIF Corp., a Eugene, OR-based workers' compensation company. Prior to this, he worked as an ergonomist for 15 years in the semiconductor, aerospace and manufacturing industries. He holds an M.S. in Environmental Health and Safety from Oregon State University.

Jim Nusser, M.S., CSP, is a senior safety management consultant at SAIF Corp. He has more than 15 years' experience consulting on ergonomics and occupational safety. Nusser holds an M.S in Environmental Health and Safety Management from Oregon State University and a B.A. from University of Oregon. He is a professional member and Vice President of ASSP's Cascade Chapter.