PREVENTION THRO

Integrating Human Factors Prevention Through Design

By Bruce K. Lyon and Georgi Popov

THE MESSAGE IS LOUD AND CLEAR—one of the greatest opportunities for occupational risk and safety professionals is the application of prevention through ergonomics (PTE). Ergonomic-related risks abound in all types of work environments and account for a large portion of workplace incidents and their costs in almost all industries. According to studies and reports from Liberty Mutual (2019) and Bureau of Labor Statistics (BLS, 2020), soft-tissue disorders known as work-related musculoskeletal disorders account for 33% of all disabling occupational injuries and more than 40% of total workers' compensation costs. In addition to the injury and illness costs, workplace systems (e.g., facilities, premises, tools, equipment, machinery, products, processes, methods) that lack fundamental ergonomics and human factors principles often lead to lower productivity and efficiency, lower quality of products and services, lower employee morale, higher employee turnover and overall higher costs to the organization. And in addition to increased work-related musculoskeletal disorders, systems with poor ergonomics and human factors can create error-prone or error-causing situations. These facts seem to beg the question, why aren't ergonomics and human factors part of the design specifications, procurement and assessment process?

KEY TAKEAWAYS

- **Ergonomic-related risks exist in most workplaces and can negatively affect safety and health, quality, efficiency and overall operational success.**
- **While ANSI/ASSP Z590.3-2021, the prevention through design (PTD) standard, includes ergonomics and human factors engineering concepts, these considerations are sometimes overlooked by organizations and designers. The lack of ergonomic principles in workplace design can lead to inherently flawed systems that are costly to retrofit and correct.**
- **The greatest opportunity to avoid, eliminate and reduce ergonomic-related risks is by incorporating ergonomics and human factors engineering in the design and redesign of processes, equipment, facilities, tools and work methods.**
- **OSH professionals have an opportunity to help integrate prevention through ergonomics into the PTD process.**

Prevention Through Design

Prevention through design (PTD) is the concept of designing in safety up front and managing risks throughout a system's life cycle. PTD is a relatively new concept that is still evolving. It began in 1994 with a position paper issued by the then ASSE and approved by its board of directors promoting "designing for safety" concepts. In the late 1990s, the National Safety Council's Advisory Committee of the Institute for Safety Through Design concluded that significant benefits would be derived if decisions affecting safety, health and the environment are integrated into the early stages of the design and redesign processes.

These developments led to further interest by NIOSH, which in 2007 held a workshop to gather views from stakeholders on an initiative to "create a sustainable national strategy for PTD." The NIOSH initiative was based on its stated premise: "One of the best ways to prevent and control occupational injuries, illnesses and fatalities is to design out and minimize hazards and risks early in the design process" (NIOSH, 2013). Comments from the workshop sparked a need for a guideline, regulation or standard that established PTD principles and methodologies, which led to the 2009 development of the technical report, ASSE TR-Z790.001, Prevention Through Design Guidelines for Addressing Occupational Risks in Design and Redesign Processes.

Soon after, work began on a standard with Fred Manuele as chair. In 2011, a new standard, ANSI/ASSE Z590.3, Prevention Through Design: Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes, was published. The standard was reaffirmed in 2016. In 2021, the ANSI/ASSP Z590.3-2021 standard was revised to include, among other things, important concepts regarding ergonomics and human factors engineering.

One of the primary themes of the PTD concept is managing risk throughout a system's life cycle (Figure 1). It can be applied to any occupational setting and any mode of activity throughout a system's life cycle. As described in ANSI/ASSP Z590.3, the life cycle has three primary stages:

1. The preoperational stage: the design stage where the opportunities are greatest, and the costs are lowest for avoiding and reducing risk
2. the operational stage: the intended use of the system, which includes maintenance, repair and upset activities where risks are assessed and treated before incidents occur, as well as after incidents to determine causal factors, and risk treatments to achieve acceptable risk levels
3. the post-operational stage: the system's end of service phase where risks are assessed and treated.

The 2021 revision of ANSI/ASSP Z590.3 was developed to provide updated guidance in the consistent practice of identifying, assessing, and treating occupational hazards and risks in the design and redesign processes, and throughout a system's

GORODENKOFF/ISTOCK/GETTY IMAGES PLUS

UGH ERGONOMICS

s Into a

n Approach

life cycle. The revision aligns with key risk-based standards, allowing integration of a PTD process into an organization's risk management process. It is also aligned with management system standards, allowing the user to integrate PTD into an organization's safety management system.

Some of the key revisions include a PTD risk assessment and management process, updated guidance on stakeholder roles, design safety reviews, establishing safety specifications, and management of change, the new hierarchy of risk treatments model, and additional methods and addendums including guidance in ergonomics and human factors.

Ergonomics & Human Factors

According to the Human Factors and Ergonomics Society (HFES, n.d.a) and International Ergonomics Association:

> Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession applies theory, principles, data, and other methods to design in order to optimize human wellbeing and overall system performance.

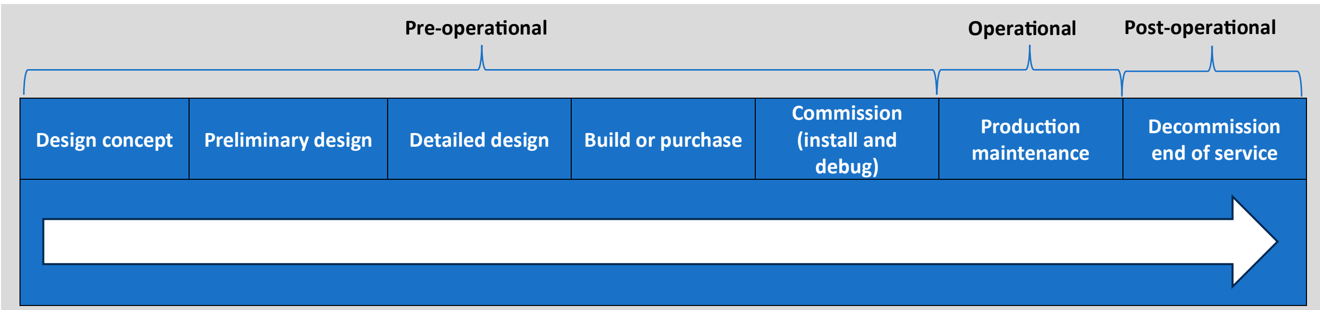
Notice the use of the word "design" in the definition. From an occupational standpoint, the following simplified definition is offered: "Ergonomics is the applied science of designing workplace demands and environment to accommodate human capabilities and limitation for well-being and optimum performance" (Lyon & Popov, 2022).

"Human factors," a term that is often used interchangeably with the term "ergonomics," is defined by Chapanis (1991) as a body of knowledge about human abilities, human limitations and other human characteristics that are relevant to design. Human factors are physical or cognitive properties specific to humans that may influence the functioning of mechanical and technological systems (Chapanis, 1991; HFES, n.d.a).

Chapanis, a psychologist, was instrumental in improving aviation safety during the World War II era with the shape coding of aircraft cockpit controls and displays, making them easier to correctly identify and distinguish. In the 1940s, after a series of runway accidents involving Boeing B-17 bombers, the U.S. Army Air Corps of Engineers commissioned Chapanis to undertake an investigation. By studying the crashes, Chapanis found that certain cockpit controls such as the switches for the flaps and the landing gear were identical and placed side by side, creating an error-prone situation with severe consequences (Syed, 2015).

Workplace systems with poorly designed human factors can lead to human error. Human error can be described as an incorrect or undesirable decision, action or inaction that reduces effectiveness, safety or performance (Sanders & McCormick, 1993). Rather than a cause, human error is a symptom and outcome of a deeper root problem in the system's design—a design flaw that leads one to commit an error. Embedded

FIGURE 1
EXAMPLE LIFE CYCLE PHASES OF A SYSTEM



Note. Adapted from ANSI/ASSP Z590.3-2021, Prevention Through Design: Guidelines for Addressing Occupational Hazards in Risks in Design and Redesign Processes, 2021.

error-causing factors or precursors such as overly complex systems, multiple steps, illogical workflows, poor instructions, unclear documentation, signage or procedures, inconsistent processes, inadequate or inconsistent communication, and poor lighting quality can be considered as design flaws in a system.

Errors can lead to unintended outcomes. According to Hollnagel (1993), actions by human operators can fail to achieve their goal in two ways: The actions can go as planned, but the plan can be inadequate, or the plan can be satisfactory, but the performance can still be deficient. Human error types might include failing to perform or omitting a task, performing the task incorrectly, performing an extra task or one that is not required, performing tasks out of sequence, failing to perform the task within the time limit associated with it, or failing to respond adequately to a contingency.

Rasmussen (1986) classifies human errors into two categories: 1. execution failure, and 2. planning failure (Figure 2). Execution errors correspond to the skill-based level of Rasmussen's levels of performance, while planning errors correspond to the rule- and knowledge-based levels. Execution failures or errors can occur as slips or lapses and involve a person intending to carry out an action that is appropriate, but it is carried out incorrectly. Execution errors result from failures in the execution or storage stage of an action sequence. Slips relate to observable actions and are commonly associated with failures in attention or perception. Lapses are more internal events and generally involve failures of memory. The second category, planning failures or mistakes, are either rule-based mistakes or knowledge-based mistakes. Such errors or mistakes involve a person intending to carry out an action and doing so correctly, but the action is inappropriate. According to Reason (1990), "Mistakes may be defined as deficiencies or failures in the judgmental and/or inferential processes involved in the selection of an objective or in the specification of the means to achieve it."

For PTD efforts to be fully effective, there is a significant need to understand and address workplace designs from an ergonomics and human factors standpoint. Almost all jobs have some aspect of ergonomics and human factors: in the workplace systems, methods, tools and equipment, and overall environment.

Human factors engineering is the integration of human factors principles into the design of tools, machines, systems, tasks, jobs and environments for safe, comfortable and effective human use. This involves an examination of a particular activity in terms of its component tasks, and then assessing the physical and skill demands, mental workload, team dynamics, aspects of the work environment (e.g., adequate lighting, limited noise, other distractions), and device design required to complete the task optimally. In essence, human factors engineering focuses on how systems work in actual practice, with real, fallible human beings at the controls, and attempts to design systems that optimize safety and minimize the risk of error in complex environments (AHRQ, 2019).

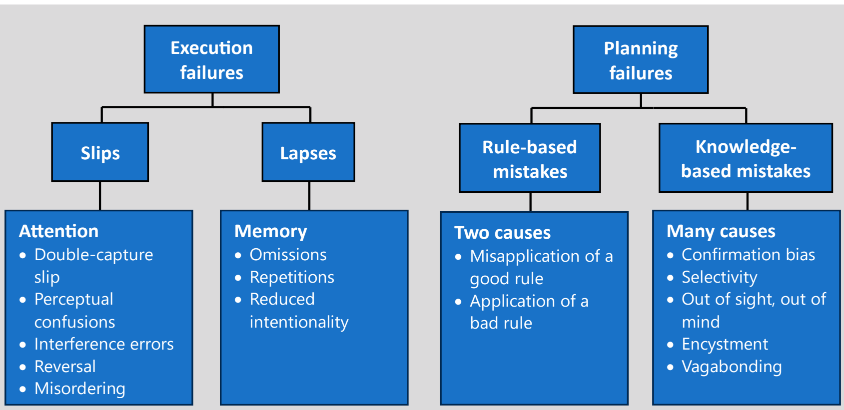
Patterns of interactions between workplace system elements (e.g., humans, tools, machinery, software, materials, procedures, environment) characterize human work. Such work is generally performed to achieve a purpose within system elements, conditions and environment over a given period. Most interactions are intentional and inconsequential; however, some things do not always go as planned or intended. Error-provocative situations such as confusing and incompatible interfaces, labels or controls that are difficult to read or distinguish, unserviceable equipment, missing tools and equipment, time pressure, inadequate staffing, prolonged work leading to fatigue and stress, varying levels of competence, or different cultures can lead to problems (Shorrock, 2016).

The Concept of Prevention Through Ergonomics (PTE)

With the revisions made in the ANSI/ASSP Z590.3-2021 standard, guidance was incorporated regarding ergonomics and human factors including an addendum due to the degree of ergonomics risk factors in most workplaces. The committee saw a need for further investigation into developing guidelines for integrating ergonomics and human factors into the design process and throughout the life cycle of a system. This led the authors to develop the PTE concept. The authors describe PTE as the integration of ergonomics and human factors principles into the design and management of workplace systems. This concept must be part of PTD, rather than an add-on; it must be integrated into the design process. The current ANSI PTD standard outlines the following elements, each of which should include aspects of ergonomics in the design process:

- responsibilities and accountabilities,
- specifications for design and procurement,
- design/redesign process,
- design reviews,
- management of change,
- hierarchy of risk treatment, and
- assessment tools.

FIGURE 2
EXECUTION & PLANNING FAILURES



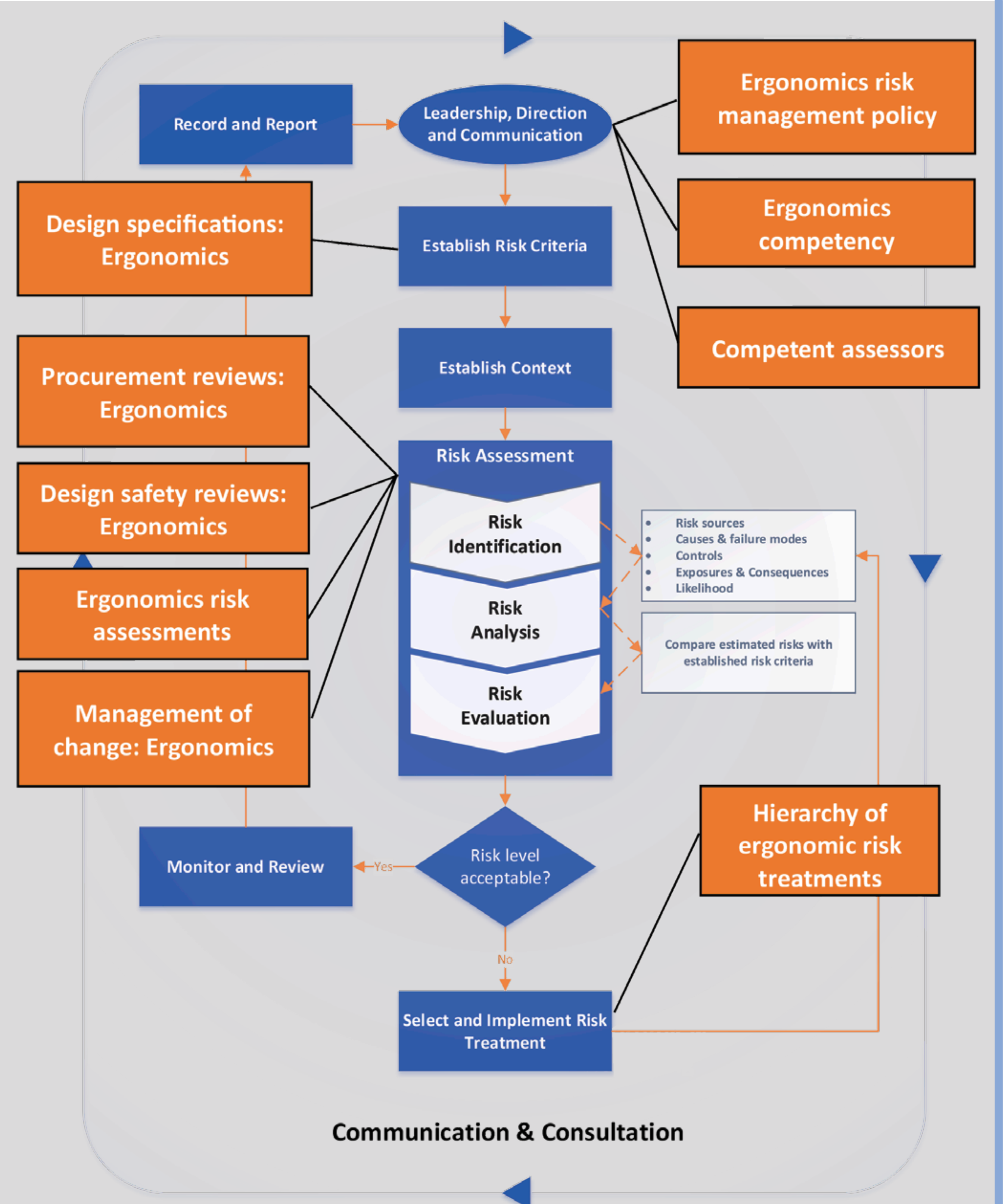
Note. Adapted from *Information Processing and Human-Machine Interaction: An Approach to Cognitive Engineering*, by J. Rasmussen, 1986, Wiley.

The PTE Risk Management Process

Management commitment and PTE champions must be in place. Before all else, to integrate ergonomics into a design and redesign process, an understanding and commitment by decision-makers is needed. This recognition should entail an understanding of an organization's risks and its own acceptable risk level in the context of its overall culture and objectives. Tying the PTE objectives to the overall objectives and how they benefit the organization should be well understood and communicated. There must be a concerted effort in applying PTD as well

FIGURE 3

PREVENTION THROUGH ERGONOMICS RISK MANAGEMENT PROCESS

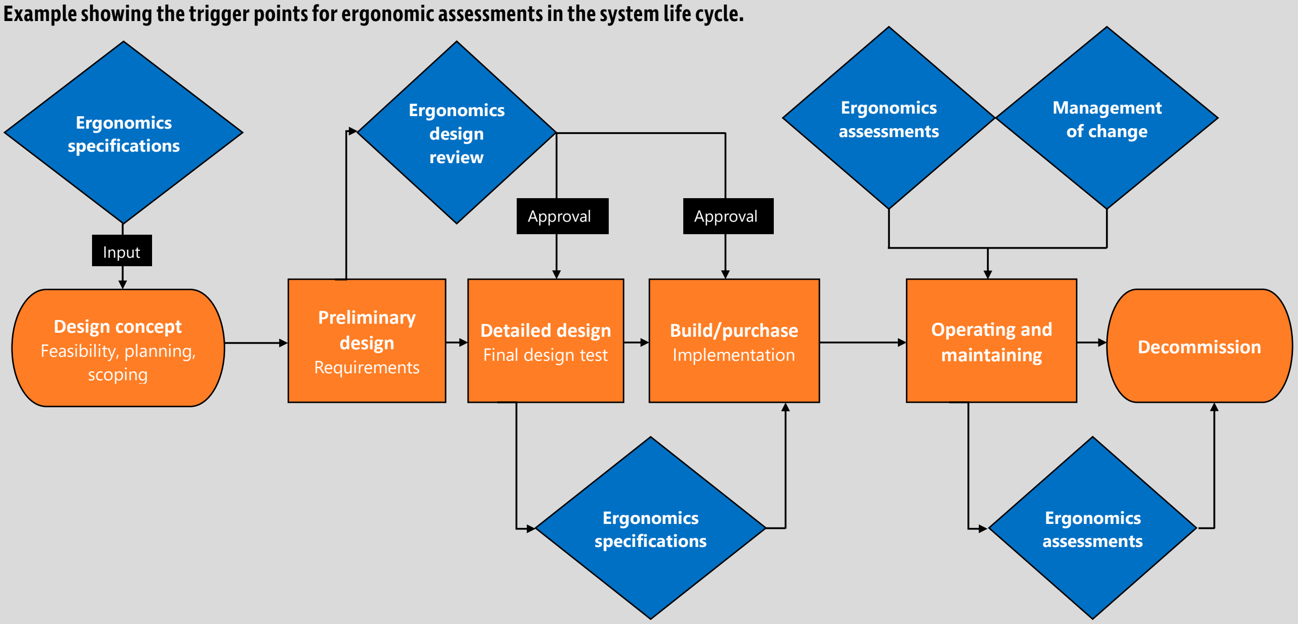


Note. From "Prevention Through Ergonomics (PTE): Incorporating PTE into PTD," by B.K. Lyon and G. Popov, ASSP Professional Development Conference, June 27-29, 2022.

FIGURE 4

EXAMPLE TRIGGER POINTS FOR ERGONOMIC ASSESSMENTS

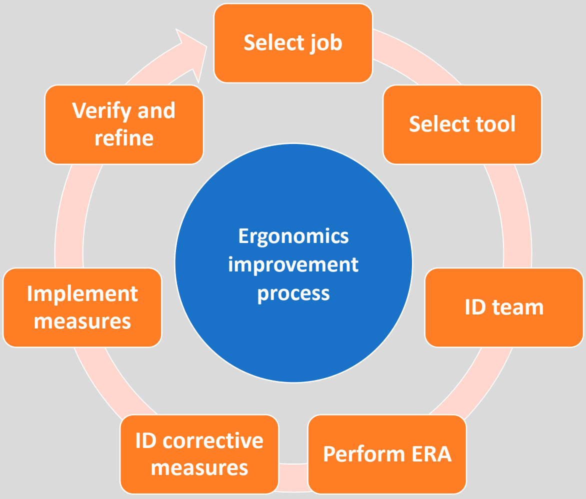
Example showing the trigger points for ergonomic assessments in the system life cycle.



Note. From "Prevention Through Ergonomics (PTE): Incorporating PTE into PTD," by B.K. Lyon and G. Popov, ASSP Professional Development Conference, June 27-29, 2022.

FIGURE 5

ERGONOMICS IMPROVEMENT PROCESS



Note. From "Prevention Through Ergonomics (PTE): Incorporating PTE into PTD," by B.K. Lyon and G. Popov, ASSP Professional Development Conference, June 27-29, 2022.

as PTE in the organization, involving all stakeholders, which requires an understanding of the reasons for and benefits to doing so (Figure 3, p. 27).

Reducing risks that are attributed to embedded ergonomics-related risks in workplace systems and the resulting benefits will likely lead to several benefits to the organization and society in general. Some of these may include improvements in production, service and quality, optimizing human performance and well-being, financial benefits, costs savings in workplace injuries and illnesses as well as insurance, a reduction in fatality and serious incident risks, increased opportunities for organizational expansion, reduced strategic and legal risk, and increased resilience and sustainability. A cost-benefit analysis approach can be useful in supporting these initiatives. Occupational risk and safety professionals are well positioned to serve as champions of this effort.

Ergonomics Management Policy

Management should develop policies for integrating ergonomics into the design process along with safety, health and environmental elements. The policy should have a stated commitment to integrating ergonomics into the workplace and be a guiding force for PTE efforts within the organization. Such policies should include the organization's goals and objectives that are specific, measurable, attainable, relevant and time based, otherwise known as SMART goals. They should include specific budgets and resources dedicated to PTE efforts, and defined stakeholder roles, responsibilities and accountabilities. As with any policy, it should be well communicated and periodically reviewed and updated.

Competency in Ergonomics Policy

For a PTE initiative to be effective requires the involvement of competent stakeholders knowledgeable in its mission and application. Management must commit to obtaining and maintaining competent and knowledgeable stakeholders in ergonomics, either internally or with third-party consultants. An ergonomics training process should be considered to provide stakeholders with the necessary understanding of ergonomic principles and risk factors, design guidelines and ergonomic risk assessment methods. In particular, designers and engineers should understand ergonomic design principles, and risk assessors should be competent in this area and in the use of ergonomic risk assessment methods.

Design & Procurement Specifications

Ergonomics-related design specification minimums should be established for an organization's workplace system designs and redesigns. Such specification must consider the performance objectives needed and the workforce capacities, optimal abilities and limitations including anthropometric percentiles for user populations. In addition, ergonomics-related specifications should be established for procurement selection of all equipment, furniture, tools, materials and other supplies. To supplement, a procurement review process should be in place that not only includes safety, health and environmental elements, but also ergonomics and human factors.

Design and procurement specifications should include anthropometric data for the user population. Anthropometrics are the physical measures of a person's size, form and functional capacities that are measured in percentiles. This includes body segment measurements such as standing height, seated height, reach, foot measurement and hand size. A common design problem when using anthropometric data to specify product dimensions is to estimate what percentage of users a given combination of dimensions will accommodate.

For example, when selecting a chair for a workplace, the overall population must be considered. What percentage of the user population will a chair seat fit if it is 15 in. wide, 12 in. deep, and adjusts in height between 15 and 22 in.? A multivariate analysis is required to provide an answer. An anthropometric spreadsheet from HFES called the Virtual Fit Tool can be used by designers to determine what percentage of North American users will be accommodated by a given set of measurements (HFES, n.d.b).

Other examples of available data and tools are myAnthro (a source for the National Health and Nutrition Evaluation Survey and Anthropometric Survey of U.S. Army Personnel data), and PeopleSize, which generates anthropometric estimates for different target user populations. (Information on these can be found at **https://bit.ly/3WzbhJy**.)

Design Reviews & Procurement

Using established ergonomics specifications, new designs should be reviewed and evaluated to ensure that ergonomics and human factors are accounted for in new workplace systems as well as redesigned systems. Design reviews should consider the performance objectives needed and the workforce capacities, optimal abilities and limitations. This includes all stages of the system's life cycle such as installation or construction, operation, maintenance and service, upsets, and decommission and end of use.

Design reviews are used to anticipate, identify and assess ergonomics-related risks as well as safety hazards during the design and redesign of new facilities, expansions in existing buildings, new or modified processes and systems, equipment and machines, and products. The purpose of a design review is to avoid potential hazards in the design of a new system or redesign of an existing system. A sign-off or approval process from the OSH, ergonomics and compliance stakeholders should be incorporated into the design review.

To be effective, the design review should be systematically applied to all designs, changes in existing designs, procurement and construction of new systems, and used to anticipate, identify, avoid, eliminate or reduce ergonomics-related risk factors. This requires a commitment from management to integrate PTE completely and consistently into the process.

As part of the design review, a qualified and competent leader and cross-functional team should be selected to perform the design review. Design team members should have expertise and be competent in assessing ergonomics and human-factors-related risks as well as possess knowledge of the system being assessed. In some cases, it may be necessary to include outside consultants or specialists to assist in the review.

For each design, appropriate risk assessment methods should be selected, modified or combined for conducting the design review based on the complexity of the system and the established context. In the conceptual stages, and as objectives are being discussed, a design review that includes ergonomics

FIGURE 6

EXAMPLE INITIAL ASSESSMENT USING THE ERAT

Job task | Dept
Evaluator(s) | Date

Risk factor	Duration of task				Score C1	Controls comments
Repetition	**<1 hr**	**1-4 hrs**	**>4 hrs**	**N/A**		
Every few minutes	0	0	1		0	
Every few seconds	0	1	3		3	
Lift	**<1 hr**	**1-4 hrs**	**>4 hrs**	**N/A**		
5 to 15 lb	0	0	1		1	
15 to 30 lb	1	1	2		0	
30 to 50 lb	2	2	3		0	
Over 50 lb	3	3	3		3	
Push/pull	**<1 hr**	**1-4 hrs**	**>4 hrs**	**N/A**		
Easy	0	0	1		0	
Moderate	0	1	2		0	
Heavy	1	2	3		0	
Carry >10 ft	**<1 hr**	**1-4 hrs**	**>4 hrs**	**N/A**		
5 to 15 lb	0	0	1		0	
15 to 30 lb	0	1	2		0	
Over 30 lb	1	2	3		0	
* C1 = Category 1			Subtotal C1		7	

Risk factor	Duration of task				Score C2	Controls comments
Postures	**<1 hr**	**1-4 hrs**	**>4 hrs**	**N/A**		
Head tilt	0	1	2		2	
Shoulder abduction	0	1	2		1	
Flying elbow	0	1	2		2	
Bent wrist-pinch grip	0	1	2		2	
Bending/flexing/twisting	0	1	2		1	
Environment	**<1 hr**	**1-4 hrs**	**>4 hrs**	**N/A**		
Noise	0	1	2		2	
Lighting/glare	0	1	2		1	
Impact/compression	0	1	2		0	
Power tools/vibration	0	1	2		0	
Keyboard use	0	1	1		0	
Excessive pace	0	1	1		2	
Extreme temperature	0	1	1		2	
				Subtotal C2	15	
				Total (C1 + C2)	22	
* C2 = Category 2				Total	22	

Action level 1	Total score of 10 or less may require further analysis
Action level 2	Total score of 11-22 requires intervention in the near future
Action level 3	Total score of 23-36 requires immediate intervention

FIGURE 7
EXAMPLE POST-TREATMENT ASSESSMENT USING THE ERAT

Job task							Dept						
Evaluator(s)							Date						
Risk factor	Duration of task				Score C1	Controls comments	Risk factor	Duration of task				Score C2	Controls comments
Repetition	**<1 hr**	**1-4 hrs**	**>4 hrs**	**N/A**		Eliminated	**Postures**	**<1 hr**	**1-4 hrs**	**>4 hrs**	**N/A**		Eliminated
Every few minutes	0	0	1		0		Head tilt	0	1	2		0	
Every few seconds	0	1	3		3		Shoulder abduction	0	1	2		0	
Lift	**<1 hr**	**1-4 hrs**	**>4 hrs**	**N/A**		Eliminated	Flying elbow	0	1	2		0	
5 to 15 lb	0	0	1		0		Bent wrist-pinch grip	0	1	2		0	
15 to 30 lb	1	1	2		0		Bending/flexing/twisting	0	1	2		0	
30 to 50 lb	2	2	3		0		**Environment**	**<1 hr**	**1-4 hrs**	**>4 hrs**	**N/A**		
Over 50 lb	3	3	3		0		Noise	0	1	2		2	
Push/pull	**<1 hr**	**1-4 hrs**	**>4 hrs**	**N/A**			Lighting/glare	0	1	2		1	
Easy	0	0	1		0		Impact/compression	0	1	2		0	
Moderate	0	1	2		0		Power tools/vibration	0	1	2		0	
Heavy	1	2	3		0		Keyboard use	0	1	1		0	
Carry >10 ft	**<1 hr**	**1-4 hrs**	**>4 hrs**	**N/A**			Excessive pace	0	1	1		0	
5 to 15 lb	0	0	1		0		Extreme temperature	0	1	1		2	
15 to 30 lb	0	1	2		0						Subtotal C2	5	
Over 30 lb	1	2	3		0						Total (C1 + C2)	5	
* C1 = Category 1			Subtotal C1		0		* C2 = Category 2				Total	5	
						Action level 1	Total score of 10 or less may require further analysis						
						Action level 2	Total score of 11-22 requires intervention in the near future						
						Action level 3	Total score of 23-36 requires immediate intervention						

TABLE 1
HIERARCHY OF ERGONOMIC RISK TREATMENT

Method	Phase/application	Examples	Effectiveness
Avoidance	Conceptual stage design/redesign	Prevent entry of hazard into workplace by design through selection of technology and work methods	High
Elimination	Existing processes redesign	Eliminate hazard by changes in design, equipment and methods	High
Substitution	Existing processes	Substitute materials, sizes, weights and other aspects to a lower hazard severity or likelihood	Moderately high
Engineering controls	Existing workstations redesign	Reduce hazard by changes to workplace, tools, equipment, fixtures, adjustability, layout, lighting, work environment	Moderate
Administrative controls	Practices and procedures	Reduce exposure to hazards by changes in work practices, training, job enlargement, job rotation, rest breaks, work pace	Moderately low
PPE	Worker	Reduce impact of hazard to employee by use of protective equipment and materials such as vibration attenuation gloves	Low

Note. Adapted from "Improving Ergo IQ: A Practical Risk Assessment Model," by B.K. Lyon, G. Popov and K. Hanes, 2013, *Professional Safety, 58*(12), 26-34.

and human factors risks should be performed to anticipate and identify both potential risks and potential design solutions or treatments. If deviations from stated standards or specifications are requested, management personnel including OSH, ergonomics, legal, procurement, accounting or other key stakeholders must review the request and determine if it should be approved or denied. Upon agreement, a sign-off by the project leader should be required to verify that the design review has been completed and a consensus reached by the team and engineering group.

Risk Assessment & Management of Change

Design ergonomics reviews and assessments will vary in degree of complexity depending on the context and the system being reviewed. Methods include:

- design checklists and guide words
- preliminary risk assessments
- failure mode and effects analysis
- what-if analyses and what-if/checklist analyses
- ergonomics risk assessment tool (ERAT)
- rapid entire body assessment
- rapid upper limb assessment

Design reviews and risk assessments are most effective when performed early in the design process while objectives are being discussed and should be considered in any major planned change. An example showing the trigger points for ergonomic assessments in the life cycle of a system is presented in Figure 4 (p. 28).

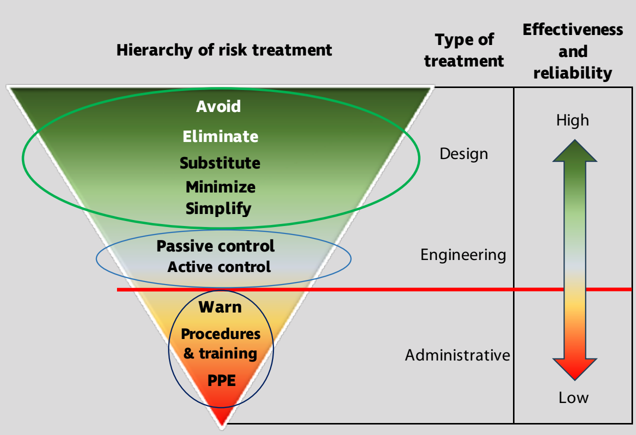
The ergonomics improvement process shown in Figure 5 (p. 28) can be viewed as a continual improvement cycle beginning with the selection of the task or system to be assessed. The appropriate methods are selected, and the assessment team identified. The assessment is then performed, and corrective measures identified. A plan for implementing the measures is put into place and then monitored to verify effectiveness and to make any refinements necessary.

Ergonomics Risk Assessment Tool

The ERAT is based on an ergonomics checklist that was part of a working draft document, withdrawn in 2003, developed by the Management of Work-Related Musculoskeletal Disorders Accredited Standards Committee. Developed by the authors in 1999 and further refined in 2012, the method was first published in Manuele's (2013) On the Practice of Safety and in the *Professional Safety* article, "Improving Ergo IQ: A Practical Risk Assessment Model" (Lyon et al., 2013). The relatively simple tool provides a standardized way to quickly identify, assess and score ergonomic risks to upper extremities in most work environments. It is spreadsheet-based and has an initial assessment worksheet (Figure 6, p. 29), a post-controls assessment worksheet (Figure 7), used after the initial assessment and control implementation

FIGURE 8

HIERARCHY OF RISK TREATMENT



Note. Adapted from ANSI/ASSP Z590.3-2021, Prevention Through Design: Guidelines for Addressing Occupational Hazards in Risks in Design and Redesign Processes, 2021.

to establish a current risk factor score and a hierarchy of ergonomic risk treatments (Table 1).

The ERAT tool is simple to use and only requires limited training time to learn how to use it. Training should include a review of the checklist and explanation of risk factors with examples of scoring, followed by hands-on application. For each row that applies, the assessor scores the task based on the duration and observed risk factor. If the action level is considered a 2 or 3, the PTD hierarchy of risk treatment (Figure 8) and hierarchy of ergonomics risk treatment (Table 1) models should be considered.

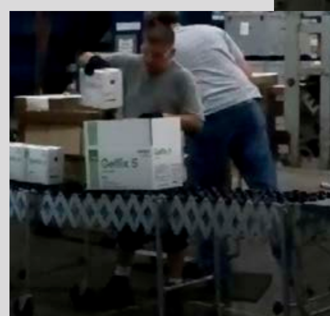
A case study is presented to demonstrate the applicability of ERAT and the hierarchy of ergonomic risk treatment.

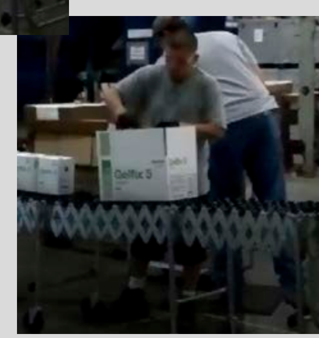
Case Study

Supply chain management often depends on just-in-time delivery of products. In this case study, the key elements for achieving the organization's business objectives include production, packaging and shipping of quality products. As shown in Photos 1 through 4, packaging of products requires a significant number of repetitive movements. The packer picks up small 5-lb boxes and fits four of them into a bigger shipping box.

This is an example of repetitive movements; the workers are packaging small boxes for 8 hours or more per day. The conveyor line speed is adjusted depending on the production schedule. Photo 1 shows an example of the packer repetitively gripping the packages. The photos also show other repetitive movements and awkward postures such as elevated elbow, shoulder abduction, head tilting, bent wrist or gripping, and upper body bending, flexing or twisting. In addition, the work environment has excessive noise, insufficient lighting in the morning and glare in the afternoon, excessive pace and extreme (high) temperatures. Based on the described operation, the ERAT initial assessment results are presented in Figure 6 (p. 29).

The initial assessment of this case study resulted in a score of 22, which is a high-end action level 2 (borderline action level 3) requiring immediate to near-future intervention. Therefore, the PTE team should consider recommending risk treatment measures that reduce the identified ergonomic risk factors. Since that is an existing operation, avoidance of the ergonomics risk factors is not an option. However, it is possible to eliminate some existing ergonomic risk factors associated with the packing task. For example, complete automation of the packing line could be considered to eliminate the exposure to repetitive manual handling risk factors.





(Top to bottom) Photos 1-4 show examples of repetitive movements and awkward postures required to package products such as gripping (Photo 1), lifting a 5-lb box (Photo 2), raised elbow and shoulder abduction (Photo 3), and fitting a 5-lb box into the cardboard shipping box (Photo 4).

While some new risks may be introduced with this proposed automation, the original risks associated with the manual material handling would be eliminated. A review of the potential risks that might be introduced to the workplace should be performed as well as a cost-benefit analysis prior to any decision. Following the approval and implementation of the automated system, a post-treatment assessment is performed to assess the resulting ergonomics risk score. By comparing the ergonomic risk level before and after implementation of the ergonomic risk treatments, a residual risk level and risk-reduction percentage can be estimated and communicated with decision-makers to document workplace risk-reduction improvements. Post-treatment ERAT risk level estimation is presented in Figure 7.

Full automation of the packaging process will lead to elimination of manual repetition, lifting forces and awkward body postures associated with manual handling of packages. However, the noise levels, insufficient lighting in the morning and glare in the afternoon will receive the same rating. Excessive pace will be eliminated; however, the extreme temperatures will remain unchanged.

OSH professionals must be prepared to answer the question of whether the solution is beneficial from a financial perspective. A business case tool that is freely available from AIHA (n.d.) can be used to help calculate the financial benefits of automating the packing line and eliminating the repetitive manual handling exposures.

In this hypothetical scenario, the authors have included a conservative estimate of one case of De Quervain's disease (a painful condition affecting the tendons on the thumb side of the wrist) and a case of rotator cuff tendinitis. Costs associated with administration, productivity loss, new employee hiring and training were included as well. However, OSH professionals should consider legal costs, failure to complete orders, loss of clients and other applicable costs. An example cost-benefit analysis is presented in Figure 9.

This cost-benefit analysis shows 97% annual cost reduction due to a fully automated packing operation. However, the implementation of an automation system will require a significant up-front investment. In this example, the automated packaging system will cost $755,000. Such investment will require a more detailed financial analysis. For example, in this case the net present value is positive, the net return on investment would be 95%, and the internal rate of return is 39%. For this capital investment, the payback period is only 2.177 years. Based on these numbers, such an investment is justifiable from a financial perspective. An example financial analysis is presented in Figure 10.

In addition, OSH professionals should be able to communicate the importance of nonfinancial benefits, such as company reputation and achieving acceptable risk levels. The ERAT is relatively easy to use and includes the assessment of repetition, lifting, push or pull force, carrying, postures and environmental ergonomic risk factors. This case study demonstrates the importance of including environmental conditions in the ergonomic risk assessment. An important concept in ergonomic risk assessment is understanding the additive or synergistic effects of multiple risk sources.

PTE is an area of opportunity for OSH professionals to move the needle in reducing risk and improving workplace systems.

Conclusion

With musculoskeletal disorders making up approximately 33% of claims and 40% of the costs, as well as the significant number of human-error-related fatalities and serious injuries that occur, it is apparent additional guidance is needed for integrating ergonomics and human factors engineering into the design process. Unfortunately, no OSH standards or technical reports exist for incorporating ergonomics principles and human factors into workplace systems.

The concept of PTE described in this article includes the integration of ergonomics and human factors principles into the design and redesign of workplace systems throughout their life cycle including their procurement, development, construction, manufacture, use, maintenance and end of service, disposal or reuse. The case study presented clearly demonstrates the importance of PTE, risk reduction, financial and nonfinancial benefits. PTE is an area of opportunity for OSH professionals to move the needle in reducing risk and improving workplace systems. The authors hope that development of a technical report providing guidance in the integration of PTE into PTD processes can be achieved to help OSH professionals lead the way in reducing design-related ergonomic risks. OSH professionals must have a role in influencing decision-makers to make better decisions. **PSJ**

References

Agency for Healthcare Research and Quality (AHRQ). (2019, Sept. 7). Human factors engineering. Patient Safety Network. https://psnet.ahrq.gov/primer/human-factors-engineering

American Industrial Hygiene Association (AIHA). (n.d.). AIHA business case in EHS tool. https://bit.ly/3MIkISi

ANSI/ASSP. (2021). Prevention through design: Guidelines for addressing occupational hazards and risks in design and redesign processes (ANSI/ASSP Z590.3-2021). https://store.assp.org/PersonifyEbusiness/Store/Product-Details/productId/226753699

Bureau of Labor Statistics (BLS). (2020). Employer-reported workplace injuries and illnesses, 2021 [News release]. www.bls.gov/news.release/osh.nr0.htm

Chapanis, A. (1991). To communicate the human factors message, you have to know what the message is and how to communicate it. *Human Factors Society Bulletin, 34*(11), 1-4.

FIGURE 9

EXAMPLE COST-BENEFIT ANALYSIS

Return on investment (ROI)

$$\text{Simple ROI} = \frac{P_b - P_c}{P_c}$$

Benefits (Cost FS)		Costs CS		Cost of ergonomic treatments		
De Quervain's disease	$0	De Quervain's disease	$95,000	Automated packaging system	$755,000	One-time investment
Rotator cuff tendinitis	$0	Rotator cuff tendinitis	$75,000	Utilities	$21,640	Annual cost
Administrative cost	$0	Administrative cost	$124,100	Annual maintenance	$10,500	Annual cost
Loss of productivity	$0	Loss of productivity	$55,000			
Operator hiring/training	$11,680	Employee hiring/training	$46,720			
P_b =	**$11,680**	P_c =	**$395,820**	Total=	**$787,140**	
	$384,140 Annual benefit	**-0.970491638 or 97.05% Simple ROI**				

FIGURE 10
EXAMPLE FINANCIAL ANALYSIS

Risk treatment: Financial benefits

Main Menu

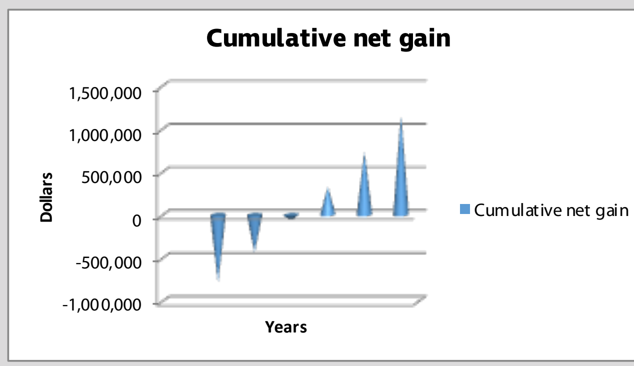
		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Interest rate	Total improvements cost						
5%	Auto pack	$ 787,140.00	$ 32,140.00	$ 33,747.00	$ 35,434.35	$ 37,206.07	$ 39,066.37
	Total costs to implement	$ 787,140.00	$ 32,140.00	$ 33,747.00	$ 35,434.35	$ 37,206.07	$ 39,066.37

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Benefits						
Benefits		$ 384,140.00	$ 403,347.00	$ 423,514.35	$ 444,690.07	$ 466,924.57
Total Benefits	$ -	$ 384,140.00	$ 403,347.00	$ 423,514.35	$ 444,690.07	$ 466,924.57

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Net savings	$ (787,140)	$ 352,000	$ 369,600	$ 388,080	$ 407,484	$ 427,858
Cumulative net gain	$ (787,140)	$ (435,140)	$ (65,540)	$ 322,540	$ 730,024	$ 1,157,882

BCA - ROI

Financial analysis	US $	
PV(costs) =	$895,417	
PV(savings)=	$1,742,132	
NPV=	$846,715	
Payback (years)=		2.17732684
ROI (net) =	95%	
IRR =	39%	



Hollnagel, E. (1993). *Human reliability analysis: Context and control.* Academic Press.

Human Factors and Ergonomics Society (HFES). (n.d.a). What is human factors and ergonomics? https://bit.ly/3q3JHYF

HFES. (n.d.b). Virtual fit multivariate anthropometric tool. www.hfes.org/Publications/Technical-Standards

Liberty Mutual Insurance. (2019). 2019 workplace safety index: The top 10 causes of disabling injuries at work. https://bit.ly/425emCb

Lyon, B.K. & Popov, G. (2022, June 27-29). *Prevention through ergonomics (PTE): Incorporating PTE into PTD.* Safety 2022 ASSP Professional Development Conference, Chicago, IL, USA.

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

NIOSH. (2013, Oct. 9). Prevention through design. www.cdc.gov/niosh/topics/ptd/default.html

Manuele, F.A. (2013). *On the practice of safety* (4th ed.). Wiley.

Rasmussen, J. (1986). *Information processing and human-machine interaction: An approach to cognitive engineering.* Wiley.

Reason, J. (1990). *Human error.* Cambridge University Press.

Sanders, M.S. & McCormick, E.J. (1993). *Human factors in engineering and design* (7th ed.). McGraw-Hill.

Shorrock, S. (2016, Feb. 27). Never/zero thinking. *Humanistic Systems.* https://humanisticsystems.com/2016/02/27/neverzero-thinking

Stephans, R.A. (2004). *System safety for the 21st century: The updated and revised edition of system safety 2000* (2nd ed.). Wiley.

Syed, M. (2015). *Black box thinking: Why most people never learn from their mistakes—But some do.* Penguin.

Cite this article

Lyon, B.K. & Popov, G. (2023, June). Prevention through ergonomics: Integrating human factors into a prevention through design approach. *Professional Safety, 68*(6), 24-33.

Bruce K. Lyon, P.E., CSP, SMS, ARM, CHMM, FASSP, is vice president of risk management services with Brown & Brown. He is chair of the ISO 31000 U.S. TAG, vice chair of ANSI/ASSP Z590.3, advisory board chair to University of Central Missouri's (UCM) Safety Sciences, and board president of BCSP. Lyon is coauthor of *Assessing and Managing Risk: An ERM Perspective; Risk Management Tools for Safety Professionals* and *Risk Assessment: A Practical Guide to Assessing Operational Risk*. He holds an M.S. in Occupational Safety Management and a B.S. in Industrial Safety from UCM. In 2022, he received the ASSP Thomas Bresnahan Standards Medal Award and the CSP Award of Excellence from BCSP in 2018. Lyon is a professional member of ASSP's Heart of America Chapter, and a member of the Society's Ergonomics and Risk Management/Insurance practice specialties.

Georgi Popov, Ph.D., CSP, QEP, SMS, ARM, CMC, FAIHA, is the chair of Occupational Risk and Safety Sciences at UCM. He is coauthor of *Assessing and Managing Risk: An ERM Perspective; Risk Management Tools for Safety Professionals* and *Risk Assessment: A Practical Guide to Assessing Operational Risk*. Popov holds a Ph.D. from the National Scientific Board, an M.S. in Nuclear Physics from Defense University in Bulgaria and a post-graduate certification in environmental air quality. He graduated from the U.S. Army Command and General Staff College in Fort Leavenworth, KS. Popov is the chair of ANSI/ASSP Z590.3, vice chair of ISO 31000 U.S. TAG, a professional member of ASSP's Heart of America Chapter and a member of the Society's Risk Management/Insurance Practice Specialty. In 2017, Popov received ASSP's Outstanding Safety Educator Award.