A DMAIC Perspective on PHYSICAL FATIGUE MANAGEMENT

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In a study funded by the ASSP Foundation, researchers examined fatigue among manufacturing employees and looked at interventions for addressing fatigue. This article outlines a practical approach that OSH professionals can use to apply the research to improve their efforts to manage workplace fatigue.

Worker fatigue has been shown to be a significant problem in the manufacturing industry (Lu, Megahed, Sesek, et al., 2017). Due to its high prevalence and serious consequences, a need exists for practical solutions to create awareness toward monitoring fatigue to prevent injuries and safety incidents. As with other areas of the manufacturing system, fatigue management requires continuous process improvement. Therefore, safety professionals can look to existing process improvement frameworks such as six sigma to outline the stages of fatigue monitoring. In its traditional application in manufacturing and service industries, the six sigma method focuses on investigating how to enhance business performance and satisfy customer needs. However, the focus is usually on external customers rather than internal customers (i.e., the workers in occupational safety settings). In this article, the authors show how the data-driven define, measure, analyze, improve and control (DMAIC) framework can be used as a guide for continuously improving fatigue management practices in the workplace (Figure 1).

Stage 1: Define

The first step is to identify process characteristics, which are critical to the process/product quality as defined by the customer. In terms of fatigue management, this means identifying a) the priority areas in the operation; and b) those workers who are at high risk of becoming fatigued while performing their jobs. An important part of this is talking with the workers to understand the likelihood of fatigue and its associated symptoms. This helps isolate the type of fatigue being experienced. Along with interviews, historical data on injuries should be evaluated to determine the jobs and body parts that experience higher rates of injury. The result of this stage is an understanding of which workers, tasks and body parts are important to be monitored during the safety-critical tasks in the next stage. For example, consistent reports of low-back fatigue and discomfort will require a different monitoring and mitigation plan than an inability to concentrate due to sleepiness. We also recommend creating visual summaries or infographics based on the collected data to inform the different constituents and work with them toward improving safety outcomes. One example of such visualizations can be found in Maman, Yazdi, Cavuoto, et al. (2017).

Stage 2: Measure

The goal of stage two is to determine the metrics by which to measure the work tasks. Based on these metrics and the information gathered in stage one, the means of measurement can be identified. This can include a) data on product quality per station; b) the use of wearable or camera-based sensors; and c) periodic worker questionnaires. The choice of approach would depend on the budget, intensity of work and type of job.

Using the authors' recent work involving wearable sensors as a discussion example, the first task within this stage would be selecting the appropriate type, number and body location for the sensors. Based on experimental studies, the authors have shown that a full set of sensors may not be needed for accurate physical fatigue monitoring. Specifically, the accuracy from one optimally placed sensor can equate to that of five arbitrarily placed sensors (Maman, Chen, Baghdadi, et al., 2019). Thus, it is important to choose the right wearable, both sensor type and wear location, for the industry and problem of interest. Improper selection of measures, sensors and sensor locations are the key factors that can lead to failure in subsequent stages of the DMAIC cycle.

Once sensors and metrics are chosen, data collection and monitoring should be conducted for limited durations. Continuous monitoring is not recommended, as it can leave more room for data misuse, a common concern for the implementation of wearables in the workplace (Schall, Sesek & Cavuoto, 2018). Note that the assigned tasks for the critical workers who will be monitored should be standardized (Maman, et al., 2017). The approximate costs of this stage can vary depending on the required number of sensors and the amount of data storage capacity. The output of this stage (the collected sensor data) is to be used for occupational safety analysis and improvement.

Stage 3: Analyze

The next stage focuses on the causes of variation and errors from the measured data. This is accomplished by discovering the hidden patterns in the data collected in the previous phase. The patterns are further considered to identify the important variables or root causes for the fatigue outcome. Here, the safety professional discovers how fatigue is developing and what body responses are occurring from the fatiguing jobs, along with providing information on how fatigue should be prevented. Three types of data analytics are implemented in this phase: descriptive, diagnostic and predictive. Descriptive analytics include consolidation of the collected data and preparation of potential variables for representing fatigue. Then, the diagnostic analytics involve a deeper look at the data to ascertain the important variables that are the causes of fatigue and the type of fatigue. Predictive analytics are then performed for the likelihood of a worker being fatigued as s/he continues the current job. The output of this stage is the determination of a group of fatigued workers, their fatigue type and the likelihood of future fatigue development.

Stage 4: Improve

Once fatigue has been detected and root causes analyzed, appropriate intervention measures can be provided to help workers recover from fatigue symptoms to ensure worker safety and work performance. This stage includes a) building a database of existing fatigue interventions and their historical application information [e.g., source of the intervention, sample characteristics, experiment type and duration, targeted industry and job tasks, targeted types of fatigue, methods of fatigue measurement, effects of outcomes, methodological quality, levels of evidence of the interventions (Lu, Megahed & Cavuoto, 2019)]; b) conducting pilot studies that apply potential effective interventions and examining the degree of recovery or time to recovery; and c) establishing a system that contains validated and tested interventions for different types of fatigue and provides personal recommendations that optimize fatigue recovery with constraints of worker safety, work performance and costs. The ultimate goal of this stage is to effectively improve workers' fatigue state through personalized measures. The authors believe that personalized/individualized interventions can improve safety outcomes, similar to the revolution caused by personalized medicine in healthcare settings (see Ashley, 2015, for a detailed discussion of personalized medicine and its potential benefits).

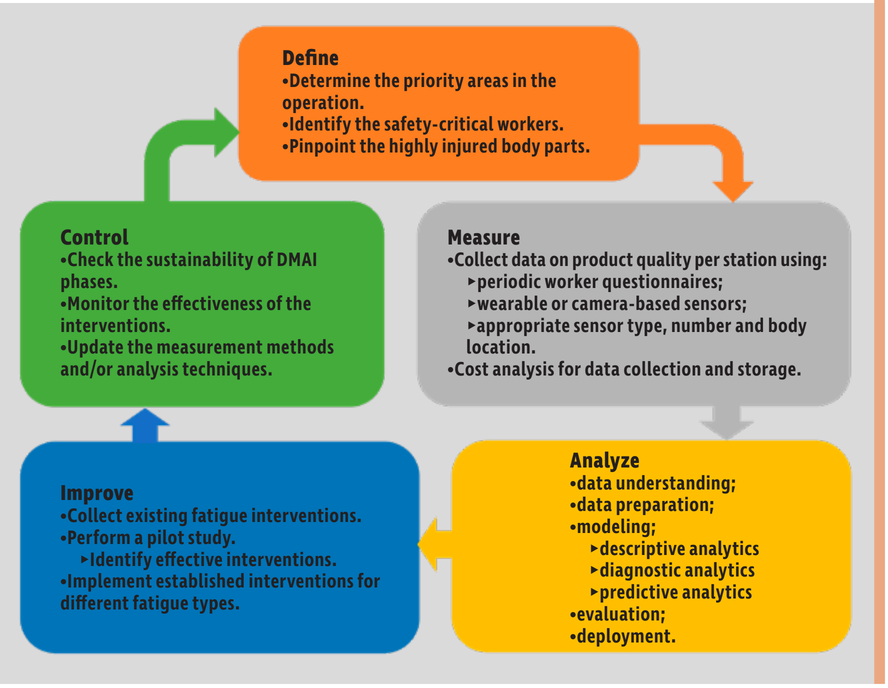
Stage 5: Control

The first four stages of this framework (i.e., DMAI) achieve a cycle of fatigue management through defining, measuring, analyzing and intervening fatigue. However, with the development and further studies of fatigue, the continuous improvement of these processes must be maintained, such as refining/detailing the existing definitions, introducing more accurate and practically implementable measurement methods, applying advanced analysis techniques and enriching/validating the intervention measures. Only through the adaptive adjustment of these phases and their outputs can a lean approach to managing fatigue be achieved.

Conclusion

In conclusion, the DMAIC cycle provides a systematic approach to managing fatigue by breaking down the fatigue problem into a sequence of smaller tasks represented by the define, measure, analyze, improve and control stages. Perhaps more importantly, it enables the incorporation of production and operations personnel in continuously improving safety outcomes since it a) uses a framework that is used in other parts of manufacturing operations; and b) allows for measuring the negative/monetary consequences of suboptimal safety/ergonomic conditions, which is an important component of obtaining management buy-in for safety initiatives. **PSJ**

FIGURE 1
DMAIC FRAMEWORK



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