The XXIXth Annual Occupational Ergonomics and Safety Conference
Seattle, Washington, USA
June 1-2, 2017

Fatigue Risk Assessment & Management in high risk Environments (FRAME): The FRAME scale

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Abstract: Worker fatigue plays a major role in terms of performance, safety, and productivity. It is estimated that over 50% of the working population experience fatigue symptoms. But fatigue in the oil and gas sector is a critical and complex issue, as workers are exposed to long work periods, high levels of physical and mental workload, coupled with rigorous shift work. Currently, a major barrier for effective fatigue mitigation practices is the lack of adequate, feasible, and effective assessment methods for oil and gas extraction. While there are several objective and subjective fatigue assessment methods available for scientific and practical purposes, none are comprehensive, relevant, and feasible for the energy industry. This study is part of a larger initiative on Fatigue Risk Assessment & Management in high risk Environments (FRAME). The aim of this study was to develop a FRAME scale that would enable feasible and safe evaluations of fatigue risks in onshore/offshore oil and gas rig environments, thereby increasing the chances of successful adoption and subsequent implementation of effective practices to reduce fatigue-related incidents in the energy industry. A preliminary fatigue inventory was systematically gathered from existing fatigue surveys, which considered various factors including physical and cognitive demands, psychosocial stressors, sleep and shift work. The preliminary fatigue inventory yielded 209 items. This inventory was refined for relevance to the energy industry and properly identifying specific symptoms of fatigue by 5 industry stakeholders and 8 fatigue experts using the Delphi consensus method. The refined inventory yielded 33 items for employees to review. Finally, the inventory was revised for language and relevance to work by 11 oil and gas employees, who are the intended end user. Items in the refined inventory were coded based on relevance to work (i.e. yes=2, somewhat=1, no=0) and the ability to classify fatigue symptoms. Items with an average score of less than one were eliminated from the inventory. The next stage of this study is to test and validate the survey in an on-shore well servicing operation, ultimately aiding to facilitate improved fatigue mitigation practices in high-risk environments.

Keywords: oil and gas extraction, shift work, survey

1. Introduction

Worker fatigue is a critical occupational risk that has cost lives, injured workers, reduced productivity, and is associated with an economic losses estimated at $18 billion a year (Caruso, 2014; Lerman et al., 2012). This is a big problem, particularly in the oil and gas extraction (OGE) industry, as OGE workers are exposed to intensive shift patterns and long work durations, coupled with intense physical and mental workload inherent of the OGE environment. From 2003–2014, 1,331 OGE workers died while working, resulting in an annual fatality rate seven times higher than that for all U.S. workers (BLS, 2015). Fatigue, generally defined as a physiological state of reduced mental or physical performance capability resulting from sleep loss, circadian phase, and workload, has been implicated as a serious risk factor in a majority of the cases affecting worker safety (Mason, Retzer, Hill, & Lincoln, 2015; Retzer, Hill, & Pratt, 2013). Both industry and federal agencies have determined that "*decreasing fatigue-related injuries and fatalities in the OGE industry*" is one of their top strategic research (to practice)

priorities. However, one of the major barriers that currently impact the development of effective fatigue mitigation practices in OGE workers is the assessment of fatigue. Fatigue is a complex multidimensional construct, making it exceedingly difficult to assess properly. Several objective and subjective fatigue assessment methods exist, but none are comprehensive, relevant, and feasible for the OGE workforce (Mehta et al., 2017). This presents challenges in identifying high-risk workers and developing fatigue management practices that are targeted and effective in reducing fatigue-related incidents in the OGE industry. The aim of this study was to develop a comprehensive fatigue assessment inventory specific for OGE operations through a collaborative academic-industry partnership. This was one of the first collaborative efforts involving participation from the OGE industry and occupational health and safety researchers on development of a fatigue assessment tool.

2. Methods

A qualitative approach was adopted utilizing industry partner inputs and health and safety experts. Similar methods have been used for the development of a fatigue survey for construction workers (Zhang et al., 2015). This study was completed in three phases (Figure 1). Phase 1 included the systematic gathering of existing fatigue survey based on predetermined criteria to develop a preliminary fatigue inventory. Phase 2 included the refinement of the inventory for content validation, brevity, and relevance to OGE operations through industry stakeholders and health and safety researchers using the Delphi consensus technique. Phase 3 involved further refinement of the inventory by OGE workers, who are the intended end-user.

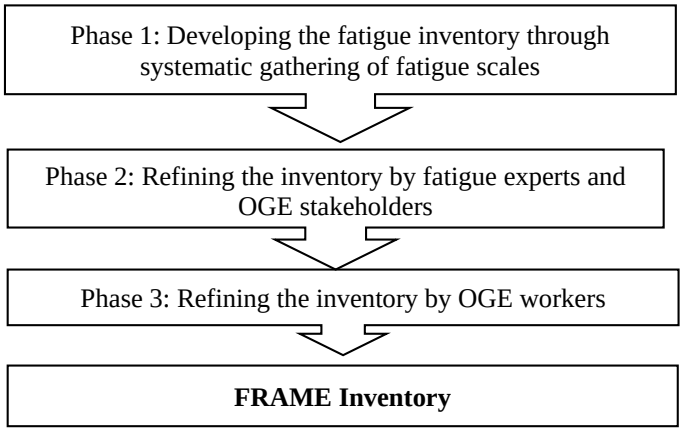

Figure 1. Protocol for FRAME development

2.2 Phase 1: Inventory Development

We operationally define fatigue in the OGE environment as a physiological state of reduced mental or physical performance capability resulting from sleep loss, circadian phase, and workload (physical and mental). Preliminary fatigue items were categorized based on OGE-related risk factors, such as sleep, shift-related, physical and cognitive demands, and psychosocial stress. Potential items within this inventory were obtained from an exhaustive literature review from multiple scientific databases, such as PubMed and PsycINFO among others, and the criteria for inclusion was: 1) ability to identify distinct fatigue symptoms 2) applicability to a healthy workforce and 3) the ability to rate fatigue range on levels. The preliminary fatigue inventory yielded 209 items.

2.2 Phase 2: Delphi Consencous

Phase 2 involved the refinement of the preliminary inventory for content validation, brevity, and relevance to OGE operations through industry stakeholders and health and safety researchers using the Delphi consensus technique (Hsu & Sandford, 2007). Upon informed consent, the Delphi panel was presented with the preliminary fatigue inventory (209 items) and was instructed to exclude items based on the following criteria: 1) too general at describing a symptom of fatigue 2) redundant and 3) not relevant to OGE operation.

This phase was completed in two steps: 1) refined by 8 health and safety professionals for grammar and language, along with redundant items. This step reduced the inventory to 50 items. Next, 5 OGE stakeholders refined the inventory for OGE relevance. The final refined inventory from the Delphi panels yielded 33 items for employees to review.

2.3 Phase 3: Focus Group

Finally, the inventory was revised for language and relevance to work by 11 oil and gas employees (Table 1), who are the intended end user. Upon informed consent, the refined fatigue inventory was presented to OGE employees. They were informed to refine inventory based on relevance to their work and the ability to classify fatigue symptoms. For each item, workers rated each item on the relevance to OGE work with a 3-point scale (i.e. yes=2, somewhat=1, no=0). The average score of each item was calculated and items with a score of less than one will be removed from the inventory. Additionally, workers were asked to classify each item based on the 5 categories determined in phase 1: 1) sleep, 2) shift-related, 3) physical demand 4) cognitive demands, and 5) psychosocial stress. Items were removed if less than 80% of the workers classify the item into the expected dimension (Stein, Martin, Hann, & Jacobsen, 1998; Zhang et al., 2015).

Table 1. Participant Demographic (n=11)

Gender (Male)	100%
Age (Years)	44.36(3.98)
Race	
American Indian	18.2%
Black or African American	9.1%
White	18.2%
More than one race	8.3%
Unknown or not reported	41.7%
Ethnicity	
Hispanic or Latino	54.6%
Not Hispanic or Latino	27.3%
Unknown or not reported	18.2%
Education	
Some High School	18.2%
HS Graduate or Equivalent	54.6%
Some College	9.1%
Unknown or not reported	18.2%
Experience (Years)	16.11

3. Findings and Conclusions

Preliminary results yielded 19 final items (e.g. 11 physical fatigue, 6 mental fatigue, and 2 sleep/ shift). The FRAME inventory is brief, relevant, and comprehensive in assessment of OGE operations. This immediate outcome is filling a current gap in fatigue assessments in the OGE sector. Current subjective and objective fatigue assessment methods are not effective, feasible, or safe for monitoring fatigue, which in turn creates a critical barrier for proper identification, assessment, and control of fatigue-related injuries and incidents. By involving industry stakeholders throughout the development of the proposed inventory the likelihood of successful adoption of assessment method is greatly increased. Future research include validating the survey and testing the sensitivity across different OGE application such as onshore and offshore operations.

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