Co-existence of muscle fatigue, mental fatigue and possibility of mental burnout during manual handling of low load at high frequency in the industry: A survey and analysis

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Abstract: The purpose of the study was to investigate the co-existence of mental fatigue, muscle fatigue and possibility of mental burnout with the help of internationally accepted questionnaires like NORDIC-E, OLBI and BMS. The main focus was on tasks involving lifting low loads at high frequency in the industry. The data obtained from the survey was analyzed with the help of suitable statistical tools such as Karl Pearson's coefficient to find the correlation between these fatigues. The results suggest that industrial workers are affected by all the above mentioned fatigues simultaneously even while performing purely physical tasks. The outcome of the study motivates considering mental fatigue, muscle fatigue and possibility of mental burnout while designing any work station or risk assessment technique.
Key words: Muscle fatigue, mental fatigue, mental burnout, correlation coefficients, neuroergonomics.

1 Introduction

Neuroergonomics is the study of the behavior of brain at work. It is an interdisciplinary area where neuroscience and ergonomics are jointly under investigation. It is legitimate to question the necessity and relevance of this new venture. As of now, the main focus in the field of Ergonomics is primarily on muscle fatigue while mental fatigue has mainly been studied for mental tasks like grid recall, mental addition, image learning, digit-span etc. mostly in the service industry and not for typical physical jobs in the production industry. Also, risk assessment techniques like RULA, REBA etc. designed for analyzing risk involved in physical jobs in the industry generally have rating of perceived exertion (RPE) as the basis for their development. In view of the above, an effort has been made to see whether mental and muscle fatigue should be considered simultaneously while designing work stations in the industry so that the safest possible environment is provided to workers while forestalling the onset of any disorder due to accumulation of fatigues. There have been some studies (Zadry et al., 2010) where efforts have been made on parallel monitoring of EEG and EMG for mental fatigue and muscle fatigue respectively during normal physical tasks in electric iron assembly in the industry and the results encourage further investigation. Thereby, the format of the present study is to record the response of the workers with respect to their physical and mental stress using some internationally approved questionaries' (Deakin et al., 1994, Demerouti and Bakker, 2008 and Dickinson et al., 1992). Subsequently the gathered data is

processed statistically (Meng et al., 1992, Kothari, 2004, Singh, 2009 and Steiger, 1980) to find correlations for co-existence of these parameters in order to justify the relevance of Neuroergonomics.

2 Methodology

Sample population

In total, 416 employees involved in manual handling of low loads at high frequency from 15 different industries participated in the study. All industries were involved in manufacturing and belonged to the industrial cities around Chandigarh, India. The sample population was demarcated on the basis of their work experience as follows: 36.6 % had less than 5 years of work experience, 37.8 % were experienced between 5 to 10 years, 15.4 % were between 10 to 15 years, 6 % were between 15 to 20 years and 4.1% had more than 20 years of work experience.

Procedure and survey instrument

Three internationally accepted survey instruments on muscle fatigue, mental fatigue and possibility of mental burnout were used to assess the sample population. Options based on a five point Lickert scale were available to the employees to answer each question. Each survey instrument was translated into Hindi, Punjabi and English for the convenience of the sample population. Also, the consents of the management and the workers were taken before conducting the survey on the factory premises. The respondents were ensured of the confidentiality and anonymity of their responses.

Mental fatigue

These were derived with short scales derived from the BMS inventory (original in German: Ermūdung-Monotonie-Sättigung-Streß; Plath and Richter, 1984). It is a reliable and valid questionnaire measuring subjectively represented short-term, reversible effects of task performance and job conditions (Demerouti et al., 2010). It contained 40 questions and the demarcation of the total score of the questionnaire is as follows: A score of 40 – 48 indicates little sign of mental fatigue, 49 – 87 indicates little sign unless some factors are severe, 88 – 130 indicates risk of mental fatigue if some scores are high, 131 – 159 indicates severe risk and 160 – 200 indicates a very severe risk.

Possibility of mental burnout

To assess possibility of burnout, Oldenburg Burnout Inventory (OLBI) was used. Rationale behind using OLBI is that contrary to exhaustion as operationalized in the Maslach Burnout Inventory (MBI, utilized by majority of the studies), the OLBI covers the physical and cognitive aspects of exhaustion in addition to the affective aspects. This facilitates the application of the questionnaire to those employees who perform physical work. The factorial validity of the OLBI has been confirmed in studies conducted in Germany, the United States

and Greece. Furthermore, the convergent validity of the OLBI and MBI has been confirmed in the United States and Greece (Demerouti and Bakker, 2008).

The questionnaire contained 15 questions and the demarcation of the total score of the questionnaire is as follows: A score of 15 – 18 indicates little possibility of mental burnout, 19 – 32 indicates little possibility unless some factors are severe, 33 – 49 indicates risk of possible mental burnout if some scores are high, 50 – 59 indicates severe risk and 60 – 75 indicates a very severe risk.

Muscle fatigue

Muscle fatigue was assessed using the extended version of the Nordic Musculoskeletal Questionnaire (NMQ-E). The reliability of the NMQ-E is substantiated by Dawson et al. (2009) who presented a range of coefficients in favor of the survey tool.
The questionnaire contained 16 questions (7 main + other 3 main each having 3 sub-parts) and the demarcation of the total score of the questionnaire is as follows: A score of 16 – 19 indicates little sign of muscle fatigue, 20 – 34 indicates little sign unless some factors are severe, 35 – 50 indicates risk of muscle fatigue if some scores are high, 49 – 63 indicates severe risk and 62 – 80 indicates a very severe risk.

The relevance of each question in the questionnaires was also evaluated using equation for importance index (Singh, 2009) and majority of the questions (about 75%) fell in the important category.
Karl Pearson's Correlation coefficient (r)

The scale selected for data collection is based on rating scale and thereby this coefficient is applicable. The correlation between mental fatigue, possible mental burnout and muscle fatigue (two at a time) is estimated using Karl Pearson's coefficient of correlation (Kothari, 2004):

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{n \cdot \sigma_x \cdot \sigma_y} \qquad (1)$$

where n is the total number of respondents, $\bar{x}$ and $\bar{y}$ are means of variables being correlated and σ_x and σ_y are their standard deviations respectively.

3 Results

The data of 416 persons with 71 questions per head (29536 questions in total) was processed in SPSS 20.0 and the results are as follows:
Mental fatigue

The BMS inventory responses were evaluated and the results are illustrated in Figure 1. It may be observed that no employees were recorded in the minimum range of 40-48 signifying that mental fatigue is quite common. Meanwhile, 87.74% of the employees were recorded in the range of 88-130 which corresponds to the onset of severe mental fatigue.

Also illustrated in the figure are average scores from the BMS inventory of different work experience groups which shows that mostly employees with work experience of 10 – 15 years have the highest average score.

Possibility of mental burnout

Results from the OLBI are illustrated in Figure 2. Most respondents were recorded in the ranges 19 – 32 and 33 – 49 corresponding to little sign of possible burnout unless some factors are severe and at risk of mental fatigue. Also illustrated in the figure are average scores from the OLBI of different work experience groups which again attributed the highest average to employees who have in service for 10 – 15 years.

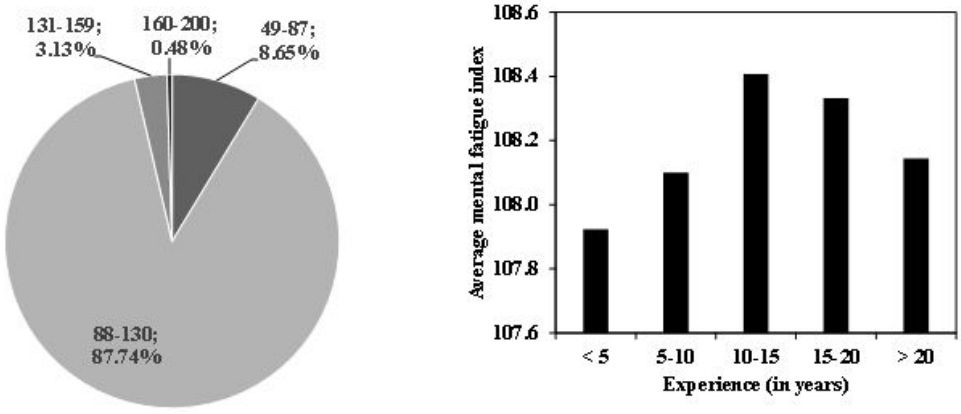

Figure 1. **(a)** Percentage of employees falling under different score ranges of mental fatigue and **(b)** Average mental fatigue index versus work experience in years.

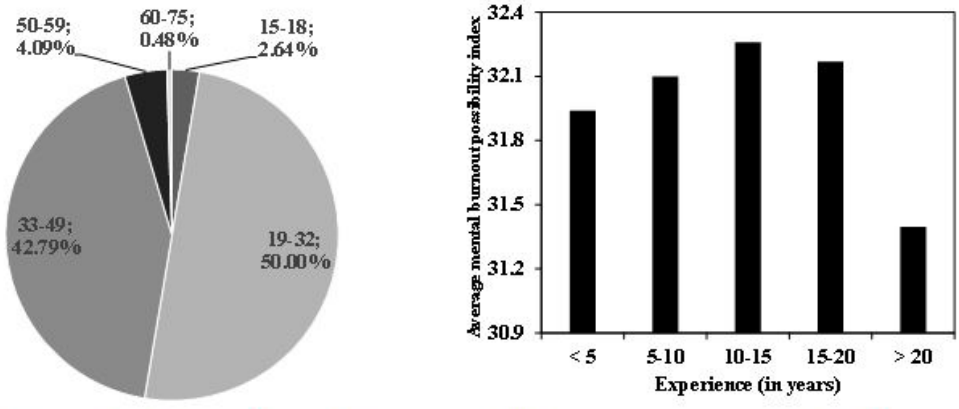

Figure 2. **(a)** Percentage of employees falling under different score ranges of mental burnout and **(b)** Average mental burnout possibility index versus work experience in years.

Muscle fatigue

Results from the NMQ are shown in Figure 3. Most employees were recorded in the ranges of 0 – 15, 16 – 19 and 20 – 34 corresponding to no sign of muscle fatigue, little sign of muscle fatigue and onset of severe muscle fatigue respectively. In keeping with the

trends, employees in the work experience range of 10 – 15 years were again recorded with the highest average score for muscle fatigue.

Karl Pearson's Correlation Coefficient

The computed correlation coefficient of two characteristics taken two at a time using Eq. (1) is shown in Figure 4. These values are [R = 0.184, p < 0.01], [R = 0.359, p < 0.01] and [R = 0.456, p < 0.01] for muscle vs. mental fatigue, muscle fatigue vs. possibility of mental burnout and mental fatigue vs. possibility of mental burnout respectively. The results predict that these three parameter under study complement each other and must be investigated comprehensively.

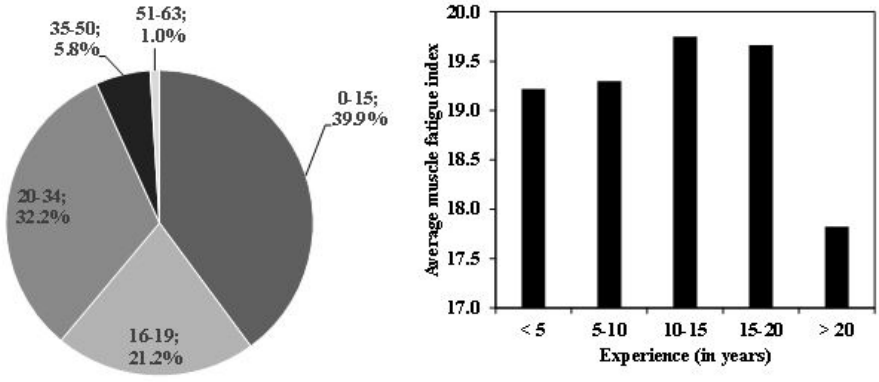

Figure 3. **(a)** Percentage of employees falling under different score ranges of muscle fatigue and **(b)** Average muscle fatigue index versus work experience in years.

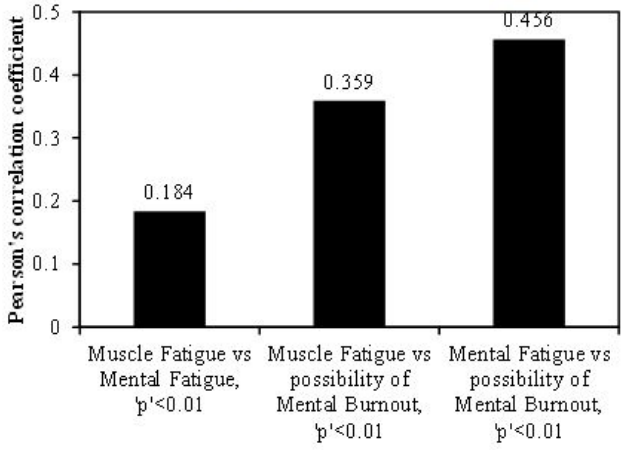

Figure 4. Computed Pearson's co-efficient correlations.

4. Conclusions

The average values of scores of muscle fatigue, mental fatigue and possibility of mental burnout were observed to follow a trend wherein the values attained maxima

for employees with 10 – 15 years of experience and followed a gradual decline thereon after. This might be due to a lower portion of employees surveyed with experience greater than 15 years (only 10 %). Nevertheless, this shows that there is a significant probability of onset of diseases due to cumulative effects of the fatigues in time to come. The correlation coefficients having positive values at a significant level are indicative of the co-existence of these parameters. The study of development and progression thereafter of these parameters in parallel during physical work encourages to go for deliberate merger of neuroscience and ergonomics to facilitate better design of risk assessment techniques with muscle and mental fatigue physiology incorporated. The findings of the study may also be helpful in design of modified works stations and work cycles.

5. References

1. Dawson, A.P., Steele, E.J., Hodges, P.W., Stewart, S. 2009. "Development and Test–Retest Reliability of an Extended Version of the Nordic Musculoskeletal Questionnaire (NMQ-E): A Screening Instrument for Musculoskeletal Pain." The Journal of Pain, vol. 10: 517 – 529.
2. Deakin, J., Stevenson, J., Vail, G., Nelson, J. 1994. "The use of the Nordic questionnaire in an industrial setting: A case study." Applied Ergonomics, vol. 25: 182 – 185.
3. Demerouti, E., Bakker, A.B., Nachreiner, F., Ebbinghaus, M. 2002. "From mental strain to burnout." European Journal of Work and Organizational Psy-chology, vol 11: 423 – 441.
4. Demerouti, E., Mostert, K., Bakker, A.B. 2010. "Burnout and Work Engage-ment: A Thorough Investigation of the Independency of Both Constructs." Journal of Occupational Health Psychology, vol. 15: 209 – 222.
5. Demerouti, E. & Bakker, A.B. 2008. "The Oldenburg Burnout Inventory: A good alternative to measure burnout and engagement." International Journal Halbesleben (Ed.). Stress and burnout in healthcare: 65 – 78.
6. Dickinson, C., Campion K., Foster A., Newman, S., O'Rourke, A., Thomas, P. 1992. "Questionnaire development: An examination of the Nordic Musculoskeletal questionnaire." Applied Ergonomics, vol. 23: 197 – 201.
7. Meng, X.L., Rosenthal, R., Rubin, D.B. 1992. "Comparing correlated correla-tion coefficients." Psychological Bulletin, vol. 111: 172 – 175.
8. Kothari, C.R. 2004. Research Methodology Methods and Techniques. New Age International Publishers.
9. Singh, P.J. 2009. "Development of Performance Measures for Environmentally Conscious Manufacturing." PhD. Thesis, Panjab University, Chandigarh, India.
10. Steiger, J.H. 1980. "Tests for comparing elements of a correlation matrix." Psychological Bulletin, vol. 87: 245 – 251.
11. Zadry, H.R., Dawal, S.Z., Taha, Z. 2010. "Effect of Load on Upper Limb Muscle and Brain Activity in Light Assembly Task." vol 3, IMECS March 17-19, Hong Kong.