Demographic Factors Affecting Perceived Fatigue Levels among CNC Lathe Operators

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ABSTRACT

Fatigue in industrial workers is a multifactorial phenomenon. There are demographic factors that may have a significant influence on the perception of fatigue, but they remain almost unexplored to date.. The present study addresses this issue. A survey to assess fatigue was conducted among CNC lathe operators in three industrial concerns where automotive parts are manufactured. Homokinetic joints in site 1 (121 workers); camshafts in site 2 (121 workers); pistons in site 3 (21 workers). The subjects completed a survey instrument that included two questionnaires to assess fatigue: SOFI−S and OFER−S. There was also a section asking for demographic information. The MANOVA procedure was used to explore the influence of the demographic factors on fatigue. Factors affecting the fatigue dimensions (SOFI−S) were gender, body weight, stature, total length of sleep during a day, and age. Factors affecting the fatigue states (OFER-S) were weight of load being handled, gender, total length of sleep during a day, length of stay in the firm. Non-influential factors were educational status and whether the worker has a second paid job.

Keywords: Human fatigue, CNC Lathe, operators, demographic factors.

INTRODUCTION

Fatigue is commonly used to indicate a physiological status, but some psychologists argue that this term should be used only to define a subjective experience that affects the performance of a task (Kroemer, Kroemer, and Kroemer-Elbert, 2003). According to Bridger (2003), there are at least three different meanings to the term ‘fatigue’. Sometimes it is used to mean sleepiness (fatigue as a result of sleep deprivation or disruption of circadian rhythms). It is also used as a synonym for ‘tiredness’ (e.g. after running a marathon or lifting heavy weights). Finally, it is used when referring to the kind of habituation to a mental task that occurs after prolonged execution that manifests itself

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as a desire to do something else. This kind of 'mental fatigue' is task-specific. So, even after driving for many hours, our brain is quite capable of processing the information required to understand a book or enjoy a symphony. Fatigue is usually inferred from its effects: most directly, decline in physical or mental task performance. Like stress, it is a term that is used in everyday life and its value as a scientific construct has long been questioned. Ream and Richardson (1996), offer the following definition, however: Fatigue is a subjective, unpleasant symptom which incorporates total body feelings ranging from tiredness to exhaustion, creating an unrelenting overall condition which interferes with individual's ability to function in their normal capacity.

Fatigue in industrial workers is a multifactorial phenomenon. Workload, length of work shift, extended shift, manual handling of heavy loads are among the better known factors. However, there are demographic factors which may have a significant influence on the perception of fatigue, but to date most publications about fatigue have not referred to this facet of the phenomenon. Authors as Yoshitake (1978), Åhsberg, E., Gamberale, F., and Kjellberg, A. (1997), Åhsberg, E. and Gamberale, F. (1998), Åhsberg (2000), Fürst and Åhsberg (2001), Leung, A., Chan, C., & He, J. (2004), Gonzalez, Moreno, Garrosa, and López (2005), Sebastián, Idoate G., Llano, and Almanzor E. (2008), and Hernandez-Arellano, J.L., Ibarra-Mejia G., and Serratos, J. N. (2013) have focused on dividing the fatigue into dimensions or factors using statistical procedures, and they have not reported results about the influence of demografic factors on fatigue.

Some of the most widely used subjective methods for assessing work-related fatigue are the Swedish Occupational Fatigue Inventory (SOFI) (Åhsberg, Gamberale, and Kjellberg, 1997), and the Occupational Fatigue Exhaustion Recovery scale (OFER) (Winwood and Casalli, 2005). These two questionnaires have shown high levels of internal consistency and structural stability. In the present study SOFI-Spanish (Gonzalez, Moreno, Garrosa, and López, 2005) and OFER-Spanish (Hernández-Arellano, García-Alcaraz, Flores-Figueroa, and Vazquez-Alvarez, 2011) versions are applied. The study's main aim is to widen our understanding on the causes of fatigue, inquiring about demographic factors that may significantly influence the perception of fatigue among CNC lathe operators.

METHODOLOGY

Study design

The study design is non-experimental, descriptive, cross-sectional, and correlational. The survey was applied to workers classified as CNC lathe machine operators in three sites manufacturing automotive parts in Central Mexico. In all cases permission was obtained from the company´s management, and workers were advised of the survey beforehand.

Sample

A sample of 263 workers was obtained from the three sites, using proportional simple random method. Once selected, workers were individually screened for the following inclusion criteria: at least six previous month experience as a CNC lathe operator, no history of musculoskeletal injuries in the past six months, and no history of cardiovascular disease. After being screened and upon accepting to participate, workers signed a consent form which also informed them on the purpose, information to be collected, procedures, risks and benefits, and measures to assure confidentiality.

Survey integration

To conduct the study, a three-part survey instrument was applied. Two sections focused on the assessment of fatigue perception; the third one asked about demographic factors.

The first questionnaire was the SOFI-S (Gonzalez, Moreno, Garrosa, and López, 2005). This is an adaptation and validation of SOFI (Åhsberg, Gamberale, and Kjellberg, 1997) to Spanish language. This instrument was developed to assess fatigue in 5 dimensions: *lack of energy, physical exertion, physical discomfort, lack of motivation and sleepiness*. Each dimension includes 3 items. The extent of fatigue is assessed by adding the values assigned by the subject to the 3 items in each dimension.

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The second section was the Spanish version of the OFER questionnaire, OFER-S (Hernández-Arellano, García-Alcaraz, Flores-Figueroa, and Vazquez-Alvarez, 2011). This is a translation and validation of the OFER questionnaire (Winwood and Casalli, 2005). It was adapted and validated for use in Mexican workers. This instrument assesses three states of fatigue: *acute fatigue*, *chronic fatigue* and *recovery between shifts*. Each state is assessed with 3 items.

The third section included 14 questions about demographic and work factors. Salient among them were gender, age, body weight, stature, marital status, number of economically dependent persons, total length of sleep during a day, length of stay in the firm, seniority in current job, weight of load being handled, educational status and whether the worker holds a second paid job.

Procedure

The survey was applied at each site during off-duty periods. After selection and screening of subjects, trained research assistants administered the instrument. Selected participants were summoned to a meeting room where they were informed about the study and its aims, and further instructed on how to complete the instrument. The research assistant was at hand all the time to answer questions from the subjects. After completing the three sections, every participant received a small present.

Data analysis

Data handling was performed using descriptive analyses. Percentages were estimated for nominal and categorical data; both central tendency and dispersion were estimated for scale data. Reliability and internal consistency were assessed using Cronbach's alpha index, whose values larger than 0.7 indicate that data is reliable (Nunally, 1995; Levy, Varela, and Gonzalez, 2003). The Kayser-Meyer-Olkin (KMO) index was used to check sample adequacy; a value larger than 0.7 indicates that the sample size is adequate, and so factor and structural analyses can be performed (Alvarez, 1995; Pett, Lackey, and Sullivan, 2003). Multivariate Analysis of Variance (MANOVA) was applied to identify the relationship between demographic factors and perceived fatigue. Significance level was set at p= 0.05. SPSS v17.0 software was used.

RESULTS

Two-hundred and sixty three subjects from the three sites were selected and completed the questionnaire; one-hundred and twenty-one were at the constant velocity joint manufacturing facility, one-hundred and twenty-one were involved in camshaft manufacturing, the remaining twenty-one worked at the pistons manufacturing site. The average time to complete the survey was 15 (±3) minutes. There were more males (217) than females (46) in the sample. Most workers held a technician’s qualification (63.1%); only 34.6% had completed high school. Five per cent of the sampled subjects performed also as team leader. The average length of work within the company was 3.5 years. A summary of the full collected information is shown in table 1.

Internal consistency

Internal consistency (Cronbach’s alpha index) and sample adequacy (KMO index) were assessed prior to data analysis proper. For SOFI-S data, Cronbach’s alpha index ranged from 0.558 to 0.885; KMO index ranged from 0.565 to 0.873. For OFER-S data, Cronbach’s alpha index ranged from 0.637 to 0.751; KMO index ranged from 0.756 to 0.803. All calculated values are shown in table 2.

Table 1. Demographic data

Variable			Variable			Variable		
Gender	**N**	**%**	**Age (years)**	**N**	**%**	**Body weight (kilos)**	**N**	**%**
Men	217	82	<20	9	3.4	<60	44	16.7
Women	46	18	21-30	143	54.4	61-70	73	27.8
			31-40	64	24.3	71-80	60	22.8
			41-50	18	6.8	81-90	38	14.4
			>51	3	1.1	>90	20	7.6
			No answer	26	9.9	No answer	28	10.6
Body stature (cm)	**N**	**%**	**Length of stay in the firm (years)**	**N**	**%**	**Seniority in current job (years)**	**N**	**%**
<150	10	3.8	<1	87	33.1	<1	100	38
151-160	42	16	1-3	81	30.8	1-3	69	26.2
161-170	99	37.6	3-6	56	21.3	3-6	45	17.1
171-180	57	21.7	6-9	6	8	6-9	1	0.4
>181	9	3.4	>9	21	4.6	>9	5	1.9
No answer	46	17.5	No answer	12	14	No answer	43	16.3
Number of dependent persons	**N**	**%**	**Marital status**	**N**	**%**	**Work position**	**N**	**%**
0	20	7.6	Single	66	25.1	Operator	250	95
1-2	137	52.1	Married	161	61.2	Operator and team leader	13	5
3-4	73	27.8	Divorced	6	2.3			
>5	11	4.2	Common law marriage	3	1.1			
No answer	21	8	No answer	27	10.3			
Second paid job	**N**	**%**	**Total length of sleep during a day (hours)**	**N**	**%**	**Educational status**	**N**	**%**
Yes	42	16	<5	8	3	Middle School	91	34.6
No	214	81	5-6	74	28.1	High school	86	32.7
No answer	7	3	6-7	76	28.9	Technic degree	80	30.4
			7-8	61	23.2	No answer	5	1.9
			8-9	26	9.9			

			>9	5	1.9			

Table 2. Reliability analysis

Instrument	**Fatigue dimension**	**KMO**	**α**
SOFI-S α: 0.885, KMO: 0.873.	Lack of energy	0.709	0.841
	Physical exertion	0.565	0.558
	Physical discomfort	0.635	0.713
	Lack of motivation	0.633	0.702
	Sleepiness	0.660	0.778
OFER-S α: 0.678 KMO: 0.803.	Acute fatigue	0.756	0.637
	Chronic fatigue	0.756	0.695
	Recovery between shifts	0.756	0.751

α: cronbach alpha index, KMO: Keiser Meyer Olkin index.

Fatigue scores

Mean, median and standard deviation were calculated for dimensions (SOFI-S) and states of fatigue (OFER-S). For the former, minimum value is 3 and maximum is 15; for the latter, minimum value is 15 and maximum is 75. All descriptive measures are shown in table 3.

Table 3. Descriptive results for measured fatigue dimensions and fatigue state

Questionnaire	**Fatigue dimensions**	**Mean**	**Median**	**Std. Dev.**
SOFI-S	Lack of energy	7.95	8	2.71
	Physical exertion	6.71	7	2.26
	Physical discomfort	6.27	6	2.63
	Lack of motivation	6.29	6	2.51
	Sleepiness	5.72	5	2.51
OFER-S	Fatigue states	**Mean**	**Median**	**Std. Dev.**
	Acute fatigue	43.17	40	14.33
	Chronic fatigue	59.07	60	10.87
	Intershift Recovery between shifts	53.52	52	10.20

Relationship between demographic data and fatigue

Multivariate Analysis of Variance (MANOVA) found that the variables *gender, body weight, height, hours of sleep during a day and age* showed significant effects with at least one SOFI-S fatigue dimension ($p<0.05$). The whole results appear in table 4.

Table 4. Demographic and work variables on dimensions of perceived fatigue

Demographics and work variables	**Fatigue dimensions**				
	Lack of energy	Physical exertion	Physical discomfort	Lack of motivation	Sleepiness
Gender	0.005**	0.058	0.060	0.795	0.426
Body weight	0.601	0.334	0.270	0.018*	0.410
Body stature	0.030*	0.140	0.332	0.109	0.206
Number of dependent persons	0.118	0.285	0.524	0.069	0.188
Total length of sleep during a day	0.017*	0.004**	0.001**	0.073	0.000**
Seniority in current job	0.075	0.077	0.342	0.270	0.120
Age	0.136	0.003**	0.329	0.891	0.150

p values are shown in boxes. * is significant using $\alpha=0.05$, ** is significant using $\alpha=0.01$

Multivariate Analysis of Variance (MANOVA) found that the variables *weight of load being handled, gender, total length of sleep during a day, length of stay in the firm* showed significant effects with at least one OFER-S fatigue states ($p<0.05$). Table 5 exhibits the whole results.

Table 5. Demographic and work variables on states of perceived fatigue

Demographic and work variables	**Fatigue states**		
	Acute fatigue	Chronic fatigue	Recovery between shifts
Weight of load being handled	0.010**	0.001**	0.144
Gender	0.748	0.022*	0.864
Total length of sleep during a day	0.128	0.002**	0.760
Length of stay in the firm	0.008**	0.000**	0.019*

p value are shown in boxes. ** are significant using $\alpha=0.01$, * is significant using $\alpha=0.05$.

DISCUSSION

The analysis on the probable relationship between demographic variables and SOFI-S results showed a significant effect of the variables *gender* and *body stature* on the dimension *lack of energy*, with women reporting higher levels. This finding is in line with the fact that female subjects were shorter (and lighter) than males, albeit in the sample they are in a proportion of one to four, respectively. It is difficult to ascertain if the findings would stand in case a larger number of women participated in the study.

It is true as well that the variable *body weight* reached significance against the dimension *lack of motivation*. However, at the moment it is almost impossible to advance a conjecture as to the meaning of this fact. It will obviously be a main focus for attention in future research.

Total length of sleep during a day was certainly the most influential demographic variable. It had a significant effect on four fatigue dimensions: *lack of energy, physical exertion, physical discomfort and sleepiness.* In truth, this is not surprising, and points to the relevance of the subjects having access to conditions that allow them an adequate rest. There is an obvious connection between these relationships and the timing of work shifts, which at the moment of the study were 12 hours long, in a one-week rotation scheme. Clearly, this too affects the workers' performance and limits their possibilities to carry out properly other daily activities. They declared often having to rob time from their rest, which very much explains the extremely strong effect of the variable on the *sleepiness* dimension.

Age had a very significant effect on perceived *physical exertion.* This dimension being more accused as the worker's age increased. This result is to be expected, although it is rather surprising that the increase in age did not seem to affect other physical dimensions as lack of energy or discomfort. Perhaps this might be explained in part by the very poor relationship between *age* and *lack of motivation*, but this is clearly a conjecture that needs to be further explored.

Regarding the relationship between demographic variables and the fatigue states assessed by the OFER-S questionnaire. *The weight of load being handled* had a significant effect on both *acute fatigue* and *chronic fatigue*, these being more accused as the weight increased. This factor is clearly related to a major physical demand, but it is very surprising that the observed effect was not evident on the physical dimensions explored by the SOFI-S instrument. Nonetheless, as has been already pointed out, the two questionnaires have shown high levels of internal consistency and structural stability.

The variable *gender* has a significant effect only on the *chronic fatigue* state. Women report feeling more fatigued than men. However, as has been already said, this apparent effect might be due to the relatively scarce presence of female subjects in the studied sample.

Total length of sleep during a day significantly affected only the *chronic fatigue* state. This is rather surprising, taking account of the very strong effect the same variable had on the fatigue dimensions assessed by the other instrument employed in the study. In considering this fact, we have hypothesised that it might be influenced by the wording employed in the description of the fatigue states. Clearly, this remains to be tested in future research.

The *length of stay in the firm* was a variable with a very significant effect on all three states of fatigue, particularly on *chronic fatigue*. The effect grew stronger with the increase of time spent as an employee in the firm, and this immediately could rise the question as to whether this is rather an effect of age. However, the latter did not reflect on the subjects' perception of fatigue.

CONCLUSIONS

Not only work-related factors as the weight of load being handled, shift length, overall workload are relevant in the investigation of human fatigue; there are other factors that may cause fatigue to workers. Through the results obtained from the performance of Multivariate Analysis of Variance (MANOVA), this study has found that variables as *gender, age, body weight, body stature, total length of sleep during a day* and *length of stay in the firm,* relate to an increased perception of fatigue. *Total length of sleep during a day* was the most significant factor for human fatigue; it showed significant effects on four fatigue dimensions (lack of energy, physical exertion, physical discomfort and drowsiness) and on the chronic fatigue state.

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