Application of Seemingly Unrelated Regression (SUR) in Determination of Risk Factors of Fatigue and General Health among the Employees of Petrochemical Companies

Shahla Heidari[1], MSc;
Sareh Keshavarz[1],
Alireza Mirahmadizadeh[2], MD, MPH, PhD

Abstract

Background: In this cross-sectional study, 501 employees of petrochemical companies were selected by simple sampling method.

Methods: Data were collected using Swedish Occupational Fatigue Inventory (SOFI-20), Occupational Fatigue/Exhaustion Recovery (OFER-15), and General Health Questionnaire (GHQ-28). To identify the factors associated with fatigue and general health, we used ordinary least squares regression (OLS) and SUR and the results were compared. The analysis showed that satisfaction, mental disorder and sleepiness were the important factors associated with fatigue among these workers. However, the SUR estimator provided higher precision of the estimates than the OLS estimator as the parameters obtained by SUR are characterized by lower standard errors. As the models are intended to predict the fatigue risk factors, we particularly focused on the SUR method because it assesses the precision of the model in predicting fatigue determination. SUR estimators performed consistently better than the OLS estimators since SUR takes the correlation between error terms into account.

Results: The findings showed that the study population were young and almost had a low job tenure. The correlation test showed that there was a significant relationship between fatigue and general health with job satisfaction (P=0.05), sleep disorder (P=0.01) and mental disorder (P=0.001). Finally, the analysis showed that fatigue as the result of work was affected by some organizational and individual risk factors, among which "general health status" in general fatigue and "job satisfaction and mental disorders" in mental, physical, shift work, chronic and acute fatigue had the most effect.

Conclusion: The prevalence of fatigue among the study population was assessed high. Thus, elimination and reduction of casual risk factors are necessary to reduce the prevalence of fatigue at work environmental.

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[1]Department of Epidemiology, School of Health, Shiraz University of Medical Sciences, Shiraz, Iran;
[2]Non-communicable Diseases Research Center, Shiraz University of Medical Sciences, Shiraz, Iran

Correspondence:
Alireza Mirahmadizadeh, MD, MPH, PhD;
Department of Epidemiology, School of Heath, Razi Blvd, P.O. Box: 71645-111, Shiraz, Iran
Tel: +98 912 5169146
Fax: +98 71 32347315
Email: mirahmadia@sums.ac.ir
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Introduction

Fatigue is known as a common occupational health problem. Studies have shown that fatigue occurs as a result of physical and mental activities and emotional stresses and depends on environmental and individual factors.[1] It is clear that fatigue in work environment has numerous negative consequences including human error, accident, injury, and performance reduction.[2-4] Despite the above-mentioned contexts and because of the complicated and multi-dimensionality of fatigue phenomenon[5-8] and use of the same words (phrases) for description of different conditions and states, the concept of fatigue is not well defined.[9]

There are various definitions for fatigue. However, fatigue and general health are subjective constructs. Generally, there are different statistical methods for identifying the risk factors. A common feature of the studies published on the prediction of fatigue risk factors is the use of single-equation models. In this approach, several independent equations are estimated separately by ordinary least squares (OLS) and the estimated parameters are used to predict different dimensions of fatigue;[10-12] also, Zellner (1962) developed the co-called "Seemingly Unrelated Regression" (SUR) estimator that accounts for these contemporaneous correlations and allows the p dependent variables to have different sets of explanatory variables.[13, 14] The SUR method estimates the parameters of all equations simultaneously, so that the parameters of each single equation also take the information provided by other equations into account. The determinants of fatigue in the OLS and SUR models were ninety percent of the cases, but they were only different in some of the fatigue bouts. In fact, it can be said that both models are the same for determining the determinants of fatigue and the results are the same. This results in greater efficiency of the parameter estimates because additional information is used to describe the system. These efficiency gains increase with increasing correlation among the error terms of different equations, as well as with larger sample size and higher multi-collinearity between the regressors.[15] In the case of the models for predicting the risk factors of fatigue, the SUR method can be used to estimate all parameters of all equations simultaneously, while the correlations among the fatigue determination are taken into account. However, in spite of these proprieties, the SUR method has (to our knowledge) not yet been used for estimating the fatigue risk factors prediction models. Here, we describe and evaluate the multidimensional fatigue of workers in petrochemical company and investigate the associated factors of fatigue dimensions through two methods (OLS and SUR estimation methods); then, we compare the efficiency of the OLS and SUR estimators.

Methods

In this cross-sectional study, the samples were selected by simple random sampling method from two petrochemical industries at South Persian Zone in the summer of 2015. In this study, 501 employees of petrochemical companies (operational and administrative sections), who were the only employees with a job record were studied for more than a year. Data were collected using Swedish Occupational Fatigue Inventory (SOFI-20), Occupational Fatigue/Exhaustion Recovery (OFER-15), General Health Questionnaire (GHQ-28) questionnaires. SOFI-20 is a multidimensional questionnaire, composed of 20 items[16] in five domains: lack of energy, physical exertion, physical discomfort, lack of motivation, and sleepiness.[17, 18] After coordination, the questionnaires were distributed during the working hours and completion of the questionnaires lasted about 17 minutes. Finally, the questionnaires were collected the next day. The validity and reliability of the translated inventory were examined by confirmatory factor analysis (CFA) and Cronbach's alpha coefficient, respectively. The results of CFA revealed an acceptable fit for the Persian version of SOFI-20. The total Cronbach's alpha coefficient for the SOFI-20 was 0.95. Cronbach's alpha coefficients for different dimensions of the SOFI-20 were found to range from 0.690 to 0.887.[19] The OFER-15 is composed of 15 items in three domains: acute fatigue, chronic fatigue, and occupational recovery.[20] CFA, exploratory factor analysis (EFA) and Cronbach's alpha coefficient were used to determine the validity and reliability of the questionnaire and the results revealed that the Persian version of OFER-15 questionnaire had acceptable reliability and construct validity for assessing the work-related fatigue.[21] The GHQ-28 questionnaire is composed of 28 items in four domains: physical health disorder, insomnia, social disorder, and depression.[22, 23] The results were expressed in mean, standard deviation (SD) and minimum and maximum values, or absolute and relative frequencies, according to the type of the variable. Chi-square test was performed to examine the differences in basic characteristics and the potential-related factors within the two age groups. Analysis of variance (ANOVA) was used to examine the scores of different dimensions of fatigue among the three education groups. For summary measures and initial analysis, the Statistical Package for Social Sciences (SPSS) for Windows (version 19) was used. Univariate analysis was initially performed and all explanatory variables that had a parameter with a marginal level of significance ("P value") larger than 0.25 were removed. Thus, variables that reached a value of $P<0.25$, considered as potential factors, were incorporated into the second phase of analysis, i.e. OLS and SUR estimation methods. In the investigation of possible factors associated with different dimensions of fatigue, socio-demographic and clinical characteristics, as well as reproductive health characteristics of workers were considered as independent variables, while different dimensions of fatigue were considered as dependent variables. The significance level adopted for statistical tests was 5% ($P<0.05$). The statistical analysis system (SAS) for windows software, version 9.2 (SAS Institute Inc, Cary, USA) was used for the second phase of analysis. To explore the associated factors of different fatigue dimensions, OLS regression and SUR were used.

Ordinary Least Squares (OLS)

In this approach, several equations were estimated separately by OLS without taking a potential correlation between these equations into account. Hence, it is implicitly assumed that the error terms are not correlated.[24] However, if the error terms are correlated, as is most likely in the case of fatigue dimensions, the estimation procedure should take this into account.

Seemingly Unrelated Regression (SUR)

Zellner developed the SUR estimator that accounts for these correlations in the error terms and allows different dependent variables to have different sets of independent variables. The SUR method estimates the parameter of all equations simultaneously, so that the parameters of each single equation also take the information provided by the other equations into account.[13] This results in greater efficiency in estimation by combining the information on different equations. These efficiency gains increase with increasing correlation among error terms of different equations, as well as with larger sample size and higher multicollinearity between the independent variables.[14, 15]

The SUR model is a generalization of multivariate regression using a vectorized prarameter model. The OLS estimates are obtained while ignoring any correlation between the error terms of different equations. However, if the error terms are contemporaneously correlated, as is most likely in the fatigue dimension, the estimation procedure should take this into account. In this case, the SUR estimator leads to efficient parameter estimates.[15]

In the present study, the contribution of potentially related factors of different dimensions of fatigue was explored by both OLS and SUR estimation methods, and the efficiency of these two estimators was compared together. The fitting quality of single equations for both OLS and SUR estimators was evaluated by the coefficients of determination of model (R^2), root mean squared errors of the estimate (RMSE), and by standard errors (SE) of the estimated parameters. In the SUR estimation method, the fitting quality of the whole system of equations was evaluated by system weighted MSE and system weighted R^2. The system weighted MSE and R^2 measure the fit of the joint model obtained by stacking all the models together and performing a single regression with the stacked observation weighted by the inverse of the model error variances.[25]

To demonstrate how the SUR model can be used to analyze the associated factors of fatigue, suppose a situation in which we have three independent variables including age, BMI, and income; age and income showed $P<0.25$ in univariate analysis for all dimensions, but BMI exhibited $p<0.25$ only for chronic fatigue dimension. The correctly specified SUR model would be:[24]

$$\text{Physical disorders}=\beta_{01}+\beta_{11}\text{ age}+\beta_{21}\text{ income}+\beta_{31}\text{ BMI}+\alpha_1$$

$$\text{Insomnia}=\beta_{02}+\beta_{12}+\beta_{22}\text{ income}+\alpha_2$$

$$\text{Social disorders}=\beta_{03}+\beta_{13}\text{ age}+\beta_{23}\text{ income}+\alpha_3$$

$$\text{Depression}=\beta_{04}+\beta_{14}\text{ age}+\beta_{24}\text{ income}+\alpha_4$$

These SUR models allow for inclusion of different independent variables in each estimation equation and accounts for the correlation among error terms.[24]

Results

At the first step, reliability and validity of SOFI-20 and OFER-15 were checked using SPSS 19 and SAS 9.2 software. Then, the data were analyzed using SPSS 19 software. As to the normality of data, parametric tests like Independent-sample T test, Chi square and One-way ANOVA were employed. The significance level for determining the fatigue-related factors was set at less than 5%.

The findings showed the study population were young and almost had low job tenure. The results of confirmatory and exploratory analysis showed these tools had acceptable reliability and construct validity in Iranian working population.

Fatigue assessment by SOFI-20 demonstrated that the prevalence of general, mental, physical and shiftwork fatigue was more than 48% at the moderate and more than 25% at the high level. Moreover, the prevalence of chronic and acute fatigue obtained more than 48% and 21%, respectively, by OFER-15. The OLS analysis showed that fatigue related to work was affected by some organizational and individual risk factors, among which general health status in general fatigue and job satisfaction in mental, physical, shiftwork, chronic and acute fatigue had the most effect.

Descriptive Statistics

The mean, standard errors, minimum and maximum along with the correlation coefficients among variables are shown in Table 1. The workers' mean±SD age was 34±7 years. A low percentage of the workers had high school education (37%), while

Table 1: Characteristics of the study participants

Variable	Index		
	min	max	Mean±SD
Age (Year)	22	70	34±7.08
Weight (kg)	46	120	78±11.78
Height (cm)	130	198	174.7±7.3
Body mass index (BMI) Kg/m^2	17.3	39.6	25.5±3.24
Work history in year	1	38	7.4±4.96
Work in day	4	15	11±1.88
Work in week	20	110	71±17.81

63% were undergraduate or had master education. The majority (73%) of the participants were satisfied with their work change. The workers' mean weight was 78±12kg. The mean of the workers' BMI was 25.5±3.2 (kg/m2). Some of the workers reported previous accident (18 %), while most had service charge (70.9 %). The means of work in a day and work in a week were 11±2 (day), 71±18 (week).

Results of OLS and SUR estimations

The estimated parameters and summary statistics based on OLS estimator for different dimensions of fatigue:

For the lack of energy domain of SOFI, digestion disorder, sleepiness, work change purpose and satisfaction and age were the significant factors. Workers with digestion and sleep disorders, work change tendency, dissatisfaction and lower age were positively related to lack of energy domain of fatigue or general fatigue. Lower education level; lower work history; digestion; sleep, mental and breathing disorders; work change tendency; dissatisfaction; and lower age were positively related to physical exertion and discomfort domains of fatigue or physical fatigue.

Participants with higher education level, lower work history, digestion, sleep and breathing disorders, work change, dissatisfaction, and lower age had higher mental fatigue. Having lower education level, lower work history, digestion, sleep and mental disorders, and dissatisfaction were positively related to chronic fatigue of OFER domains. Participants with sleep and mental disorders, work change tendency and dissatisfaction had highly acute fatigue; also, having lower work history, sleep disorder, work change tendency and dissatisfaction were negatively related to occupational recovery domain of fatigue.

For the physical health disorder of GHQ, sleep and mental disorders and previous accident were the significant factors. Mental disorder and shift were positively related to insomnia. Having sleep, mental and breathing disorders and previous accident with social disorder were the significant factors. Finally, having lower work history, migraine, sleep and mental disorders and dissatisfaction were positively related to depression. Table 2 shows the estimated parameters and summary statistics based on OLS estimator for different dimensions of GHQ.

Results of SUR Estimation

The estimated parameters and summary statistics based on SUR estimator for different dimensions of fatigue:

Participants with bachelor or higher education level, public service, digestion and sleep disorders, work change tendency, dissatisfaction and lower age were positively related to lack of energy in these workers or general fatigue. For the physical fatigue, education level, work history, digestion, sleep, mental and breathing disorders, work change tendency, satisfaction, and age were the significant factors. Having higher education level, lower work history, digestion, sleep and breathing disorders, work change, dissatisfaction and lower age were positively related to mental fatigue.

For the chronic fatigue, education level, work history, digestion, sleep and mental disorders and satisfaction were the significant factors. Workers with sleep and mental disorders, work change tendency, no previous accident and dissatisfaction were positively related to acute fatigue. On the other hand, workers who had a work history, no sleep disorder, no work change tendency and satisfaction showed a positive occupational recovery.

Participants with cardiovascular disease, digestion, sleep and mental disorders and previous accident had more physical health disorders. For the insomnia, mental disorder and shift were the significant factors. Sleep, mental and breath disorders and previous accident were positively related to social disorder domains of GHQ. Finally, depression was positively related to having lower work history, migraine, sleep and mental disorders and dissatisfaction. Table 3 shows the estimated parameters and summary statistics based on SUR estimator for different dimensions of GHQ.

Comparison of OLS and SUR revealed that in some cases variables which were significant in the OLS equation became significant in the SUR similarly. However, the SUR estimates provide lower standard errors and, hence, provide more efficient estimates than OLS estimates. The reduction of the

Table 2: Estimation results for determinants of fatigue domains based on OLS estimates

Variables	Domains questionnaire(OLS) 28 -GHQ											
	Physical disorders			Insomnia			Social disorders			Depression		
	Coefficient	t-ratio	SE	Coefficient	t-ratio	SE	Coefficient	t-ratio	SE	Coefficient	t-ratio	SE
Intercept	20.14***	6.61	3.04	14.08***	10.02	1.40	16.27***	5.99	2.71	15.57***	5.69	2.73
Sex	-0.18	-0.28	0.66				-0.50	-0.86	0.59			
Marriage	-0.50	-1.52	0.33									
Education							-0.00	-0.00	0.12	0.03	0.26	0.13
Employment	0.27	1.70	0.15	0.01	0.08	0.14						
Work history	-0.01	-0.54	0.02				0.01	0.65	0.02	-0.06*	-2.37	0.02
Work day	0.05	0.51	0.10				0.13	1.34	0.09			
Work week	-0.01	-0.94	0.01				-0.00	0.83	0.01	-0.00	-0.27	0.00
Overtime	-0.43	-1.50	0.28							0.36	1.39	0.26
Cardiovascular	-1.16	-1.70	0.68				-0.55	-0.88	0.63	-0.55	-0.85	0.64
Digestion	-0.61	-1.73	0.35				-0.30	-0.95	0.32	-0.40	-1.23	0.33
Migraine	0.19	0.43	0.45				-0.28	-0.69	0.41	-1.28**	-3.08	0.41
Sleep	-1.32***	-4.51	0.29				-0.58*	-2.23	0.26	-0.90**	-3.26	0.27
Mental	-2.02***	-5.17	0.39	-1.24***	-3.47	0.36	-0.99**	-2.78	0.35	-1.64***	-4.42	0.37
Breath	-0.59	-1.54	0.38	-0.21	-0.61	0.35	-1.49***	-4.23	0.35	-0.70	-1.94	0.36
Diabetes	1.43	1.03	1.39				-0.06	-0.05	1.26	1.24	0.96	1.30
Work change	-0.50	-1.62	0.31	-0.30	-1.06	0.29	0.00	0.03	0.28	-0.32	-1.09	0.29
Accident	-0.86**	-2.72	0.31	-0.38	-1.30	0.29	-0.74*	-2.57	0.28	-0.32	-1.08	0.30
Shift	-0.18	-0.65	0.28	-0.59**	-2.47	0.24				0.09	0.36	0.27
BMI				-0.06	-1.83	0.03						
Satisfaction	-0.37	-1.73	0.21	-0.21	-1.08	0.19	-0.20	-1.05	0.19	-0.45*	-2.22	0.20
Age	-0.68	-1.02	0.67							-0.12	-0.19	0.64
Model R^2	0.26			0.07			0.17			0.24		
Adjusted model R^2	0.22			0.05			0.14			0.21		
Root MSE	2.42			2.30			2.23			2.31		

*P<0.05; **P<0.01; ***P<0.001

Table 3: Estimation results for determinants of fatigue domains based on SUR estimates

Variables	Domains questionnaire(SUR) -28 GHQ											
	Physical disorders			Insomnia			Social disorders			Depression		
	Coefficient	t-ratio	SE	Coefficient	t-ratio	SE	Coefficient	t-ratio	SE	Coefficient	t-ratio	SE
Intercept	21.96***	7.74	2.83	13.79***	10.65	1.29	18.33***	7.75	2.36	16.47***	6.41	2.57
Sex	-0.54	-0.95	0.56				-0.72	-1.50	0.48			
Marriage	-0.49	-1.76	0.28									
Education							-0.03	-0.36	0.10	0.07	0.63	0.11
Employment	0.19	1.42	0.13	-0.05	-0.45	0.12						
Work history	-0.01	-0.43	0.02				0.02	1.06	0.01	-0.05*	-2.37	0.02
Work day	0.03	0.33	0.09				0.09	1.14	0.07			
Work week	-0.00	-0.87	0.01				-0.00	-0.68	0.00	-0.00	-0.35	0.00
Overtime	-0.48	-1.88	0.25							0.35	1.50	0.23
Cardiovascular	-1.39	-2.17	0.64				-0.88	-1.63	0.54	-0.73	-1.21	0.60
Digestion	-0.68	-2.05	0.33				-0.42	-1.52	0.27	-0.47	-1.52	0.31
Migraine	0.24	0.58	0.42				-0.25	-0.71	0.35	-1.28**	-3.26	0.39
Sleep	-1.24***	-4.52	0.27				-0.52*	-2.30	0.22	-0.84**	-3.25	0.26
Mental	-2.01***	-5.17	0.38	-1.23***	-3.43	0.35	-0.97**	-2.77	0.35	-1.62***	-4.41	0.36
Breath	-0.57	-1.51	38/0	-0.21	-0.61	0.35	-1.45***	-4.17	0.34	-0.67	-1.86	0.36
Diabetes	1.09	0.84	1.30				-0.47	-0.44	1.08	0.88	0.72	1.22
Work change	-0.49	-1.59	0.31	-0.31	-1.07	0.28	-0.00	-0.01	0.28	-0.32	-1.10	0.29
Accident	-0.83**	-2.63	0.31	-0.35	-1.22	0.29	-0.70*	-2.47	0.28	-0.30	-1.03	0.29
Shift	-0.14	-0.56	0.26	-0.62**	-2.95	0.21				0.11	0.49	0.24
BMI				-0.04	-1.64	0.03						
Satisfaction	-0.38	-1.79	0.21	-0.21	-1.10	0.19	-0.20	-1.06	0.19	-0.45*	-2.24	0.20
Age	-0.67	-1.10	0.61							-0.11	-0.20	0.56
Model R^2	0.26			0.07			0.17			0.24		
Adjusted model R^2	0.22			0.05			0.14			0.21		
Root MSE	2.42			2.30			2.23			2.31		

*P<0.05; **P<0.01; ***P<0.001

standard errors through SUR estimation method is especially visible for intercepts in all equations. The SE of these intercepts decreases by6 .4, 16.1, 16.7, 1.1and 15% for lack of energy, physical exertion, physical discomfort, lack of motivation and sleepiness domains; 4.7, 1.8, 8.8% for chronic fatigue, acute fatigue and occupational recovery domains; and 6.9, 7.8, 12.8 and 16.1% for physical health disorder, insomnia, social disorder and depression domains, respectively.

The coefficients of determination of the models (R^2) and RMSE are equal for both OLS and SUR estimators. The highest coefficient of determination is related to sleepiness domain in both OLS and SUR methods (R^2=0.371).

The correlations between the residuals of multivariate model with the SUR estimator indicate that all equations are moderately interrelated. For instance, the second equation (insomnia) is moderately interdependent with the third one (social disorder) (r=0.509). As the OLS approach does not take these interrelationships into account, the OLS estimates should be inefficient (not as precise as possible).

Discussion

Due to its negative impacts on the workers' safety, performance and general health, occupational fatigue has been increasingly considered. Considering the consequences of perceived work-related fatigue, assessing fatigue at workplace is critical to work-related fatigue risk management.[19, 21] Additionally, fatigue and general health are conceptualized as a generic, multidimensional construct in which dimensions of fatigue and general health may be interrelated as they are measured simultaneously. Hence, it might be worthwhile to consider these potential correlations while evaluating the associated factors of different dimensions of fatigue. Two types of estimators known as OLS and SUR can test the associated factors across equations in which SUR may perform better since it takes the correlation between the error terms into account.[24] As different dimensions of fatigue and general health are usually correlated and affected by different variables, it is expected that using the SUR method leads to more efficient estimates. A linear regression model may contain multiple equations that are independent of each other on the surface; they do not estimate the same dependent variable, or they have different independent variables, etc. However, if the equations use the same data, the errors may be correlated across the equations. SUR models are extensions of linear regression models which allow correlated errors between equations. Thus, rather than estimating the equations in the system individually by least-squares methods, more behaviours on SUR models need to be characterized, and various estimation methods and their equivalences are worth considering.[26] The SUR model explains the variation of not just one dependent variable, as in the univariate multiple regression model, but also the variation of a set of m dependent variables.[27]

Multivariate regression requires the design matrix for each of p dependent variables to be the same in form. Zellner (1962) formulated SUR models as p correlated regression equations. SUR models allow each of the p dependent variables to have a different design matrix with some of the predictor variables being the same. Of particular relevance to path analysis, SUR models allow for a variable to be both in the Y and X matrices. SUR models are a flexible analytic strategy.[28] However, in Zellner's study (1962), it was shown that when the error terms are correlated across the equations, the equations are related, and joint estimation, rather than equation-by-equation estimation, leads to more precise estimates of the regression coefficients and predictions of future values of the dependent variables.[27]

The OLS method was used in previous studies of fatigue and general health.[10-12] In these studies, different dimensions of the questionnaire have been considered as dependent variables, evaluating the associated factors of fatigue and general health through multiple linear regression or univariate analysis.[10-12] The linear regression analysis showed that fatigue related to work was affected by some organizational and individual risk factors; "general health status" in general fatigue and "job satisfaction" in mental, physical, shift work, chronic and acute fatigue had the most effect.[10]

This study is a report of using ordinary least squares (OLS) and seemingly unrelated regression (SUR) models to examine the determinants of the risk factors of fatigue and general health. Hence, it is a novel approach used to simultaneously predict the fatigue components using the SUR technique. Among the factors related to fatigue, sleepiness and satisfaction in the SOFI and OFER domains, in GHQ domains mental disorder was associated with all dimensions in both OLS and SUR. Other factors such as digestion, mental and breath disorders, work change purpose, education level, work history and age were the associated factors of different dimensions of fatigue and were not common for all dimensions.

Furthermore, our findings showed that the SUR estimator for multivariate regression analysis, unlike OLS estimator, allows us to estimate multiple models simultaneously while considering the correlated error terms, hence providing more efficient estimated parameters as they considered the interrelationships between the domains. The SUR estimator provides the lowest standard errors of the estimated parameters, and consequently the higher precision of the estimates. Hence, the results of other studies on SUR showed that SUR estimates were consistently better than the OLS (equation-by-equation) estimates since the SUR estimator takes the correlation between the error terms into account.[24, 29]

Also, the determinants of fatigue are almost the same, with a slight difference in the study of the determinants of fatigue. For example, the GHQ questionnaire was the only difference in the dimension of health disorders, which in addition to the same variables in the OLS and SUR models, only cardiovascular and gastroduodenal diseases were significant in the SUR model. Also, noteworthy in the GHQ questionnaire was that in determining the determinants of fatigue, mental disorder was common in all four dimensions of the GHQ questionnaire which indicates that mental status is one of the most important and influential factors in individual fatigue.

Finally, our results revealed that SUR was a robust methodology for predicting the fatigue components. In spite of the elegant properties of the SUR estimator, it is an underused multivariate regression technique, especially for predicting the fatigue risk factors.

Strengths and Limitations

The OLS estimator ignores any correlation among the errors across equations; in this approach, several independent equations for each domain are estimated separately. However, this assumption of independence is not supported for fatigue as responses to different subscales of a fatigue questionnaire could be related due to the similarity of the method to obtain these responses. As different dimensions of fatigue are usually correlated and affected by different variables, the SUR estimators performed consistently better than the OLS estimators since SUR estimator takes the correlation between the error terms into account.

The SUR estimator provided higher precision of the estimates than the OLS estimator, as the parameters obtained by SUR are characterized by lower standard errors. This study presents a novel approach to simultaneously predict fatigue and general health domains using the SUR technique, and the results are relevant for implementing objective fatigue. In spite of the valuable features of the SUR estimator, it is an underused multivariate regression technique for determining the factors associated with fatigue and general health domains.

Conclusion

To identify the associated factors of fatigue dimensions, we used OLS and SUR and the findings were compared. The estimated parameters for these factors were in close agreement in both OLS and SUR estimation methods. The SUR estimator provides the lowest standard errors of the estimated parameters, and thus the highest precision of the estimates. Our results showed that the SUR estimator performed better in predicting fatigue and general health than the OLS estimator. The prevalence of fatigue among the study population was assessed high. Thus, elimination and reduction of casual risk factors are necessary to reduce the prevalence of fatigue at work environments.

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