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Mental Workload, Occupational Fatigue and Musculoskeletal Disorders of Forestry Professionals: The Case of a Loblolly Plantation in Northern Iran

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Abstract

Musculoskeletal disorders (MSD) comprise one of the most important occupational health issues in forestry professions. The purpose of the study was to examine the association among musculoskeletal disorders, anthropometric and personal data, mental workload and occupational fatigue in forest professionals in northern Iran by means of the Nordic Musculoskeletal Questionnaire (NMQ), the National Aeronautics and Space Administration Task Load Index (NASA-TLX), and the Swedish Occupational Fatigue Inventory (SOFI). More than eight out of every ten subjects reported at least one MSD symptom during the past 12 months, with lower back (72.5%), feet and ankles (49%) and neck (41.2%) being the more frequently affected body regions. Similar MSD prevalences were reported for the period of seven days prior to data collection. Both the mental workload (grand mean 73.18±7.54) and occupational fatigue (grand mean 106.20±24.53) achieved high scores. MSD prevalence was found to be correlated with the SOFI score and the NASA-TLX score during the last year and seven days prior to data collection, respectively.

Overall, the study results confirm the very demanding nature of the forest professions, which are characterized by high MSD prevalence, increased occupational fatigue and high mental workload. Given the small-scale forestry characteristics in the study area, taking measures such as introducing vocational training and promoting the use of personal protective equipment are some first necessary steps for the local forestry workforce.

Keywords: motor-manual harvesting, mental strain, SOFI, NASA-TLX, forest operations

1. Introduction

Forest operations are considered to be among the most dangerous jobs in all fields of production (Bentley et al. 2005, Klun and Medved 2007, Lindroos and Burström 2010, Tsioras et al. 2011), with a poor professional profile (Tsioras 2012) and low attractiveness (Egan and Taggart 2004a). Heavy physical work, inappropriate work methods, and techniques combined with inadequate and inappropriate facilities and equipment, result in high prevalence of occupational illnesses and fatigue, as well as low productivity rates. The improvement of safety, health, well-being, and efficiency of the employed workforce is recognized as one of the main preconditions for the development of the forest sector, and the implementation of ergonomic knowledge into practice is the tool to achieve these goals (Zare et al. 2016).

Musculoskeletal disorders (MSD) refer to any type of tissue damage in the skeletal, muscular and/or nervous system that disrupts the function of each of them. These disorders manifest with pain in body regions. Exposure to occupational biomechanical risks often damages tissues such as ligaments, tendons, muscles, and nerves and, in some cases, bones and cartilages. Work-related musculoskeletal disorders are often attributed to workplace ergonomics (Bernard 1997). MSD are very common causes of occupational injuries and disability factors in developing and developed countries (Maul et al. 2003) and they are among the most important issues that ergonomists examine around the world (Vanwonterghem 1996). According to the World Health Organization (2013), among all occupational diseases, work-related MSD rank second in terms of frequency, following respiratory diseases.

Increased prevalence of work-related MSD is directly related to suboptimal ergonomic configuration of the workplace (Kumar 2001). In performing motor-manual work in forest operations, operators are exposed to the increased risks of MSD (Gallis 2006, Grzywiński et al. 2014) due to the specific work postures of such operations (Calvo 2009, Cheța et al. 2018, Corella Justavino et al. 2015). Mechanized forest operations, where operators are not directly exposed to weather conditions or weight lifting, nevertheless, still fail to provide a healthy working environment, by being responsible for high prevalence of MSD in the neck, shoulder and lower back regions (Axelsson and Pontén 1990, Lynch et al. 2014).

The main problem in the prevention of work-related MSD is their multifactorial nature, including physical, organizational, psychosocial, individual and sociocultural factors. One common characteristic among different production sectors is the exposure of the working personnel, in addition to the physical demands of their activities, to factors causing increased psychological pressure. This is also valid for forest operations, which can be easily identified when specific production targets are set (De Souza et al. 2012, Sundström-Frisk 1984). Psychological factors can become very serious, affecting cognitive abilities (i.e. perception and problem solving) through affecting the workers' mental reserves (Bloemsaat et al. 2005, Davis et al. 2002). Although even the definition of mental workload is very difficult (Sharples and Megaw 2015), cognitive disorders that cause mental stress increase the biomechanical response of the musculoskeletal system to physical factors, which can double the risk of musculoskeletal disorders (Habibi et al. 2015).

Increased workload demands can lead to higher worker fatigue. So far, there is a lack of a clearly defined and agreed upon definition of fatigue. This is due to the nature of fatigue as a hypothetical construct, which is inferred because it produces measurable phenomena even though it may not be directly observable or objectively measurable (Williamson et al. 2011). Fatigue is related to lower levels of performance, safety and health (Minette et al. 2016) and consists of a risk factor for musculoskeletal disorders and accidents (Gallagher and Schall Jr 2017). Today, despite the increasing mechanization, work-related fatigue is still a major problem that the forest industry faces. If work-related fatigue is not properly identified, it can lead to chronic occupational problems (Fell 1995). Machine operators are subject to fatigue in the hand and foot area due to repeated control movements resulting in increased risk of MSD (Oliver and Jack 2008). Work fatigue is more pronounced in motor-manual forest operations carried out at steep terrain or, in most cases, in developing countries, where many tasks require increased mechanical effort of the working force, combined with poor working posture (Gallis 2006).

Despite the advances made in wood harvesting systems in the last decades, the level of mechanization of forest operations in northern Iran is relatively low. Generally, forest workers suffer from occupational injuries and MSD (Arman et al. 2019) but more detailed information on this topic is not available. Unfortunately, human factors in Iranian forestry have not been a topic of extensive research so far, despite their widely recognized important role in the quality of wood products and optimal use of machinery (Ergowood 2006). Furthermore, research results originating from similar examinations, performed in other mostly developed countries, cannot be used in Iran, due to the different prevailing ecological and socioeconomic conditions in the northern forested part of the country (Nikooy et al. 2015). This suggests the need for ergonomic research in the Iranian forests with the objective to enrich and clarify the existing conditions and organize targeted interventions.

This study aims to examine, for the first time in Iran, the perceptions of forest professionals concerning (1) the prevalence of musculoskeletal disorders, (2) the mental fatigue and (3) the occupational fatigue levels that they experience. These data have been jointly analyzed with anthopometric and personal information of the study subjects in order:

⇒ to identify in a more holistic way the mechanisms that lead to MSD

⇒ to propose correctional measures to the benefit of the employed workforce.

2. Materials and Methods

2.1 Selection of Participants

The study was carried out in summer of 2018 in a loblolly pine (*Pinus taeda*) plantation with an area of 11,000 ha managed by the Shafarood forest harvesting company, in northern Iran (37°06'44''N, 49°23'31''E), where harvesting operations are carried out throughout the year. A total of 51 forestry male workers employed as tree fellers, skidder drivers and manual loaders were selected to participate. All of them had a work experience of at least one year, in order to satisfy the 12-month recall period required by the NMQ (Gallis 2006). In the past, they had worked in forest operations in natural forests as well and were found to be characteristic of the forest workforce in the area. None of them had previously received any kind of vocational training, as such training has not been offered in Iran, so far.

2.2 Questionnaires

Standardized questionnaires are often used as a scientific tool to obtain interesting and valid insight from the ergonomic standpoint (Beurskens et al. 2000). One of the most extensively used questionnaires in the assessment of work-related musculoskeletal disorders is the Nordic Musculoskeletal Questionnaire (NMQ), often referred to as »Nordic Questionnaire« (López-Aragón et al. 2017). The NASA Task Load Index (NASA-TLX) is another widely used assessment tool (National Aeronautics and Space Administration 2019) in the form of subjective multi-dimensional scale designed to obtain workload estimates from one or more operators while they are performing a task or immediately afterwards (Hart 2006). Finally, the Swedish Occupational Fatigue Inventory (SOFI) has been developed in order to measure work-related perceived fatigue (Åhsberg 2000).

From the above-mentioned indices, NMQ has been the most frequently used questionnaire for data collection in forest professions (Hagen et al. 1997, Hagen et al. 1998, Gallis 2006, Miranda et al. 2002a, Miranda et al. 2001, Miranda et al. 2002b, Østensvik et al. 2009). There are two references regarding the use of NASA-TLX in the forestry sector (Englund 2014, Spinelli et al. 2020) and only one, to our knowledge, of the SOFI (Arman et al. 2021).

In the first part of the research, a set of personal information was asked, in the form of a short questionnaire that was administered by an experienced interviewer. The NMQ, NASA-TLX, and SOFI questionnaires were also used for data collection. Considering that one of the limitations of this research is the self-reporting nature of the questionnaire, responses may be affected by inaccurate answers. Therefore, the participants in this study were assured that the data were confidential and information was provided so that the questionnaires were completed correctly.

2.2.1 Anthropometric and Personal Information

The study participants were asked to fill in information on their age, height, weight, level of education, insurance coverage, smoking habit (or not) and working experience.

2.2.2 Nordic Questionnaire

In the second part, the NMQ questionnaire developed by Kuorinka et al. (1987) was used to determine the prevalence of musculoskeletal disorder symptoms in the participating forest workers. This questionnaire has been used in various similar studies in a large number of production sectors worldwide. The present study was carried out by means of a modified Persian version of this questionnaire, prepared by Choobineh et al. in 2004. The questionnaire is composed of two parts, a general and a specific one. The first part presents an investigation of disorder signs in the whole body, whereas the second part deals with a more detailed analysis of these symptoms in certain areas of the body such as the waist, neck, and shoulders (Choobineh 2004).

2.2.3 NASA-TLX Questionnaire

The NASA-TLX questionnaire was used to determine the individual's mental workload. This index has been widely used for mental workload evaluation from a personal perspective (Noyes and Bruneau 2007). This multi-dimensional process index has different degrees of evaluation and presents a model to estimate the mental workload by using a six-scale self-assessment. This model includes three dimensions of the demands imposed on the worker during the work (mental need, physical need and timing need), and three factors related to the outcome of the work (performance score, level of effort and disappointment score).

The NASA-TLX has been primarily used to measure the individual's mental workload after the completion of a specific task. However, there are also reports of multi-tasking situations where the NASA-TLX has also been implemented (Grier 2015, Chen and Terrence 2008). Our study has been planned in such a way that during the working time of the subjects no tasks, deviating from the typical task for each professions, should be carried out.

This process consists of three steps: the first step is to determine the weight of the load of the six scales. At this stage, all the scales are in pairs, and they are evaluated and selected in 15 different modes by the workers themselves, and then each dimension of the workload is determined between 0 and 1. The second step is to determine the degree the load of each six scales. At this stage, the participant will score each of the six dimensions, based on his working conditions ranging from 0 to 100. It should be noted that for the guidance of the participants, the definitions of these six scales have been given in the questionnaire. In the third step, after determining the weight and degree of load, the final weight, which is between 0 and 100, is obtained by multiplying the two factors. The workload score is evaluated at four levels of low (0–25), moderate (26–50), high (51–75) and very high (76–100) workload. The face validity of NASA-TLX technique has been evaluated and approved in previous studies (Mazloum et al. 2008).

2.2.4 SOFI Questionnaire

The last section of data collection included the Swedish Occupational Fatigue Inventory (SOFI). Designed by Åhsberg in 1998, it has been used in several studies and its validity and reliability have been investigated in various occupations. SOFI was chosen to measure the perceived work-related fatigue of the subjects because of the strength of its theoretical structure, shown in a wide range of studies worldwide. The questionnaire consists of five dimensions: lack of energy, physical discomfort, physical effort, lack of motivation and sleepiness, and each dimension is measured with four items (Åhsberg 2000). Each item is rated by an 11–point Likert scale ranging from 0 (never) to 10 (very high). Occupational fatigue score is evaluated as low (score 0–49), suitable (score 50–99), high (score 100–149) and very high (score 150–200) (Yarmohammadi et al. 2018).

2.3 Statistical Analysis

After filling in the questionnaires, the checklists and all related forms, data analysis was performed with SPSS Ver. 23. The normality of the data was examined by the Shapiro-Wilks test due to the relatively limited sample size of 51, and the homogeneity of variance by the Levene's test. One-way ANOVA analysis of variance and Kruskal-Wallis *H*-test, its non-parametric equivalent, were used to identify statistical differences among the three forest professions in terms of:

⇒ number of MSD affected body regions during the last seven days and 12 months

⇒ dimensions of mental workload

⇒ dimensions of occupational fatigue, depending on whether the data were or not from a normal distribution.

Where significant differences were identified, the Bonferoni post-hoc test and the Mann-Whitney *U*-test were used to identify significant differences between professions. The level of significance was set to a=0.05.

General Linear Models (GLM) were built to detect the effects of subject anthropometric and personal information, individual SOFI and NASA-TLX scores on:

⇒ MSD prevalence during the last year

⇒ MSD prevalence during the last seven days prior to data collection.

Fixed factors included the Age class and the Body Mass Index (BMI) class of the subjects. Continuous variables that were treated as covariates included the number of work experience in years (Experience), the subject's SOFI score (SOFI), and NASA-TLX score (NASA-TLX).

Initially, data were checked for outliers. Full factorial models were formed to examine possible interaction effects on the dependent variables. *F*-tests were conducted to examine the goodness-of-fit of regression models and *t*-tests were used to test the significance of model coefficients. In a second step, insignificant factors were removed in order to create reduced models for predictive purposes of the dependent variables. Validation of model normality and homoscedasticity was obtained graphically.

3. Results

A total of 51 forest workers participated in the study. The average study participant was 43.9±9.80 years old and the most frequent age groups were those of 41–50 (43.1%) and 31–40 (33.3%) (Table 1). The mean BMI was 25.68±3.87, with 45.1%, 39.2% and 13.7% of

Table 1 Anthropometric and personal information of study participants

Variable, unit	Mean (SD)	Range	Distribution
Age group, years	43.98 (9.80)	24–67	<30: 5.9%
			31–40: 33.3%
			41–50: 43.1%
			51–60: 9.8%
			>61: 7.9%
Height group, cm	1.72 (0.06)	155–185	<1.65: 17.6%
			1.66–1.75: 56.9%
			1.76–1.85: 25.5%
Weight group, kg	75.86 (10.95)	55–100	<64.9: 15.7%
			65–74.9: 31.4%
			75–84.9: 29.4%
			85–94.9: 17.6%
			>95: 5.9%
BMI, kg/m^2	25.68 (3.87)	17.76–33.71	<18.5: 2%
			18.5–24.99: 45.1%
			25–30: 39.2%
			>30: 13.7%
Experience, years	15	2–35	1–10: 41.2%
			11–20: 35.3%
			21–30: 19.6%
			>31: 3.9%
Education Level			Not completed high school: 74.5%
			Completed high school: 25.5%
Smoking			Smoker: 64.7%
			Non-smoker: 35.5%
Insurance			Insured: 82.4%
			Not insured: 17.6%

Table 2 Prevalence of musculoskeletal disorders per body region during the last 12 months and the last seven days (n=51)

Body region (L – left, R – right)	Symptoms during the last 12 months	Symptoms during the last 7 days
Neck	41.2%	39.2%
Upper back	23.5%	25.5%
Lower back	72.5%	70.6%
Shoulders (L/R)	15.7/27.5%	9.8/15.7%
Elbows (L/R)	23.5/29.4%	21.6/25.5%
Hand/wrists (L/R)	21.6/35.3%	17.6/31.4%
Hips/thighs (L/R)	7.8%	7.8%
Knees	2%	5.9%
Feet/ ankles	49%	49%

the study participants having a normal weight, being overweight and obese, respectively. The mean working experience was 15±9.36 years and ranged considerably among the subjects (2–39 years). Only one out of every four forest workers (25.5%) had completed high school, 64.7% were smokers and 82.4% were insured.

3.1 Prevalence of MSD Symptoms

Based on the results of the NMQ, 84.3% of the subjects suffered from pain and discomfort at least in one of the nine areas of the musculoskeletal system during the last 12 months and 82.4% during the week prior to the data collection. The prevalence of MSD symptoms varied among the different body regions. The highest frequencies were reported for the lower back (72.5% and 70.6% during the last 12 months and the last seven days, respectively), followed by the unified feet/ankles region (49% in both cases) (Table 2). Another frequently affected region was the neck (41.2% during the last 12 months and 39.2% during the last seven days). Shoulders, elbows, and hands/wrists exhibited MSD prevalences in the range of 15.7–35.3%, and the right part of the body was more affected. Low MSD prevalence was evidenced in the knees (2–5.9%) and the hips/thighs region (7.8% in both cases).

In average, the forest workers suffered from 3.49±2.78 MSD symptoms during the last 12 months and 3.25±2.77 MSD symptoms during the last seven days. More MSD symptoms during the last 12 months were reported by tree fellers (4.31±3.07) than by skidder drivers (2.50±1.99) or manual loaders (2.25±1.90). A Kruskal-Wallis H-test did not reveal any statistical differences among the three professions (χ^2=5.124, df=2, p=0.077). In the case of MSD symptoms during the last seven days, tree fellers were more affected (3.86±3.09) then manual loaders (2.75±2.49) and, finally, skidder drivers (2.29±1.90). These differences were not found to be statistically significant (χ^2=2.782, df=2, p=0.249).

3.2 Mental Workload

The dimensions of »Mental need« (99.12), »Disappointment score« (94.12), »Physical need« (90.98) and »Level of effort« (81.47) had the highest mean scores (Table 3). On the contrary, »Timing need« (11.67) and »Performance score« (7.16) were characterized by low mean scores. Statistically significant differences in terms of mental workload were evidenced among the three professions (χ^2=8.074, df=2, p=0.018). Mann-Whitney pairwise U-tests confirmed that only tree fellers experienced a significantly higher mean mental workload of 75.48 compared to 65.12 experienced by manual loaders (U=36, Z=-2,954, p=0.003). On the contrary, the mean mental workload of 73.02 experienced by skidder drivers was marginally non-significant to that of manual loaders (U=28.5, Z=-1.883, p=0.059).

Further analysis revealed differences in terms of mental workload dimensions. Tree fellers gave higher scores to »Mental need« (99.66) and »Timing need« (13.62), while skidder drivers had the highest »Disappointment score« (94.64). Finally, manual loaders

Table 3 Mental workload dimension statistics per forestry profession (n=51)

	Tree feller (n=29)		Skidder driver (n=14)		Manual loader (n=8)		Total (n=51)	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Mental need	99.66 (1.86)	9–100	98.21 (5.41)	80–100	98.75 (3.54)	90–100	99.12 (3.42)	80–100
Physical need	90.52 (18.63)	20–100	87.14 (27.92)	5–100	99.38 (1.77)	95–100	90.98 (20.32)	5–100
Timing need	13.62 (18.85)	5–100	7.86 (5.79)	5–25	11.25 (7.91)	5–25	11.67 (14.92)	5–100
Performance score	6.90 (8.39)	5–50	5.36 (1.34)	5–10	11.25 (10.94)	5–35	7.16 (7.76)	5–50
Disappointment score	93.79 (12.58)	40–100	94.64 (7.96)	70–100	94.38 (7.76)	80–100	94.12 (10.66)	40–100
Level of effort	81.03 (26.47)	5–100	76.79 (33.60)	5–100	91.25 (13.02)	60–100	81.47 (27.04)	5–100
Mental workload	75.48 (5.66)	63–87	73.02 (8.28)	61–84	65.12 (7.41)	57.66–81	73.18 (7.54)	57.66–87

Table 4 Subjects aggregate listing of occupational fatigue dimensions (n=51)

Dimensions of fatigue	Average	SD	Range
Lack of energy	25.29	7.25	11–37
Analysis and exhaustion	6.72	3.27	0–10
Impatient	4.70	3.02	0–10
Getting out of energy	5.39	3.25	1–10
Over-worked	8.49	1.57	3–10
Physical effort	20.80	9.26	4–39
Heart beat	4.86	3.10	0-10
Sweating	8.98	2.48	1–10
Breathe out	3.21	3.27	0–10
Heavy breathing	3.74	3.49	0–10
Physical discomfort	23.51	9.64	4–40
Having muscular contractions and under pressure	6.86	3.46	0–10
Numb	3.86	3.54	0–10
Having irreparable joints	5.66	3.65	0–10
Having muscle aches	7.11	3.29	0–10
Lack of motivation	17.53	6.06	8–33
Carefree and with worries	4.90	3.29	0–10
Passivity	7.56	2.39	0–10
Indifferent	2.33	2.35	0–9
Uninterested	2.72	2.80	0–10
Sleepiness	19.06	8.80	4–35
Sleep while working	2.84	2.88	0–10
Lethargy	4.54	3.17	1–9
Yawning	6.15	3.66	0–10
Sleepy	5.50	3.53	0–10
Total fatigue score	106.20	24.53	52–151

scored higher in »Physical need« (99.38), »Performance score« (11.25) and »Level of effort« (91.25). Despite the different scores, no statistically significant differences per mental workload dimension were found among the three subject groups.

3.3 Occupational Fatigue

The grand mean of occupational fatigue index was 106.20±24.53 (Table 4). »Lack of energy« (25.29), »Physical discomfort« (23.51), and »Physical effort« (20.80) had the highest means compared to other dimensions. The dimension items »Over-worked«, »Sweating«, »Having muscle aches«, »Passivity« and »Yawning« had the highest mean scores in the respective dimensions.

The occupational fatigue index was slightly higher in manual loaders (110.63) than in tree fellers (107.72) or skidder drivers (100.50), however, these differences were not statistically significant (F=0.554, df=2, p=0.578) (Table 5). Furthermore, no statistical differences were identified among the three professions in terms of individual dimension scores. Tree fellers scored higher in »Physical effort« (21.83) and »Lack of motivation« (18.34) and skidder drivers in »Sleepiness« (21.57). On the contrary, manual loaders scored higher in »Lack of energy« (26.00) and »Physical discomfort« (27.25).

3.4 GLM Analysis of Variance and Prediction Models

The main factors affecting MSD prevalence during the last year (Model 1) were Age class, Profession, Experience and SOFI, with the latter expressing total fatigue (Table 6). The interactions of Age class * Experience, Age class * Profession, Age class * SOFI and SOFI * Experience also increased the predictive power of the model. Tree fellers had more MSD symptoms compared to skidder operators and manual loaders, while increasing work experience and SOFI score seems to

Table 5 Occupational fatigue dimension statistics per profession of study participants (n=51)

	Tree feller (n=29)		Skidder driver (n=14)		Manual loader (n=16)		Total (n=51)	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Lack of energy	25.28^a (7.26)	11–37	24.93^a (8.83)	12–37	26.00^a (4.41)	18–32	25.29^a (7.25)	11–37
Physical effort	21.83^a (9.39)	8–39	18.21^a (9.01)	4–38	21.63^a (9.50)	12–37	20.80^a (9.26)	4–39
Physical discomfort	24.07^a (9.39)	4–40	20.21^a (10.47)	4–36	27.25^a (8.28)	11–38	23.51^a (9,64)	4–40
Lack of motivation	18.34^a (5.54)	9–30	15.57^a (6.56)	8–33	18.00^a (7.03)	8–30	17.53^a (6.06)	8–33
Sleepiness	17.53^a (6.06)	4–32	21.57^a (9.47)	10–35	17.75^a (10.77)	4–34	19.06^a (8.80)	4–35
Total Fatigue	107.72^a (23.36)	72–146	100.50^a (25.71)	52–151	110.63^a (28.12)	66–146	106.20^a (24.53)	52–151

Different letters on the same line denote statistically significant differences at the 0.05 level

Table 6 Analysis of variance table and goodness of fit for GLM examining i) 12-month and ii) seven-day prevalence of musculoskeletal disorder symptoms (MSD)

Model	Dependent variable	Adj. R^2	Source	*SS*	*Df*	*F*	*P*-value	Partial η^2
1	Number of MSD symptoms during last year	0.575	Corrected Model	512.803	21	7.494	0.000	0.663
			Intercept	46.785	1	14.357	0.000	0.152
			Age class	98.344	4	7.545	0.000	0.274
			Profession	133.531	2	20.489	0.000	0.339
			Experience	59.900	1	18.382	0.000	0.187
			SOFI	69.760	1	21.408	0.000	0.211
			Age class * Experience	78.742	3	8.055	0.000	0.232
			Age class * Profession	53.611	4	4.113	0.004	0.171
			Age class * SOFI	35.383	3	3.619	0.017	0.120
			Experience * SOFI	34.210	1	10.498	0.002	0.116
			Error	260.687	29			
2	Number of MSD symptoms during last week	0.672	Corrected Model	587.813	29	8.128	0.000	0.766
			Intercept	10.657	1	4.273	0.042	0.056
			Age class	68.209	3	9.117	0.000	0.275
			BMI class	33.991	2	6.815	0.002	0.159
			Profession	44.588	2	8.940	0.000	0.199
			Experience	31.001	1	12.431	0.001	0.147
			NASA-TLX	21.913	1	8.787	0.004	0.109
			Age class * BMI class	76.323	3	10.201	0.000	0.298
			Age class * Experience	33.586	1	13.467	0.000	0.158
			Age class * Profession	30.104	2	6.036	0.004	0.144
			Age class * NASA-TLX	15.061	1	6.039	0.016	0.077
			BMI class * NASA-TLX	31.844	2	6.384	0.003	0.151
			Profession * NASA-TLX	44.559	2	8.934	0.000	0.199
			Error	179.560	21			

have an additive impact to MSD prevalence during the last year (Fig. 1 and Table 7). The interactions of Age class * Experience and Age class * Profession had the higher effect sizes to the model. More specifically, the larger the experience an individual had that belonged to the Age class <30, the fewer the MSD symptoms he reported. Furthermore, tree fellers having an age up to 30 years seemed to have less MSD symptoms than the other professions. This trend continued, but to a lesser extent, up to the Age class of 41–50.

In the case of MSD prevalence during the last week (Model 2), its magnitude was largely determined by the subject Age class, BMI class, Profession, Experience and mental fatigue, with the latter expressed by means of the NASA-TLX score. Tree fellers and skidder operators reported less MSD symptoms compared to manual loaders (Fig. 2). The impact of Age class was more pronounced for the Age groups 31–40 and 41–50 (Table 8). Normal BMI subjects seem to suffer from fewer MSD symptoms during the last week compared to other BMI class subjects. Furthermore, low BMI subjects belonging to Age groups 31–40 and 41–50 seem to benefit most.

It should be noted that NASA-TLX interactions with Age class, BMI class and Profession were also found statistically significant. The interactions Age class * BMI class and Profession * NASA-TLX had the highest effect sizes to the model. Increasing

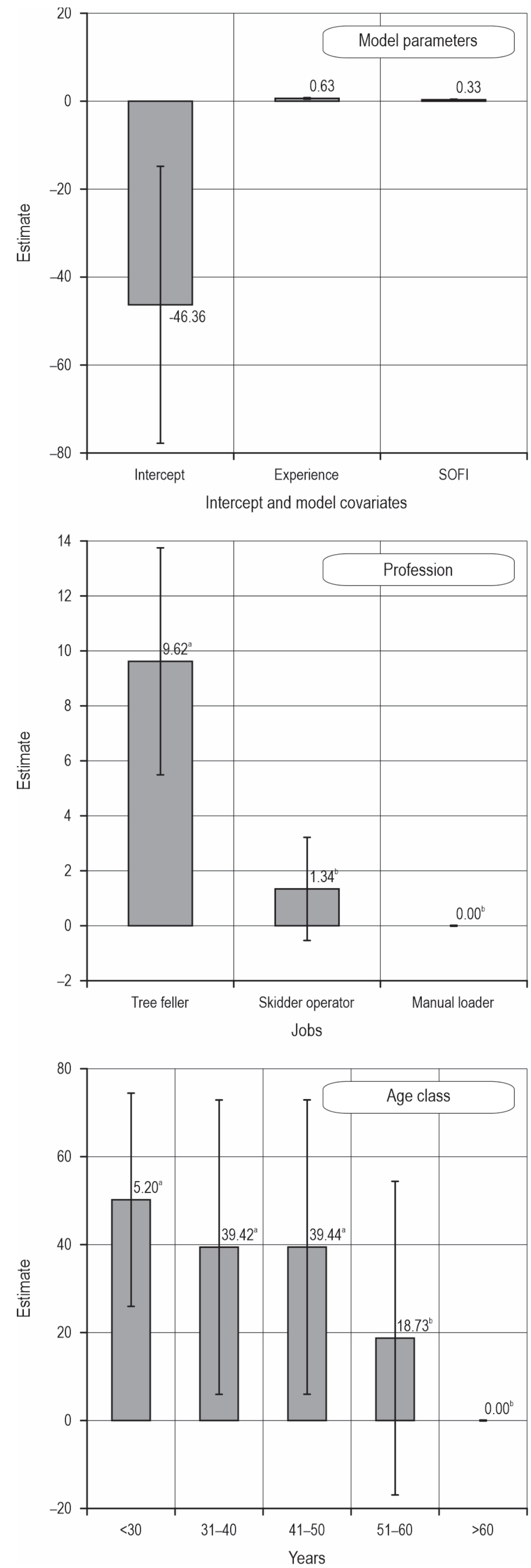

Fig. 1 Model 1 parameter estimates

NASA-TLX score resulted in slightly higher MSD prevalence in tree fellers and skidder operators compared to manual loaders.

4. Discussion

4.1 Limitations of the Study

The current study aimed to investigate the prevalence of musculoskeletal disorders in different forestry professions and their relationship with demographic and employment characteristics, mental workload and occupational fatigue. For this purpose, the prevalence of musculoskeletal disorders was examined by using the NMQ, and related risk factors were extracted by using the NASA-TLX and SOFI methodologies.

A weakness of this study is the relatively limited number of subjects. This is largely due to the prohibition of harvesting activity in natural forests in Iran for a period of five years, commencing from 2018, our predefined data collection period. As a result, our study was limited to plantation forests where only a small portion of the Iranian forest workforce is employed. A second major difficulty that we encountered was the unwillingness of some forest workers to participate, as they have not done so in the past. Finally, the study participants were asked to provide their answers to four questionnaires, which demanded from them to spend considerably more time than for completing only one questionnaire instead. This has inevitably led to a number of incomplete questionnaires that were excluded from further analysis.

Furthermore, in similar studies the reported results often refer to modified versions of the NMQ, enriched with extra questions by the researchers to focus on a specific, in most cases, body region. This approach may be suggested for body region specific MSD prevalence but, at the same time, this makes any comparison among different studies impossible. For example, although Grzywiński et al. (2016) justified and suggested the inclusion of information on subjects' handedness, this information is not available across all studies on MSD prevalence in forest professions.

4.2 MSD Prevalence

MSD prevalence is very high with more than 84.3% of the study participants suffering from at least one musculoskeletal disorder in at least one body region during the last 12 months. This rate is among the highest in similar studies but lower than the rate of 94% reported by Grzywiński et al. (2016) for professional loggers in Poland. MSD symptoms in a single body region have been reported by 13.7% of the study

Table 7 Parameter estimates for Model 1 (dependent variable: subject MSD prevalence during the last year)

Parameter	*B*	*Std. Error*	*t*	*Sig.*	95% Confidence Interval		Partial η^2
					Lower Bound	Upper Bound	
Intercept	–46.364	16.730	–2.771	0.007	–79.66	–13.07	0.088
Age: <30	50.201	12.182	4.121	0.000	25.96	74.45	0.175
Age: 31–40	39.417	16.828	2.342	0.022	5.93	72.90	0.064
Age: 41–50	39.444	16.827	2.344	0.022	5.96	72.93	0.064
Age: 51–60	18.733	17.921	1.045	0.299	–16.93	54.40	0.013
Age: 60<	0	–	–	–	–	–	–
Profession: Tree feller	9.620	2.076	4.634	0.000	5.49	13.75	0.212
Profession: Skidder operator	1.338	.944	1.418	0.160	–0.54	3.22	0.025
Profession: Manual loader	0[a]	–	–	–	0.00	0.00	–
Experience	.632	.174	3.641	0.000	0.29	0.98	0.142
SOFI	.325	.129	2.513	0.014	0.07	0.58	0.073
[Age: <30] * Experience	–2.056	.437	–4.710	0.000	–2.92	–1.19	0.217
[Age: 31–40] * Experience	–.189	.101	–1.865	0.066	–0.39	0.01	0.042
[Age: 41–50] * Experience	–.193	.092	–2.095	0.039	–0.38	–0.01	0.052
[Age: 51–60] * Experience	.208	.110	1.893	0.062	–0.01	0.43	0.043
[Age: 60<] * Experience	0[a]	–	–	–	–	–	–
[Age: <30] * [Profession: Tree feller]	–38.564	8.406	–4.588	0.000	–55.29	–21.84	0.208
[Age: <30] * [Profession: Skidder operator]	0[a]	–	–	–	–	–	–
[Age: 31–40] * [Profession: Tree feller]	–7.279	2.323	–3.134	0.002	–11.90	–2.66	0.109
[Age: 31–40] * [Profession: Skidder operator]	–.900	1.400	–.643	0.522	–3.69	1.89	0.005
[Age: 31–40] * [Profession: Manual loader]	0[a]	–	–	–	–	–	–
[Age: 41–50] * [Profession: Tree feller]	–8.095	2.258	–3.586	0.001	–12.59	–3.60	0.138
[Age: 41–50] * [Profession: Skidder operator]	0[a]	–	–	–	–	–	–
[Age: 41–50] * [Profession: Manual loader]	0[a]	–	–	–	–	–	–
[Age: 51–60] * [Profession: Tree feller]	–5.965	2.384	–2.502	0.014	–10.71	–1.22	0.073
[Age: 51–60] * [Profession: Manual loader]	0[a]	–	–	–	–	–	–
[Age: 60<] * [Profession: Tree feller]	0[a]	–	–	–	–	–	–
[Age: 60<] * [Profession: Manual loader]	0[a]	–	–	–	–	–	–
[Age: <30] * SOFI	0[a]	–	–	–	–	–	–
[Age: 31–40] * SOFI	–.247	.130	–1.898	0.061	–0.51	0.01	0.043
[Age: 41–50] * SOFI	–.245	.130	–1.880	0.064	–0.50	0.01	0.042
[Age: 51–60] * SOFI	–.123	.137	–.898	0.372	–0.40	0.15	0.010
[Age: 60<] * SOFI	0[a]	–	–	–	0.00	–	–
Experience * SOFI	–.004	.001	–3.240	0.002	–0.01	0.00	0.116

[a] This parameter is set to zero because it is redundant

participants, in two by 11.8%, in three by 9.8% and in four body regions, which was the most frequent case, by 17.6%. The respective rates reported by Grzywiński et al. (2016) were 6.1%, 9.3%, 12.8% for one, two and three body regions. While in our study, 52.9% of the subjects reported up to four affected body regions in the last 12 months, in the study of Grzywiński et al. (2016) the situation is reversed, with 65.2% of the subjects suffering from at least four MSD.

The distribution of affected body regions varies among similar studies. An earlier but very broad survey was carried out in Sweden from 1980 to 1987, with

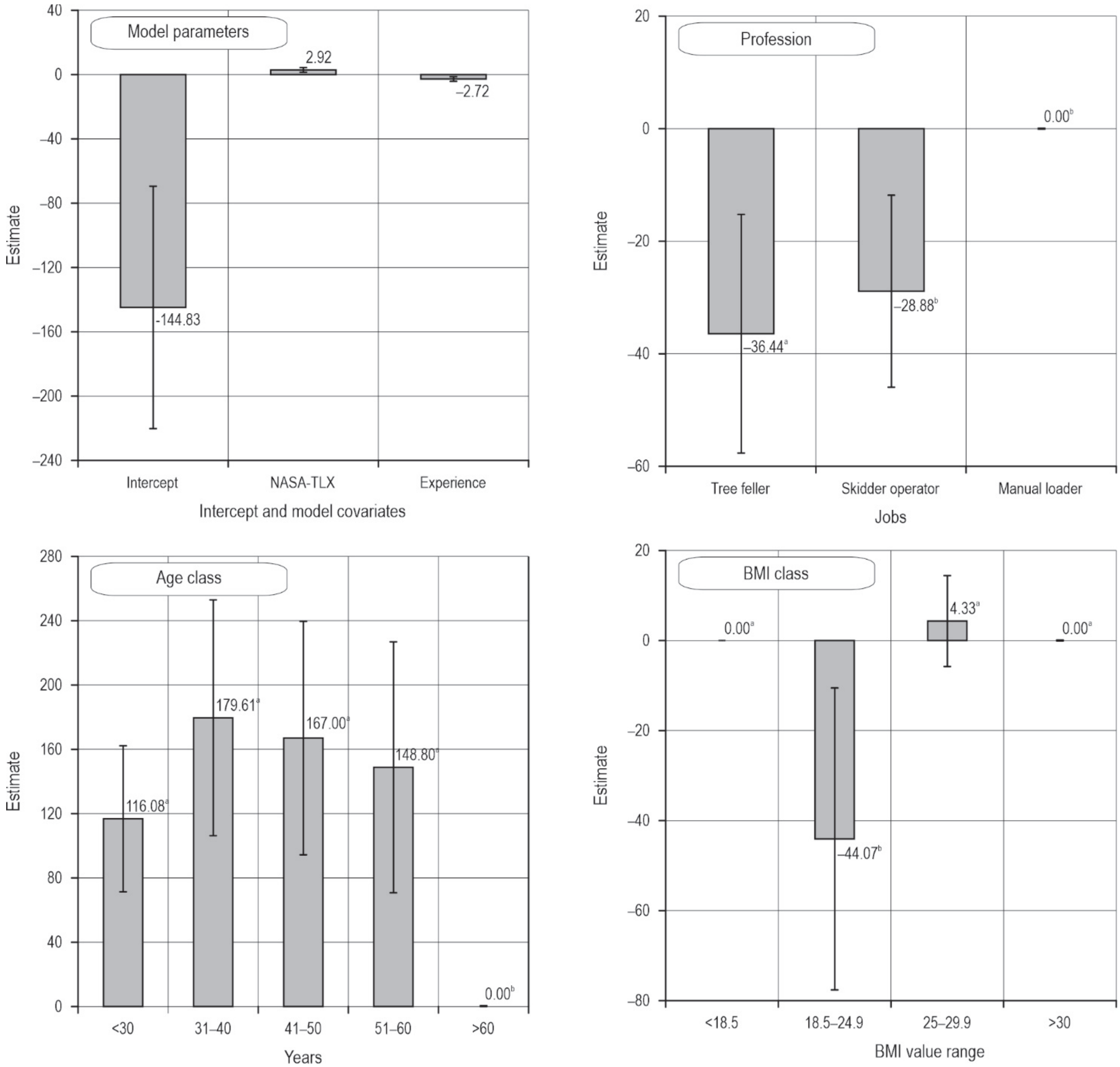

Fig. 2 Model 2 parameter estimates

the participation, among others, of 3600 chainsaw operators (Pontén 1988). According to the results of this study that often serve as a comparison baseline, out of every ten chainsaw operators, five had complains in the lower back and two in the shoulders, two in the knees and two in the hips body regions. Our results are in line with the previous study in respect to the shoulders region, however, differ considerably in some areas, most notably in the neck (four out of ten), hips and thighs (less than one out of ten) and knees (only 2%). Our results are closer to those reported by Gallis (2006) especially with regard to the lower back region (eight out of ten) and the neck region (four out of ten) but differ widely in the remaining body regions.

The hips and thighs region of the Iranian forest workers were found to be considerably less affected than those of their Swedish, Polish or Greek counterparts, especially during the 12 months preceding the data collection. Only in one case, in that of MSD prevalence in the hips and thighs regions during the last seven days, the rates between the Iranian and Polish forest workers are identical. Finally, a very sensitive area of the Iranian subjects seems to be the feet and ankles region where almost every second forest

Table 8 Parameter estimates for Model 1 (dependent variable: subject MSD prevalence during the last seven days prior to data collection)

Parameter	*B*	*Std. Error*	*t*	*Sig.*	95% Confidence Interval		Partial η^2
					Lower Bound	Upper Bound	
Intercept	–144.83	37.80	–3.83	0.000	–220.19	–69.47	0.17
Profession: Tree feller	–36.44	10.74	–3.39	0.001	–57.85	–15.02	0.14
Profession: Skidder operator	–28.88	8.56	–3.37	0.001	–45.94	–11.82	0.14
Profession: Manual loader	0[a]	–	–	–	–	–	–
Age: <30	116.08	22.72	5.11	0.000	70.78	161.37	0.27
Age: 31–40	179.61	36.78	4.88	0.000	106.30	252.92	0.25
Age: 41–50	167.00	36.39	4.59	0.000	94.47	239.54	0.23
Age: 51–60	148.80	39.13	3.80	0.000	70.79	226.82	0.17
Age: 60<	0.00	–	–	–	–	–	–
BMI: <18.5	0.00	–	–	–	–	–	–
BMI: 18.5–24.9	–44.07	16.84	–2.62	0.011	–77.64	–10.50	0.09
BMI: 25–29.9	4.33	5.06	0.86	0.395	–5.76	14.43	0.01
BMI: 30<	0.00	–	–	–	–	–	–
NASA-TLX	2.92	0.71	4.13	0.000	1.51	4.33	0.19
Experience	–2.72	0.75	–3.64	0.001	–4.20	–1.23	0.16
[Age: <30] * Experience	–6.95	1.32	–5.27	0.000	–9.57	–4.32	0.28
[Age: 31–40] * Experience	2.93	0.75	3.92	0.000	1.44	4.43	0.18
[Age: 41–50] * Experience	2.71	0.75	3.62	0.001	1.21	4.20	0.15
[Age: 51–60] * Experience	0.75	0.23	3.31	0.001	0.30	1.20	0.13
[Age: 60<] * Experience	0[a]	–	–	–	–	–	–
[Profession: Tree feller] * [Age: <30]	–189.76	35.85	–5.29	0.000	–261.23	–118.29	0.28
[Profession: Tree feller] * [Age: 31–40]	–10.09	4.85	–2.08	0.041	–19.76	–0.43	0.06
[Profession: Tree feller] * [Age: 41–50]	–1.78	4.78	–0.37	0.711	–11.31	7.75	0.00
[Profession: Tree feller] * [Age: 51–60]	27.57	6.68	4.13	0.000	14.26	40.88	0.19
[Profession: Tree feller] * [Age: 60<]	0[a]	–	–	–	–	–	–
[Profession: Skidder operator] * [Age: <30]	0[a]	–	–	–	–	–	–
[Profession: Skidder operator] * [Age: 31–40]	–8.24	2.38	–3.46	0.001	–12.99	–3.49	0.14
[Profession: Skidder operator] * [Age: 41–50]	0[a]	–	–	–	–	–	–
[Profession: Manual loader] * [Age: 31<][†]	0[a]	–	–	–	–	–	–
[Age: <30] * NASA-TLX	0[a]	–	–	–	–	–	–
[Age: 31–40] * NASA-TLX	–3.41	0.70	–4.90	0.000	–4.80	–2.02	0.25
[Age: 41–50] * NASA-TLX	–3.26	0.70	–4.68	0.000	–4.64	–1.87	0.23
[Age: 51–60] * NASA-TLX	–2.40	0.60	–3.97	0.000	–3.60	–1.19	0.18
[Age: 60<] * NASA-TLX	0[a]	–	–	–	–	–	–
[Profession: Tree feller] * NASA-TLX	0.61	0.14	4.22	0.000	0.32	0.90	0.20
[Profession: Skidder operator] * NASA-TLX	0.48	0.14	3.52	0.001	0.21	0.75	0.15
[Profession: Manual loader] * NASA-TLX	0[a]	–	–	–	–	–	–
[Age: <30] * [BMI: <29.9][†]	0[a]	–	–	–	–	–	–
[Age: 31–40] * [BMI: 18.5–24.9]	66.88	16.36	4.09	0.000	34.26	99.49	0.19
[Age: 31–40] * [BMI: 25–29.9]	3.15	1.45	2.17	0.034	0.25	6.05	0.06
[Age: 31–40] * [BMI: 30>]	0[a]	–	–	–	–	–	–

Parameter	*B*	*Std. Error*	*t*	*Sig.*	95% Confidence Interval		Partial η^2
					Lower Bound	Upper Bound	
[Age: 41–50] * [BMI: 18.5–24.9]	60.74	16.52	3.68	0.000	27.81	93.67	0.16
[Age: 41–50] * [BMI: 25>][†]	0[a]	–	–	–	–	–	–
[Age: 51–60] * [BMI: All BMI groups] [†]	0[a]	–	–	–	–	–	–
[Age: 60<] * [BMI: 18.5–29.9] [†]	0[a]	–	–	–	–	–	–
[BMI: <18.5] * NASA-TLX	0[a]	–	–	–	–	–	–
[BMI: 18.5–24.9] * NASA-TLX	–0.25	0.07	–3.27	0.002	–0.39	–0.10	0.13
[BMI: 25–29.9] * NASA-TLX	–0.07	0.07	–1.00	0.319	–0.21	0.07	0.01
[BMI: 30<] * NASA-TLX	0[a]	–	–	–	–	–	–

[a] This parameter is set to zero because it is redundant, [†] Merged groups of second interaction term having the same parameter estimate

worker has a history of musculoskeletal discomfort. This rate is by far the highest for this body region with regard to MSD prevalence in the existing literature, where rates of up to 30% are to be expected (Grzywiński et al. 2016, Gallis 2006).

The highest frequency of disorders is identified in the lower back, a body region that is especially affected in forestry professions, especially where lifting of heavy objects, such as the chainsaw or logs, is part of the profession (Gandaseca and Yoshimura 2001). Our finding is in line with the previous studies of Choina et al. (2018) and Gallis (2006), who also reported the highest incidence of musculoskeletal disorders in the lower back area. Manual loading is associated with excessive bending and muscular exertion that primarily affect the lower back region (Verbeek et al. 2012). Tree fellers are the second professional group with frequent MSD symptoms in the lower back. This is due to the awkward postures, the static load connected with chainsaw operation and the lifting of heavy weights that is often needed. Bad working postures can be linked with MSD symptoms (Vieira and Kumar 2004) and in the case of forestry these are more frequent during tree felling than in any other operation (Grzywiński 2011). The introduction of modern machinery in forest operations has increased productivity rates, however never solved MSD problems of their operators (Attebrant et al. 1997) Hanse and Winkel (2008) neither in lower back nor in other body regions. Phairah et al. (2016) have also reported higher prevalence in the lower back body region in forestry machine operators, however, the distribution of symptoms per body region differed compared to those of our study. This could be attributed to the different physiological demands in various industries or even professions in one industry, as in our case (Rowshani et al. 2013).

Almost every second subject in our study had MSD symptoms in the feet and ankles body region. The rate of 49% exceeds by far the findings of similar researches in the forestry sector. The respective prevalence frequency reported by Gallis (2006) was in the range of 30% both in the last 12 months and last seven days preceding data collection. This high prevalence may be attributed to the bad footwear used by the forest workers as they pay low attention to this part of their equipment. However, footwear quality has been recognized as an important risk factor in terms of MSD prevalence in the foot ankle area (Anderson et al. 2017a) and accident prevention (Kirk and Parker 1994). Furthermore, footwear is the only interface between the standing body and the ground, and, inevitably, its features influence the forces acting through the body, posture and movement. Thus, good quality footwear can reduce the risk for future MSD not only in the foot/ankle area but also in higher body regions (Anderson et al. 2017b). Interestingly, our findings report very low MSD prevalence in the knees and hips and thighs areas, ranging from 2 to 7.8%, whereas prevalence higher than 20% (Grzywiński et al. 2016) or even up to 60% (Gallis 2006) has been reported. This point suggests more investigation in the future.

The neck area was the third most frequently affected body region with MSD prevalence in four out of every ten subjects and was followed by upper limbs disorders in three out of every ten cases. Chainsaw operation, especially for prolonged periods, causes a high static load on the muscles of the upper limbs due to the holding of the tool, and a dynamic load resulting from its operation (Grzywiński et al. 2016). Furthermore, the tree feller is exposed to hand-arm vibrations, which accelerate the development of MSD of the upper limbs, in particular the hands and wrists (Bovenzi et al. 1991).

In all cases the right part of the body was more affected than the left part both during the last 12 months and during the last seven days. This finding was expected due to the right handedness of most workers. These rates are lower than those reported by (Gallis 2006) and relatively close to those by Grzywiński et al. (2016) with the exception of the hands and wrists region. For this region, 51% of Polish and 64.1% of Greek forest workers have reported discomfort during the past 12 months. These differences may be attributed to the different types of equipment used as well as the aggregate of working hours in the period of a working year. However, further analysis is not possible due to lack of more elaborate data.

The initial statistical analysis indicated relatively weak correlations between the prevalence of musculoskeletal disorders per subject and certain demographic and employment characteristics of the study participants. MSD symptoms frequency during the past 12 months was only weakly correlated with subjects' age and work experience. These demographic characteristics were also correlated with MSD symptoms frequency during the last seven days, with the addition of subjects' weight. Similar studies have linked increasing age, weight and work experience as important factors that can increase MSD prevalence. Increased work experience has been linked with increased osteoporosis and bone mass loss and decreased tendon and muscle stimulation at older ages (Ferrucci et al. 2014). These natural aspects of the ageing process combined with the accumulation of traumas during the working life may result in higher MSD prevalence in forest professions (Hagen et al. 1998, Grzywiński et al. 2016, Axelsson and Pontén 1990, Lynch et al. 2014). However, Marras (2012) has questioned this trend on the basis of the different genetic material of the examined subjects and the multifactorial and complex nature of MSD prevalence. Hence, there are cases in the relevant literature where increasing age was not associated with higher muscular discomfort (Østensvik et al. 2009), or younger workers suffered more (Phairah et al. 2016).

Another finding is the weak correlation of subjects' weight with MSD prevalence. Generally, weight gain can be a cause of musculoskeletal pains, especially in the lower back, legs and knees. Maintaining normal body weight reduces pressure on the spine, and extra weight applies a pressure on the vertebrae that can cause chronic spasms in the waist area. On the contrary, our finding may be due to the fact that only 13.7% of the subjects were obese and 45.1% had moderate weight. Similarly, other risk factors such as smoking (Bos et al. 2006, Boshuizen et al. 1993), lack of insurance (Lotfalian et al. 2012) and educational level did not have a strong association with MSD prevalence in our subjects. The forest workers in our case did not have any kind of vocational education. Thus, the lack of association between the level of MSD prevalence and the level of general education cannot be characterized as unexpected. Nevertheless, vocational training can make an important difference in the promotion of safety and health in forest operations (Tsioras 2012, Axelsson and Pontén 1990).

4.3 Association of Mental and Occupational Fatigue with MSD Prevalence

The results of the NASA-TLX show that the mean mental workload of workers (73.18) is at a high-risk level (Tynkkynen 2001, Mazloumi et al. 2014, Haghi et al. 2016, Arghami et al. 2015). Tree fellers and skidder drivers had higher mental workload compared to manual loaders, an expected result as they have to take more decisions and they use equipment that requires special skills. This is depicted in their high scores in »Mental need« and »Timing need« for the first group and in »Disappointment score« in the second group. On the contrary, manual loaders realize their profession as one of increased »Physical need« and »Level of effort«.

Many factors contribute to mental fatigue. An earlier study by Lotfalian et al. (2012) provides very interesting background information on the working conditions in the area. More than half of forest operators (57.4%) and skidder operators (53.7%) were found to experience increased levels of mental stress. A wide range of factors contributed to this result, such as the lack of satisfactory compensation, exposure to high noise levels during work and high disappointment levels or even insecurity regarding their future employment. The »Disappointment score« dimension was very high in all three forest professions with rates close or exceeding 95%. Disappointment is a common feature of forest workers in many countries such as Indonesia (Gandaseca and Yoshimura 2001), Turkey (Yoshimura and Acar 2004) and Greece (Tsioras 2012). Lack of insurance has been previously linked with job dissatisfaction by Lotfalian et al. (2012).

Hagberg et al. (1995) defined the psycho-organizational factors as »the worker's subjective perceptions of organizational factors, which in turn are the objective aspects of how the work is organized, supervised and carried out«. When the worker feels that he is not able to cope with the work demands, he perceives increased psychosocial job stress connected to increased prevalence of MSD (Hagen et al. 1998). Thus, Malchaire et al. (2001), after conducting a wide cross-sectional study, as well as Hagen et al. (1998), after examining a cohort of forestry workers, strongly suggest that more attention should be given to psychosocial and psycho-organizational factors in future MSD-related research. Furthermore, Malchaire et al. (2001) questions the inclusion of very common factors, such as the subjects' weight in similar research.

The mean occupational fatigue value of 106.20 suggests a high-risk level. All professions exceed the threshold value of 100, suggesting high risk occupations, with »Lack of energy« and »Physical discomfort« having the highest scores. It should be noted that mental workload levels and occupational fatigue are also associated. Occupational fatigue and high workload of workers cause physiological response to muscular tension and ultimately discomfort in the body (Bos et al. 2006, Arellano et al. 2015). Furthermore, workers in physically demanding and dangerous professions that get little compensation may experience low job satisfaction (Gandaseca and Yoshimura 2001), which can be a reason for depression and even loss of function (Yarmohammadi et al. 2018).

Analysis has shown that MSD prevalence during the last year is associated with the SOFI score, while its value during the last seven days prior to data collection is associated with the NASA-TLX score. Arman et al. (2021) have demonstrated a connection between net productivity and SOFI under similar working conditions in the same area. Unfortunately, our data does not allow for further analysis, as our study did not focus on time studies. One possible explanation could be that the mental strain potentially affects the forestry professionals whereas occupational fatigue is more pronounced in longer periods of time. However, further analysis with larger sample size should be carried out to verify this hypothesis.

Organizational changes and ergonomic improvements that will lower the disappointment rates are imperative. Such measures along with strengthening labor law enforcement are expected to increase job safety and improve the working conditions. The development of a well-adjusted payment system is a precondition for recruitment of forest personnel, which has also been connected with decreased accident rates and lower frequency of work-related illnesses (Toupin et al. 2007). An increase in job satisfaction of the forest workforce is necessary, because otherwise there will be difficulty in finding workers to carry out the forest operations in the study area, as it has been reported in other countries (Jacob et al. 1994, Egan and Taggart 2004b, Tsioras 2010). Policy measures can increase job satisfaction (Cubbage et al. 2007) and also lower the physiological demands for the same tasks. Incentives for equipment acquisition may help replace older equipment with newer one that is less physically demanding and can increase work productivity. Finally, special attention should be given to the transfer and development of new skills and dexterities of the workforce, which can be done by providing a well-organized vocational training system and specialized seminars on forest operations topics.

5. Conclusion

The purpose of the study was to investigate the prevalence of MSD and assess mental and occupational workload in three forest professions in northern Iran. The three most affected body regions were the lower back, feet and ankles and neck. These results are partially in accordance with the aforementioned studies that are cited in the paper and the identified differences, as in the case of feet and ankles regions, may be attributed to the prevailing local conditions. Furthermore, the study subjects had high levels of mental workload and occupational fatigue.

Given the physically and mentally demanding nature of the three examined professions, organizational and ergonomic improvements are deemed necessary. More attention should be given to the improvement of the working conditions, such as the development of a better compensation that will lower the high disapointment rates and the respective job-related stress. The implementation of policy measures should aim at higher mechanization rates of forest operations that will lower the need for manual loading. Furthermore, in terms of providing better ergonomic conditions, a new vocational system should be introduced focusing on the needs of the workforce and forest management in the area.

Methodologies such as the NMQ, NASA-TLX, and SOFI that have been widely implemented in other production sectors to determine the risk of musculoskeletal disorders can also be used in forest operations and provide reliable results. This study represents an effort to combine prevalence rates and index scores, collected by these methodologies, with anthropometric and personal data. Similar approaches can be accompanied by higher exploratory power, contributing to better understanding of the multifactorial nature of MSD prevalence in working populations.

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Appendix

Table A1 Parameter estimates for Model 1 (dependent variable: subject MSD prevalence during the last year)

Parameter	*B*	*Std. Error*	*t*	*Sig.*	95% Confidence Interval		Partial η^2
					Lower Bound	Upper Bound	
Intercept	–46.364	16.730	–2.771	0.007	–79.66	–13.07	0.088
Age: <30	50.201	12.182	4.121	0.000	25.96	74.45	0.175
Age: 31–40	39.417	16.828	2.342	0.022	5.93	72.90	0.064
Age: 41–50	39.444	16.827	2.344	0.022	5.96	72.93	0.064
Age: 51–60	18.733	17.921	1.045	0.299	–16.93	54.40	0.013
Age: 60>	0	–	–	–	–	–	–
Profession: Tree feller	9.620	2.076	4.634	0.000	5.49	13.75	0.212
Profession: Skidder operator	1.338	.944	1.418	0.160	–0.54	3.22	0.025
Profession: Manual loader	0[a]	–	–	–	0.00	0.00	–
Experience	.632	.174	3.641	0.000	0.29	0.98	0.142
SOFI	.325	.129	2.513	0.014	0.07	0.58	0.073
[Age: 21–30] * Experience	–2.056	.437	–4.710	0.000	–2.92	–1.19	0.217
[Age: 31–40] * Experience	–.189	.101	–1.865	0.066	–0.39	0.01	0.042
[Age: 41–50] * Experience	–.193	.092	–2.095	0.039	–0.38	–0.01	0.052
[Age: 51–60] * Experience	.208	.110	1.893	0.062	–0.01	0.43	0.043
[Age: 60>] * Experience	0[a]	–	–	–	–	–	–
[Age: <30] * [Job: Tree feller]	–38.564	8.406	–4.588	0.000	–55.29	–21.84	0.208
[Age: <30] * [Job: Skidder operator]	0[a]	–	–	–	–	–	–
[Age: 31–40] * [Job: Tree feller]	–7.279	2.323	–3.134	0.002	–11.90	–2.66	0.109
[Age: 31–40] * [Job: Skidder operator]	–.900	1.400	–.643	0.522	–3.69	1.89	0.005
[Age: 31–40] * [Job: Manual loader]	0[a]	–	–	–	–	–	–
[Age: 41–50] * [Job: Tree feller]	–8.095	2.258	–3.586	0.001	–12.59	–3.60	0.138
[Age: 41–50] * [Job: Skidder operator]	0[a]	–	–	–	–	–	–
[Age: 41–50] * [Job: Manual loader]	0[a]	–	–	–	–	–	–
[Age: 51–60] * [Job: Tree feller]	–5.965	2.384	–2.502	0.014	–10.71	–1.22	0.073
[Age: 51–60] * [Job: Manual loader]	0[a]	–	–	–	–	–	–
[Age: 60>] * [Job: Tree feller]	0[a]	–	–	–	–	–	–
[Age: 60>] * [Job: Manual loader]	0[a]	–	–	–	–	–	–
[Age: <30] * SOFI	0[a]	–	–	–	–	–	–
[Age: 31–40] * SOFI	–.247	.130	–1.898	0.061	–0.51	0.01	0.043
[Age: 41–50] * SOFI	–.245	.130	–1.880	0.064	–0.50	0.01	0.042
[Age: 51–60] * SOFI	–.123	.137	–.898	0.372	–0.40	0.15	0.010
[Age: 60>] * SOFI	0[a]	–	–	–	0.00	–	–
Experience * SOFI	–.004	.001	–3.240	0.002	–0.01	0.00	0.116

[a] This parameter is set to zero because it is redundant

Table A2 Parameter estimates for Model 1 (dependent variable: subject MSD prevalence during the last seven days prior to data collection)

Parameter	*B*	*Std. Error*	*t*	*Sig.*	95% Confidence Interval		Partial η^2
					Lower Bound	Upper Bound	
Intercept	–144.83	37.80	–3.83	0.000	–220.19	–69.47	0.17
Profession: Tree feller	–36.44	10.74	–3.39	0.001	–57.85	–15.02	0.14
Profession: Skidder operator	–28.88	8.56	–3.37	0.001	–45.94	–11.82	0.14
Profession: Manual loader	0[a]	–	–	–	–	–	–
Age: <30	116.08	22.72	5.11	0.000	70.78	161.37	0.27
Age: 31–40	179.61	36.78	4.88	0.000	106.30	252.92	0.25
Age: 41–50	167.00	36.39	4.59	0.000	94.47	239.54	0.23
Age: 51–60	148.80	39.13	3.80	0.000	70.79	226.82	0.17
Age: 60>	0.00	–	–	–	–	–	–
BMI: <18.5	0.00	–	–	–	–	–	–
BMI: 18.5–24.9	–44.07	16.84	–2.62	0.011	–77.64	–10.50	0.09
BMI: 25–29.9	4.33	5.06	0.86	0.395	–5.76	14.43	0.01
BMI: 30>	0.00	–	–	–	–	–	–
NASA-TLX	2.92	0.71	4.13	0.000	1.51	4.33	0.19
Experience	–2.72	0.75	–3.64	0.001	–4.20	–1.23	0.16
[Age: <30,00] * Experience	–6.95	1.32	–5.27	0.000	–9.57	–4.32	0.28
[Age: <31–40] * Experience	2.93	0.75	3.92	0.000	1.44	4.43	0.18
[Age: <41–50] * Experience	2.71	0.75	3.62	0.001	1.21	4.20	0.15
[Age: <51–60] * Experience	0.75	0.23	3.31	0.001	0.30	1.20	0.13
[Age: 60>] * Experience	0[a]	–	–	–	–	–	–
[Profession: Tree feller] * [Age: <30]	–189.76	35.85	–5.29	0.000	–261.23	–118.29	0.28
[Profession: Tree feller] * [Age: 31–40]	–10.09	4.85	–2.08	0.041	–19.76	–0.43	0.06
[Profession: Tree feller] * [Age: <41–50]	–1.78	4.78	–0.37	0.711	–11.31	7.75	0.00
[Profession: Tree feller] * [Age: <51–60]	27.57	6.68	4.13	0.000	14.26	40.88	0.19
[Profession: Tree feller] * [Age: 60>]	0[a]	–	–	–	–	–	–
[Profession: Skidder operator] * [Age: <30]	0[a]	–	–	–	–	–	–
[Profession: Skidder operator] * [Age: <31–40]	–8.24	2.38	–3.46	0.001	–12.99	–3.49	0.14
[Profession: Skidder operator] * [Age: <41–50]	0[a]	–	–	–	–	–	–
[Profession: Manual loader] * [Age: <31–40]	0[a]	–	–	–	–	–	–
[Profession: Manual loader] * [Age: <41–50]	0[a]	–	–	–	–	–	–
[Profession: Manual loader] * [Age: <51–60]	0[a]	–	–	–	–	–	–
[Profession: Manual loader] * [Age: 60>]	0[a]	–	–	–	–	–	–
[Age: <30,00] * NASA-TLX	0[a]	–	–	–	–	–	–

Parameter	*B*	*Std. Error*	*t*	*Sig.*	95% Confidence Interval		Partial η^2
					Lower Bound	Upper Bound	
[Age: <31–40] * NASA-TLX	–3.41	0.70	–4.90	0.000	–4.80	–2.02	0.25
[Age: <41–50] * NASA-TLX	–3.26	0.70	–4.68	0.000	–4.64	–1.87	0.23
[Age: <51–60] * NASA-TLX	–2.40	0.60	–3.97	0.000	–3.60	–1.19	0.18
[Age: 60>] * NASA-TLX	0[a]	–	–	–	–	–	–
[Profession: Tree feller] * NASA-TLX	0.61	0.14	4.22	0.000	0.32	0.90	0.20
[Profession: Skidder operator] * NASA-TLX	0.48	0.14	3.52	0.001	0.21	0.75	0.15
[Profession: Manual loader] * NASA-TLX	0[a]	–	–	–	–	–	–
[Age: <30,00] * [BMI: <18.5]	0[a]	–	–	–	–	–	–
[Age: <30,00] * [BMI: 25–29.9]	0[a]	–	–	–	–	–	–
[Age: <31–40] * [BMI: 18.5–24.9]	66.88	16.36	4.09	0.000	34.26	99.49	0.19
[Age: <31–40] * [BMI: 25–29.9]	3.15	1.45	2.17	0.034	0.25	6.05	0.06
[Age: <31–40] * [BMI: 30>]	0[a]	–	–	–	–	–	–
[Age: <41–50] * [BMI: 18.5–24.9]	60.74	16.52	3.68	0.000	27.81	93.67	0.16
[Age: <41–50] * [BMI: 25–29.9]	0[a]	–	–	–	–	–	–
[Age: <41–50] * [BMI: 30>]	0[a]	–	–	–	–	–	–
[Age: <51–60] * [BMI: 18.5–24.9]	0[a]	–	–	–	–	–	–
[Age: <51–60] * [BMI: 25–29.9]	0[a]	–	–	–	–	–	–
[Age: <51–60] * [BMI: 30>]	0[a]	–	–	–	–	–	–
[Age: 60>] * [BMI: 18.5–24.9]	0[a]	–	–	–	–	–	–
[Age: 60>] * [BMI: 25–29.9]	0[a]	–	–	–	–	–	–
[BMI: <18.5] * NASA-TLX	0[a]	–	–	–	–	–	–
[BMI: 18.5–24.9] * NASA-TLX	–0.25	0.07	–3.27	0.002	–0.39	–0.10	0.13
[BMI: 25–29.9] * NASA-TLX	–0.07	0.07	–1.00	0.319	–0.21	0.07	0.01
[BMI: 30>] * NASA-TLX	0[a]	–	–	–	–	–	–

[a] This parameter is set to zero because it is redundant

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