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Work strain predictors in construction work

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Abstract. The aim of this study was to predict the work strain indicators for construction workers and to work out measures for prevention of strain at work. Subjective and objective research methods were utilized in the research, including survey, work intensity measurements (Borg Scale), work strain index, fatigue index and work ability index determination, objective blood pressure and pulse measurements. Statistical analysis with significance calculations was carried out. The limitation of this study is the small number of subjects involved in the research. Subjective evaluation of fatigue index and strain index resulted in moderate and somewhat hard work heaviness categories accordingly to Borg Scale. Measurements of heart rate, blood pressure approved work strain of employees of both professions does not exceed the admissible heart rate limit during physical load. The research proved that the strongest work strain predictors were connected with psycho-social risks rather than with physical ones.

Key words: fatigue, work heaviness, auxiliary workers, road workers, heart-rate, blood pressure.

INTRODUCTION

One of the leading branches of national economy in Latvia is construction, in which the greatest number of economically active population is employed. The employed, irrespective of wider and more dynamic introduction of new technologies in a lot of branches of Latvian national economy, incl. construction, are still subjected to increased strain at work. Work related musculoskeletal disorders (MSDs) and injuries are among the most frequently reported causes of lost or restricted work time (Occupational Safety and Health Administration, 2015) in construction, comparing to other branches. There is the highest number of accidents and the employed mostly suffer from musculoskeletal and connective tissue diseases, there have also been lethal cases at work places. Data from literature prove that construction workers' work is characterized by the following strain indicators: physically heavy work, forced work postures in bent or turned aside positions, long working hours, restricted time for task completion, fast speed of work, different microclimate (Kaukiainen et al., 2002; Kalkis et al., 2016). Construction works require a good physical condition from an employee as well as the ability to control diversity of work situations. The restricted time limit and work at increased rate promote physical and mental fatigue (Leino-Arjas et al., 1999; Roja et al., 2016), which in a long-term period affect the development of work related musculoskeletal disorders (WRMSD) (Wiker et al., 1989). Data from literature reveals that WRMSD and other health problems are related with employees' age, and that older employees suffer more often from these disorders than younger ones (Higgset et al., 1993, Okunribido & Wynn, 2010). The cases have been described when construction workers, lifting and moving heavy loads, quite often exceed the admissible lifting limit, which, without doubt, affects employees' health and work ability (Koningsveld & Molen, 1997; Van den Berg et al., 2008). Strain can also result in changes of arterial blood pressure and heart rate in employees. According to research of European and American scientists dynamic exercise of high intensity in normal conditions can cause the maximum value of systolic blood pressure to increase up to 250 mm/Hg and that of diastolic pressure up to 110 mm/Hg (Astrand, 1960).

The aim of this study was to predict the work strain indicators for construction workers and to work out measures for prevention of strain at work. The study was approved by the Human Ethics and Institutional Review Board of Riga Stradiņš University, Latvia in 2015.

MATERIALS AND METHODS

The study was carried out in a medium size construction enterprise in Latvia. It involved 15 auxiliary workers, employed in construction of buildings, and 5 workers, employed in road construction. All participants were male right-handers. Selection criteria were: all participants were clinically healthy without acute or chronic musculoskeletal or cardiovascular diseases. All the employees had agreed to participate in the study.

Duties of workers employed in building construction include: loading and unloading of building refuse with hands, its pushing, participation in processes of preparation for construction works, etc., which are related with physical effort. In general it is manual work. Road workers are employed in levelling of asphalt or road fractions, which involves hands mainly. Representatives of both studied professions work in forced postures.

The survey of employees was carried out with specially worked out questionnaire in order to find out their opinion on existing work conditions, work strain and factors, affecting workability. The following questions were included in this questionnaire: age, length of service, height, weight, smoking status, MSDs after work, physical activity in the leisure time, supervisor support at the work, colleagues support, requirements for work, work intensity, work ability. Smoking status was determined by the question: 'do you smoke or have you ever smoked?' with the four response alternatives: no, never (0), yes, but not anymore (1), yes, occasionally (2) and yes, every day (3). Musculoskeletal disorders after work in neck, shoulders, back, elbow, hip, knee and foot/ankle were evaluated by assessing pain/discomfort intensity after the work. Pain/discomfort intensity was classified by participants to be no pain/discomfort, mild pain/discomfort, moderate pain/discomfort or severe pain/discomfort.

About leisure-time physical activity the participants reported which of the following activities levels that corresponded best to their own level: inactive (e.g., reading, watching TV, movies); some physical activity (e.g., bicycling, walking,); regular activity (e.g., running, gymnastics).

Borg Scale of Ratings of Perceived Exertion (RPE) was used to measure work intensity (strain) and work heaviness category (WHC) (Borg, 1982). The RPE or Borg Scale measures a performer's rate of perceived exertion – that is, how hard workers think they are working. It is a scale from 6 to 20, where 6 means – no intensity (strain) at all, and 20 is maximum intensity. The RPE measurements were done during the work process, not just after they had stopped the work.

In the studied groups, blood pressure (mm/Hg) and heart rate checking by the pulse (beats per minute, beats min^{-1}) were measured by the device Omron HEM-780. The measurements were performed in the following order: before starting work, during the rest pauses and at the end of the work cycle. Length of the work cycle was 40 minutes (for auxiliary workers – loading building refuse, for road construction workers – levelling of road fractions.) Before measurements the workers had a 5-minute rest. Heart rate by checking the pulse, was evaluated at rest after 5-minute break, workers being in a quiet room in comfort temperature.

Work strain was evaluated applying a special computer program ErgoIntelligenceTM Upper Extremity Assessment (UEA) (NexGen Ergonomics Inc., 2015). The Strain Index (SI) is a score value based on a multiple of six variables: intensity of exertion, duration of exertion, efforts per minute, hand/wrist posture, rate of performing the work and duration of task. The variables and score in the SI are derived from physiological, biomechanical, and epidemiological principles. Moore & Garg (1995) conducted a study in the poultry industry using the SI and found that with the increase of the SI score the mean incidence rate for distal upper extremity disorders also increased. Based on these findings, they recommended a cut-off score of 7 for the SI, as an identification criterion to determine high-risk jobs.

Degree of fatigue. In order to determine tiredness of the employees, the fatigue index (FI) was calculated and computer programme HSE Fatigue Index was utilized, which according to fatigue index determines degree of tiredness: 0...20 – low, 21...40 – medium, 41...60 – high, 61...80 – very high, 81...100 – extremely high (see the Table 1) (Calculator of fatigue index, 2015).

Table 1. Fatigue index (FI) value scale points and fatigue level

FI	Degree of tiredness
0...20	Low
21...40	Medium
41...60	High
61...80	Very high
81...100	Extremely high

Work ability was evaluated calculating Work ability index (WAI) (Ilmarinen J., 2007).

The WAI is an instrument used in research to assess work ability during workplace surveys. The index is determined basing on the answers to a series of questions which take into consideration the demands of work, the worker's health status and resources. WAI is a summary measure of seven items (range 7–49) (Table 2).

Table 2. Items of the Work Ability Index

	Items	Range
1	Current work ability compared with the lifetime best	0–10
2	Work ability in relation to the demands of the job	2–10
3	Number of current diseases diagnosed by a physician	1–7
4	Estimated work impairment due to diseases	1–6
5	Sick leave during the past year (12 months)	1–5
6	Own prognosis of work ability 2 years from now	1–7
7	Mental resources	1–4

Statistical analysis. The results acquired were entered into the computer and processed using *MS Excel* software and statistical data processing program *SPSS.20.0* according to popular descriptive statistical methods, including statistical significance calculations with ANOVA and Student t-test ($p < 0.05$). Reliability interval (inter-rater agreement) was also calculated determining Cohen's Kappa coefficient (k) (Landis & Koch, 1977). This coefficient identifies connectivity of the experimental data, the number of participants and the proportion or correlation of the participants' acceptance of the experimental data:

$$k = (P_O - P_C) / (1 - P_C), \quad (1)$$

where P_O – correspondence proportion of objective experimental data with respondents' responses ('yes' or 'no'), P_C – correspondence proportion of data with number of participants ($P_C = \Sigma p_i^2$, where p_i is acceptance of each participant expressed in percent or as fractional number).

RESULTS AND DISCUSSION

The results reveal that workers from building construction fall in different age groups: 46.6% – age group from 18–30, 20.0% – 40 to 50, 33.3% – 60 to 72 years of age. Length of service in the profession: 53.3% – from 0 to 5 years, 26.6% – from 6 to 10 years and 20.0% – more than 11 years. It should be noted that older employees in the studied enterprise had worked longer than 11 years. Road construction workers were at the age of 18 to 65 years, length of service in the profession of three older workers was from 14–16 years. Both categories of workers had increased BMI. Heart rate by checking the pulse during the rest period was in norm. The background factors with mean differences in analysed groups with statistical significance of the research group and analysed aspects are shown in Table 3.

Obtained data and analysis of mean differences with t-test indicate that there are no statistically significant differences between the analysed groups (auxiliary construction workers and road workers).

Education: 11 construction workers had primary school education, 7 – secondary education, 2 – secondary education specialized in construction. All the studied employees smoked. Participants don't have physical activity in the leisure time.

Work conditions were evaluated by the respondents as follows: representatives of both studied professions considered their work as very intensive, at increased rate. The work is dynamic, it involves mainly hands. The respondents – road workers (90%) mention also load on the lower back, as the body takes bent posture during the work, but

80% of auxiliary workers note additional load on shoulder girdle. All participants indicated that the job requires high demands, lack of the management support and low control of the work process.

Table 3. Background factors of the research groups: mean age and range, length of service, mean height, mean weight, mean body mass index (BMI), heart rate at rest (beats min^{-1}), standard deviation (± SD), t – test statistics and *p* – probability

Profession	n	Age (years)	Range of age (years)	Length of service (years)	Height, cm	Weight, kg	BMI, kg m-2	Resting heart rate (beats min^{-1})
Auxiliary construction workers	15	41.9 ± 20.9	18–72	7.1 ± 5.1	170.3 ± 0.5	76.0 ± 10.3	26.2 ± 2.9	68 ± 8
Road workers	5	42.2 ± 19.5	18–65	9.8 ± 7.2	172.8 ± 0.8	79.6 ± 7.4	26.8 ± 3.1	64 ± 7
Mean difference		-0.333		-2.733	-2.53	-3.60	-0.582	
t		-0.031		0.942	-0.817	-0.715	-0.376	
p		0.975		0.358	0.425	0.484	0.711	

Applying Borg Scale in order to determine work strain it was found out that 80% of older auxiliary workers in building construction recognized that their work corresponds to very heavy work category (17–18 points), but 20% – heavy (15–16 points). At the same time all the road workers recognized their work as very, very heavy (19–20 points). It allows us to consider that the employees, involved in the study work with intensive work load and increased strain. To ascertain the correspondence of the employees' subjective opinion with the performed work, measurements of heart rate by counting the pulse were done. Results are revealed in Tables 4 and 5.

Table 4. Results of the measurements of heart rate by counting the pulse (beats min^{-1}), blood pressure (mm/Hg) (systolic – Sys, diastolic – Dias, mm/Hg) for road workers, mean values, standard deviation (± SD), standard error of the mean (± SEM), statistical significance – *p* (t-test)

		Before the work			During the rest			After the work		
Indicator	Age, years	Sys, mm/Hg	Dias, mm/Hg	Pulse rate, beats min^{-1}	Sys, mm/Hg	Dias, mm/Hg	Pulse rate, beats min^{-1}	Sys, mm/Hg	Dias, mm/Hg	Pulse rate, beats min^{-1}
	18	110	70	70	122	72	68	140	96	76
	26	112	74	72	130	70	74	142	90	80
	51	140	90	80	150	94	80	160	98	84
	65	138	80	62	140	78	74	150	80	78
	51	130	70	82	138	74	80	148	100	86
Average	42.20	126.00	76.80	73.20	136.00	77.60	75.20	148.00	92.80	80.80
± SD	19.51	14.21	8.44	8.07	10.58	9.63	5.02	7.87	8.07	4.15
± SEM		6.36	3.77	3.61	4.73	4.31	2.24	3.52	3.61	1.85
t-value		19.82	20.35	20.27	28.34	18.01	33.50	42.03	25.70	43.56
p		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Table 5. Results of the measurements of heart rate by counting the pulse (beats min^{-1}), blood pressure (systolic – sys, diastolic – dias, mm/Hg) for auxiliary workers in building construction, mean values, standard deviation (SD), statistical significance *(p)* (ANOVA)

Age group		Before the work			During the rest			After the work		
	Age, years	Sys, mm/Hg	Dias, mm/Hg	Pulse rate, beats min^{-1}	Sys, mm/Hg	Dias, mm/Hg	Pulse rate, beats min^{-1}	Sys, mm/Hg	Dias, mm/Hg	Pulse rate, beats min^{-1}
	18	120	90	62	122	90	66	130	86	70
	19	120	80	78	128	86	82	135	90	86
	20	110	90	90	116	80	94	130	90	94
	20	110	70	80	115	78	84	128	80	88
	22	130	80	82	138	90	84	144	92	90
Mean	19.80	118.00	82.00	78.40	123.80	84.80	82.00	133.40	87.60	85.60
± SD	1.48	8.37	8.37	10.24	9.50	5.59	10.10	6.47	4.77	9.21
	27	130	90	70	140	92	74	156	94	78
	28	140	90	76	142	90	78	148	96	82
	40	120	82	56	130	80	60	136	82	66
	50	136	72	60	138	74	62	146	92	68
	50	148	90	80	150	86	82	156	90	88
Mean	39.00	134.80	84.80	68.40	140.00	84.40	71.20	148.40	90.80	76.40
± SD	11.27	10.55	7.95	10.24	7.21	7.40	9.76	8.29	5.40	9.32
	62	138	88	78	140	90	80	154	92	86
	65	130	80	80	148	84	82	150	88	84
	65	140	80	82	144	88	84	150	90	86
	70	140	90	70	144	92	76	152	98	80
	72	136	90	74	140	90	78	152	92	82
mean	66.80	136.80	85.60	76.80	143.20	88.80	80.00	151.60	92.00	83.60
± SD	4.09	4.15	5.18	4.82	3.35	3.03	3.16	1.67	3.74	2.61
ANOVA F-value	8.060	8.443	0.335	1.859	10.578	0.933	2.390	12.489	0.450	1.069
ANOVA p	0.06	0.05	0.722	0.198	0.02	0.420	0.134	0.01	0.648	0.162

Results of the measurements of heart rate by counting the pulse (beats min^{-1}), blood preassure (mm/Hg) (systolic – sys, diastolic – dias) for road workers does not show statistically significant differences by all analysed aspects for all road workers – confirmed by t-test ($p \leq 0.001$).

Analysis of results by all indicated age groups by ANOVA has indicated that there are no significant differences of the measurements of heart rate by counting the pulse (beats min^{-1}), blood pressure (mm/Hg) (before the work systolic – sys) with significance level 0.05; for the measurements of heart rate by counting the pulse (beats min^{-1}), blood pressure (mm/Hg) (during the rest systolic – sys) with significance level 0.02 and the measurements of heart rate by counting the pulse (beats min^{-1}), blood pressure (mm/Hg) (after the work systolic – sys) with significance level $p \leq 0.01$. For all other analysed aspects differences by age groups are statistically significant.

The average blood pressure measurements reveal that during intensive work systolic and diastolic pressure increases in older participants of both professions, and the mean values are: in building construction auxiliary workers 151.60 ± 1.67 and 92 ± 3.74, but in the oldest road construction worker 150.00 ± 1.54 and 91.78 ± 8.11. Analysing heart rate according to pulse it can be concluded that work strain of employees of both professions does not exceed the admissible heart rate limit during physical load, which shows that the load is appropriate for employees' age. For older (age group 51–75 years) building construction auxiliary workers, according to RPE evaluation, maximum Heart Rate should be 170 or 180 beats per minute, but actually performing work duties intensively for 40 minutes, the average heart rate was 83.60 ± 2.61, but the calculated admissible limit is from 101.40 to 116.9 beats min^{-1}, respectively. In road construction workers of different age heart rate also does not exceed the admissible limit: in 18 years old from 121.12 to 161.6, but in the older (65 years) from 93.0 to 124.0 beats min^{-1}.

The research results can be compared with other authors' investigations on the assessment of blood pressure. In several investigations it is pointed that systolic blood pressure increases significantly and proportionally to workload during exercise test in healthy adults (Wielemborek-Musial et al., 2016). Heart rate results acquired in our study do not correspond to above mentioned authors' results, since within the assessment of heart rate it was found that physical load in the studied employees, in fact, did not increase regardless their subjective evaluation. The present study clearly demonstrated that work stress is closely related to blood pressure *ie* blood pressure was higher in individuals reporting high job strain in combination of high job demand and low job control (Karasek et al., 1981). That is in accordance with our research survey results on job requirements and lack of management support.

To assess employees' work strain more profoundly, work strain index and fatigue index were determined. Calculation results are shown in Table 6.

Analysing the acquired results, it should be concluded that for building construction auxiliary workers SI = 4.9 ± 1.6 and it is higher than that for road construction workers (SI 4.2 ± 1.6), which could be related with different stress situations (heavy work load, increased requirements at work, lack of support from colleagues, restricted time limits, etc.). The same refers to fatigue index, for building construction auxiliary workers it is higher (37.5 ± 4.1) than that for road construction workers (31.2 ± 3.3). It could be explained by the fact that road construction workers have regulated rest pauses, whereas work of building construction auxiliary workers proceeds at increased rate and restricted time limits.

Table 6. Mean values of work strain index (SI) and fatigue index (FI), standard deviation (± SD) and Cohen's kappa (κ), the rate of perceived exertion (RPE, scale 6–20), work heaviness category (WHC)

Professions	Mean RPE ± SD	WHC	SI ± SN	κ	FI ± SD	κ
Road construction workers (n = 5)	14 ± 2	Moderate	4.2 ± 1.3	0.81	31.2 ± 3.3	0.81
Building construction auxiliary workers (n = 15)	16 ± 2	Somewhat hard	4.9 ± 1.6	0.85	37.5 ± 4.1	0.80

It should be noted that evaluating work strain and fatigue in the studied groups, their subjective evaluation corresponds to the calculated evaluation. At the same time the calculated stress index and fatigue index do not exceed admissible levels. It is explained in other findings that the cumulative fatigue in industry would likely to ensue if the heart rate exceeds 110 beats min^{-1} (Brouha, 1967).

Workability evaluation is shown in Table 7.

Table 7. Workability index and criteria (n = 20)

Workability index (WAI)	Scores	Rating scores ± SD
Road construction workers (n = 5)	7…49	40 ± 2.91
Building construction auxiliary workers (n = 15)	7…49	35 ± 3.32

Analysis of workability revealed the following results: building construction auxiliary workers evaluate their workability as moderate (WAI = 35 ± 3.32), but road construction workers – as good (WAI = 40 ± 2.91).

Analysing workability of the studied employees it should be concluded that though, in the survey, the employees noted increased work strain and physically heavy work, their workability is medium and good. In older employees it was even better than in younger ones, and 64% of older employees considered their workability as very good. Apart from that they did not mention any case of illness within recent years. This corresponds with other authors 'research conclusions that physical load at work is related to the age of employees rather than to employees' workability and subjective health evaluation, incl. musculoskeletal pain (Lunde et al., 2016.). All questioned employees consider that they will be able to work in future as well. 36% of younger building construction auxiliary workers noted that they were not sure of being able to work in future relating it with physically heavy work and excessive work load. The 'good' workability indices could be explained by big unemployment in Latvia and fear of work loss due to what employees do not give the true information.

The limitation of this study is the small number of subjects involved in the research (road construction workers n = 5, building construction auxiliary workers n = 15). Such small investigation group can increase the chance of assuming as true a false premise (Faber & Fonseca, 2014), but at the same time such research is quick to conduct with regard to enrolling subjects, reviewing subject records, performing analyses or asking subjects to complete study survey (Hackshaw, 2008).

CONCLUSIONS

The research proved that the strongest work strain predictors were associated with psychosocial risks rather than with physical ones. Survey results concludes that all employees in our research are subjected not only to physical, but also to psychosocial risk factors indicating high job demand, lack of management support, restricted control of the work process. The calculated BMI can be related to unhealthy life style of employees. Borg Scale results allowed to consider that older auxiliary workers and all road construction workers have highest work categories. Despite this fact, work strain index and fatigue index resulted in higher levels for building construction auxiliary workers than that for road construction workers. That can be explained with more regulated rest breaks and lower work pace. Objective measurements of heart rate, blood pressure approved work strain of employees of both professions does not exceed the admissible heart rate limit during physical load, which shows that the load is appropriate for employees' age. Statistical analysis with ANOVA and t-test showed that there are no significant differences of the measurements of heart rate and blood pressure in all indicated age groups, but the results can be explained with the limitation of this study that included small number of subjects. Both study groups in our research indicated moderate and good workability that was proved with WAI determination, but such results can be linked with false information from employees due to fear of work loss.

According to this study some management interventions in construction work organisation with effective management tools can significantly help to cope with Work strain predictors in the workplaces. Therefore, the research will be continued paying more attention to studies of psycho-social risks for auxiliary workers and road construction workers. Possibilities to improve work organisation will be studied.

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