Agronomy Research **22**(3), 1351–1361, 2024
https://doi.org/10.15159/AR.24.059

Exposure to job related risk factors and work-related musculoskeletal disorders among medical laboratory workers

K. Vahur[1,2,*], Ü. Parm[2] and E. Merisalu[1]

[1]Estonian University of Life Sciences, Institute of Forestry and Engineering, Chair of Biosystems Engineering, Kreutzwaldi 56, EE51006 Tartu, Estonia
[2]Tartu Health Care College, Physiotherapy and Environmental Health Department, Nooruse 5, EE50411 Tartu, Estonia
[*]Correspondence: kristivahur@nooruse.ee

Received: April 26th, 2024; Accepted: June 9th, 2024; Published: June 29th, 2024

Abstract. Work-related musculoskeletal disorders (WRMSDs) are the most common work-related diseases among health care workers including medical laboratory workers (MLW). Laboratory workers, when performing different work tasks, are exposed to repetitive movements, static and uncomfortable forced positions. The aim of this study was to explain the occurrence of WRMSDs among medical laboratory workers in relation to job related risk factors, tools and equipment, when performing specific work tasks.
Material and methods: The study involved the Estonian MLWs from three regional and four central hospitals. The criteria of the study group were experience ≥ 1 year and workload ≥ 0.5 staff. The e-questionnaire was sent to 502 laboratory workers.
Results: The response rate was 25.1%. To the questionnaire answered 126 MLWs, whereas the sample criteria met 122 respondents. There was significant association between nature of the work and shoulder pain in past month and 12 months among MLWs ($p < 0.05$). The most affected body regions were low back and neck. Work tasks which involved repetitive movements and forced position more than 1 hour were related to pain in low back, neck, and shoulders (in all cases $p < 0.05$). Those who worked in sitting posture, reported less neck pain both in the past and 12 months, compared to the workers who worked in both sitting and standing posture ($p < 0.05$, $p < 0.01$). Conclusions: MLW are at high risk of WRMSDs. So, improvement of workplace ergonomics and rising risk awareness are very important interventions among MLWs.

Key words: job tasks, laboratory workers, musculoskeletal pain, tools and equipment.

INTRODUCTION

Laboratory medicine is important subject field in health care sector (Hallworth, 2011; Sikaris, 2017; Wilson et al., 2022) due to approximately 60.0–70.0% of clinical decisions are based on the results of laboratory tests (Olver et al., 2023). Although medical laboratories are specialized in different work tasks, the nature of the work and risk factors in the work environment does not vary so much. Medical laboratories are located both at hospitals and family medicine centres. In these institutions highly educated and well-trained personnel is working in different positions (laboratory

technician/biomedical scientist, laboratory specialist, physician, administrative staff etc) (Laboratory medicine development plan, 2011–2020). They perform various duties followed by the job descriptions. The main task of laboratory technician/biomedical scientist is to perform clinical analyses (Occupational Qualification Standards: Biomedical scientist, level 7, 2023). For the laboratory specialist work process in the area of responsibility it is the management of medical laboratory (Occupational Qualification Standards: Medical laboratory specialist, level 7, 2022). The main work responsibility area of the laboratory doctor/physicians is the selection and interpretation of laboratory tests' results addressing them to specialist consultation (Laboratory medicine development plan 2011–2020).

Historically, the most of work tasks in the medical laboratory have performed manually, while the MLWs were responsible for many steps involved in the analytical process (Wilson et al., 2022). In general, the laboratory workers are exposed to high risk of WRMSDs due to repetitive movements, static and uncomfortable forced positions for pipetting, screwing caps on and off test tubes, performing analyses on Petri dishes with a seed loop, inoculating, using microscope and computer (Agrawal et al., 2014; Holm et al., 2016; El-Helaly et al., 2018). The survey of Estonian pathology laboratories revealed that the majority of the laboratory technicians worked with repetitive movements (86.7%) and forced position (81.3%) (Haava, 2007). Usual daily work involves a lot of routine but high-responsibility tasks, coupled with fast-paced work tasks and time constraints that can cause stress for employees (Agrawal et al., 2014). However, laboratory work put a lot of physical and mental strain on laboratory staff (Kricka & Savory, 2011). Positive correlation between psychosocial hazards causing work stress and WRMSD has approved in the many of research results (Hämmig, 2020; Afsharian et al., 2023; Bezzina et al., 2023). Nowadays laboratories are highly automated and integrated that perform millions of test each year (Kricka & Savory, 2011; Wilson et al., 2022). Laboratory workers are using different tools and equipment to perform their work tasks. There are different laboratory software programmes as very important and decisive tools in use. So, a number of computer hours have inhered to MLW work, but it depends on the working tasks. A study conducted by Lopez et al. (2019) revealed that more than 10 hours a week used the computer 56.7% Spanish laboratory workers. Laboratory workers tend to perform their tasks standing more than sitting (Lòpez-Gonzàlez et al., 2019) which puts additional strain on the musculoskeletal system.

The aim of this study is to explain the occurrence of WRMSDs among medical laboratory workers in relation to job related factors, tools and equipment to perform specific work tasks.

MATERIALS AND METHODS

Study group

The study involved Estonian medical laboratory workers from the 3 regional hospitals and 4 central hospitals. The hospitals were chosen to cover most of the districts and the majority part of medical laboratory staff in Estonia. The invitation to participate in the study was sent to seven hospitals five units have approved the participation. Based on the data obtained from the laboratories who consented to participate in the study, there were 502 MLWs as of 2021 year. The criteria for selection of the study group were: having work experience in a medical laboratory at least 1 year and workload ≥ 0.5, since

it is difficult to assess the impact of work on the musculoskeletal system with lower workload and seniority. According to the position, the subjects were divided into four groups: laboratory technicians and biomedical scientists (LT/B), laboratory specialists (LS), physicians (P) and administrative workers (reception and logistics department, quality leader, head of laboratory ect) (ADM).

Questionnaire

The e-questionnaire survey was conducted from April to September 2021. The questionnaire was based on an internationally validated standardized questionnaire 'Cultural and Psychosocial Influences on Disability' (CUPID) (Coggon et al., 2012) and adapted to laboratory medicine specificity. The questionnaire consisted of five topics: 1) socio-demographics data, 2) work-related questions including specific questions related to laboratory work (using microscope, automatic pipettor, seed loop ect), 3) pain in different body regions in the past 12 months and past month,) and 4) the questions on health behaviour, psychosocial risk factor and out-of-work physical activity were added. 5) The time duration of the pain and sick leave and assistance by the doctor and how the presence of pain affected daily activities have assessed. The individual and work-related risk factors, health conditions in general and the questions related to rotation, shift and night work. The questionnaire was introduced with the cover letter to the employees, explaining the aim and methods of the study and the ethical aspects of the research.

The questions answered to evaluate risk factors according to a 3-point Likert-type scale, where: 2 – yes, always; 1 – yes, sometimes; 0 – no, never. The questions answered to evaluate work chair ergonomics according to a 5 – point Likert-scale, where: 1 – very uncomfortable; 2 – uncomfortable, 3 – satisfactory, 4 – good, 5 – very good. The binary questions 'Yes'/'No', and the open and closed questions were used.

Complaints in the right, left, both upper limbs (shoulder, elbow, wrist/hand) were combined into complaints in the upper limb. Work chair ergonomics were combined into two groups: comfortable (satisfactory, good, very good) and uncomfortable (very uncomfortable; uncomfortable).

Ethical aspects

To conduct the research, written consent was obtained from authorized signatories of hospitals and the Human Research Ethics Committee of the University of Tartu (protocol number: 333/T-24; 18.01.2021). After getting consent the link of e-questionnaire was sent to the e-mail addresses of the study group. The consent to participate in the study was given when answering to the questionnaire.

Statistical analysis

The MS Excel program was used for the primary statistical analysis, followed by the Statistical Package for Social Sciences (SPSS 23.0), the software programs Sigma Plot for Windows version 11.0 (GmbH Formation, Germany) and R 2.6.2 (A Language and Environment, http://www.r-project.org) were used. Descriptive statistics and $\chi 2$-test and *Fisher Exact* test were performed to measure the group differences between job related risk factors and WRMSDs in different body regions of the MLWs in the past month and the past 12 months. Bonferroni correction was used to conduct multiple comparisons across the four groups to check if group means differ (Table 2 and 3).

RESULTS

Study group

The invitation to participate in the study was sent to seven hospitals, five units have approved the participation (Table 1). Unfortunately, it is not possible to list the respondents by hospital because respondents answered rather in which department they work.

Table 1. Study sample by the hospitals and occupations (n = 126)

Hospital	TNEMC	TUH	ETCH	EVCH	PH	All
No of participants (n)	108	196	93	59	46	126
LT/B	55	77	46	28	26	53
LS	14	55	14	9	9	40
P	12	32	10	4	2	21
ADM	27	32	23	18	9	12

TNEMC – The North Estonia Medical Centre; TUH – Tartu University Hospital; ETCH – East Tallinn Central Hospital; EVCH – East Viru Central Hospital, PH – Pärnu Hospital, and profession LT/B – laboratory technician/biomedical scientist, LS – laboratory specialist, ADM – administrative worker, P – physician.

The questionnaire received 502 MLW, answered 126, response rate was 25.1%. After eliminating those who didn't allow to the criteria (two respondents seniority was < 1 year and two workload was < 0.5) of selection 122 were considered as valid cases. Most of the respondents were female, right hand as dominant hand. The average age of the study group was 45 ± 13.1 years (the youngest 23 and oldest 72 years old). The average workload was 0.8 ± 0.2, working experience 14.6 ± 12.3. From the respondents 40.2% were specialised as laboratory technicians/biomedical scientists (LT/B). MLWs can perform their tasks in both sitting and standing (69.7%). Most of them (90.2%) are using chair with a back rest and 84.4% rated their work chair ergonomics comfortable. More than half of respondents (68.9%) reported that they do mainly manual work and 28.7% fill administrative tasks. From the respondents 76.2% regularly use different machines and technical tools (analysers, computer et al).

Table 2. Sociodemographic and job-related factors of the study group (n = 126)

Variables		LT/B	LS	ADM	P
Participants (n)		49	40	12	21
Female (%)		89.8	95.0	91.7	90.5
Age (yrs)		44.4 ± 12.^{acb}	45.5 ± 12.8	51.7 ± 9.2	50.2 ± 9.9
Computer work (hr)		7.98 ± 6.66	7.64 ± 7.75^{c}	8.67 ± 5.23^{b}	6.86 ± 5.61
Hand dominance (%)	Right	93.9	90.0	100.0	85.7
	Left	2.0^{b}	10.0	0.0^{b}	9.5
	Ambidextrous	4.1	0.0	0.0	4.8
Nature of the job (%)	Manual	87.8^{b}	62.5	41.7	52.4
	Machine	81.6^{a}	27.5^{b}	58.3	85.7
	Administrative	10.2^{ac}	70.0	50.0	38.1
Working posture (%)	Sitting	14.3^{b}	30.0	33.3	61.9
	Standing	0.0	0.0	8.3	0.0
	Sitting and standing	85.7^{b}	70.0^{a}	58.3	38.1

Medical laboratory workers, (n = 122) by profession: LT/B – laboratory technician/biomedical scientist; LS – laboratory specialist; ADM – administrative worker; P – physician.
$p \leq 0.008$ (Bonferroni correction) – ^{a} vs LS; ^{b} vs ADM; ^{c} vs P.

Five respondent pointed out that their work includes manual work, work with equipment and administrative tasks. In average MLW are using computer 7.7 ± 6.7 hours per day (min 1 h; max 24 h), physicians using computer less than other occupations (Table 2).

Chi-square analysis with Bonferroni correction showed that LT/B were working manually more than other professions and performing job tasks more in variating posture (sitting and standing) than ADM and P. At the same time performing less administrative tasks than other three professions (Table 2).

Equipment and tools in laboratory work

Table 3. shows tools and equipment the respondents use in their work by occupation. More than half respondents are using computer and analysers. All ADM workers are using computer, but they don`t use microscope, fume hood and vortex, the past two tools are not used by physicians in their work either. The largest number of analyser users are among LT/B. Centrifuge is used mainly by AMD. The analysers are using more among LT/B than other three professions.

Table 3. Tools and equipment used in the laboratory work in the whole sample and by the specialization (n = 126)

Tools, equipment	Whole sample n = 122	LT/B n = 49	LS n = 40	P n = 21	ADM n = 12
Manual work (%)					
Pipets	33.6	42.9	30.0	19.0	33.3
Microscope	31.1	32.7	30.0	38.1	16.7
Work under fume hood/ laminar cabinet	12.3	10.2	22.5	-	8.3
Office supplies	9.0	2.0[b]	7.5	14.3	33.3
Vortex	6.6	12.2	2.5	-	8.3
Machine work (%)					
Computer	62.3	51.0	62.5	71.4	91.7
Analysers	55.7	81.6[acb]	45.0	28.6	33.3
Centrifuge	31.1	34.7	30.0	9.5[b]	58.3

LT/B – laboratory technician/biomedical scientist; LS – laboratory specialist; ADM – administrative worker; P – physician (percent (%) of respondents). $p \leq 0.008$ (Bonferroni correction) – [a] vs LS; [b] vs ADM; [c] vs P.

In addition to the tools and equipment in the Table 3, the respondents pointed out a whole range of different working tools (scalpel, saw, quick tests, tweezers ect) and equipment (microtome, densitometer, nucleic acid purification equipment ect), as this list was very varied, they were categorized as other tools. Almost half of respondents pointed out using other tools (46.7%), ADM, LS and LT/B are using other tools similar amount (40.0%, 50.0%, 53.1%) but only 23.8% P were using them. Chi-square analysis showed that LT/B were using more analysers than other three professions. LT/B and LS were using less office supplies than ADM (Table 3).

Nature of the work and working posture

There were no statistical association between nature of the work (manual work, administrative tasks, using different machines/technical tools) and WRMSD in past month (p = 0.544) and 12 months (p = 0.850) in the neck. But there were statistical association between nature of the work and WRMSD in past month and 12 months in

the shoulders. MLW who report doing mainly administrative work had less shoulder pain in past 12 months (22.9% vs 46.4%, $p = 0.017$) and past month (2.9% vs 22.6%, $p = 0.012$) than workers doing mainly manual work. Same result was found in past month comparing with workers using different equipment (2.9% vs 20.4%, $p = 0.015$) but there was no statistical difference in past 12 months shoulder complaints (22.9% vs 34.3%, $p = 0.172$). Workers who report doing mainly manual work comparing workers using different equipment reported similarly pain at the shoulder both in past month (22.6% vs 20.4%, $p = 0.139$) and past 12 months (46.4% vs 34.3%, $p = 0.732$).

Respondents who were working sitting and standing compered to workers who perform tasks by sitting have reported more pain at the neck both past month (36.5% vs 16.7%, $p = 0.030$) and 12 months (56.5% vs 25.0%, $p = 0.001$). But at the same time MLW who worked alternately by sitting and standing reported less pain in low back in past month (30.6% vs 44.4%, $p = 0.143$) and 12 months (61.2% vs 69.4%, $p = 0.747$) compared to those who worked by sitting but it was not statistically associated.

Specific work tasks and MSD in past month and 12 months

Chi square test was used to measure associations between the specific work tasks and occurrence of WRMSD in different body region in the past month and 12 months. N-value shows respondents rate who were doing specific work tasks. Table 4 and Table 5 shows the percentages of respondents who had complaints in a specific area of the body and p-value shows statistical association between specific work tasks and WRMSD in different body region in past month and 12 months.

Table 4. Specific job tasks and occurence of WRMSD in the past month (%) ($n = 126$)

Job tasks	Low back	Neck	Shoulder	Elbow	Wrist/ Hand	Knee
Putting on and removal of lids and caps ($n = 57$)	42.1*	38.6	22.8	5.2	22.8	19.3
Loading and unloading machines > 4 hrs ($n = 35$)	45.7*	42.9	25.7	5.7	17.5	22.9
Use of manual whirl mixer (vortex mixer) > 4 hrs ($n = 10$)	40.0	60.0	20.0	0.0	40.0	20.0
Other tasks involving repetitive wrist finger movement > 4 hrs ($n = 62$)	46.8**	45.2*	25.8	4.8	25.8	22.6
Repetitive elbow flexion and extension > 1 hrs ($n = 64$)	43.8*	43.8*	21.9	3.1	26.6	18.8
Working in position hands above the shoulders > 1 hrs ($n = 11$)	36.4	36.4	27.3	0.0	36.4	9.1
Working in the forced position, head-neck forward tilt shoulder tension ($n = 87$)	36.8*	43.7*	21.8*	5.7	25.3	19.5
Working in the forced position, where the low back does not rest on the back of the chair ($n = 76$)	38.2*	42.1*	23.7	5.3*	23.7	19.7
Working under time pressure with multiple tasks pilling up ($n = 74$)	35.1	41.9	21.6	5.4	25.7	17.6

*$p < 0.05$; ** $p < 0.001$.

Repetitive wrist and finger movement > 4 hours and repetitive elbow flexion and extension > 1 hours per working day was statistically associated pain in the low back both past month and 12 months and in the neck past month and in the shoulder past 12 months. Working in forced position when low back does not rest on the back of the chair was statistically associated with pain in the neck, wrist/hand and knees in the past 12 months and past month in the low back, neck and elbow. Making cell preparation > 4 hours per working day was statistically associated with pain in the wrist/hand in the past 12 months and in the knee in past month. Working in the forced position, head-neck forward tilt/shoulder tension was significantly associated with pain in the low back in the past month and in the neck and shoulder both past and 12 months. Compared to past month laboratory workers had more WRMSD at every body region in 12 months, most affected body regions by specific work tasks were neck and low back. Table 4 and 5 shows only those specific work tasks where was a significant association in any body region.

Table 5. Specific job tasks and occurrence of WRMSD in the past 12 months (%) (n = 126)

Job tasks	Low back	Neck	Shoulder	Elbow	Wrist/ Hand	Knee
Putting on and removal of lids and caps (n = 57)	57.9*	57.9	38.6	8.8	35.1	31.6
Loading and unloading machines > 4 hrs (n = 35)	54.3	54.3	45.7	14.3*	42.9	28.6
Use of manual whirl mixer (vortex mixer) > 4 hrs (n = 10)	50.0	80.0	40.0	20.0*	50.0	30.0
Other tasks involving repetitive wrist/ finger movement > 4 hrs (n = 62)	56.5*	69.4	50.0*	11.3	41.9	33.9
Repetitive elbow flexion and extension > 1 hrs (n = 64)	56.3*	67.2	50.0*	9.4	42.2	31.2
Working in position hands above the shoulders >1 hrs (n = 11)	63.3	72.7	63.3	18.2	45.5	27.3
Working in the forced position, head-neck forward tilt, shoulder tension (n = 87)	50.6	73.6**	44.8*	12.6	36.8	32.2
Working in the forced position, where the low back does not rest on the back of the chair (n = 76)	51.3	71.1*	43.3	13.2	34.2*	28.9*
Working under time pressure with multiple tasks pilling up (n = 74)	50.0	77.0**	39.2	13.5	37.8	27.0*

*$p < 0.05$; ** $p < 0.001$.

DISCUSSION

The present study results showed that the most affected body regions were the low back and neck among MLWs. As in previous studies, discomfort was associated with working in a forced posture (Patel & Pandya, 2017) and repetitive tasks (El-Helaly et al., 2018).

The majority of the respondents were women, as shown in previous studies (Maulik & Iqbal 2014; El- Helaly et al., 2018; Roudi & Zakerian 2019; AlNekhilan et al., 2020). Medical laboratory staff varies by profession (laboratory technician/biomedical scientist, laboratory specialist, physician, administrative workers [reception and logistics department, quality leader, head of laboratory ect]) who perform various tasks based on job descriptions and using different tools and equipment. It is difficult to point out an equipment and/or tool that was used only by a representative of a specific job description, because the majority of tools and equipment were used by everyone, regardless of occupation. For example, although the main task of the medical laboratory specialist is to organize the work processes of medical laboratory in her/his area of responsibility, whereas a part of job duties is also performing laboratory analyses (Occupational Qualification Standards: Medical laboratory specialist, level 7, 2022). Half of MLWs use automatic and semi-automatic analysers.

Although work in the laboratory is increasingly mechanized and automated (Kricka & Savory 2011), more than half of respondents (68.9%) reported that they do mainly manual work. According to the study conducted in Saudi Arabia laboratory workers, who performed manual work, had more neck ($p = 0.001$) and shoulder ($p = 0.046$) pain than those who do not work manually (AlNekhilan et al., 2020). In our study, we did not find a relationship between the nature of work and neck complaints in the past 12 months and past month. But there was positive relationship between the nature of the work and shoulder pain in past month. Workers who performed manual work and machine work had more shoulder pain than workers who performed administrative work.

Due to the specific work tasks of MLWs, they have to work in forced posture and with repetitive movements. The main tools and equipment in use, are microscopes, pipettes, computers (Patel & Pandya, 2017). Similar results were shown in this study where more than 30.0% of respondents used microscope, computers, pipettes in addition to them, analysers, and centrifuges. Microscopy is performed in forced posture, the head-neck is forward tilted, with raised shoulders, and in awkward posture with hands, arms and wrists (Arora & Uparkar, 2015). The previous studies have showed that laboratory workers, who are working hours behind microscope have reported pain in the neck and low back (Lorusso et al., 2007; Patrao et al., 2022), also in upper back (Patrao et al., 2022) and hand/wrist region (Lorusso et al., 2007). But our study results did not show relation between working behind microscope > 4 hours per day and WRMSD in any body part.

When pipetting, the worker is constantly in an uncomfortable and static working posture, the upper arms in adduction and hands, forearms and wrists in a rotated and/or flexed position. Laboratory workers can pipet for several hours a day, and the longer the working hours, the greater WRMSD risk (Costello, 2004). Similar relationship was also reported by El-Helaly et al. (2018) it was found that laboratory workers who have been engaged in pipetting for a long time, reported more WRMSDs in the past 12 months, compared to those who worked less hours. Holm et al. (2016) pointed out in their study, that the amount of pipette work was associated with symptoms in dominant upper limb, especially in the hand/wrist and thumb, and also with impingement syndrome and muscle pain in dominant shoulder. In the study, conducted among Biomedical scientists, demonstrated significant association between the shoulder ($p = 0.045$) and low back

complaints (p = 0.054), and significantly related to pipetting (Alwahaibi et al., 2021). But in our study no associations were found between pipetting and WRMSD in any body region (Table 4).

It was surprising, that using a computer keyboard and touch screen > 4 hours per working day did not show significant relation with WRMSD among MLWs, despite the average computer working time was 7.7 ± 6.7 hours per day. At the same time, it has been found that workers who worked at least 5 hours on a computer, had significantly more WRMSDs (Kadivar et al., 2021).

In common to Holm et al. (2016), there were no significant associations between job specific and repetitive activities (working with culture dishes and using inoculating loop or needle) and WRMSDs in the present study. But at the same time, the respondents who pointed out that their work involves repetitive wrist and finger movement > 4 hours per working day, reported discomfort in low back, neck and shoulders. Certainly, pain in low back is related to the specific job tasks as cell preparation, putting on and removal of lids and caps and/or loading and unloading machines, because these activities involve repetitive wrist and finger movements. Sure, we did not find significant association between the above-mentioned job activities and neck and shoulder pain.

However, the respondents, who made cell preparation > 4 hours per working day, had knee pain in the past month and wrist/hand pain in the 12 months. Hand and wrist complaints may be related to the job specific tasks, but here we see also job relatedness of knee problem (Garcia et al., 2017). Likewise, the respondents who make cell preparation, putting on and removal of lids and caps, loading and unloading machines and manual lifting of weights > 25 kg reported pain in the low back. These activities require a standing work posture, adding strain on the low back.

The strength of the study was that still few studies have been carried out in the world and also in the Estonian hospital laboratories. The relationships between specific job tasks and WRMSDs of different body regions among MLWs have observed.

The limitation of the study was low response rate, which may influence on making the evidence-based conclusions and confident solutions for the particular intervention activities.

CONCLUSIONS

The current study confirmed, that MLW are at high risk of WRMSDs. Low back, neck and shoulder were the most affected body regions among MLWs, whereas discomfort was associated with working in a forced posture and repetitive movements. MLW assessed more often WRMSD in the past 12 months compared to the past month, especially in the body regions as neck, shoulders, and low back. Automatizing and digitalizing of work processes does not reduce the impact of physiological risk factors on musculoskeletal system.

Training on work place ergonomics is important to improve awareness of physiological risks among MLWs. Prevention and intervention programs need to be implemented in the medical laboratories.

ACKNOWLEDGEMENTS. My gratitude to the medical laboratory workers who agreed to participate in the present study.

REFERENCES

Afsharian, A., Maureen, F., Dollard, M.F., Glozier, N., Richard, W., Morris, R.W., Bailey, T.S., Ha Nguyen, H. & Crispin, C. 2023. Work-related psychosocial and physical paths to future musculoskeletal disorders (MSDs). *Safety Science* **164**, 106177. doi: 10.1016/j.ssci.2023.106177

Agrawal, P.R., Maiya, A.G., Kamath, V. & Kamath, A. 2014. Work related musculoskeletal disorders among medical laboratory professionals: a narrative review. *International Journal of Research in Medical Sciences* **2**(4), 1262–1266. doi: 10.5455/2320-6012.ijrms20141105

AlNekhilan, A.F., AlTamimi, A.M., Alaqeel, B.Y., AlHawery, A.A., AlFadhel, S.F. & Masuadi, E.M. 2020. Work-related musculoskeletal disorders among clinical laboratory workers. *Avicenna Journal of Medicine* **10**(01), 293–4. doi: 10.4103/ajm.ajm_67_19

Alwahaibi, N., Al Sadairi, M., Al Abri, I. & Al Rawahi, S. 2021. Prevalence of laboratory-related musculoskeletal disorders among biomedical scientists. *Clinical Journal of Pain* **22**(8), 717–724. doi: 10.1101/2021.06.04.21258372

Arora, A. & Uparkar, S. 2015. Ergonomic Risk Assessment In: Pathology Laboratory Technicians. *International Journal of Therapies and Rehabilitation Research* **4**(3), 15. doi:10.5455/ijtrr.00000057

Bezzina, A., Austin, E., Nguyen, H. & James, C. 2023. Workplace Psychosocial Factors and Their Association with Musculoskeletal Disorders. A Systematic Review of Longitudinal Studies. *Workplace Health and Safety* **71**(12), 578–588. doi: 10.1177/21650799231193578

Coggon, D., Ntani, G., Palmer, K.T., Felli, V.E., Harari, R., Barrero, L.H., Felknor, S.A., Gimeno, D., Cattrell, A., Serra, C., Bonzini, M., Solidaki, E., Merisalu, E., … Gray, A. 2013. Patterns of multi-site pain and associations with risk factors. *Pain* **154**(9), 1769–77. doi: 10.1016/j.pain.2013.05.039. Epub 2013 May 29.

Costello, K.J. 2004. *Laboratory Workers Commonly Report Work-Related Musculoskeletal Disorders from the Use of Manual Pipettes*. https://vistalab.com/wp-content/uploads/2016/03/Ergonomic-Science-May-Hold-the-Key-to-Prevention.pdf.

Garcia, M.G., Graf, M. & Läubli, T. 2017. Lower limb pain among workers: a cross-sectional analysis of the fifth European Working Conditions Survey. *International Archives of Occupational and Environmental Health* **90**, 575–585. doi: 10.1007/s00420-017-1220-4

Haava, M. 2007. *Assessment of the risks of the work environment and the health status of employees in Estonian pathology laboratories*. MSc Thesis, University of Tartu, Tartu, Estonia, 71 pp. (in Estonian).

Hallworth, M.J. 2011. The '70% claim': what is the evidence base? *Annals of Clinical Biochemistry: International Journal of Laboratory Medicine* **48**(6), 4874–88. https://doi.org/10.1258/acb.2011.011177

Holm, J.W., Mortensen, O.S. & Gyntelberg, F. 2016. Upper limb disorders among biomedical laboratory workers using pipettes. *Cognet Medicine* **3**(1), 1256849. doi: 10.1080/2331205X.2016.1256849

Hämmig, O. 2020. Work- and stress-related musculoskeletal and sleep disorders among health professionals: a cross-sectional study in a hospital setting in Switzerland. *BMC Musculoskeletal Disorders* **21**(319), 2–11.

El-Helaly, M., Elsherbeny, E., Haji, A., Assiri, M. & Fademula, A. 2018. Reported musculoskeletal symptoms among laboratory workers, in relation to individual and work-related physical factors. *Egyptian Journal of Occupational Medicine* **42**(1), 799–2.

Kadivar, M., Kabir-Mokamelkhah, E. & Habibi-Shams, Z. 2021. Work-related hazards among pathologists and residents of pathology: Results of a Cross-sectional Study in Iran. *Iran Journal of Pathology* **16**(3), 274–283. doi:10.30699/ijp.2021.132380.2473

Kricka, L.J. & Savory, J. 2011. A Guide to the History of Clinical Chemistry. *Clinical Chemistry* **57**(8), 1118–1126.

Occupational Qualification Standards: Biomedical scientist, level 7. (2023). https://www.kutseregister.ee/ctrl/et/Standardid/exportPdf/11203088/?nocache = be3fee15 a9 (in Estonian).

Occupational Qualification Standards: Medical laboratory specialist, level 7. (2022). https://www.kutseregister.ee/ctrl/et/Standardid/exportPdf/11017726/?nocache = g1d6f0d4a8 (in Estonian).

Laboratory medicine development plan 2011–2020. Laboratory medicine development plan https://www.elmy.ee/wp-content/uploads/2018/02/Laborimeditsiini_arengukava_2012-2020.pdf (in Estonian).

Lòpez-Gonzàlez, J.M., González, S. & González-Menéndez, E. 2019. Prevalence of musculoskeletal problems in laboratory technicians. *International Journal of Occupational Safety and Ergonomics (JOSE)* **27**(3), 840–851. doi: 10.1080/10803548.2019.1646531

Lorusso, N.L.A., Bruno, S. & Caputo, F. 2007. Risk factors for musculoskeletal complaints among microscope workers. *Giornale Italiano di Medicina del Lavoro Ed Ergonomia* **29**(4), 932–7.

Maulik, S. & Iqbal, R. 2014. Evaluation of the working posture and prevalence of musculoskeletal symptoms among medical laboratory technicians. *Journal of back and Musculoskeletal rehabilitation* **27**, 4534–61.

Olver, P., Bohn, M.K. & Adeli, K. 2023. Central role of laboratory medicine in public health and patient care. *Clinical Chemistry and Laboratory Medicine* **61**(4), 666–673. https://doi.org/10.1515/cclm-2022-1075

Patel, H. & Pandya, U. 2017. Prevalence of Neck Pain in Laboratory Technicians. *Journal of Novel Physiotherapies* **7**(4), 10–13. doi:10.4172/2165-7025.1000340

Patrao, A.I.D., Pais, S., Mohandas, L. & Shah, M. 2022. Activities of Microscopy and Pathology cause the most musculoskeletal discomfort for medical laboratory professionals - Results from a detailed ergonomic analysis. *International Journal of Industrial Ergonomics* **92**, 103349. doi: 10.1016/j.ergon.2022.103349

Roudi, E. & Zakerian, S.A. 2019. Evaluating the Microscope Users Occupational Health Status Considering Musculoskeletal Disorders and Visual Fatigue at Tehran University of Medical Sciences. *International Journal of Occupational Hygiene* **11**(4), 1–8.

Sikaris, K.A. 2017. Enhancing the Clinical Value of Medical Laboratory Testing. *Clinical Biochemis*t. Review, **38**(3), 107–114.

Wilson, S., Steele, S. & Adeli, K. 2022. Innovative technological advancements in laboratory medicine: Predicting the lab of the future. *Biotechnology & Biotechnological Equipment* **36**(1), 9–21.