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ERGONOMIC ANALYSIS OF OPHTHALMIC NURSE WORKPLACE USING 3D SIMULATION

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Abstract
The number of work-related musculoskeletal disorders has been increasing in most industries and occupations. Since these injuries impose high costs on employers and society it is important to prevent it through ergonomic assessment and job redesign. The paper presents a research of the workplace ophthalmic nurse regarding strain and stress. In the workplace the Intravenous Fluorescein angiography or fluorescent angiography is made which is a technique for examining the circulation of the retina and choroids using a fluorescent dye and specialized camera. The working procedure is complex and since nurses must assist in several forced positions for longer time ergonomic analyses were made aimed to determine strain and stress at workplace. For assessment of body postures OWAS analysis was performed manually and using computer simulation. The results obtained using computer simulations are comparable to manually performed research for most body positions except for bent and twisted back. Body postures of upper limb, lower limb and neck were exposed as harmful for nurse during working procedure and according to OWAS changes are needed in near future.
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Key Words: Ergonomic Analysis, Computer Simulation, OWAS Method, Workplace Design, Ophthalmic Nurse

1. INTRODUCTION

Nurses have been the subject of many studies to examine how physical stress and other work related factors may affect their health and well-being [1-4]. Many of these studies focused on disorders of back, trunk, upper extremities, neck and lower extremities which are generally known as leading work- related illnesses and injuries. Also most research has been carried out in general hospitals; there is no available data about physical work load of ophthalmic nurse in functional diagnostics. Since diagnostics and treatment procedures of macula diseases become more complex and advanced also related nurse assistance become more complicated and stressful. Nurses must assist in several forced positions for longer time therefore ergonomic analysis were made aimed to determine possible health problems and to prevent them where possible.

For the purpose of our research we used one of the widely used methods of observation in working posture studies, the Ovako Working Posture Analysis System (OWAS) and later also Rapid Upper Limb Assessment (RULA) for the comparison. OWAS method is used to identify and evaluate harmful working postures and is widely spread in all professions. The purpose of OWAS is to provide a system for analysing and classifying working postures with the aim of developing working methods consistent with the promotion of occupational health.

Since manual performance of OWAS method is time consuming we performed also computer aided simulation and research presented problem using computer analysis (OWAS analysis as primary and RULA for confirmation and comparison). Comparison of manually performed OWAS with computer aided gave us the real insight into benefits and weaknesses of both performances. For present-day computer aided analysis could be estimated as more user friendly and less disturbing for the worker.

2. RESEARCH PROBLEM

While working, the workers are exposed to various strains and stressors that contribute to stress. Strains and stresses belong to an important group of factors that reduce human efficiency at work due to disturbed hemostasis, resulting in fatigue [2, 3, 5-7]. To reduce the effects of this phenomenon, working hours should be interrupted by several rest periods and breaks [8]. Beside that workplace should be designed considering human dimensions using anthropometric measures. From the ergonomic point of view the most important factors that influence stress at work can be divided into:

1. working environment with working conditions such as noise, heat, humidity, illumination, air velocity and
2. body postures; especially awkward postures that can cause health problems.

Since there were some complaints evidenced about back and neck pains in Fluorescein angiography ambulance we decided to observe all nursing activities during nurse's workday. Intravenous Fluorescein angiography or fluorescent angiography is a technique for examining the circulation of the retina and choroid using a fluorescent dye and specialized camera. It involves injection of sodium fluorescein into the systemic circulation, and then an angiogram is obtained by photographing the dynamic fine structure of retinal blood vessels and vascular hemodynamics and vascular physiology, pathology, diagnosis and treatment of ocular fundus.

Nursing approach to management involves patient consent, ophthalmic preparation (visual acuity, drops are then instilled into both eyes to dilate the pupils, measuring OCT, inserting IV cannulla), the procedure and also after the procedure.

To minimize risk at work scientifically design of workplaces based on methodical approach is very important [9-11].

3. METHODOLOGY

For the presented problem consideration the following steps were taken:

- workplace analysis and evaluation; analysis of the existent workstation dimensions with respect to working postures and workers' perceptions; Fluorescein angiography ambulance is working once a week but for clinical patients the procedure can be done every day; for our research we followed up patients in the ambulance, three sequence ambulances; the observation was conducted all day, three times per hour on 27 (3×9) patients,
- workplace analysis considering working environment; accurate measures of noise, illumination, heat, humidity and air velocity were taken,
- the extended OWAS method was used to evaluate the strain caused by different operators' postures at nursing workstations,
- examined workplace was designed and analysed using Jack software package made by Technomatics,
- several simulations were made and above all comparison between manual performed OWAS analysis and software OWAS analysis was made to research the reliability of used software.

3.1 Workplace Fluorescein angiography

The following figures demonstrate the different operators' postures at observed workstation. Operator seat near the table and make visual acuity (Fig. 1). When putting lances to the glasses the operator has to twist thoraxlumbal spine, upper limb is raised above the head and hands are loaded to, because a lot of precise grasps is needed.

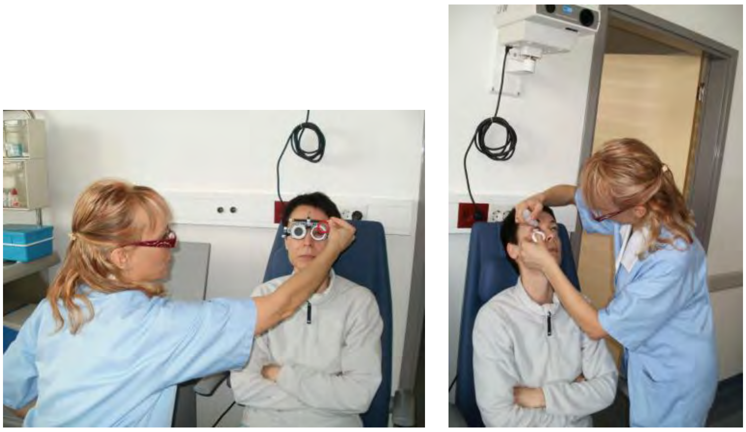


Figure 1: Operators make vision acuity and instil drops into both eyes.

Operator is banding to the patient and pouring a drop into patients' eyes. Thoraxlumbal spine is bending in lumbar and cervical area, upper limb is raised above and hands are loaded to, because a lot of precise grasps is needed, too.

Figure 2: Operator assists in the procedure.

During the procedure (Fig. 2) operator is banding near the patient. Thoraxlumbal spine is bending and twist in lumbar and cervical area, upper limb is raised above the head and hands are loaded to, because a nurse must hold an eyelid apart to enable photograph eye fundus. The duration of performed examination is at least 10 minutes sometimes even 13 or 14 minutes and nurse must stay in described position which is extremely damaging for back, arm with shoulder and neck.

3.2 OWAS method

OWAS, the Ovako Working Posture Analysis System, was developed in Finland for examining workers postures in steel industry in 1973 [5, 12]. The method was successful and therefore further developed and modified. It is considered a practical method for identifying and evaluating working postures. The OWAS procedure consists of two parts: an observational technique to classify body postures, and a set of criteria for the redesign of working methods and workplaces. Body postures are classified into 28 positions including the positions of back (four positions), upper limbs (four), hands (three), lower limbs (nine), head and neck (five), as well as load or force handled (three). Each body area consists of ranked postures that describe the risk or severity of that body area's posture.

Since OWAS is a time-sampling method it requires the time sampling of tasks in intervals that can be planned or randomly selected. The system was originally developed for use in manufacturing industries, where workstations are static and job tasks repetitive and predictable in nature. Later other methods were developed, too, such as RULA for upper limb assessment [13, 14] and REBA for entire body assessment [15]. According to Roman-Liu [16] OWAS, RULA and REBA are the most common methods for assessing the load of the whole body. Our Laboratory for Production and Operations Management has many years' of experiences with OWAS method therefore we decided to use OWAS for working postures assessment.

As explained before by OWAS method body postures are classified into 28 positions. Each of these positions has pre-defined high risk and low risk postures, which are coded by the observer. After calculating the amount of time the worker is in these postures, the final step is to assign a four-level action code for task improvement. The four action codes are defined as follows: changes are not needed, changes are needed in near future, changes are needed immediately, needed intensive observation.

3.3 Computer aided OWAS analysis

For assessing presented workplace ergonomic software package Jack was used made by Siemens PLM Software. Jack is a complete system for generating 3D environments and interacting with them in a powerful graphical environment. It is based on a detailed link segment model with biologically accurate motion prediction and joint kinematics. Using Jack we can design real-time environment with interactive viewing, multiple windows, lights and cameras, textures and mirrors.

The most important and useful part of Jack software is a possibility to perform different analysis. The Jack analysis toolkit is a set of Ergonomic analysis tools that help us to design better work areas and evaluate physical tasks. Some of analyses are:

- Lower back analysis tool,
- Static Strength prediction,
- NIOSH,
- Metabolic energy expenditure,
- Fatigue recovery,
- Ovako Working Posture Analysis (OWAS) tool,
- Rapid Upper Limb Assessment (RULA),
- Manual handling limits,
- Forcesolver,
- Predetermined time.

Using different analyses Jack enable us to design a workplace that minimizes the risk of low back injuries, to determine if workers have enough strength to perform a prescribed job, to design and evaluate lifting jobs, to determine metabolic energy requirements of a job and to compare alternative job designs based on their relative risk of exposing workers to fatigue. Beside that help us to assessing a working posture for its potential to expose workers to injury, identify manual tasks that expose workers to increased risk of upper limb disorders, evaluate manual handling tasks and predict whether a worker can be expected to perform a job under predefined cycle time requirements.

We used Jack for designing the workplace of ophthalmic nurse (Fig. 3), simulate working postures and above all to perform several analyses.

Figure 3: Computer designed nurse position at work.

3.4 Comparison of used methods

Since manual performance of OWAS method is very time consuming we were interested if computer aided simulation and analysis is enough accurate and reliable. Therefore we compare results of both used methods.

Manual performance was performed by student that observed ophthalmic nurse workplace in three sequence ambulance. Student first observed nurse to get familiar with working procedure and operations performed. After that we started with OWAS. Beside time spent for nurses' observation students were first trained in the laboratory to get enough skills to perform manual evaluation. It is not easy to recognize position of all body parts and to write down results in correct place without practice.

On the other hand for computer aided analysis video tape of working procedure is enough to create virtual workplace, make simulation of all workers (and robots – safety!) movement and perform analysis [17, 18]. The biggest advantage of this way is that we can observe video many times and thus create environment that is almost identical to real environment including time spent for particular operation.

4. WORKPLACE ANALYSIS AND RESULTS

For workplace analysis considering working environment accurate measures of noise, illumination, heat and air velocity were taken (Table I). Measured values of temperature and air velocity are suitable for work they are doing. Also noise level is within recommended values since conversation between patients and medical personnel is needed (doctor is giving instructions to the patient and patient can also ask questions). Workplace illumination is extremely low and this is a problem because the working procedure requires darkness.

Table I: Noise level, illumination, temperature and air velocity.

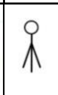
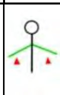
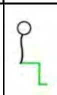
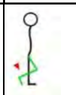
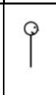
	Measured values			
	Noise [dB]	Illumination [lx]	Temperature [ºC]	Air velocity [ms^{-1}]
	50	20	24,7	0,07
	45	10	24,6	0,14
	45	10	24,8	0,09
Average value	46,6	13,3	24,7	0,10

Results of manually performed OWAS analysis (conducted 3 days, 3 times per hour, 27 people) used to evaluate the strain caused by different operators' postures at observed workstations are presented in Table II and in Fig. 4. Percentage of each body posture was calculated using eq. (1) and also time portion for that body posture was calculated using eq. (2).

$$p = \frac{\sum F_p}{\sum F_s}[\%] \tag{1}$$

$$t_p = \frac{450 \cdot p}{100}[\min] \tag{2}$$

Table II: OWAS – calculated results with recommended measures.

Body parts	Thoraxlumbal spine				Upper limb			Hands		Lower limb		Head		
	1.1	**1.2**	**1.3**	**1.4**	**2.1**	**2.2**	**2.3**	**3.1**	**3.2**	**4.1**	**4.3**	**5.1**	**5.2**	**5.3**
														
Nr. of measures	24	6	12	39	21	6	54	54	15	30	51	21	33	27
p_i [%]	29,6	7,4	14,8	48,1	25,9	7,4	66,7	78,3	21,7	37	62,9	25,9	40,7	33,3
t_{pi} [min]	53,3	13,3	26,6	86,6	46,6	13,3	120,1	140	39,1	66,6	113,2	46,6	73,3	59,9
Measure	□	□	□	▲	□	□	●	★	□	□	●	□	●	●

Legend: □ – changes are not needed ▲ – changes are needed immediately
● – changes are needed in near future ★ – needed intensive observation

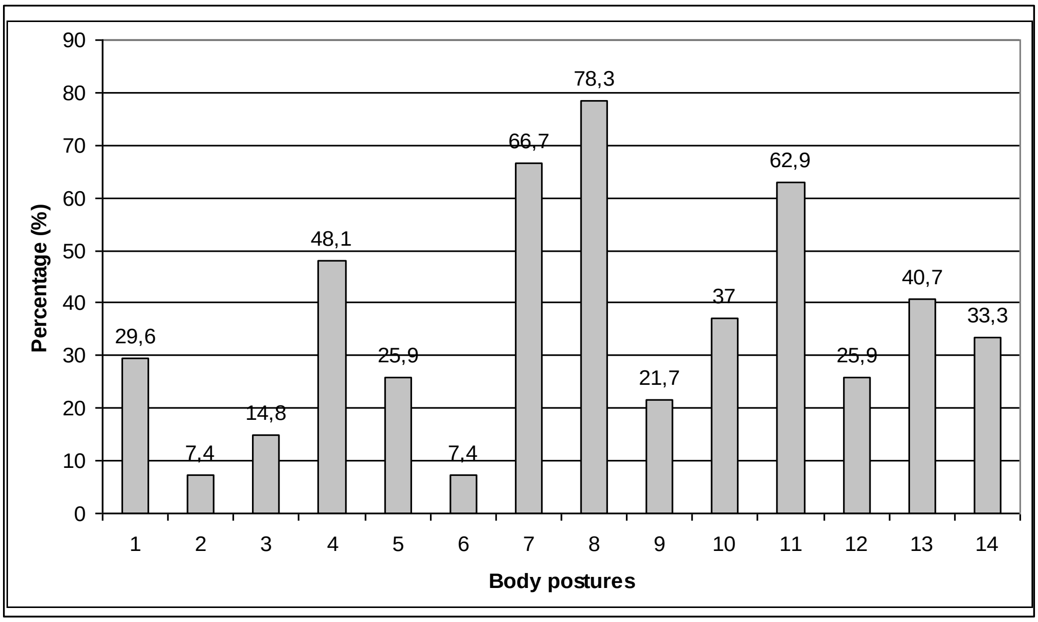


Figure 4: The histogram of the OWAS results applied at the inspected workplace.

Obtained results were compared with recommended measures (Table III) and results are presented with signs. Results confirmed previous prepositions showing that body posture 1.4 – bent and twisted back could be harmful for nurse and changes are needed immediately. Also postures 2.3 – one arm above shoulders, 3.1 – fine grasp and 4.3 – standing on one leg have high percentage and therefore changes are needed in near future and for fine grasp intensive observation is proposed. Also for head postures 5.2 – bent forward head and neck and 5.3 – bent to side head and neck changes are needed in near future. For another postures changes are not needed unless it makes discomfort.

Table III: OWAS – review table of recommended measures.

Part	Thoraxlumbal spine				Upper limb			Hands		Lower limb		Head		
	1.1	**1.2**	**1.3**	**1.4**	**2.1**	**2.2**	**2.3**	**3.1**	**3.2**	**4.1**	**4.3**	**5.1**	**5.2**	**5.3**
OWAS / %														
10	□	□	□	●	□	□	□	□	□	□	□	□	□	□
20	□	□	□	●	□	□	□	□	□	□	□	□	□	□
30	□	□	●	●	□	□	□	□	□	□	□	□	●	●
40	□	●	●	▲	□	●	●	□	□	□	●	□	●	●
50	□	●	●	▲	□	●	●	□	□	□	●	□	●	●
60	□	●	▲	▲	□	●	●	□	□	□	●	□	▲	▲
70	□	●	▲	▲	□	●	●	□	□	□	●	□	▲	▲
80	□	▲	▲	▲	□	▲	▲	★	★	□	▲	□	▲	▲
90	□	▲	▲	▲	□	▲	▲	★	★	●	▲	□	▲	▲
100	□	▲	▲	▲	□	▲	▲	★	★	●	▲	□	▲	▲

Legend: for the meaning of all symbols see Table II.

Computer aided simulation using Jack OWAS analysis gave as very similar results as manually performed OWAS except for bent and twisted back. Regarding to manually performed observation for this body part orange colour should appear but computer simulation stayed at yellow (Fig. 5). For body postures of upper limb, lower limb and neck changes are needed in near future that is identical to results got with manually performed procedure.

Comparison of manually and computer aided analysis shows that results are very identical for most parts but there are also exceptions that demands attention. Of course there are benefits and obstacles for each mode. Although for computer aided simulation exact design of body motions is the most time consuming part it is later much easier to analyse simulated movements and software package even enables us to perform different analysis. Beside that all analysis can be performed in much shorter time as performing manual analyses.

To support results gained with OWAS also RULA method was performed (Fig. 6). RULA assesses the risk of upper limb disorders based on posture, muscle use, the weight of loads, task duration and frequency. Beside that assigns the evaluated task a score that indicates the degree of intervention required to reduce the risk of an upper limb injury. Results of RULA confirmed previous results obtained with OWAS: investigation and changes are required soon.

As could be evidenced from the presented problem the computer simulation is very useful, is less disturbing for the worker, it is not necessary to spent all day for observation; we only need video record of the procedure. Since video record could be stopped whenever we want computer simulation can be designed very exactly with exactly defined individual positions. Using different simulations we could confirm results of one analysis with results of another analysis thus increasing scientific value of performed research.

On the other hand presented case evidenced minor deviations between manually and computer aided analysis meaning that manual research should be performed periodically with the aim to propose improvements in computer simulations.

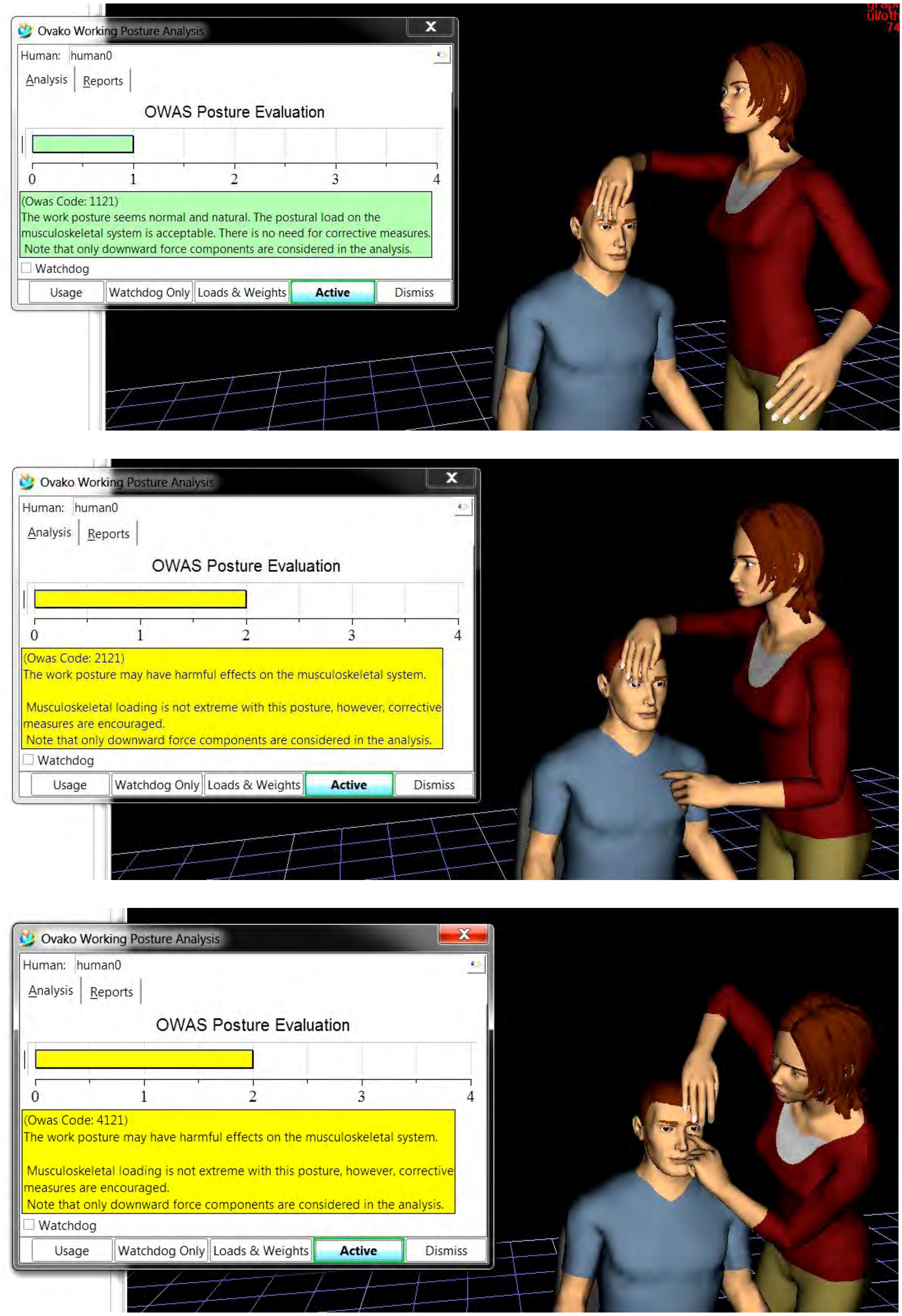


Figure 5: Typical working posture during investigation simulated and analysed with Jack.

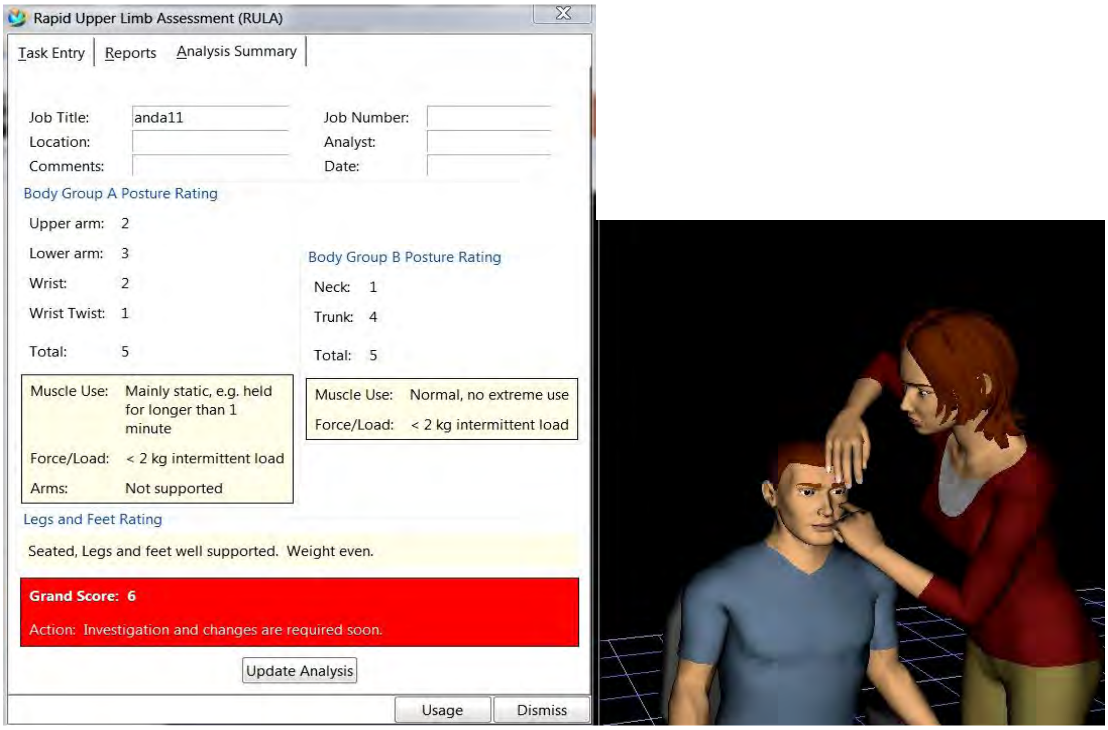


Figure 6: Workplace ophthalmic nurse analysed using RULA method.

5. CONCLUSIONS

The results of the presented research using OWAS method confirmed the nursing complaints about high back pains and high load on hands. According to manually performed OWAS for body postures of back changes are needed immediately and for postures of upper limb, lower limb and neck changes are needed in near future. The similar results were gained also using computer aided simulation using OWAS analysis thus confirming the reliability of performed research in most parts except for body part 1.4 – bent and twisted back. Based on the presented case it can be concluded that the results of an OWAS tool analysis can be used to design a manual task for minimal risk of postural discomfort but also periodical comparison with manual performed research is useful since little changes exist.

Beside musculoskeletal problems also attention to eyestrain of operators that perform photography on specialized camera should be drawn. The problem is operators' presbiopia and lens accommodation that lead to fatigue. The problems usually occur after investigations and demands rest therefore shorter rest periods could be of benefit.

Workplace analysis considering working environment show that measured values of noise, temperature, humidity and air velocity are within recommended values except illumination which is extremely low, only 13.3 lux. According to theory and recommendations this is a problem but the working procedure requires darkness.

Another problem is lighting that appear at every flash. For solving this problem an assistant should wear protective glasses.

The presented problem is complex and further investigation should be taken. Since the investigation procedure of Intravenous Fluorescein angiography is prescribed and should be performed in defined sequence the nurse work postures cannot be changed immediately. For solving this problem different solutions should be considered otherwise nurse complaints about high back pains and high load on hands will stay the same and can lead to health problems. The only possible measure in the presented situation is greater number of nurses that will rotate on different workplaces.

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