Analysis of musculoskeletal disorders due to repetitive work and low back load in the working environment

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Introduction

In spite of extensive industrial automation, disorders often develop during work as a result of physical effort. Whereas physiological overload was previously a key issue, localised overload disorders are now more frequent, resulting from repetitive tasks and static muscle load of the arms or lower back.

An important aim of this project was to detect the risks of musculoskeletal disorders while performing a task in the working environment. Electromyography (EMG) was the technique used.

To understand the origin of these disorders, the relation between force production and the electromyographic signal was studied on fatigued and non-fatigued muscles. The influence of local fatigue on the coordination of different muscles was analysed, and the possibility of determining a scale of fatigue for muscles was also considered.

In a practical study, expertise was applied to analysing problems in the working environment, and to proposing interventions. This study was undertaken on a suitcase assembly line. The project included an evaluation of different interventions (adaptation of work places and training) to check whether the aims were achieved.

Materials and methods

The use of EMG in the working environment is the common thread throughout the project. In the theoretical part the project, a number of studies were designed to throw more light on data resulting from electromyographic tests in the laboratory. Different electromyogram processing methods were used to investigate how muscle fatigue could be evaluated objectively. An EMG signal was generated using a simulation program, allowing the development of fatigue indicators to be studied. The results from the computer model were tested against data from the laboratory studies. As muscles never work alone, research on muscle coordination is necessary, for both fatigued and non-fatigued muscles. Using muscle models on a Silicon Graphics system, it is possible to simulate movements and to identify the various contributions of the acting muscles. Finally, we investigated whether it was possible to predict the endurance time of muscles, using the fatigue indicators identified in the first part of the research.

In the applied part of the project, EMG methods were used to reduce the number of overload disorders during assembly tasks. EMG was used to detect risk-entailing tasks, to evaluate workplace adaptations, to evaluate the effect of training, and to determine fatigue in the back muscles. All subjects in the working environment participated voluntarily.

Results

Theoretical research

A regression model was built to determine indicators of muscle fatigue. Increases in RMS and ACT and a decrease in MPF are changes in muscle status during prolonged tasks, and can therefore be used as indicators of muscle fatigue. It is clear from the experiments that these parameters each evolve following a typical pattern. In tests on different percentages of MVC, the amplitude parameters correlated highly with the force achieved. There was no correlation between MPF and force. From this part of the research, it appears that changes in RMS and ACT can be used to show muscle fatigue. Another study investigated how the muscle recovers after effort, and how fatigue parameters behave in a repeated endurance test. MPF and RMS changed significantly in both tests, whereas there were no significant changes in ACT. The regression between the endurance time and the EMG parameters of the two sessions did not seem to differ, the relative increase and decrease being similar. However, the endurance time differed significantly, being shorter in the second test. There seemed to be no significant differences between the start values of each of the parameters. The start value for the second test was lower for MPF and higher for ACT and RMS, which could point to incomplete recuperation.

Explanations for changes in indicators of muscle fatigue are sought in simulation models. From the results of these simulation studies it can be concluded that the four fatigue indicators follow a similar pattern in the non-fatigued and experimental situations. It was also possible to change the parameters in the model so that the EMG parameters followed the same course in fatigued simulations as under experimental conditions. The most important combination of parameters contributing to the origin of fatigue seems to be: a decrease in motor unit force production of about 10%, an increase in neural activation, a decrease in fibre conducting velocity, a decrease in maximal motor unit firing frequency, and selective failure of the strong and fast motor units.

To produce voluntary motions or maintain postures, different muscles need to work together. This phenomenon is called contraction synergies. When a certain posture or an isometric force is delivered, agonists and antagonists have to work together. The agonists try to deliver the force, the antagonists try to stabilise the joint. Contraction synergies are more complex for voluntary controlled motion. Interactive software can test the findings reported in the literature against data from simulations. The use of computer models for simulating muscle coordination patterns seems an interesting approach, whereby specific parameters can be changed and the influence of each parameter on coordination can be identified.

Results of previous research indicate that it should be possible to determine the level of fatigue of a muscle. The extent to which the parameters change at the beginning of the muscle effort can be related to the endurance time. This means that a certain level of effort can be determined which a person can maintain comfortably for a period of eight hours. In this method the load and individual capacities of the employee are taken in account. The MPF parameter is the most suitable for making predictions. Absolute values for the initial phase and also initial changes in MPF are used.

Applied research

Applied research was carried out at Samsonite Europe N.V. in Oudenaarde, focusing on repetitive tasks for the upper limbs and back load. The study began on an assembly line where there were complaints regarding the upper limbs and back. The work place was optimised in an interactive way. Electromyography was used for monitoring and evaluation. Both risk tasks and the workplace setup could be addressed here. The findings of the evaluations were discussed with the heads of the prevention departments. A training programme was developed, based on the results of the study, for a new assembly line, to ensure that employees performed only safe operations. An ergonomics checklist was also drawn up so that the company could provide continued support.

Conclusions

Interest in ergonomics is increasing both in industry and in the field of law. The law on well-being at work assigns to prevention services a number of tasks which are fulfilled by ergonomists. Ergonomics still has a way to go to prove its value in industry and its importance alongside safety and the environment. This research project shows that when working on a scientific basis, employers, employees, and industrial unions will listen to the arguments of ergonomists.

Electromyography is the central theme in this project. The theoretical and applied approaches are both important. A number of methods previously used only under laboratory conditions are now used in practice. The advantage is that the relevance of such techniques can be shown clearly, even when it is difficult to set up large, standardised studies in the working environment. The information recorded on each participating individual is very useful.

Regarding the theoretical part of the project, high-level research has been performed in recent years. The laboratory collaborates with a group of famous European research institutes. The ergonomic approach using EMG is particularly important, as other centres use more clinical applications. The use of surface EMG is sometimes criticised because the information gained is a summation of several signals. On the other hand it has the advantage that information is gathered from a larger part of the muscle, giving better insight into the behaviour of the whole muscle. Surface EMG is more relevant when describing behaviour of the whole muscle than when describing the behaviour of a single muscle fibre. This project clarifies how EMG parameters are influenced by fatigue. With the use of the simulation model it has become clearer how the signal is influenced by a combination of factors.

In the future, the coordination model will clarify interactions between the different muscles. How muscles work together, and what happens when muscles are fatigued are questions that can be answered with such models. The models are currently under development, and ergonomic applications will follow their development.

The prediction of endurance time is a new aspect of the project. With increased knowledge about the indicators of muscle fatigue, it should be possible using initial parameters to predict how long an exertion can be maintained. It seems that the frequency parameters are the most reliable for making predictions. Both the start value and the initial slope should be used for the prediction. The important advantage of this EMG method is that individual capabilities and task aspects are integrated. Different employees may perform the same task in completely different ways. Depending on a number of intrinsic factors, the physical load for the individual may vary. Each employee performs his working tasks in his own way, depending on his capabilities. When his capabilities are no longer sufficient, he may adopt poor movement patterns, which may lead to overload risks. With this prediction method, overload disorders can be avoided.

We may conclude from the applied research that the use of EMG in the working environment is feasible in practice, and in many cases necessary to avoid complaints or reduce their number. The information gained from EMG cannot be obtained in any other way, and indicates how a person with certain capabilities copes with a load. Reactions in the field to this kind of evaluation of working tasks are very positive. Similar recordings and analyses have been performed in the textile, car assembly and tertiary sectors. Improvements to EMG devices and portable computers have made it possible for prevention services to use these techniques themselves.

Another project conclusion is that it is necessary to provide good follow-up to ergonomic interventions. It should be checked whether the aims of the interventions are achieved, particularly to ensure that problems are not just transferred elsewhere. Despite the frequent use of subjective questionnaires in ergonomics, it became clear that employees are not always aware of the best (risk-minimising) way to perform a working task. Continuous professional support and consultation with employees is essential to achieving results.

During the project, there has been extensive liaison with the prevention consultant, company doctor, and safety manager. The laboratory has also participated in many seminars for company doctors, safety managers, and ergonomists providing information on the state of the art in ergonomic research and on possibilities in the field. The results of this research project can contribute to the specification of standards for physical effort during working tasks. The translation from scientific knowledge to appropriate standards will not be simple, because characteristics of the individual need to be taken into account.