An investigation into the relevance of the pattern of temporal activation with respect to erector spinae muscle endurance

Jaap H. van Dieën1,2, Huub H. E. Oude Vrielink1, and Huub M. Toussaint2

1 Work Study and Ergonomics Department, Institute of Agricultural Engineering (IMAG-DLO), P.O. Box 43, NL-6700 AA, Wageningen, The Netherlands
2 Faculty of Human Movement Sciences, Vrije Universiteit, Van der Boechorststraat 9, NL-1081 BT, Amsterdam, The Netherlands

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Summary. The aim of the present study was to evaluate the viability of a relationship between the temporal activation pattern of parts of the erector spinae muscle and endurance. Seven subjects performed intermittent isometric contractions [4 s at 70% maximal voluntary contraction (MVC), 2 s rest] until exhaustion, during which the electromyographical (EMG) activity of the multifidus, iliocostalis thoracis and longissimus muscle segments was recorded. Endurance was defined as the time until exhaustion. Subjects were divided into a high and a low endurance group. The high endurance group showed significantly more variability of EMG amplitude over succeeding contractions. This group demonstrated significantly more alternations of EMG activity between parts of the muscle also. Variability of the EMG amplitude within the contractions did not differ between the groups, nor did MVC. The results indicated that alternating activity between different parts of the erector spinae muscle may function to postpone exhaustion of this muscle as a whole.

Key words: Erector spinae muscle - Endurance - Intramuscular coordination

Introduction

Endurance of low back musculature in isometric extension has been shown to be inversely related to the first time occurrence of low back pain in men in a general population (Biering-Sorensen 1984). In a population which was homogeneous as regards occupational activities (mail delivery), a similar relationship has been found retrospectively for both men and women (Nicolaïsen and Jørgensen 1985; Jørgensen and Nicolaïsen 1987).

Endurance has been shown to be influenced by a large number of individual and situation factors (Dieën and Oude Vrielink, in press). In view of the results of the studies in the occupational group described above, individual factors determining the endurance of the low back musculature are of considerable interest. These can be divided into anatomical, physiological and functional factors. Examples of the former group are for example fibre type composition and capillarization (Tesch et al. 1985). Among factors of a physiological nature are for instance hormonal balances and blood lactate concentration (Dieën and Oude Vrielink, in press). Variation in the temporal pattern of activation can be considered to be a functional factor. The present study focuses on the influence of this latter factor.

In relation to endurance of the erector spinae muscle, fibre type composition has been investigated by Sirca and Kostevc (1985) and Johnson et al. (1973). From their studies it can be concluded that in general the erector spinae muscle contains a high proportion of type I fibres. The average proportion was reported to range between 56% and 60%. The interindividual differences are, however, considerable; standard deviations amounting to 12% have been reported. Jørgensen and Nicolaïsen (1991) have investigated the relationship between fibre type composition and capillarization determined from biopsies on the one hand and isometric endurance on the other. Only weak correlations (r<0.60) were found, a finding which indicates that the anatomical factors mentioned are only of limited importance for erector spinae muscle endurance.

A functional factor, which might influence endurance is the temporal activation pattern of the muscle or parts of the muscle. Variation in the level of activation of parts of a synergic muscle group might allow for recovery to occur during the activity. Sjøgaard et al. (1986) have found alternating activation between parts of the quadriceps muscle during sustained activity at 5% maximal voluntary contraction (MVC). Duchêne and Goubel (1990) have demonstrated likewise alternation in the grade of activation of parts of the triceps surae muscle, during isometric activity at 80% MVC. The latter authors speculated on the influence of this phenomenon on endurance but did not analyse this presumed rela-
tionship. In line with these findings Veiersted et al. (1990) have found the electromyographical (EMG) activity of the trapezius descendens muscle to be interrupted for short durations (0.2–2 s) during light occupational activity in some subjects. Subjects who demonstrated this phenomenon were shown to suffer significantly less from cervico-brachial disorders. The relationship among these so-called EMG gaps and endurance was not investigated but an influence relating to their occurrence seems plausible. In conclusion, variation in the activation level of parts of a synergistic muscle group, possibly compensated for by the other parts to keep force output at the desired level, may contribute to prevent excessive fatigue and even muscle pain.

The aim of the present study was to investigate the influence of interindividual differences in temporal activation pattern, if any, on the endurance of the erector spinae muscle during isometric extension, and to test methods to quantify the occurrence of these phenomena. To this end data collected in a previous study (Dieën et al. in press) were re-analysed.

Methods

Subjects. Seven healthy male students participated in the experiment. Their mean age, height and mass were 24.4 (SD 3.5) years, 184.5 (SD 5.1) cm, and 72 (SD 7.2) kg, respectively. All subjects signed informed consent forms prior to the experiment. None of the subjects had experienced low back pain.

Instrumentation. The experimental setup has been described in detail (Dieën et al. 1991; Dieën et al. 1992). The subjects were seated in a chair. Trunk extension force was applied to a stiff harness, which was placed around the subject's trunk just beneath the spinous process C7. The harness was connected to a strain gauge by means of a steel cable. The force signal was amplified and subsequently displayed by a digital voltmeter for direct control of the force and feedback to the subject.

Prior to the experiment surface EMG electrodes (silver chloride, Sentry Medical Products) were bilaterally attached to the subject's back after cleaning and gentle abrasion of the skin. The EMG signals were recorded from parts of the left and right erector spinae muscle at electrode locations according to Roy et al. (1989) (multifidus muscle 3-cm lateral to the spinous process L5, iliacostalis lumborum muscle 6-cm lateral to the spinous process L2, longissimus thoracis muscle 3-cm lateral to the spinous process L1). The inter-electrode distance was 2.5 cm. The earth electrode was attached over the C7 spinous process. The EMG signals were amplified with special purpose pre-amplifiers and transmitted to a Biomes-8 receiver. Both force and EMG signal were stored on tape (AMPEX) with a portable data recorder (TEAC SR-70). The raw EMG and force signal were printed using a Gould ES 1000 printer (paper speed 25 mm s⁻¹) for an immediate global impression of signal quality.

Procedure. Prior to the actual experiment the MVC force of the erector spinae muscle was determined, according to the protocol proposed by Caldwell et al. (1974). The experiment itself consisted of a series of contractions (approximately 70% MVC) which lasted 4 s, separated by 2 s of rest. The experiment was continued until force remained below 60% MVC after repeated encouragement, or up to a maximal period of 15 min. Endurance was defined as the duration of this series. Both the determination of the MVC and the actual experiment were performed while sitting in a chair with the trunk upright.

Data analysis. The force signal of a window of six contractions around each full minute of the endurance time was low-pass filtered (cutoff frequency 100 Hz) and A-D converted (sample frequency 400 Hz). No corrections for the moment arm were made, as length differences between subjects were negligible. The concomitant EMG signals were band-pass filtered (25–200 Hz) and A-D converted at a sample frequency of 400 Hz. From the six contractions the signal with the most stable force level was selected. From this 4-s contraction the data from a period of 2 s during which the force was stationary was used for further analyses.

Analysis of EMG-gaps. To assess the occurrence of gaps, plots of the rectified and 25-Hz low-pass filtered EMG were produced in which the average amplitude was set at 100%. In these time-series of rectified and averaged EMG (RA-EMG), amplitudes remaining below a preset detection level for at least 0.2 s were detected by the software. The minimal duration of a gap was defined in line with Veiersted et al. (1990). The latter authors used a detection level representing 0.5% of the MVC. However, since we did not subtract noise levels from our EMG data we used a higher detection level – 5% of the mean RA-EMG. Assuming linearity of the force-EMG relationship, the 100% level representing 70% MVC, this level would represent about 3.5% MVC. Nonlinearity of the relationship as demonstrated by Stokes et al. (1987) would imply that this was a minor underestimation.

Analysis of alternating activity. The occurrence of variation in the activity of parts of the muscle and alternation between the various parts was assessed within contractions and over succeeding contractions. Alternations among the three homolateral electrode locations and between the summed activity of the left and right erector spinae muscles were evaluated separately. The RA-EMG was computed with a window of 40 ms for the analysis within contractions. For the analysis over succeeding contractions, the EMG signal was averaged over the whole 2-s period of each contraction analysed. The RA-EMG was then normalized to the concomitant force. Since a fatigue related positive trend in the RA-EMG: force ratio exists, this trend was subtracted from the resultant time-series of the RA-EMG. Varying and alternating activity was quantified by means of three indicators. The coefficient of variation of the RA-EMG was used to indicate the variability of the activation level at each electrode location. The averaged coefficient of variation of all electrode locations was used as the first indicator (Ind1). For the calculation of an indicator of alternating activity, three pairs of homolaterally obtained signals were compared. The proportion of samples at which the two signals compared deviated from their respective means in an opposite direction was determined and multiplied by the average deviation from the mean occurring at these samples normalized to the mean (Fig. 1). This indicator averaged over the three pairs of signals will be referred to as Ind2. To quantify alternating activity between the left and right erector spinae muscles, the sum of the right erector spinae muscle signals was in the same way compared with the sum of the left erector spinae muscle signals. The third indicator (Ind3) was derived in a similar way as the second but only deviations from the mean larger than one standard error of mean were taken into account (Fig. 1).

Statistics. On the basis of their endurance times the subjects were divided over two groups, one containing three subjects the other four, which was the most appropriate grouping for the test used. The high endurance group might thus contain three or four subjects. It was decided that it should contain three subjects since this yielded the largest absolute difference in endurance between the lowest endurance time of this group and the highest of the second group – or, in other words, clustering within groups was maximized. All tests for differences between the groups were performed using the nonparametric Mann-Whitney U-test (one-sided P<0.05). No corrections for ties were applied, which leads to a more conservative test (Siegel 1956). To ascertain the viability of a relationship among the indicators for varying activity and endu-