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VARIABILIY OF TRUNK MUSCLE CO-ACTIVATION DURING REPEATED THORACOLUMBAR FLEXION IN 4-POINT KNEELING

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SUMMARY

The aim of this study was to evaluate intra and inter-participant variability of trunk muscle co-activation during thoracolumbar flexion in 4-point kneeling. Kinematic data were collected using 10 high speed cameras to identify reflective marker movement, positioned over the 11th thoracic vertebra (T11) in 12 healthy participants. Surface electromyography (EMG) electrodes were attached to external oblique (EO) and internal oblique (IO) muscles (left and right sides). EMG signals were transmitted via telemetry and synchronised with kinematic data collected during 4-point kneeling whilst thoracolumbar flexion was performed (10 trials). EMG data after processing were expressed as a percentage of the Maximally Observed EMG (%MOE). Significant differences between muscles for the smallest maximal %MOE, mean %MOE and time difference between EMG maximum and 90% of T11 z-displacement were calculated. Intra-participant muscle variability was defined as the difference from the mean (DM) across the trials and correlations between muscles were performed. Correlations of the line-of-best-fit from the DM were calculated across participants. The slope of the line of best fit identified co-activation of the left OE and OI, and the left and right sides of OI across all participants, as identified by significant positive correlations. Within-participant variation in muscle co-activation was high. OI right and OI left showed the most frequent significant correlations in variation from the mean. IO and EO show synchronous co-activation during thoracolumbar flexion across healthy participants, but intra-individual variability of these muscles is considerable.

INTRODUCTION

Back rehabilitation programmes frequently include exercises in 4-point kneeling, and the stabilising role of the trunk muscles during progressively more challenging exercises in 4-point kneeling has been reported [1,2]. Range of motion exercises of the thoracolumbar spine have also been described in 4-point kneeling, although trunk muscle activation in these movements is not known. Minimal variability of muscle co-activation during repeated movements could be considered an optimization of movement efficiency. This concept has not been evaluated for thoracolumbar spine movements in 4-point kneeling. Therefore, the aim of this study was two-fold: firstly, to evaluate variability of co-activation and timing of internal and external oblique muscles between participants during thoracolumbar flexion in 4-point kneeling; secondly, to evaluate the effect of multiple repetitions on the variability of co-activation of the same muscles within each participant.

METHODS

Twelve asymptomatic participants (female n=6, male n=6, age 22.4 ± 1.24 years, body mass 67.5 ± 16.6 kg, height 174.9 ± 14.1 cm, and Body Mass Index 21.7 ± 2.2) were recruited as part of another larger study. Exclusion criteria included back pain in the last 12 months, previous spinal surgery or fracture, neurological conditions, abdominal surgery, or a BMI in excess of 25. Normal range of thoracolumbar movement during stance and during 4-point kneeling was assessed in each participant, to ensure that all movements were within physiological limits and pain free. All participants except one were right handed and right footed. Ethical approval was granted from the ethics commission at the Medical University of Vienna and all participants signed a consent form.

For this study, reflective markers attached to the skin overlying the bony landmarks of the left and right styloid process, lateral femoral condyle and spinous process of the 11th thoracic vertebra (T11), were included for data analysis. Three-dimensional kinematic data were collected using 10 high speed cameras (Eagle Digital Real Time System, Motion Analysis Corp., USA) recording at 120Hz using kinematic software (Cortex 3.6.1). After skin preparation with sandpaper and alcohol, surface electromyography (EMG) electrodes (Delsys Trigno, Boston, USA) were attached to the left and right sides of the external oblique (EO) and internal oblique (IO) muscles and data collected at a sample rate of 1200Hz. EMG signals were transmitted via telemetry and kinematic and EMG data collected synchronously over ten seconds.

Ten trials were recorded whilst each participant was positioned in 4-point kneeling in a subjectively perceived neutral spinal position and performed thoracolumbar flexion and returned to the starting position in a continuous movement. At the start of each trial, the participants were instructed to inhale and exhale just before performing thoracolumbar flexion as far as their own range of motion would allow. All participants had a chance to briefly practice the test movement prior to data collection.

Surface EMG data were full-wave rectified, re-sampled to match kinematic data sampling and a 4^{th} order 6Hz low pass Butterworth filter was applied to obtain a linear envelope using scripts written in MATLAB (2008b). Plots of the T11 z-displacement within each participant were phase-shifted to match the maximum displacements, so that they could be visually inspected for outlying movements. EMG data were expressed as a percentage of the Maximally Observed EMG (%MOE) for each individual and muscle. Data were statistically analysed using IBM SPSS 19. The normal distribution of data was tested using the Shapiro-Wilk test. A one-way ANOVA with Bonferroni correction was used to test for significant differences between the smallest maximal %MOE and for the mean %MOE of all four investigated muscles across all participants. A Kruskal-Wallis test was used to determine the difference in time between the occurrence of the maximal EMG amplitude and the occurrence of 90% of the range of T11 z-displacement increase from the starting position. Variability of each muscle across the 10 trials was reported as the difference in maximal mV from the mean, reported as a percentage of the mean maximum for each trial, and a line of best fit drawn through the data points using Microsoft Excel 2010. A Spearman's correlation was performed to compare the slope of the lines of best fit across the participants for all four investigated muscles. To compare variability of muscle co-activation within an individual, a Pearson's or Spearman's correlation was applied to the percentage variation from the mean.

RESULTS AND DISCUSSION

After inspection of the kinematic data, all data sets were included for each participant except the first trial of participant 1 as the flexion was sustained throughout the trial. The mean range of T11 z-displacement was 108.33 mm (± 30.49). A significant positive correlation was found between the range of T11 z-displacement and the smallest maximal %MOE for OE right (r=0.607, p=0.036), mean %MOE for OE left (r=0.681, p=0.015) and mean %MOE for OI right (r=0.589, p=0.044). There were no significant differences between OI and OE left and right for the smallest maximal %MOE, mean %MOE, or for the difference in time between maximal EMG amplitude and 90% of the T11 z-displacement from the starting position. The slope of the line of best fit identified co-activation of the left OE and OI, and the left and right sides of OI across all participants, as identified by significant positive correlations (OI left and OE left r=0.650, p=0.022, and OI right and OI left r=0.664, p=0.018). Within-participant variation in muscle co-activation was high, with a range of zero to six significant positive correlations out of a possible six (median=2). OI right and OI left showed the most frequent significant correlations in variation from the mean (8 out of 12 participants).

This study has demonstrated the synchronous activation of both sides of OI and OE in respect to smallest maximal and mean %MOE and in maximal activation relative to symmetrical thoracolumbar flexion in 4-point kneeling. This is similar to the synchronous activation of the same muscles reported for a basic front bridge exercise [2] and during an abdominal hollowing exercise in 4-point kneeling [3]. Even though these were both measurements of static body positions rather than dynamic movements, this comparison is the most relevant as no other studies reporting EMG activity of these muscles during a more similar exercise to the one investigated in the present study were identified.

High inter-individual differences, reflected by a large variation in the number of positive correlations between muscle activations in the present study, are not unique as other authors have also reported high inter-individual findings in EMG investigations [4]. A high intra-individual variability over the ten repetitions indicates that there is no optimum number of repetitions for the exercise investigated in this study in novice patients. This may change after the movement has been carried out over several days, as muscle co-activation and efficiency depends on the learned neuromuscular pattern which requires time and training to develop. The implication for clinical practice in the education of back rehabilitation exercises is that at least in the beginning a highly individualised exercise programme may be required for each patient, rather than a standard repetition protocol issued.

CONCLUSION

Although the left and right IO and EO show synchronous co-activation relative to thoracolumbar flexion across a group of healthy participants, intra-individual variability in co-activation of these muscles is considerable.

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