Reduced cortical activity in bilateral contractions: An fMRI Study

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Introduction
During simultaneous activation of two contralateral homologous muscles the force production is often lower than the sum of the unilateral contractions. This phenomenon is known as “bilateral deficit” (BLD) (3; 9). It is understood that a bilateral deficit only occurs during activation of two homologous muscles (1) and is influenced by training (6). However, the underlying mechanism is still unknown. The most likely cause of BLD is a decrease in the motor drive to the muscles during bilateral contractions (5-7). This hypothesis implies that during bilateral contractions cortical activity has to be reduced. Although some studies have tried to find evidence for a reduction in neural drive (1; 2; 5; 6; 8), only one study took has measured the brain activity (4). However, this study was not especially interested in the bilateral deficit and did not use a proper task for investigating the BLD. In this study we have used functional Magnetic Resonance Imaging (fMRI) to measure brain activity in combination with EMG and force measurements. Subjects were asked to perform simple unimanual and bimanual tasks in the fMRI scanner. It was the aim of our study to obtain new evidence for a neural basis of the bilateral deficit.

Methods
Twenty-two healthy right-handed subjects participated in this study after written informed consent. Each subject performed nine maximal voluntary isometric contractions (MVCs) with their index fingers. The contractions were performed in a random order: 3 contractions with the right index finger, 3 with the left index finger and 3 with both fingers simultaneously. The contractions were performed in a 3T Phillips MRI scanner (Best, the Netherlands); force was measured with two custom-made MR compatible force transducers. In addition, surface electromyography (EMG) of the first dorsal interosseus (FDI) in both hands was recorded using the BrainAmp MR plus system of Brain Products GmbH (Munich, Germany). SPM99 was used for processing and analysing the fMRI data. A random effect analysis was conducted with a one-sampled t-test as second level analysis. The EMG data was first pre-processed to correct for the artefact of the fMRI scans. After this, the areas under the curve were analysed for both rectified EMG and force. To detect differences in the hemodynamic responses in separate motor areas, a Region of Interest (ROI) analysis for the primary motor area (M1) and cerebellum was performed. For each ROI a contrast value was calculated. For all measurements BLD was determined as (1-(unilateral / bilateral)*100%). The data of EMG, force and the ROI analysis were statistical analyzed with a 2x2 [condition (Unilateral, Bilateral) x side (Right,Left)] repeated-measures analysis of variance to test for differences. For the ROI analyses threshold for significance was set at 0.001; for force and EMG data a threshold of 0.05 was used.

Results
For both force (F(1,18)=7.872,p<0.05) and EMG (F(1,18)=4.440,p<0.05) a significant difference in the areas under the curve was found between the unilateral and the bilateral contractions. For the right index finger we found a deficit of 7.44% +/-13.80 (SD) in the rectified EMG and a deficit of 3.92% +/-8.86 in the force. For the left index finger it was respectively 2.64% +/-11.52 and 7.72% +/- 5.81. The analysis of the MRI data revealed significant activated areas in the primary motor cortex (M1), cerebellum and in the supplementary motor area (SMA) in all contractions. The ROI analysis of the M1 revealed stronger activation patterns during the unilateral condition than during the bilateral condition (F(1,18)=6.123:p<0.05). A deficit of 6.04% +/- 14.20 was found for the ROI analyses of the cerebellum, no significant difference was observed.

Discussion/Conclusion
The existence of a bilateral deficit in EMG and in the areas under the curve for force and EMG-data was confirmed in this study. In order to include the effect of the duration of the contraction on the fMRI data we have chosen to analyse the areas under the curves of our EMG and force data rather than only peak measurements. This analysis is imperative, because both the amplitude and the duration of the contraction influence fMRI data. While we found a significant decline in brain activation pattern in M1 during bilateral contractions, we conclude from our data that the BLD in our study is indeed caused by a decline in activity in the motor areas.

References