Frequency of coactivation of arm muscles in primary bowing tremor

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Task-specific tremors (TST) are a tremor entity occurring predominantly during a certain task. In violinists, TST may occur in the right arm while playing the instrument. This primary bowing tremor (PBT) is highly disabling for the affected musician and may threaten his/her professional career. To better understand the pathophysiological mechanism of TST, we measured antagonist EMG-activity to investigate a possible relationship between PBT and coactivation. We found EMG activity specific for PBT in the frequency range of 3-8 Hz as well as coactivation of antagonist muscles in the same frequency range (3-8 Hz) at a mean frequency of 6.6 Hz. Notably we did not find any PBT related EMG activity in at the resonance frequency of the wrist (8-12 Hz). Our findings firstly indicate an association between coactivation and PBT. Secondly, the absence of EMG-activity at the resonance frequency of the wrist indicates that mechanical reflex mechanisms play a less dominant role than central mechanisms.

Keywords: tremor; task-specific; musician; coactivation; dystonia

Task-specific tremors (TST) occur only or predominantly during a certain task (Deuschl et al. 1998). The most common TST is primary writing tremor (PWT; Rothwell et al. 1979), which can be sub-classified into two types: type-A, which refers to tremor induced by writing (task-induced); and type-B, which refers to tremor induced when holding the arm in the position for writing (position-sensitive). In string-instrument players, tremor may occur in the right arm while playing the instrument (Lederman 2007, Lee and Altenmüller 2012). This primary bowing tremor (PBT) is highly disabling for
the affected musician and may threaten his/her professional career. To understand its pathophysiological mechanism, EMG-properties in PWT have been repeatedly described. To our knowledge, however, coactivation of EMG-activity in TST has not been characterized in a quantitative manner so far. The aim of our study was thus twofold: first, to quantify EMG features in the spatial and frequency domains in PBT, and second, to assess the relation of coactivation to PBT.

METHOD

Participants

We included four professional violinists (patients), three male and one female, aged 48-62 years. Four gender-matched healthy violinists, aged 34 to 44 years, were measured as a control group (control).

Materials

EMG was recorded with AG/AG2+ surface electrodes (biovision, Wehrheim, Germany), which were placed above the muscle belly of the wrist flexor and extensor of the right arm.

Procedure

Two conditions were measured that required a slow bowing movement and clearly induced PBT, paced by a metronome at 40 bpm: (1) a G-major scale across three octaves, starting from the open g-string (GM) with two beats per bowing direction; and (2) open strings in the order of g-string, d-string, a-string, and e-string (OS) with four beats per bowing direction. To investigate an influence of bowing-speed or of bimanual coordination on tremor, bowing-speed was different for the two conditions and one condition (GM) required using the fingers of the contralateral hand.

EMG-data were filtered, rectified, and normalized and a fast fourier analysis (FFT) was applied to obtain the power spectra and the peak-frequency. We subdivided the frequency into three bands (1-3 Hz, 3-8 Hz, and 8-12 Hz) and calculated the mean power for each frequency band. We chose 3-8 Hz because it includes the frequency of TSTs (Elble et al. 1990, Bain et al. 1995, Deuschl et al. 1998, Bain 2011, Hess and Pullman 2012). To investigate a possible contribution of mechanical reflex mechanisms, 8-12 Hz—being the frequency band for the mechanical-reflex component of the wrist (Elble 1996) and for physiological tremor (Elble 1986, Hallett 1998, Deuschl et al. 2001)—was chosen. A third frequency range covering lower frequencies was chosen.
to account for possible tremor as, for example, cerebellar or rubral tremor (Elble 1996, Deuschl and Bergman 2002). To investigate the role of coactivation in PBT, we calculated the time-varying coactivation of the wrist antagonist muscles by computing the overlap of the waveforms of these muscles (Furuya et al. 2012) and performed FFT to obtain coactivation frequency as mentioned above.

A t-test was performed for the two conditions (GM/OS). A 3-way ANOVA with group (patient/control), condition (GM/OS), and frequency bands (1-3 Hz, 3-8 Hz, 8-12 Hz) as independent variables and another 3-way ANOVA with factors conditions, group, and muscle group (flexor/extensor) as independent variables were conducted.

**RESULTS**

Quantification of coactivation revealed a mean (±SD) of the peak frequency of the coactivation of 6.4 (±0.4) Hz (OS) and 6.9 (±0.4) Hz (GM). Difference between conditions was not significant (p=0.34; see Figure 1, left). No coactivation was found in the controls (see Figure 1, right).

The first three-way ANOVA (condition; group; muscle group) showed a significant effect only for group (p<0.01) and muscle-group (p<0.01) but not condition (p=0.9). An interaction between group and muscle-group was found. EMG-activity was higher for patients in both muscle-groups for both conditions (p<0.05). The second three-way ANOVA (group; condition; frequency band) revealed a significant effect only for group (p<0.01) and frequency-range (p<0.01) but not condition (p=0.7). An interaction effect was identified for group and frequency-range, indicating a group-difference at a particular frequency-range. Indeed, tremor-power was significantly higher in the frequency-range of 3-8 Hz (p<0.05). Differences between 1-3 Hz and 8-12 Hz were not significant. Group difference was significant for 3-8 Hz only (p<0.01; see Figure 2).

**DISCUSSION**

We described EMG-properties of four professional violinists with PBT. A comparison to healthy controls demonstrated clear differences in the spatial and frequency features of muscular activity. This, to our best knowledge, provided the first quantitative evidence of altered muscular control in bowing tremor.

Coactivation. We found coactivation activity occurring at the same frequency as flexor and extensor muscle activity at a comparable intensity. Rather than a skipping between an alternating and coactivation activity (Bain
Figure 1. Left: FFT for patient 4 with a peak frequency at 6.2 Hz for the wrist extensor and flexor as well as the coactivation. Right: group mean of FFT for the OS-condition for patients and controls for the wrist flexor and extensor muscles and coactivation.

Figure 2. Group mean and SD of the mean frequency at each frequency band of patients and controls for the two conditions (OS/GM). (See full color versions at www.performancescience.org.)

2011) we observed a continuous coactivation throughout the entire movement. This provides evidence supporting a relation of coactivation to TST. Alternating as well as synchronous activity of antagonist forearm muscles has been observed in PWT. Elble et al. (1990) described coactivation in PWT as dystonia that increased as writing continued. Bain (2011) found coactivation only in type-B PWT. Kachi et al. (1985) found coactivation in only two out of ten patients. By contrast, all our patients (including type-A TST) had a coactivation of antagonist wrist flexor and extensor muscles. Explaining this find-
ing is not straightforward and remains speculative. Byrnes et al. (2005) found a reduced intracortical inhibition (ICI) in PWT. In healthy musicians however, ICI is already reduced as compared to healthy non-musicians (Nordstrom and Butler 2002, Rosenkranz et al. 2005). The emergence of PBT in violinists may therefore be associated with excess reduction of ICI elicited by musical practice.

Frequency ranges. Two findings became apparent. First, power of the EMG signal was significantly stronger for the 3-8 Hz range as compared to the other frequency ranges only within the patient group. Second, tremor was significantly stronger in patients as compared to controls only in the 3-8 Hz frequency range (see Figure 2). These findings suggest that neither mechanical reflex properties nor physiological tremor nor other neurological tremor with a slower frequency, emerged in the bowing tremor. In addition, no significant differences were found between the task conditions (OS, GM), which suggests robustness of the tremor-related muscular activity against bowing speed or bimanual coordination by using the fingers of the contralateral hand.

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References


