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Age-related changes in the frequency profile of children's finger tremor

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Abstract

Little consensus exists as to the age-related pattern of change in the frequency characteristics of postural tremor through childhood. We investigated postural finger tremor of children (6 and 10 years) and adults (18–22 years) using accelerometers under dual and single limb conditions (10 s trials). The postural tremor of the children exhibited proportionally more power below 10 Hz and less power above 20 Hz than that of the adults. It also showed a significantly lower peak frequency and lower proportion of power at the peak frequency than the adults in the 15–30 Hz frequency band but did not differ significantly from the adults in peak frequency or proportion of power at the peak frequency in the 5–15 Hz frequency band. The greater relative contribution of fast time scales over the 1–30 Hz frequency band in the organization of the postural tremor of the adults in comparison to the children may be a contributing factor to adult's typically observed reduced motor skill performance variability.

Keywords: Children's tremor; Postural tremor; Frequency profile

Postural tremor, the involuntary oscillations produced by a limb such as the hand or finger while maintaining a position against gravity, provides a window into the interaction of central and peripheral processes in the control of movement and posture [7]. Because the task is steady state in nature and the oscillations are involuntary, an examination of age-related differences in the variability (oscillations) of postural finger tremor may enhance our understanding of age-related changes in the underlying organization of the sensorimotor system processes driving the motor output and serve as a basis for comparison with children who suffer from neuromuscular disease(s). In previous studies examining the structure of force tremor [5,6], we found that age-related reductions in motor performance variability between childhood and adulthood were primarily due to an increasing representation of fast time scales in the organization of the motor output.

Traditionally, two prominent frequency bands among the oscillations that comprise postural tremor are reported. One reflects physiological tremor (8–12 Hz) and is primarily determined by neural influences (neural component); therefore, it does not vary significantly when mechanical conditions are changed. The second is determined largely by the resonant frequency of the limb (mechanical component, for example, 20–25 Hz for the finger, 2–3 Hz for the arm), which depends on the limb's inertia and stiffness, and is assumed to be maintained through stretch reflex activation [7,18], although neural influences may also contribute [19]. It has been found that hand volume, a measure of size and, therefore, indirectly related to the limb's inertia and stiffness, is inversely related to peak hand tremor frequency in adults [23]. Children's limbs increase as they grow older; therefore, the peak frequency of the mechanical component of postural tremor should decrease from childhood to adulthood. Changes in stretch reflex characteristics with age [2,8] may also contribute to age-related changes in this component of tremor.

Studies examining postural tremor in children have not differentiated between the two main frequency components, but instead reported a single peak frequency and the amplitude at that frequency. Tremor studies have also typically grouped children into large age ranges such as 3–15 years [15], 3–9 years and 10–19 years [25]. As a result, little consensus exists as to the age-related pattern of change in the frequency and amplitude characteristics of postural tremor through childhood. For example, it has been reported that the peak frequency of postural tremor increases from 7 years through young adulthood [3,16], decreases from 1 month up to the age of 5–6 years with-

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out further changing with age up to adulthood [9], and is similar between children as young as 3 or 4 years of age and adults [4,15,25]. Reports are similarly inconsistent with respect to the amplitude of postural tremor, which has been shown to increase [15,25], decrease [3,9,13], and not change significantly [4] with advances in children's age up to adulthood.

The discrepancies in the findings of these studies of children's postural tremor may also be due to technical issues including the placement of the measurement instrument relative to the posture of the participants. In some studies, participants held the arm outstretched against gravity but the instruments were placed on the end effectors [3,16,25]; therefore, the tremor recorded in these studies reflected the synergistic coupling of the various segments of the upper limb to maintaining the finger or hand posture [20]. In addition, the foundational experiments of Marshall used older equipment that is not very precise and visually determined the frequency profiles.

Although it has not received much emphasis, the distribution of power across different frequency bands of the power spectrum may reveal additional insights into the sources of tremor and how these change through childhood. For instance, Marsden et al. [15] found an inverse relation between the peak frequency of postural tremor and the amount of low frequencies represented in the spectral profile. In addition, children's resting and postural tremor tend to contain a greater proportion of power in the low frequencies in contrast to adults [3,15].

In the current study, we examine postural finger tremor over a larger band of frequencies (1–30 Hz) than typically studied in three independent age groups (6 years, 10 years and adults aged 18–22 years) in order to determine how the mechanical and neural components of tremor vary through childhood to adulthood over the multiple time scales that accompany adaptive change in tremor. We hypothesized that an examination of a large band of the frequency spectrum under controlled conditions would more clearly isolate the age-related differences in the frequency profile of postural tremor. The age groups were selected because they were sufficiently distinct maturationally to provide a clear picture of differences in the characteristics of tremor as a function of age, with the youngest chosen for their ability to understand and follow instructions.

The spectral profile was examined in single limb and dual homologous limb conditions to allow for inferences as to whether the motor output from both limbs share a common neural influence. The frequency relation, or coherence, between the dominant and nondominant fingers was examined since children tend to have a greater degree of coupling between their limbs during the performance of motor skills which decreases as they become older [11].

The time-dependent properties of the tremor output were also examined using approximate entropy (ApEn) [22] to assess the potential age-related changes in the dynamical output. These properties of postural tremor have not yet been examined as a function of children's age. Correlations between the two main peak frequencies in the frequency profile and limb lengths were calculated in order to determine the relation between the mechanical influence due to physical growth and the frequency profile.

Sixty subjects were tested: 20 6-year-olds (M = 6.4 years, S.D. = .3 years, 11 males, 9 females), 19 10-year-olds (M = 10.5 years, S.D. = .3 years, 10 males, 9 females), and 21 undergraduate students (M = 20.8 years, S.D. = 1.4 years, 10 males, 11 females). They were recruited through advertisements and given compensation for their participation. None reported they were suffering from neurological disorders that could influence tremor. The experiments were conducted in accordance with the Declaration of Helsinki. All procedures were carried out with the adequate understanding and written consent of the subjects (and parents, in the case of children), which was provided according to the procedures of The Pennsylvania State University's Institutional Review Board.

A uniaxial accelerometer (Coulbourn T45-10, weight 8 g; calibrated on each day of testing) was taped onto the dorsal surface of the tip of the distal segment of each index finger (on top of the nail). The index finger was extended parallel to the table top with the remaining fingers of the hand curled in a fist (forearms and hands parallel and shoulder width apart). Postural tremor was measured for the dominant and nondominant finger separately and simultaneously with the other finger (three 10-s consecutive trials; ∼5 s breaks between trials). The dominant hand was established as the hand used for writing. For all conditions, the subject sat in a chair with the testing forearm(s), wrist(s), and hand(s) resting on the table and the other hand on his/her lap. The subject was instructed to maintain visual contact with the finger(s) being tested in order to maintain it (them) in a steady position with as little movement as possible. The order of testing was counterbalanced across subjects within each age group.

The accelerometer signals were sampled at 200 Hz, and amplified (Coulburn transducer coupler Model S72-25, Coulburn Instruments, Allentown, PA, USA; excitation voltage = 5 V; gain = 1000), digitized with a 16-bit analog-to-digital converter, and saved to a Master Pentium 166 computer.

The data were band-pass filtered (1 Hz, 50 Hz; 9th order Butterworth filter-25). Power spectral density analysis was calculated using Welch's averaged periodogram method [17] (Hanning window; bin width = 0.3906 Hz). The resulting power spectrum was limited (band = 0.3906–30.07 Hz) and normalized (power within each bin divided by total power in the limited band) in order to allow comparisons across all ages and conditions.

To determine the contribution of the neural and mechanical components to the tremor frequency profile, the peak frequency within each of two frequency bands, 5–15 and 15–30 Hz, was identified and the proportion of power exhibited at the peak frequency determined. The distribution of power across the frequency spectrum was examined by determining the proportion of power contained within each of six frequency bands: 1–5, 5–10, 10–15, 15–20, 20–25, and 25–30 Hz. The degree of coupling between the two digits was evaluated by determining the peak coherence between the digits within the 5–15 and 15–30 Hz frequency bands.

The time-dependent properties of the accelerometer signals were examined using approximate entropy (ApEn, run length $m = 2$; filter width $r = 0.2$) [22]. ApEn determines the degree to which a signal contains sequential structure, i.e., repeating