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The Graduate School
College of Health and Human Development

DYNAMICS OF DIGIT TREMOR

WITHIN AND BETWEEN HANDS

A Thesis in

Kinesiology

by

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ABSTRACT

Tremor is a very low amplitude involuntary oscillatory-like limb motion that is barely visible to the naked eye but present in all individuals. In this study, we investigated the tremor dynamics of digits within and across hands that occurred under both 0 degree postural angle and 30 degree postural angle crossed with eyes open and eyes closed conditions. Twelve healthy young adults participated in the study (4 conditions, 12 trials/condition, 30s/trial) and accelerometers were used to measure digit tremor. Amplitude analysis showed that the 30 degree posture angle increased the magnitude of acceleration regardless of vision condition. Visual information increased tremor amplitude of the left hand but not the right hand digits. Tremor amplitude was greater in the index finger and progressively smaller in the middle, ring and little fingers. Approximate Entropy (ApEn) showed that the higher postural angle led to greater tremor irregularity. The coupling of the tremor of the index and middle fingers was highest and the level of the coupling within hand decreased as the relative adjacency of digits from each other increased. There was no evidence of tremor coupling in the homologous digits across hands. Postural angle of the digits and the availability of visual information modestly changed the scaling of the tremor dynamics. It is concluded that the anatomical and physiological structures are the primary influence on the tremor dynamics of amplitude and coupling within and between digits of the hands.
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Chapter 1

Introduction

Tremor is a very low amplitude involuntary oscillatory-like limb motion that is barely visible to the naked eye but present in all individuals (Elble and Koller 1990). It is well established that tremor is related to central and peripheral neural processes and also mechanical factors (Findley and Capildeo 1984; Elble and Koller 1990). Decomposition of the dynamics of finger tremor has been used extensively in the assessment and characterization of movement disorders (Watts and Koller 1997).

Investigations of physiological tremor have been primarily conducted with the single digit of the index finger (Elble and Koller, 1990). However, on a daily basis, humans use their fingers to engage in performing a variety of grasping tasks that can use different combinations of digits from either one or both hands within many grip configurations and task functions (Connolly 1998; MacKenzie and Iberall 1994). Furthermore, certain arm and hand postural tasks require the maintenance of the position of several digits simultaneously as in postural tremor. In general, prehensile tasks can require implicitly or explicitly the digits to be coupled to some degree or to act independently to realize task goals.

The anatomy and physiology of the digits and cortico-spinal pathways to the somatosensory cortex indicates that there are functional connections to the digits between all levels of analysis of the central and peripheral systems (Porter and Lemon 1993). Nevertheless, the movement-related consequences of these functional and structural connections in human prehensile actions are less well understood. For example, in spite of all the studies on finger tremor (Elble and Koller 1990), little is known with respect to the functional coupling of physiological tremor across digits of the hand or hands.
The coupling of force output of the digits at the metacarpophalangeal and proximal interphalangeal joints within a hand has been shown in a number of grasping tasks (Li et al. 1998; Santello and Soechting 1998; Sharp and Newell 2000). The instruction to move a single digit of the hand induces motion in other digits of the hand with the degree of independence of finger movement dependent on the particular digits (Hager-Ross and Schieber 2000). Loading a digit (Hwang 2011) or a fatiguing repetition of motion on a digit (Hwang et al. 2009) has also been shown to reduce the independence of physiological tremor in the digits of the same hand. Furthermore, the thumb has been reported as experiencing less of a mechanical limitation on digit coupling (Lang and Schieber 2004). In general, these studies reveal that the independence of motion of the thumb and the index, middle, ring and little fingers is limited by both mechanical and neural coupling and, moreover, is task dependent.

An adaptive compensatory relation of tremor motion within and across upper limb segments has been shown (Morrison and Newell 1996 1999). High correlations in the time domain and significant coherence in the frequency domain have been observed in the tremor of the upper arm, forearm and hand in executing an arm postural task. The passive transmission of oscillation from upper arm and forearm had no significant contribution to the physiological tremor in the hand and fingers. In the dual arm tremor protocol, however, no coupling was observed between the arms including the homologous segments. Furthermore, the availability of visual information did not influence the tremor dynamics of the arm segments (Morrison & Newell 1996).

The main purpose of this study was to investigate the dynamics of inter-digit coupling of digit postural tremor as a function of the availability of visual information and postural angle of the digit. The focus was the tremor relations of digits within the hand and that of homologous digits across hands in multi-digit tremor posture tasks. Of particular interest within the hand was the amount and coupling of tremor between digits as a function of the degree of adjacency of the
respective digit. Across hands, the analysis focused on the amount and coupling of the tremor of the homologous digits.

It was hypothesized that: a) the coupling of physiological tremor among index, middle, ring and little fingers within hand would decrease as a function of the relative anatomical adjacency of digits from each other; and b) there would be an increased amount of tremor and coupling under the greater initial muscle stretch of a larger postural angle to hold the posture of the digits. In cross hand comparisons, we tested the hypothesis that there was a higher correlation in the time- and frequency-domains for the tremor of homologous digits than other pair-wise comparisons.

Finally, we investigated whether the availability of visual information would influence the amount and structure of the variability. The natural observation of the relevant effector in postural arm tremor has been shown to have little effect on the dynamics of tremor (Morrison and Newell 1996). The null effect has been interpreted as due to the tremor amplitude being so small that it cannot be detected by the visual system (Legge and Campbell 1981; Seobey and Johnson 1981). In contrast, augmented visual information by equipment displays or laser-pointer presentation has been shown to modify postural tremor (Keogh et al. 2004; Loncharich and Newell in press). Here we examine whether natural vision of postural motion influences tremor dynamics of the digits within and across hands. We investigated the hypothesis that the effect of the availability of visual information would be stronger under the more variable output of the 30 degree postural tremor condition.
Chapter 2

Methods

Participants

Eleven healthy adult subjects five females and six males, aged (mean 28.03 years, range 24-32 years) participated voluntarily in this study. All participants claimed no history of any neurological disorder that may affect the movement of upper arm, forearm, hand and fingers. Written consent and hand use preference was obtained from each participant before the experiment started. All participants’ indicated that the right hand was the dominant hand. The experimental protocol was reviewed and approved by Penn State University Institutional Review Board (IRB).

Apparatus

Eight uniaxial (T45-10) accelerometers were attached tightly on the nail of the index, middle, ring and little fingers of both right and left hands using medical tape. A triaxial (EGATX30) accelerometer was attached to each thumb in the same way. The Z-axis (vertical to the ground) accelerations of index, middle, ring and little fingers were obtained by the eight uniaxial accelerometers. The two triaxial accelerometers not only measured thumb accelerations in the z-axis but also from the other two dimensions; namely the X-axis vertical to finger in the horizontal plane and Y-axis running along finger length.

Each accelerometer signal was amplified by a Coulbourn strain gauge transducer coupler (V72-25) with an excitation voltage of 10 V and an amplifier gain of 100. All amplified signals
were sampled at 200 Hz and converted with 16-bit analog-to-digital converter board (DT 9804). All signals representing the oscillations from the different digits were presented on a computer for the tester to monitor subject performance during the experiment. This augmented visual feedback of digit acceleration was not provided to participants.

**Procedures**

Figure 1 shows the experimental set-up. The experiment investigated tremor of the thumb, index, middle, ring and little fingers of both hands as a function of posture angle of the digits and visual conditions. There were two posture angle conditions - 0 degree and 30 degree angle posture support. There were two vision conditions-natural vision (eyes open) and without natural vision (eyes closed). All subjects performed ten 30 s blocked posture tremor trials under each condition. A 5s interval break between trials was given to prevent fatigue occurring during experiment.

The subject was seated comfortably in a back-supported chair that could be adjusted according to sitting height, relaxed shoulders, upper arms and forearms with all fingers spread out. In order to minimize the equipment noise, a test of the acceleration signals was conducted on an isolated table that had no irrelevant equipment sitting on it. One customized block with two horizontal slots was placed on the testing table that was located slightly above the elbow height. Two security blocks sitting on the block with two adjustable screws were designed to reduce the movement from elbows, forearms and wrists (Figure.1). In the 0 degree posture task, the subject was instructed to place their elbows, forearms and wrists horizontally along the y-axis, and to position their hands on the edge of the customized block. The subject held both hands parallel to the table with the fingers unsupported to perform the 0 degree posture.
In the 30 degree posture the task, the same basic procedures were repeated except that a 30 degree triangle block was used to measure subject posture angle with 30 degree extension on both hands during the test. In order to minimize the variability of motion at the shoulders, upper arms and forearms were required to remain in the same position as much as possible during the experiment. Wrists were against the supported table extending approximately 30 degree to horizontal plane without any support from the 30-degree block. One side tape was applied to secure wires on the table to minimize the influence of wires on the experimental set-up.
Data Analysis

The data obtained from the accelerometers attached to the fingertips were processed in both the frequency and time domains. The data analyses were categorized into four segments as follows:

The amplitude of finger tremor

The amplitude of finger tremor was determined by root mean squared (RMS) of each signal, respectively. A higher value of RMS was interpreted as greater tremor motion for the given axis of the respective digit. For index, middle, ring and little fingers, only motion on the vertical direction (z-axis) was analyzed. For thumbs, all three directions (z-axis, y-axis and x-axis) were examined.

The regularity of finger tremor

Approximate entropy (ApEn) (Pincus 1991) reveals the irregularity of a time series. ApEn was determined for each tremor signal to examine the irregularity of each time series. The value of ApEn falls approximately between 0 and 2 with 0 representing the highest regularity and 2 indicating the lowest regularity. The ApEn value was calculated for each accelerometer signal of each trial using a run length $m = 2$ and a filter width $r = 0.2$.

The power spectrum of finger tremor

The frequency profile of tremor was assessed by Fast Fourier Transform (FFT) analysis. FFT was carried out to convert the signal from the time domain to the frequency domain to provide information about the oscillatory components of tremor. The analysis focused on the frequency bandwidths with the most power (amplitude) present in the signal.

The coherence of finger tremor
Magnitude Squared Coherence (mscohere) estimated $C_{xy}$ of the input signals $x$ and $y$ using Welch’s average, modified periodogram method was conducted to estimate the magnitude of coherence between two different digits as a pair. Coherence is a function of the power spectral densities $P_{xx}(f)$ and $P_{yy}(f)$ of $x$ and $y$ and the cross power spectral density ($P_{xy}(f)$) of $x$ and $y$. The value of mscohere falls between 0 and 1. A higher value indicates a stronger coherence for the paired digits while a weaker coherence was determined by a lower value.

**Statistical Analysis**

A four-way repeated measures ANOVA served as the statistical model to investigate the significance of the dependent variables. All statistics were considered as being significant when the probability of Type I error was lower than 0.05. There were four independent factors – hand, digit, vision and postural angle.

All non-statistical analyses were performed with Matlab. All statistical analyses were conducted using SAPP.
Chapter 3

Results

Amount of Tremor Variability

The root mean squared (RMS) tremor amplitude of fingers from one dimension (z-axis) of index, middle, ring and little fingers and three dimensions (x-axis, y-axis and z-axis) of thumbs for both right and left hands across 0 and 30 posture angle positions during both eyes closed and eyes open conditions was determined.

Sample raw tremor signals for index, middle, ring and little fingers while performing 0 posture angle during eyes open condition are plotted in Figure 2. The figure illustrates that the RMS tremor amplitude of homologous showed similar noise-like patterns regardless of the digit.

Figure 2: Example of a typical raw acceleration signal from index, middle, ring and little fingers (from top to bottom) with 0 posture angle under eyes open condition (left hand)
Irrespective of the condition performed there was a consistent pattern that RMS tremor amplitude of index fingers for both left and right hands was greatest, followed by a progressive reduction of motion at the middle, ring and little fingers, respectively (Fig.3).

Figure 3: Root mean square of index, middle, ring and little fingers under 0 posture angle and 30 posture angle with eyes open and eyes closed.

For the right hand, the higher posture angle (30 degree) led to greater RMS tremor amplitude for index, middle, and ring fingers. Although the left hand (Fig.4) showed the similar
trend that 30 posture degree produced slightly greater tremor amplitude, the effect was not significant.

Four way repeated ANOVA analysis showed that posture angle, F(1,10)=5.018, p=0.05, hand, F(1,10) = 7.607, p < .05, and digit, F(4,40)=28.190, p<0.001 had significant influences on tremor amplitude. Pairwise comparisons tests showed that the 30 degree posture angle tremor amplitude was greater than 0 degree posture angle, the right hand had greater tremor amplitude than the left and that there was a progressive reduction of tremor amplitude across index, middle, ring and little fingers, respectively.
There was a significant vision\*posture interaction of tremor amplitude, vision\*posture $F(1,10)=6.308$, $p=0.05$. The availability of visual information increased tremor amplitude over no vision but only at the 30 degree postural angle. The postural angle\*digit interaction ($F(4,40) = 9.624$, $p<.001$) was also significant. The effects on tremor reduction as a function of digit were stronger in the 30 degree postural angle than the 0 degree postural angle.
The anatomical structure of the thumb is different when compared to other digits. Amplitude of two additional dimensions (Fig. 5) was analyzed to determine the tremor of the thumb. As expected, the RMS tremor amplitude of y-axis for both right and left thumbs was lower than the other two axes (z-axis and y-axis) regardless of vision conditions (Fig. 6). The pattern that amplitude increased as the posture angle increased was not as significant as other digits, except for the right thumb on x-axis.

![Example of a typical raw acceleration signal from left and right thumbs](Figure 5)
Regularity of Tremor Signal

The values of Approximate Entropy (ApEn) for index, middle, ring and little fingers and thumbs under 0 posture angle and 30 posture angle across eyes open and eyes closed conditions were comparable.

Figure 6: Root mean square of thumbs under 0 posture angle and 30 posture angle with eyes open and eyes closed.
There were significant main effects of posture angle and vision for ApEn with vision $F(1,10)=5.705$, $p=0.05$ and posture $F(1,10)=8.051$, $p=0.05$.

The interactions of posture*digit, $F(4,40)=5.249$, $p=0.05$, and hand*digit $F(4,40)=2.832$, $p=0.05$ were significant. Pairwise comparison showed that the index, ring, little and thumb digits on z-axis had higher irregularity at the 30 degree postural angle. For all other digits, the left index and left ring fingers showed that ApEn values were significantly affected by posture angle with 30 degree posture angle having higher irregularity, posture $F(1,10)=5.249$, $p=0.05$. The vision condition only had a significant influence on the right index finger, $F(1,10)=5.705$, $p=0.05$. 
Figure 7: ApEn of thumbs on x-axis, y-axis and z-axis.
The homologous digits on the right hand did not show a similar pattern of ApEn (Fig. 8).

The hand*digit, F(4, 40) = 2.837, p = 0.05, and vision*hand*digit, F(4, 40) = 2.604, p = 0.05, interactions were significant. The effect of vision on ApEn was stronger at the 30 degree postural angle and for the ring and little fingers.

Figure 8: ApEn of index, middle, ring and little fingers on z-axis
Figure 9: FFT plots of index, middle, ring and little fingers with 0 posture angle under eyes open condition (from top to bottom: left hand and right hand)

The frequency profile of 0 posture angle during eyes closed condition (Fig.10) indicated that although changes in tremor output could be seen as a result of the different conditions, the changes were more sensitive about the amplitude than in the shift of frequency components (Left index $p=0.8564$; left middle $p=0.4783$; left ring $p=0.7205$; left little $p=0.7079$; right index
p=0.5423; right middle p=0.2467; right ring p=0.6951; right little p= 0.9111). The pattern that most of the posture tremor was concentrated at the 8-12 frequency band was observed as expected.

Figure 10: FFT plots of index, middle, ring and little fingers with 0 posture angle under eyes closed condition (from top to bottom: left hand and right hand)

<table>
<thead>
<tr>
<th></th>
<th>Eyes Closed &amp; 0 Posture Angle</th>
<th>Eyes Open &amp; 0 Posture Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Index</td>
<td>Middle</td>
</tr>
<tr>
<td>Left Hand</td>
<td>Mean Frequency (Hz)</td>
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<tr>
<td></td>
<td>Standard Dev (Hz)</td>
<td>1.99</td>
</tr>
<tr>
<td>Right Hand</td>
<td>Mean Frequency (Hz)</td>
<td>8.79</td>
</tr>
<tr>
<td></td>
<td>Standard Dev (Hz)</td>
<td>1.78</td>
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</table>
Table 1: Peak Frequency of 0 posture angle under eyes closed and eyes open

<table>
<thead>
<tr>
<th></th>
<th>Eyes Closed &amp; 30 Posture Angle</th>
<th>Eyes Open &amp; 30 Posture Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Left Hand</strong></td>
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<td></td>
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<tr>
<td>Mean Frequency (Hz)</td>
<td>8.52</td>
<td>8.54</td>
</tr>
<tr>
<td>Standard Dev (Hz)</td>
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<td>1.16</td>
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<tr>
<td><strong>Right Hand</strong></td>
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<tr>
<td>Mean Frequency (Hz)</td>
<td>8.92</td>
<td>9.08</td>
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<tr>
<td>Standard Dev (Hz)</td>
<td>1.24</td>
<td>1.47</td>
</tr>
</tbody>
</table>

Table 2 Peak Frequency of 30 posture angle under eyes closed and eyes open

Coherence Analysis

The Magnitude Squared Coherence analysis revealed that strong coupling existed between finger pairs within the hand under both 0 posture angle and 30 posture angle regardless of vision condition. For within hand combinations, significant magnitude squared coherence peaks appeared within 8-12 Hz frequency band and progressively approached to 0 at higher frequency bands. This result was consistent with previous findings that the mid frequency peak 8-12Hz reflects physiological tremor (Elble and Koller 1990).

In general, the typical pattern was that finger pair coherence decreased as the relative distance of the finger pair increased. This pattern was present in all digits except thumbs under both 0 posture angle and 30 posture angle conditions (see Figure 11). The highest coherence (0.75-0.80) was between the index and middle finger pair at 8-10Hz frequency band, followed by the index and ring finger pair (0.68-0.70) and the index and little finger pair being the lowest (0.55-0.60). The vision condition had no significant effect on the coherence of finger pairs within hands coherence and the spectrum plot patterns were similar and peaks were close across vision conditions (Fig.10).
Unlike the slight contribution that the vision conditions brought to finger pair coherence, the 30-posture angle had the coherence peaks appearing at the lower 7-8 Hz frequency band. Although the order of the magnitude of coherence of finger pairs remained the same, the peaks of all finger pairs were higher under the 30 posture angle with index and middle finger pair still being greatest (0.85-0.90 under the 30 posture angle, 0.75-0.80 under the 0 posture angle) (Fig.12).

Figure 11: Magnitude Squared Coherence of index vs middle, index vs ring and index vs little finger pairs (Left hand, Eyes Open vs Eye Closed, 0 Posture Angle vs 30 Posture Angle)
Figure 12: Magnitude Squared Coherence of index vs middle, middle vs ring and ring vs little finger pairs (Left hand, Eyes Open, 0 Posture Angle).

Considering the relative distance of digits from each other, the greater coherence peaks were marked for the following two finger pairs: middle and ring fingers (0.82-0.87), ring and little fingers (0.82-0.87). The lower coherence was observed in index and middle finger pair (0.78-0.80). Overall, there was no difference on the peak value or the peak position (Fig.13).
Coherence between homologous digits across hands was markedly lower (<0.15) for index, middle, ring, and little finger pairs across the entire frequency band (0-40 Hz). A consistent trend was that all four coherences started with a modest coherence (0.20) at low frequency band (2-3 Hz) while remaining at lower value (<0.10) from 4-5 Hz to the end of the frequency band (see Figure 14).
Figure 14: Magnitude Squared Coherence of homologous digits (Eyes Open, 0 Posture Angle).
Chapter 4

Discussion

The tremor dynamics of postural tremor of the digits of both hands was investigated by analyzing the acceleration signal of each individual finger and thumb under conditions of 0 and 30 degree posture angle crossed with conditions of eyes open and eyes closed. The main findings were that: (1) increasing the postural angle led to a greater amount of tremor output in all digits; (2) the tremor of the homologous digits across hands did not present enhanced or significant coupling; (3) coupling of the digits within the hand decreased as the relative adjacency of digits from each other increased; and (4) the availability of visual information had a small asymmetric influence on level of digit tremor of the left hand. The significance of these findings for theory and experimentation of tremor is now discussed (Elble and Koller 1990).

The dynamics of the individual digit tremor and the coupling of digit tremor within and between hands revealed that tremor was strongly dependent on the anatomy and physiology of the respective digit (MacKenzie and Iberall 1994; Porter and Lemon 1993). That is, the relative amount of digit tremor and the level of coupling of digit tremor were fundamentally driven by which digit(s) is (are) being considered. A central finding was that the amount of tremor acceleration was greatest in the index finger and then progressively declined across the middle, ring and little fingers, respectively. This digit specific pattern for tremor amplitude was present in both hands and under all posture angle and visual information conditions. In general, the independent variables of posture angle and the availability of visual information played a minor role in influencing the amount of tremor in that their contribution was restricted to the scaling of the amplitude of the tremor dynamics of the digits (Porter and Lemon 1993).
As anticipated the overall level of tremor was greater in the 30 degree posture angle condition. The posture angle of 30 degree enhances the stretch on the muscle compared with the 0 degree posture angle (Walsh, 1992). The enhanced motor unit recruitment activity of the stretched muscle produces a higher level of tremor acceleration that was scaled to the natural tremor acceleration of the respective digit at 0 degree postural angle (Elble and Koller 1990).

An unexpected finding was that the availability of visual information increased the overall level of tremor acceleration of the digits of the left hand. In this context, it is noteworthy that there is growing evidence that the dominant and nondominant limbs have evolved and adapted to different functional roles in action (Guiard, 1987; Sainburg, 2005). In this emerging framework, the nondominant left hand is interpreted as having a primary role in the stability of movement in action, a feature that is central to the control of postural tremor. Loncharich and Newell (in press) have also shown an asymmetry in the coupling of the tremor of the fingers of the hand as a function of visual information.

The coupling of the tremor across digits was significant for digits of the same hand but not across hands. This is consistent with the findings of Morrison and Newell (1996) who showed an adaptive compensatory relation between the tremor of the segments (finger, hand, lower arm, upper arm) of the same arm. There was no coherence, however, between the tremor of the left and right limbs even for homologous segments.

The coherence of tremor across digits of the same hand was strongest for the index and middle fingers with the coherence progressively weakening for the index and ring finger coupling, and the index and ring finger, respectively. The coupling of the middle and ring, and the ring and the little finger had the lowest common power between digits. Thus, the anatomical structure of human finger and hand served as a significantly important feature to explain the coupling of tremor dynamics across digits.
The extensor indicis, located on the topside of the forearm, enables independent extension of the index finger (Porter and Lemon 1993; MacKenzie and Iberall 1994). This anatomical feature could contribute to the finding that the amplitude of index finger acceleration was greater compared with the other fingers regardless of postural and vision conditions. The related finding that an active neuromuscular load had a small effect on index fingers has been seen previously (Lang and Schieber, 2004; Charlotte et al. 2000). A secondary potential contribution to the minimal individualization of middle, ring and little fingers is due to these three digits sharing the common flexor digitorum profundus (FDP) muscle belly. FDP tendons are also connected to each other by multiple bands of tendons, which lead to simultaneous action of middle, ring and little fingers. If one of middle, ring and little fingers was held in flexion, the other two are difficult to straighten completely. If one of these digits was kept in extension, flexion of adjacent fingers could be done barely.

Our coherence results are consistent with influence of anatomical structure on the coherence of both middle and ring finger pair and ring and little finger pair. In contrast, a lesser number of bands extend from middle, ring and little fingers to the index finger, which results in the index finger being able to function more independently. The coherence of index finger with middle, ring and little fingers was decreased as the function of relative distance from index finger to others. However, coherence of adjacent finger pairs did not reflect the similar function.

Last but not the least, the flexor digitorum superficialis (FDS) plays an important role in determining the independence of fingers (Porter and Lemon 1993). The FDS divides into four bundles that separate into a superficial and a deeper layer. The superficial layer includes tendons to the middle and ring fingers, which supported the experimental finding that no significant relative difference of acceleration was observed for middle and ring fingers. The deeper layer contains tendons to the index and little fingers.
The coherence of tremor in the homologous digits across hands was not enhanced by the presence or absence of visual information. This is consistent with the failure to show the influence of vision on inter-limb coupling in either the time or the frequency domain in arm tremor (Morrison and Newell, 1996). That the visual information does not influence digit tremor coupling is consistent with the hypothesis that the amount of movement in the tremor of healthy young adults is too small for sensori-motor modulation through the pick-up of visual information (Legge and Campbell 1981; Scobey and Johnson 1981). The use of augmented visual information techniques can change the coupling of digit tremor as well as the amount of individual digit tremor acceleration (Loncharich and Newell in press).

The 30 degree postural angle placed the muscles of the digits of the hands on stretch and required more muscle activity to maintain the postural goal compared to the 0 degree posture angle. As a consequence, it was anticipated that increasing the postural angle would enhance the level of tremor activity as reflected in mean acceleration level (Elble and Koller 1990). The findings showed that enhanced postural angle led to an overall higher level of tremor amplitude across the digits of the hands. This postural angle effect was consistent across all digits of each hand and was not greater in one hand than the other.

Postural angle also changed the time- and frequency-domain properties of the tremor in addition to the overall amplitude of tremor. Postural angle scaled the bandwidth of physiological tremor to a slightly lower frequency range (7-8 Hz), and this effect was present across all digits. The magnitude of ApEn also changed as a function of posture angle, resulting in tremor variability at the 30 degree posture angle condition that was more irregular than during the 0 degree posture angle condition. These changes in the dynamics of tremor are consistent with the notion that postural angle is associated with the change of acceleration, especially in maintaining an effector posture against gravity (Albert and Kording 2011).
References


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