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Methods of time and frequency domain examination of physiological tremor in the human jaw

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Abstract

This paper discusses, using the human jaw as a model, some of the commonly used techniques for examining physiological tremor. The EMG component driving mandibular physiological tremor ~7 Hz can be revealed in the time domain manifestation of EMG by demodulation. The co-occurrence of ~7 Hz physiological tremor (PT) in force and EMG can also be seen in the frequency domain representations of these signals and coherence analysis provides a method by which the degree of co-occurrence can be statistically investigated. Additionally, estimation of time lags between the signals by phase and cumulant density analysis provides evidence of the direction of dependence. Data presented herein using these techniques illustrates that for the human jaw, PT arises from a rhythmic component of EMG. This component is frequency and amplitude invariant across a range of bite forces indicating that it is not due to interaction between the stretch reflex and the mechanical resonance of the system.

PsycINFO classification: 2330; 2530

Keywords: Tremor; Electromyography; Jaw; Coherence

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1. Physiological tremor in the jaw

Physiological tremor (PT), defined as normally occurring low-amplitude rapid back and forth movement of a body part, is usually observed in the frequency range of 6–12 Hz [for review see Elble and Koller, 1990, and McAuley and Marsden, 2000]. This phenomenon, most commonly investigated during slow movements and isometric contractions, has been reported in many body segments. The human masticatory system is also characterized by PT yet this has been reported on in only a few instances (Jaberzadeh et al., 2003; Junge, Rosenberg, & Halliday, 1998; McFarland, Smith, Moore, & Weber, 1986; Van Steenberghe & De Vries, 1980). These investigations have revealed a peak in the tremor spectrum at around 7 Hz, which is consistent with the tremor frequency observed in other motor systems.

It has been proposed that PT arises from activity perpetuated in reflex loops involving feedback from muscle spindles (Jacks, Prochazka, & Trend, 1988; Joyce & Rack, 1974; Joyce, Rack, & Ross, 1974; Lippold, 1970; Matthews & Muir, 1980; Prochazka & Trend, 1988), however more recently this has been contested and the hypothesis that PT is generated centrally by either central pacemakers or central oscillatory circuits (Farmer, Bremner, Halliday, Rosenberg, & Stephens, 1993; Gross et al., 2000; Gross et al., 2002; McAuley & Marsden, 2000; Wessberg & Kakuda, 1999) has been widely accepted. Furthermore, the contribution of the stretch reflex to PT has been discounted (Wessberg & Kakuda, 1999). The discounting of the stretch reflex remains controversial however and recently, Durbaba, Taylor, Manu, and Buonajuti (2005), restated the position put forward by Matthews and Muir (1980) that, under true isometric conditions with the body segment fixed against a rigid transducer, the $\sim$7 Hz component of tremor is abolished. Furthermore, Durbaba and colleagues showed this to be the case in seven of nine subjects tested in their experiment, arguing that the use of acceleration, velocity or displacement to measure tremor inevitably includes stretch reflex mechanisms, as these measures require the segment to be free in its movement at the end of the lever opposite the hinge, a requirement that in turn allows the segment oscillate in space and increases the gain in the stretch reflex loop.

We argue that when measuring tremor via force recordings in most body segments, the significant compliance introduced by soft tissues when that segment is coupled to a transducer, may dampen the frequency components of interest to such an extent that they become insignificant. The teeth however provide the opportunity to fixate a body segment (the mandible) to a rigid transducer providing an almost direct coupling to the bone, thus providing the opportunity to minimise the contribution of the stretch reflex to jaw tremor whilst still being able to measure minimally damped force fluctuations representative of oscillatory activity. Moreover, under such conditions, increasing the stiffness of the muscle is possible thereby allowing examination of a further mechanical variable.

The rhythmic EMG activity that gives rise to tremulous mechanical output (Elble & Randall, 1976) can be described as amplitude modulated noise; such a description describes the relatively broadband nature of the EMG 'carrier' spectrum upon which is superimposed a narrowband oscillation responsible for the more easily measured mechanical tremor (Journee, 1983). Because the broadband and narrowband components of EMG activity overlap, it is almost impossible to recognise PT visually in raw EMG recordings. For this reason, the process of 'demodulating' EMG, described in a series of papers (Fox & Randall, 1970; Journee, 1983; Journee & Van Manen, 1983; Journee, Van Manen, & Van der Meer, 1983) was developed to provide a method by which the narrowband modulation signal can be revealed and visualized.