Journal of Neuroscience Methods 230 (2014) 1–4

Contents lists available at ScienceDirect

Journal of Neuroscience Methods

journal homepage: www.elsevier.com/locate/jneumeth

Short communication

Smart watch accelerometry for analysis and diagnosis of tremor

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ARTICLE INFO

Article history:
Received 22 January 2014
Received in revised form 23 March 2014
Accepted 16 April 2014

Keywords:
Tremor
Parkinson's disease
Essential tremor
Accelerometry

ABSTRACT

Background: Distinguishing the postural re-emergent tremor of Parkinson disease from essential tremor can be difficult clinically. Use of accelerometry to aid diagnosis is limited to laboratory settings. We sought to record and differentiate these tremors using a smart watch device in an outpatient clinic.
New method: 41 patients were enrolled. Recordings were made with a smart watch device on the predominantly affected hand (all patients), and simultaneously with an analog accelerometer (10 patients) with hands at rest and outstretched. Tremor peak frequency, peak power, and power of the first four harmonics was calculated and compared between the two devices. Mean power at the first four harmonics was calculated and used to classify tremor as parkinsonian or essential. Test characteristics were calculated to compare the device and clinical diagnoses.
Results: Mean harmonic peak power was both highly sensitive and specific for distinction of Parkinson disease postural tremor from essential tremor with an optimal threshold for our sample (sensitivity 90.9%, 95% CI 58.7–99.8%; specificity 100%, 95% CI 76.8–100%; Cohen's kappa = 0.91, SE = 0.08).
Comparison with existing methods: The smart watch and analog devices had nearly perfect concordance of peak frequency and proportional harmonic power. The smart watch recordings in clinic took 3–6 min.
Conclusions: A smart watch device can provide accurate and diagnostically relevant information about postural tremor. Its portability and ease of use could help translate such techniques into routine clinic use or to the community.

1. Introduction

While tremor caused by Parkinson disease (PD) and essential tremor (ET) are usually distinguishable on clinical grounds, differentiating the two can occasionally be difficult (Jain et al., 2006; Cohen et al., 2003; Chaudhury et al., 2005). Such cases require longitudinal follow-up, determining treatment response, and sometimes dopamine transporter imaging. Correct diagnosis directs symptomatic therapy and has prognostic implications.

Accelerometry can readily quantify tremor frequency, but this cannot reliably distinguish PD (most commonly 4–6 Hz) from ET (most commonly 5–8 Hz; Burne et al., 2002). However, some aspects of waveform morphology may be unique to PD, such as a "notched" appearance indicating nonlinear processes in tremor generators (Muthuraman et al., 2011) which appear in spectral analysis as energy at harmonics of the peak frequency. These authors proposed that the mean power of the 1st to 4th harmonics of the peak frequency is greater in PD and can differentiate PD and ET in clinically unclear cases.

We sought to determine if we could discriminate PD and ET tremor in a clinic setting using a wireless smart watch device. We first compared data from our smart watch device to data obtained using a standard analog accelerometer, then determined if the mean harmonic power could distinguish these tremors.

2. Methods

The study was approved by our institutional Research Ethics Board and informed consent was obtained. Patients with a diagnosis of PD or ET and clinically relevant tremor were identified by movement disorders neurologists and enrolled. Inclusion required agreement on the diagnosis by two neurologists with subspecialty movement disorders training; if the patient had only seen one subspecialist, clinical information and videos of rest and postural tremor were reviewed and the diagnosis verified by a second blinded expert. Patients were excluded if they had cognitive impairment, if there was diagnostic uncertainty, or if they had minimal tremor at the time of recording. Data were abstracted from an interview and chart review, including demographics, tremor topography, symmetry, duration and progression, aggravating and

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http://dx.doi.org/10.1016/j.jneumeth.2014.04.021
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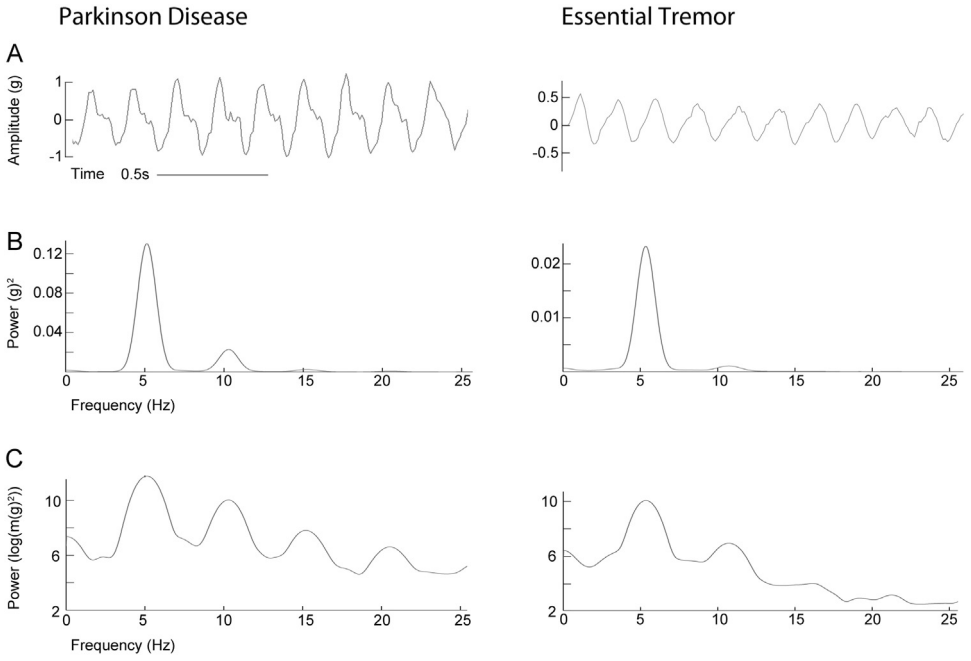

Fig. 1. Examples of recordings and analysis. (A) Sample trimmed time series from single accelerometer axis for a patient with PD (left) and with ET (right) – note "notched" appearance of PD waveform and sinusoidal appearance of ET waveform; *y* axis shows amplitude in gravities (g) (B) Welch periodograms of above recordings showing tremor peak power (gravities squared, g^2) and some energy visible at harmonic frequencies (multiples) of the peak; (C) logarithmically transformed periodograms make energy at harmonic frequencies ($\log(m(g)^2)$) more apparent – peak power and harmonic peak power are extracted from these transforms for analysis.

mitigating factors, family history, treatment response, comorbidities, and medications.

To validate the smart watch device measurements, we employed Lin's concordance correlation coefficient (Lin, 1992). This provides a test of how much a new measurement deviates from an expected perfect correlation with a gold standard measurement. Following sample size derivations described by Lin (1992), and expecting that the smart watch accelerometer would explain 99% of variation in the analog accelerometer samples, we calculated that 10 paired sets of data were required to demonstrate substantial concordance of their frequency and power estimates (Lin's concordance correlation coefficient > 0.95). We calculated that detecting excellent versus slight "agreement" (kappa 0.80 versus 0.30) between the clinical diagnosis and the accelerometer with a power of 80% required 27 participants (Schouten, 1988).

10 recordings were made in a laboratory with a 25 g triaxial analog accelerometer (ENTRAN EGAS, NJ, USA) and a 22 g smartwatch device containing an 8 g triaxial accelerometer (WIMM One, CA USA) tightly coupled using Velcro and affixed to the dorsum of the predominantly affected hand. An additional 31 recordings were made with the smartwatch device alone in clinic.

Video of the hands and acceleration was recorded for 60 s with participants instructed to keep their hands (a) resting fully supported and (b) outstretched. Participants wearing both devices were instructed to tap their hand at the start and end of recording, creating an artifact to align the recordings' start and end times during analysis. Subsequent recordings were made in the same positions with the watch only. Additional normative data were collected from 9 healthy volunteers with arms in an outstretched posture for 60 s. Only one trial was permitted for data collection in each position.

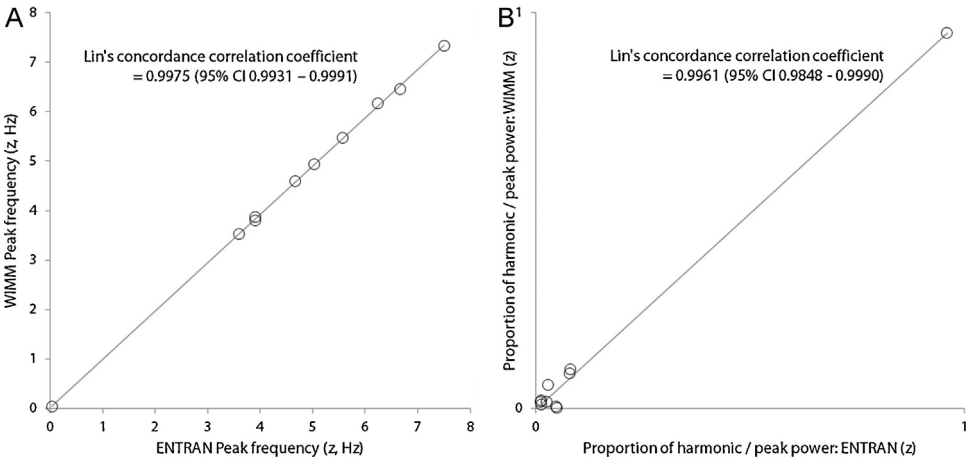

Fig. 2. Concordance of peak frequency (A) and Proportional Mean Harmonic Peak Power (B) (Mean Harmonic Peak Power divided by Peak Power) for the analog accelerometer (ENTRAN) and smart watch (WIMM).