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Tremor in normal adults: A population-based study of 1158 adults in the Faroe Islands

Elan D. Louis[a,b,c,*], Monica Ferrer[a], Eina H. Eliasen[d], Shahin Gaini[e,f,g], Maria Skaalum Petersen[d,g]

[a] Department of Neurology, Yale School of Medicine, Yale University, New Haven, CT, USA
[b] Department of Chronic Disease Epidemiology, Yale School of Public Health, Yale University, New Haven, CT, USA
[c] Center for Neuroepidemiology and Clinical Neurological Research, Yale School of Medicine, Yale University, New Haven, CT, USA
[d] Department of Occupational Medicine and Public Health, The Faroese Hospital System, Tórshavn, Faroe Islands
[e] Infectious Diseases Division, National Hospital Faroe Islands, Tórshavn, Faroe Islands
[f] Department of Infectious Diseases, Odense University Hospital/University of Southern Denmark, Odense, Denmark
[g] Centre for Health Science, Faculty of Health Sciences, University of the Faroe Islands, Tórshavn, Faroe Islands

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ABSTRACT

There are virtually no population-based data on tremor in normal individuals. Using a population-based sample of 1158 normal adults ages 40–98 years in the Faroe Islands, we characterized the extent of normal action tremor across age and gender strata. Participants drew two Archimedes spirals with each hand, and tremor was systematically quantified by a senior movement disorder neurologist using a reliable and valid ordinal rating scale (ratings = 0–3). Tremor was nearly universal - 1145 (98.9%) participants had a total mean spiral score > 0. Older age was associated with more tremor ($p < .001$) and spiral scores were higher in males than females ($p < .001$). The proportion of individuals with a spiral rating ≥ 1.5 (i.e., more than mild tremor) was low (1.8% - 8.5%); however, this value reached 19.6% in left-hand spirals of males ≥70 years old. In this population-based study of more than one thousand normal adults, the vast bulk (i.e., 98.9%) had tremor on spiral drawing. In general, the tremor was mild. The proportion of individuals with tremor above the mild range varied across age and gender strata. These extensive data may be used as a gold standard for defining normal levels of tremor within adult populations.

1. Introduction

Mild action tremor of the hands occurs in most normal people [1]. While caffeine and nicotine may exacerbate this tremor, beta blockers may lessen it [2,3]. The tremor is not without import. For example, such tremor may impair precise hand control in professional musicians [4,5], and is a source of impaired motor performance in professional sports [6], among surgeons [7–9], in airplane pilots [10], and it can impede effective shooting performance in military personnel [11–14]. In occupational medicine and toxicologic-epidemiology, which often focus on the development of abnormal neurological outcomes (e.g., hand tremor) [15–18], it is important to establish normal levels of tremor within age- and gender-defined strata. In genetic studies of essential tremor (ET), background levels of normal tremor are important to gauge in order to assign valid diagnoses to at-risk family members across the full range of age and gender strata [19]. At present, there are surprisingly few data. Indeed, there are only four prior studies of tremor in normal individuals [1,20–22], only one of which was population-based [21].

The current study utilized cross-sectional data in 1158 normal adults (ages 40–98 years) recruited to a population-based, environmental-epidemiological study of tremor in the Faroe Islands. No previous studies of tremor in the Faroe Islands have been undertaken. Each participant drew two spirals with each hand, and tremor was systematically quantified by a senior movement disorder neurologist using a reliable and valid clinical rating scale. Our aim was to paint a picture of the prevalence of normal action tremor across a wide range of age and gender strata and to assess whether action tremor covaried with age and gender as well as a range of other factors (e.g., caffeine consumption, medication usage, smoking).

Abbreviations: CI, confidence interval; ET, essential tremor; OR, odds ratio; UPDRS, Unified Parkinson's Disease Rating Scale

* Corresponding author at: Yale School of Medicine, Department of Neurology, 15 York Street, PO Box 208018, New Haven, CT 06520-8018, USA.
E-mail address: elan.louis@yale.edu (E.D. Louis).

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2. Methods

2.1. Study population and sampling frame

The Faroe Islands is an archipelago in the North Atlantic Ocean (62° north latitude) inhabited by a genetically homogenous (95%) White Caucasian population [23].

A population-based, environmental epidemiological study of tremor disorders was established by two of the authors (E.D.L. and M.S.P.) to estimate the prevalence of ET in the Faroe Islands as well as evaluate environmental determinants of that disease. This site was chosen because of its small and well-defined population (approximately 50,000 inhabitants), the geographic accessibility of population (i.e., most of the inhabitants live within 2 h or less of Tórshavn, the capital city), the long history and depth of experience in performing neuroepidemiological research there [24–29], and recent studies suggesting a high prevalence of certain movement disorders in that population [23,30]. In addition, given the genetic homogeneity of the population, it was an ideal setting for studying environmental determinants of neurological disease.

The study was undertaken between August 2016 and December 2017, with the goal of screening 3000 individuals ≥40 years old for tremor. From the total of 24,154 individuals aged ≥40 years living in the Faroe Islands, the names of 4798 individuals were obtained from the Faroese Population Registry (Fig. 1). These 4798 were selected from the Registry based on six randomly-selected birthdates (10th, 16th, 17th, 18th, 22th and 30th). From these 4798, we selected into the screening group all individuals age 70 and older (n = 1155) as well as 1845 individuals selected by random sampling using SPSS. Thus, the screening group comprised 3000 Faroese individuals aged 40 years and older (Fig. 1).

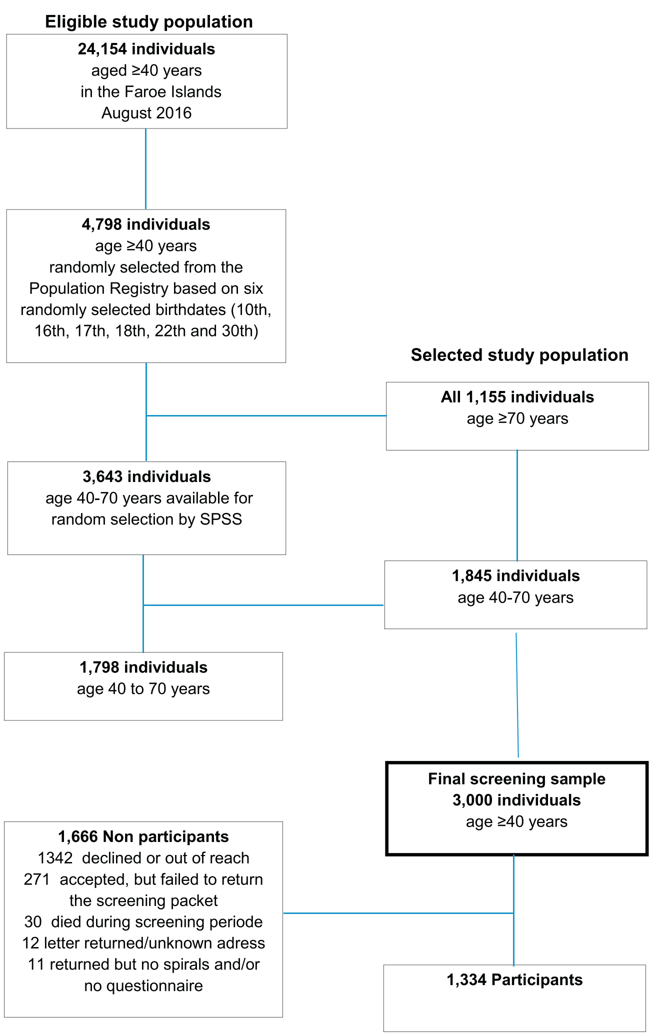

Fig. 1. Selection of screening population.
From 24,154 individuals age 40 and older, 3000 were selected for the final screening sample, of whom 1334 participated.

All study procedures were approved by the Faroese Ethical Committee and the Institutional Review Board at Yale University. Signed informed consent was obtained from each screened enrollee.

2.2. Screening for tremor

A brief screening assessment for tremor was instituted for all screenees. Each screenee was mailed a screening package, which included an invitation letter that asked them to participate in a study of lifestyle, diet and the neurological system, as well as questionnaires and a request for four hand-drawn spirals. The questionnaires collected demographic data, data on use of caffeinated beverages on the day the screening questionnaires were filled out, and included a screening questionnaire for ET [31], which comprised questions regarding tremor (e.g., "do you often have shaking or tremor that you can't control, "has a doctor diagnosed you as having familial tremor or benign essential tremor", "does your head often shake uncontrollably"). As the screening questionnaire for tremor only has modest sensitivity (73%) [31], screening spirals were also requested (see below).

For the screening spirals, clear instructions were provided in the screening package. Each screenee was instructed to use their dominant hand to draw two Archimedes spirals. As described in prior population-based settings [21,32,33], screenees were instructed to draw each spiral freely on a blank, standard 8.5 × 11 in. sheet of paper using a ballpoint pen while seated at a table. They were instructed to center the paper at right angles (horizontally) directly in front of them and to start at the center of the page, without lifting their pen and without resting their wrist on the table. This was repeated with the nondominant hand, yielding four spirals in total. Screenees were also asked about their use on the day of the screening evaluation of caffeinated coffee, tea and soda, cigarette smoking and use of an asthma inhalers, as each may produce or exacerbate tremor [32].

2.3. Return of screening items and selection for in-person assessment

The screening package included a return stamped envelope. All screenees were asked to mail or email their completed forms to the investigators in the Faroe Islands (E.H.E. and M.S.P.) After a one-month period, a reminder telephone call was made to those individuals who had not returned their questionnaires and spirals. A total of 1334 (44.5%) returned the spirals (Fig. 1). When compared to those who did not return the spirals, these 1334 were on average 5 years younger (61.2 ± 13.0 years vs. 66.2 ± 14.8 years, $p < .001$) and 6% more likely to be of female gender (52.9% vs. 46.6%, $p < .001$).

Tremor in each spiral was later rated by a blinded neurologist who specializes in movement disorders (E.D.L.). The neurologist used an ordinal clinical rating scale from 0 to 3, and including ratings of 0 (none), 0.5 (very mild), 1 (mild), 1.5 (mild-to-moderate), 2 (moderate) and 3 (severe) (see examples of spirals rated as such in prior epidemiological studies [34].

Questionnaire and spiral data were then used to select screenees for an in-person assessment: screenees were stratified into four groups: (1) those with a high likelihood of having ET (e.g., spiral ratings ≥1.5 on one or more dominant hand spirals or having been diagnosed previously with ET or having endorsed "head tremor" on the questionnaire), (2) those with an intermediate likelihood of having ET (e.g., both non-dominant hand spiral ratings ≥1.5), and (3) those with a low-intermediate likelihood of having ET (e.g., a single non-dominant arm spiral rating ≥ 1.5) and (4) those with a low likelihood of having ET (e.g., spiral ratings ≤1). The overarching goals of the parent study were to (1) determine the prevalence of ET and (2) compare ET cases to controls in terms of environmental exposures. To achieve these goals, we needed to both enroll ET cases and controls. We were concerned that the number of ET cases might be low. Therefore, to maximize enrollment of ET cases, we enrolled more individuals in groups 1 and 2 than in the other two groups, because individuals in groups 1 and 2 had the highest likelihoods of having ET. Thus, all of individuals in group 1 (i.e., high likelihood of ET) were selected and invited for an in-person assessment as well as a random selection of 80% in group 2 (i.e., intermediate likelihood of ET), 35% in group 3, and 7% in group 4. The total number targeted was 250.

We invited 282 individuals for an in-person clinical examination, expected that some would decline. A total of 227 individuals accepted participation while 54 declined and one person deceased before the examinations, i.e. the participation rate was 80.5%. In group 1, the participation rate was 78%; in group 2, 85%; in group 3, 84%; and in group 4, 76%.

2.4. In-person assessment

An in-person assessment was performed on 227 participants by a trained research assistant (E.H.E.) at the Department of Occupational Medicine and Public Health in Tórshavn or in subject's homes. During the in-person assessment, additional questionnaires were administered, including demographic and clinical data. Data on medication usage were also collected.

E.H.E. performed a videotaped neurological examination during the in-person assessment. This included one test for postural tremor and five for kinetic tremor (e.g., pouring, drinking) performed with each arm (12 tests total), the motor portion of the Unified Parkinson's Disease Rating Scale (UPDRS) [35] excluding an assessment of rigidity, and a comprehensive assessment of dystonia.

2.5. Diagnosis of ET and other neurological conditions

All *ET diagnoses* were assigned by E.D.L. based on review of questionnaires and videotaped neurological examination using published diagnostic criteria (moderate or greater amplitude kinetic tremor during three or more activities or a head tremor in the absence of Parkinson's disease or another known cause [e.g., medication-induced tremor, tremor from hyperthyroidism]) [36–39]. These diagnostic criteria for ET were developed for a population-based genetic study and, based on data from approximately 2000 normal (non-diseased controls), the criteria carefully specify the specific examination maneuvers during which tremor should be present and the severity of tremor that should be evident during these maneuvers to distinguish normal from ET. These criteria have been shown to be both reliable [39] and valid [40], and have been used by tremor investigators in the United States and internationally [41–52]. As in prior reports, *borderline tremor* was a diagnosis assigned to individuals who did not fully meet strict diagnostic criteria for ET (defined above) but were nonetheless considered by E.D.L. to have clinical features that aligned them more with ET than normal [19,36]. The diagnosis of *dystonia* was confirmed using published diagnostic criteria [53], as was the diagnosis of *Parkinson's disease* [54].

2.6. Final subject selection for current analyses of normal tremor

A total of 1334 (44.5%) returned the spirals. For the current analyses, which focused on *normal* individuals, we excluded all participants with ET (n = 38), borderline tremor (n = 36), dystonia (n = 3) or Parkinson's disease (n = 0), or abnormal limb postures of uncertain significance (i.e., possible dystonia, n = 75), as well 24 with incomplete data. Hence, the current paper focused on the data derived from the remaining 1158 normal participants.

2.7. Statistical analyses

Age, cups of caffeinated beverages, number of cigarettes smoked, and all spiral scores were not normally distributed (Kolmogorov Smirnov test p values all < 0.05); hence, non-parametric tests were used when evaluating these variables (e.g., Mann-Whitney test, Spearman's rho). There were two spirals drawn with the right hand; a mean was calculated ("right hand mean spiral score"). The same calculation was performed for the left hand ("left hand mean spiral score"). Also, the mean for both hands was reported ("total mean spiral score"). We examined the correlations between spiral scores and continuous variables (e.g., age) using Spearman's correlation coefficients. We compared spiral scores across strata (e.g., males vs. females) using Mann-Whitney tests. We used a Wilcoxon signed ranks test to compare the left hand mean spiral score to the right hand mean spiral score within individuals. We divided the total mean spiral score into two categories based on the median value (0.75): lower score (< 0.75) vs. higher score (≥0.75). We then examined the correlates of higher tremor score in bivariate logistic regression models and then multivariate logistic regression models, which yielded odds ratios (OR) and 95% confidence intervals (CI). We also performed an additional analysis that was restricted to 992 (85.7%) participants who were right-handed.

3. Results

There were 1158 participants (Table 1). Participants ranged in age from 40 to 98 years (mean = 61.0, median = 60.0 years); the vast majority (1076 [92.9%%]) was between age 40 and 80 years. Approximately one-half were women (Table 1).

1145 (98.9%) participants had a total mean spiral score > 0 (i.e., 98.9% of participants had a rating of 0.5 or higher on at least one of the

Table 1
Characteristics of 1158 Study Participants.

Age in years	61.0 ± 13.1 (60.0, 40–98)
Female gender	631 (54.5)
Education	
Less than high school graduate	347 (30.0)
High school graduate	79 (6.8)
Less than college graduate	297 (25.6)
College graduate	337 (29.1)
Masters or doctorate degree	66 (5.7)
Missing data	32 (2.8)
Current cigarette smoker	222 (19.2)
Handedness	
Right	992 (85.7)
Left	111 (9.6)
Ambidextrous	10 (0.9)
Missing	45 (3.9)
Cups of caffeinated coffee on day of screening	1.6 ± 1.8 (1.0, 0–6)
Cups of caffeinated tea on day of screening	1.2 ± 1.7 (1.0, 0–7)
Cups of caffeinated soda on day of screening	0.4 ± 0.2 (0.0, 0–1)
Smoked cigarettes on day of screening	189 (16.3)
Number of cigarettes smoked on day of screening	
All 1158 participants	1.1 ± 3.4 (0.0, 0–30)
189 participants who smoked on day of screening	6.9 ± 5.5 (5.0, 1–30)
Used an asthma inhaler on the day of screening	55 (4.7)
Hours since used asthma inhaler (55 participants)	5.9 ± 4.6 (5.5, 0.5–23)
Right hand spiral 1 score	0.56 ± 0.34 (0.5, 0–2.0)
Right hand spiral 2 score	0.54 ± 0.34 (0.5, 0–2.0)
Right hand mean spiral score	0.55 ± 0.31 (0.5, 0–2.0)
Left hand spiral 1 score	0.82 ± 0.37 (1.0, 0–2.0)
Left hand spiral 2 score	0.85 ± 0.36 (1.0, 0–2.0)
Left hand mean spiral score	0.83 ± 0.34 (1.0, 0–2.0)
Total (right and left hands) mean spiral score	0.69 ± 0.29 (0.75, 0–2.0)

Values are mean ± standard deviation (median, range) or number (percentage).

Table 2
Comparison of age and spiral scores in males and females.

	Males	Females	Significance[a]
Age in years	61.0 ± 13.0 (60.0)	61.0 ± 13.3 (60.0)	$p = .84$
Right hand mean spiral score	0.61 ± 0.30 (0.5)	0.50 ± 0.31 (0.5)	$p < .001$
Left hand mean spiral score	0.88 ± 0.33 (1.0)	0.795 ± 0.34 (0.75)	$p < .001$
Total (right and left hands) mean spiral score	0.74 ± 0.28 (0.75)	0.65 ± 0.29 (0.625)	$p < .001$

Values are mean ± standard deviation (median).
[a] Mann-Whitney tests.

four spirals). Age was associated with the right hand mean spiral score (Spearman's $r = 0.17$, $p < .001$), the left hand mean spiral score (Spearman's $r = 0.19$, $p < .001$) and the total mean spiral score (Spearman's $r = 0.20$, $p < .001$). Age was stratified into decades and the total mean spiral score was as follows: 0.60 ± 0.26 (median = 0.63) for age < 50 years, 0.69 ± 0.28 (median = 0.75) for age 50–59 years, 0.68 ± 0.28 (median = 0.63) for age 60–69 years, and 0.77 ± 0.30 (median = 0.75) for age 70 and older (Mann-Whitney z = 6.97, p < .001 for comparison of age < 50 vs. age 70 and older).

Males and females were of near-identical age, yet the spiral scores were higher in males than in females (all p values < .001, Table 2).

The proportion of individuals with spiral scores above the mild range (i.e., ≥1.5) was low (21 of 1158 [1.8%] in right hand spiral 1 and 98 of 1158 [8.5%] in left hand spiral 1) (Table 3). The proportion increased with age (Table 3). In right hand spiral rating 1, for example, the proportion with spiral scores in this range was lowest among females age 40–49 years (0.6%) and highest among males age ≥ 70 years (3.4%) (Table 3). In left hand spiral rating 1, for example, the proportion with spiral scores in this range was also lowest among females age 40–49 years (4.2%) and highest among males age ≥ 70 years (19.6%) (Table 3). Data were similar for spiral 2 (data not shown).

The left hand mean spiral score (mean = 0.83 ± 0.34, median = 1.0) was greater than the right hand mean spiral score (mean = 0.55 ± 0.31, median = 0.5) (Wilcoxon signed ranks test z = 23.16, $p < .001$).

Data on medication use were available on all 227 participants seen in person; 55 of these were normal (i.e., they did not have ET) and were included in the current dataset. Of these 55, 4 (7.3%) were on a tremor-exacerbating medication (e.g., prednisone, asthma inhaler), 10 (18.2%) were on a tremor-suppressing medication (e.g., metoprolol, diazepam), 5 (9.1%) were on both types of medication, and 36 (65.5%) on neither. We compared the total mean spiral score in the 4 participants on a tremor-exacerbating medication, the 10 participants on a tremor-suppressing medication, the 5 participants on both, and the 36 on neither type of medication, and they did not differ (Mann-Whitney test = 4.09, $p = .25$). The respective medians for the total mean spiral score were 1.0, 1.25, 0.9, and 1.0.

There was no correlation between the total mean spiral score and number of cups of caffeinated coffee on day of screening (Spearman's $r = 0.008$, $p = .79$), number of cups of caffeinated tea on the day of screening (Spearman's $r = -0.02$, $p = .44$), or number of cups of caffeinated soda on day of screening (Spearman's $r = -0.002$, $p = .95$). The total mean spiral score was significantly higher in the 55 participants who had used an inhaler on the day of screening than in the remainder who had not (0.79 ± 0.28 [median = 0.75] vs. 0.69 ± 0.29 [median = 0.75], Mann-Whitney test z = 2.77, $p = .006$). The total mean spiral score was no higher in the 189 participants who had smoked cigarettes on the day of screening than in the remainder who had not (0.71 ± 0.28 [median = 0.75] vs. 0.69 ± 0.29 [median = 0.75], Mann-Whitney test z = 0.81, $p = .42$).

We divided the total mean spiral score into two categories based on the median value (0.75): lower score (< 0.75) vs. higher score (≥0.75). We then examined the correlates of higher score, including age, gender, number of cups of caffeinated coffee on day of screening, number of cups of caffeinated tea on the day of screening, number of cups of caffeinated soda on day of screening, use of an inhaler on the day of screening, and having smoked cigarettes on the day of screening. In the final multivariate logistic regression model, older age (OR = 1.03, 95% CI = 1.02–1.04, $p < .001$), male gender (OR = 1.55, 95% CI = 1.22–1.97, p < .001), and use of an asthma inhaler on the day of screening (OR = 2.14, 95% CI = 1.17–3.92, $p = .01$) were associated with higher total mean spiral score.

In an analysis that was restricted to 992 (85.7%) of participants who were right-handed, the results were similar: the left hand mean spiral score (mean = 0.85 ± 0.34, median = 1.0) was greater than the right hand mean spiral score (mean = 0.54 ± 0.31, median = 0.5) (Wilcoxon signed ranks test z = 23.07, p < .001). In that sub-sample of 992, in the final multivariate logistic regression model, older age (OR = 1.03, 95% CI = 1.03–1.04, p < .001), male gender (OR = 1.51, 95% CI = 1.16–1.96, p < .001), and use of an asthma inhaler on the day of screening (OR = 2.39, 95% CI = 1.17–4.86, $p = .016$) were associated with higher total mean spiral score.

Table 3
Spiral score by age and gender.

	Age 40–49	Age 50–59	Age 60–69	Age ≥ 70
Right hand spiral 1 rating				
Males				
Rating = 0	21 (16.8)	11 (8.3)	10 (11.0)	17 (9.5)
Rating = 0.5	72 (57.6)	87 (66.0)	53 (58.2)	95 (53.1)
Rating = 1	31 (24.8)	30 (22.7)	27 (29.7)	61 (34.1)
Rating ≥ 1.5	1 (0.8)	4 (3.0)	1 (1.1)	6 (3.4)
Females				
Rating = 0	44 (26.2)	23 (16.0)	23 (19.2)	31 (15.6)
Rating = 0.5	99 (58.9)	89 (61.8)	76 (63.3)	110 (55.3)
Rating = 1	24 (14.3)	30 (20.8)	20 (16.7)	53 (26.6)
Rating ≥ 1.5	1 (0.6)	2 (1.4)	1 (0.8)	5 (2.5)
Left hand spiral 1 rating				
Males				
Rating = 0	7 (5.6)	6 (4.5)	1 (1.1)	1 (0.6)
Rating = 0.5	52 (41.6)	44 (33.3)	29 (31.9)	50 (27.9)
Rating = 1	60 (48.0)	68 (51.5)	51 (56.0)	93 (52.0)
Rating ≥ 1.5	6 (4.8)	14 (10.6)	10 (11.0)	25 (19.6)
Females				
Rating = 0	15 (8.9)	10 (6.9)	6 (5.0)	10 (5.0)
Rating = 0.5	81 (48.2)	54 (37.5)	56 (46.7)	63 (31.7)
Rating = 1	65 (38.7)	70 (48.6)	50 (41.7)	108 (54.3)
Rating ≥ 1.5	7 (4.2)	10 (7.0)	8 (6.7)	18 (9.0)

Values represent number (column percentage).

4. Discussion

At present, there are surprisingly few published data on normal levels of tremor within age- and gender-defined strata. Indeed, there are four prior studies of tremor in normal individuals [1,20–22], but only one of these was population-based [21]. The current study utilized spiral-drawing data in 1158 normal adults ages 40–98 years recruited to a population-based study in the Faroe Islands. We found that the vast bulk of participants (i.e., 98.9%) had tremor on spiral drawing (i.e., a total mean spiral score > 0). In general, the tremor was mild. Indeed, the proportion of individuals with spiral scores ≥1.5 (i.e., tremor on spiral above the mild range) was low (1.8% in right hand spiral 1 and 8.5% in left hand spiral 1). In general, the severity of tremor increased with age, was greater in men than women, and was greater in the non-dominant than dominant arm. Certain factors (e.g., use of asthma inhalers) were associated with increased tremor.

There are four prior studies [1,20–22], one of which was population-based [21]. That was a population-based study of 2524 young and midlife normal adults in Bangladesh (mean age = 36.1 ± 9.6 years, range = 18–60) [21]. The other three studies were not population-based. The first was of 103 normal adults in the United States (mean age = 54.4 ± 21.7 years, range = 18–93) [1], a second was of 273 normal subjects in the United States (mean age = 65.7 ± 11.5 years, range not reported) [22], and a third was of 819 normal children in Spain (mean age = 10.9 ± 3.1 years, range = 5–21) [20]. The third study differed markedly from the current study in the sense that the subjects were children [20], and the study in Bangladesh sampled individuals whose mean age and age distribution (mean age = 36.1 ± 9.6 years, range = 18–60) was significantly younger than the current in the Faroe Islands (mean age = 61.0 ± 13.1 years, range = 40–98). Only the studies in the United States had a similar age distribution; however, the respective sample sizes of those two studies were ¼ [22] to 1/10 [1] the size of the current study and the studies were not population-based.

Our aim was to paint a picture in the population of the prevalence of normal action tremor across a wide range of age and gender strata. These data have a number of clear utilities. First, in both occupational medicine and toxicologic-epidemiology, which often focus on the development of abnormal neurological outcomes such as hand tremor [15–18], it is imperative to establish normal levels of tremor within age- and gender-defined strata. In genetic studies of ET and other tremor disorders, it is imperative to establish background levels of normal tremor; these are often influenced by advancing and advanced age [19]. At present, there are surprisingly few data. Our tables may be used for both of these purposes.

These data also have clinical implications. In clinical settings, at-risk family members of ET cases as well as other individuals presenting with tremor often want to know whether tremor is a sign of an emerging disease. One approach is to establish criteria for the disease (e.g., minimal criteria for ET). The other is to establish at the other end of the spectrum what the extent of normal is.

This study should be interpreted within the context of several limitations. First, our data were restricted to those obtained from spiral-drawing. Of additional value would be data on tremor during a range of other tasks (e.g., additional writing tasks, pouring, and drinking). Second, we only examined a subset of participants. It is possible that some of the screenees who were deemed to have an intermediate, low-intermediate or low likelihood of ET and who were not seen in person, actually had ET. In other words, it is possible that some of the individuals we included as “normal”, rather, had ET. On the screening spirals, however, only 2 of 1158 (0.17%) participants had tremor that was in the traditional ET range (i.e., bilateral tremors of moderate amplitude with ratings of 2); neither of these two had been diagnosed previously with ET. But it is possible that this fraction of a percent could have had undiagnosed ET. Third, data on medication use were limited, and therefore, we were not able to fully account for the effects of medication on the expression of hand tremor within this cohort. Despite this, the data that we did have suggested that medications (aside from asthma inhalers used on the day of evaluation) did not have a significant impact on the tremor observed in our cohort. Fourth, participants were on average five years younger and were 6% more likely to be female than non-participants. Since younger age and female gender were both associated with less tremor, we may have slightly underestimated the overall amount of tremor in our participants. For this reason, we also provided age- and gender-stratified data. Finally, the population was a specific population in a distinct geographic locale with a relatively homogeneous ethnic make-up; the results of this work may not generalize to mixed populations.

The study also had considerable strengths. First, the sample size was large, with data on 1158 normal adults. Second, the study was population-based. Third, data were collected across participants in a standardized manner. Fourth, tremor was systematically quantified by a senior movement disorder neurologist using a reliable and valid clinical rating scale.

5. Conclusions

In summary, in this population-based study of more than one thousand adults, we found that the vast bulk (i.e., 98.9%) had tremor on spiral drawing. In general, the tremor was mild, with the proportion of individuals with tremor above the mild range being low (1.8–8.5%), although this varied across age and gender strata. It is hoped that these extensive data may be used as a gold standard for broadly defining expected levels of tremor within adult populations.

Conflict of interest statement

The authors declare no conflict of interest.

Author roles

EDL was involved in the conception and design of this work, the acquisition of data, the analysis and interpretation of data, and the drafting of the manuscript, and he gives final approval of the version to be published and agreement to be accountable for all aspects of the work in question. MF was involved in the design of this work, the acquisition of data, the interpretation of data, and the critical revision of the manuscript, and she gives final approval of the version to be published and agreement to be accountable for all aspects of the work in question. EHE was involved in the conception and design of this work, the acquisition of data, the interpretation of data, and the critical revision of the manuscript, and she gives final approval of the version to be published and agreement to be accountable for all aspects of the work in question. SG was involved in the design of this work and the critical revision of the manuscript, and gives final approval of the version to be published and agreement to be accountable for all aspects of the work in question. MSP was involved in the conception and design of this work, the acquisition of data, the analysis and interpretation of data, and the drafting of the manuscript, and she gives final approval of the version to be published and agreement to be accountable for all aspects of the work in question.

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