CLINICAL RESEARCH STUDY

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Internal Tremors and Vibrations in Long COVID: A Cross-Sectional Study

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ABSTRACT

BACKGROUND: Internal tremors and vibrations are symptoms previously described as part of neurologic disorders but not fully described as a part of long COVID. This study compared pre-pandemic comorbidities, new-onset conditions, and long COVID symptoms between people with internal tremors and vibrations as part of their long COVID symptoms and people with long COVID but without these symptoms.

METHODS: The Yale Listen to Immune, Symptom and Treatment Experiences Now (LISTEN) Study surveyed 423 adults who had long COVID between May 12, 2022 and June 1, 2023. The exposure variable was long COVID symptoms of internal tremors and vibrations. The outcome variables were demographic characteristics, pre-pandemic comorbidities, new-onset conditions, other symptoms, and quality of life.

RESULTS: Among study participants with long COVID, median age was 46 years (IQR, 38-56), 74% were female, 87% were Non-Hispanic White, and 158 (37%) reported "internal tremors, or buzzing/vibration" as a long COVID symptom. The two groups reported similar pre-pandemic comorbidities, but participants with internal tremors reported worse health as measured by the Euro-QoL visual analogue scale (median: 40 points [IQR, 30-60] vs. 50 points [IQR, 35-62], $P = .007$) and had higher rates of new-onset mast cell disorders (11% [95% CI, 7.1-18] vs. 2.6% [1.2-5.6], $P = .008$) and neurologic conditions (22% [95% CI, 16-29] vs. 8.3% [5.4-12], $P = .004$).

CONCLUSIONS: Among people with long COVID, those with internal tremors and vibrations had different conditions and symptoms and worse health status compared with others who had long COVID without these symptoms.

KEYWORDS: COVID-19; Long COVID; Tremor; Vibration; Neurologic

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INTRODUCTION

Internal tremors and vibrations are an understudied symptom, even though their first written descriptions appeared in the 1800s.[1] Internal tremors are described as a movement or sensation of movement at any location inside the body. They can occur either with or without visible external movement or muscle spasms,[2,3] and therefore differ from the more widely known definition of tremors as externally visible "involuntary, rhythmic, oscillatory movement of a body part."[4] Until recently, internal tremors were mostly described in Parkinson's disease and essential tremor and not described in long COVID.[1-3,5-7] In a qualitative study, we described long COVID symptoms of internal tremors and their substantial and negative impact on people's quality of life.[2]

CLINICAL SIGNIFICANCE

- Internal tremors and vibrations are distinct from externally visible tremors. Despite their significant impact on patients' lives, they are often overlooked in research on long COVID and other conditions.
- Among participants with long COVID, those who had internal tremors had worse health status and different associated symptoms and comorbidities than others who had long COVID and no internal tremors.

Herein, we compared demographic and socioeconomic characteristics, pre-pandemic comorbidities, and new-onset conditions between people with long COVID symptoms of internal tremors and vibrations and others who had long COVID and no internal tremors. In addition, we built a model to classify the presence and absence of internal tremors based on participants' other long COVID symptoms.

The terminology and definitions used throughout this article were chosen to reflect participants' epistemic authority. For example, long COVID was defined by participants' self-report rather than definitions proposed by public health and medical organizations.[8] Similarly, this article used "internal tremors" as a shortened phrase to reflect "internal tremors and vibrations," which was the language used by participants to describe their lived experience.

METHODS

Study Design

This was a retrospective observational study using data from the long COVID component of the Listen to Immune, Symptom and Treatment Experiences Now (LISTEN) Study, an ongoing, online, decentralized, participant-centric, observational study of adults.[9] The LISTEN study collected surveys, electronic health records, and biospecimens. This study focused on survey data.

Study Sample

LISTEN recruited from people who joined Hugo Health Kindred, an online patient community of individuals 18 years and older who were interested in contributing to COVID-related research. Additionally, a subset of active Kindred members was invited to join a Kindred Advisory Task Force to help recruit others by sharing information about Kindred. Eligibility criteria to join LISTEN were 1) age 18 years or older and 2) English speaking. This study included participants who enrolled in LISTEN from May 12, 2022 to June 1, 2023.

Data Collection

Kindred community members designed surveys in an iterative process that included input from researchers. Surveys were available for online completion on computers or mobile devices. Kindred members were sent electronic reminders to encourage survey completion. Kindred offered its members the opportunity to join LISTEN and share their survey data with researchers. To join LISTEN, e-consent was obtained online. This study was restricted to participants who had completed the demographic survey and the conditions and symptoms survey.

Demographic and socioeconomic survey items included age, gender, race and ethnicity, marital status, pre-pandemic employment and income, housing insecurity, and country of residence. Self-reported time of index SARS-CoV-2 infection was categorized as pre-Delta (before June 26, 2021), Delta (June 26, 2021-December 24, 2021), Omicron (December 25, 2021-June 25, 2022), and post-Omicron (after June 25, 2022), consistent with time period definitions associated with dominant variants of SARS-CoV-2.[10] SARS-CoV-2 infection severity was assessed by self-reported hospitalization history for COVID-related conditions.

The demographic survey included a question about health status, assessed by the Euro-QoL visual analogue scale (EQ-VAS), and a question about symptom severity: "We are trying to get a sense of how bad your long COVID symptoms are when you feel them the most. On the slider below, with 0 being a trivial illness and 100 being unbearable, please let us know what the worst days are like" (S1 Protocol).[11]

The conditions and symptoms survey assessed pre-pandemic comorbidities, current conditions, and long COVID symptoms. Pre-pandemic comorbidities were assessed using the question, "Have you ever been told by a doctor before January 2020 that you have any of the following?" followed by a list of 38 diagnostic categories, "other," and "none of the above" (S2 Protocol). Current conditions were assessed using the question, "Currently, have you ever been told by a doctor that you have any of the following?" followed by a list of 39 diagnostic categories, "other," and "none of the above" (S3 Protocol). For each participant, we

defined new-onset conditions as conditions that were reported as a current condition but not reported as a pre-pandemic comorbidity.

Long COVID symptoms were assessed by the question, "please select all following health conditions that you have had as a result of long COVID," followed by a list of 96 specific symptoms, "other," and "none of the above" (S4 Protocol). Symptom descriptors were created in collaborations between patients and researchers and were reported in this study's tables as the descriptors appeared on the survey. The survey formulated "tremors or shakiness" and "internal tremors or buzzing/vibration" as separate symptom choices. This article considers both "tremors or shakiness" and "internal tremors or buzzing/vibration" as participant-reported symptoms rather than clinician-observed signs.[12]

Statistical Analysis

We described participant characteristics using percentages for categorical variables, and median and interquartile range (IQR) for continuous variables. We compared participants with and without internal tremors on their demographic and socioeconomic characteristics, conditions, and long COVID symptoms. To compare responses for categorical variables, we used chi-squared tests for categorical variables with all expected cell counts ≥ 5 and Fisher's exact tests for categorical variables with any expected cell count <5. For continuous variables, we used Wilcoxon rank-sum tests and Kruskal-Wallis rank-sum tests. When comparing the 3 domains of pre-pandemic comorbidities, new-onset conditions, and long COVID symptoms between the 2 groups, we corrected for multiple testing using the Bonferroni method within each domain and reported adjusted P values. All tests were 2-sided. $P < .05$ was considered statistically significant. By using the Bonferroni method, family-wise error rates were controlled at the level of 0.05. All statistical analyses were done in R version 4.2.3 (2023-03-15).

We used variable importance in gradient boosted tree machine learning models to identify the most important symptoms for differentiating participants experiencing internal tremors from those not experiencing internal tremors.[13,14] We trained models to predict whether a participant experienced internal tremors or not, using information on presence or absence of other symptoms for each participant, with 5-fold 5-repeat cross-validation. We dropped 2 sex-specific symptom variables related to menstruation. We selected the hyperparameters with highest area under the curve (AUC) from the internal cross-validation. Then, we computed the importance of each variable in differentiating participants with and without internal tremors using a permutation-based approach.[15] We sorted the variables based on their importance and, using this fixed sorting, progressively excluded those with least importance from the model by evaluating the change in the AUC. We selected the best model and corresponding number of variables when the AUC first decreased by at least 1.5%. If a drop of this magnitude did not occur, we selected the model with the largest drop in AUC.

To assess the robustness of this process to choice of modeling methods and variable importance metrics, this process was repeated with an XGBoost model[16] with the gain in accuracy metric used to assess variable importance, as well as an XGBoost model with the Shapley value[17] used to assess variable importance. We compared each of the 3 methods' results for variable importance values using Pearson correlation coefficients.

The data that support the findings of this study are available upon reasonable request from the corresponding author, HMK. The data are not publicly available due to participant privacy. Code to reproduce machine learning analyses and generate the associated figures can be found at: https://github.com/aditharun/tremors-ml.

Ethical Considerations

The LISTEN study was approved by the Yale University Institutional Review Board on April 1, 2022 (Protocol Number 2000032207). HMK, a co-founder of Hugo Health, helped develop the Hugo Kindred platform and the Yale Conflict of Interest Committee oversees his involvement in this study. Participants were provided electronic written consent forms. LISTEN conforms to the Declaration of Helsinki and STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) reporting guidelines.

RESULTS

From May 12, 2022 to June 1, 2023, 614 people with long COVID consented to and enrolled in LISTEN and completed the demographic survey (Figure 1). Among them, 191 participants (31%) were excluded due to incomplete conditions and symptoms surveys, leaving 423 participants (69%) in the study population (Figure 1).

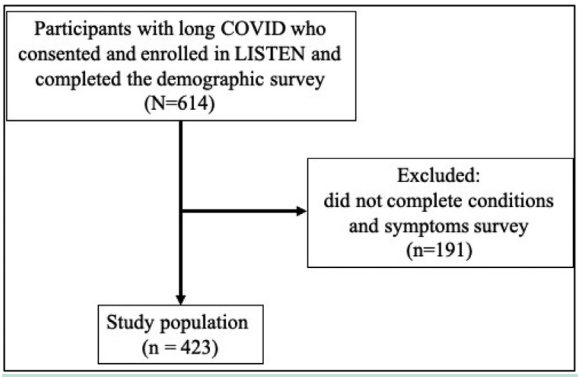

Figure 1 Study population.
LISTEN = Listen to Immune, Symptom and Treatment Experiences Now.

Demographic and Pre-Pandemic Socioeconomic Characteristics

Among participants with long COVID, median age was 46 years (IQR, 38-56), 74% were female, 87% were Non-Hispanic White, and 158 (37%) reported internal tremors (Table 1). Compared with participants without internal tremors, those with internal tremors were more likely to be female (81% vs. 70%, $P = .02$). The 2 groups were similar in age, race and ethnicity, marital status, pre-pandemic employment status, and pre-pandemic household income.

Pre-Pandemic Comorbidities

Overall, among participants, the most common self-reported pre-pandemic comorbidities were anxiety disorders (30%), depressive disorders (29%), and gastrointestinal issues, including irritable bowel syndrome and acid reflux (24%). Participants with and without internal tremors had similar rates of all self-reported pre-pandemic comorbidities (Table S1).

SARS-CoV-2 Infection Characteristics and Post-COVID Socioeconomic Characteristics

Overall, the most common period for index SARS-CoV-2 infection was during the pre-Delta wave (46%); 9.5% of participants were hospitalized due to COVID-related conditions (Table 1, Figure S1[10]). Participants with internal tremors were significantly more likely to report their index infection during the pre-Delta wave (53% [95% CI, 44-61] vs. 42% [35-48], $P = .006$) but were not significantly different in hospitalization rates due to COVID-related conditions. Participants with internal tremors had a significantly longer duration between their initial infections and the date of completing the LISTEN symptom survey (median: 74 weeks [IQR, 38-118] vs. 54 weeks [26-99], $P = .003$).

Participants with and without internal tremors had no significant differences in their health insurance status and level of social support when completing the surveys ($P > .05$; Table 1). Participants with internal tremors were significantly more likely to report having financial difficulties caused by the pandemic (very much financial difficulties, 22% [95% CI, 16-30] vs. 11% [7.3-15], $P < .001$), often feeling socially isolated (43% [95% CI, 35-52] vs. 37% [31-43], $P = .04$), and housing insecurity (worried about losing housing, 18% [95% CI, 12-25] vs. 8.3% [5.3-13], $P < .001$).

Health Status

Participants with internal tremors reported significantly worse health as measured by EQ-VAS (median: 40 points [IQR, 30-60] vs. 50 points [35-62], $P = .007$) compared with those with no internal tremors (Table 2). When asked to rate their symptom severity on their worst days using a visual sliding scale ranging from 0 to 100, with 0 being a trivial illness and 100 being unbearable, participants with internal tremors reported greater symptom severity compared with those with no internal tremors (median: 80 points [IQR 73-90] vs. 73 points [60-82], respectively, $P < .001$; Table 2). In both groups, the time period of the index SARS-CoV-2 infection was not significantly associated with EQ-VAS (Table S2).

New-Onset Conditions

Overall, the most common new-onset conditions among all participants were postural orthostatic tachycardia syndrome or other dysautonomia (25%), gastrointestinal issues (15%), myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS) (15%), and neurologic conditions (13%) (Table S3). Compared with participants without internal tremors, significantly greater proportions of participants with internal tremors reported new-onset mast cell disorders (11% [95% CI, 7.1-18] vs. 2.6% [1.2-5.6]), neurologic conditions (22% [95% CI, 16-29] vs. 8.3% [5.4-12]), anxiety disorders (20% [95% CI, 14-27] vs. 8.7% [5.7-13]), and trauma- and stressor-related disorders (12% [95% CI, 7.6-18] vs. 3.4% [1.7-6.6] (Bonferroni-adjusted $P < .05$ for each; Figure 2, Table S3).

Symptoms Differentiating Participants Experiencing Internal Tremors From Those Not Experiencing Internal Tremors

Rates of long COVID symptoms among participants with internal tremors and those without internal tremors are reported in Table S4. We used variable importance in gradient boosted tree machine learning models to identify which long COVID symptoms are most important for differentiating participants who experience internal tremors from those who do not (Figure 3A; Table S5). We reported the 6 symptoms that were most important in the selected final gradient boosted model (Figure 3B).

The same number of variables ($n = 6$) and overall performance were observed for the selected final models when we repeated our analysis with 2 other methods: XGBoost Gain and XGBoost Shap (Figure S2). The final models in each of the 3 methods were compared and the selected variables and their relative rankings were concordant (Figure S3). The Pearson correlation of the non-zero variable importance values between each of the methods was between 0.97 and 0.99, all with P value < 1.3e-11, further suggesting that the results of the modeling approach were robust (Figure S3).

Participants with internal tremors had significantly higher rates for all 6 of the most important symptoms, compared with participants without internal tremors: tremors or shakiness (65% [95% CI, 57-72] vs. 22% [18-28]), floaters or flashes of light in vision (47% [95% CI, 39-55] vs. 16% [12-21]), hair loss (56% [95% CI, 48-64] vs. 30% [24-36]), tingling, pins and needles, and numbness (72% [95% CI, 64-78]) vs. 41% [35-47]), sharp or sudden chest pain (47%

Table 1 Participant Demographic, Socioeconomic, and SARS-CoV-2 Infection Characteristics

	Overall, *N* = 423 *n/N*, % (95% CI)	No Internal Tremors, *N* = 265 *n/N*, % (95% CI)	Has Internal Tremors, *N* = 158 *n/N*, % (95% CI)	*P* Value*
Age (years), median, IQR	46, 38-56	46, 39-58	46, 38-53	.225
Gender				.02
Female	313/423, 74% (69%-78%)	185/265, 70% (64%-75%)	128/158, 81% (74%-87%)	
Male	108/423, 26% (21%-30%)	78/265, 29% (24%-35%)	30/158, 19% (13%-26%)	
Non-binary	2/423, 0.5% (0.08%-1.9%)	2/265, 0.8% (0.13%-3.0%)	0/158, 0% (0.00%-3.0%)	
Race and ethnicity				.46
Asian	11/423, 2.6% (1.4%-4.7%)	9/265, 3.4% (1.7%-6.6%)	2/158, 1.3% (0.22%-5.0%)	
Black	8/423, 1.9% (0.88%-3.8%)	6/265, 2.3% (0.92%-5.1%)	2/158, 1.3% (0.22%-5.0%)	
Latino/a	15/423, 3.5% (2.1%-5.9%)	7/265, 2.6% (1.2%-5.6%)	8/158, 5.1% (2.4%-10%)	
Multiracial or other	21/423, 5.0% (3.2%-7.6%)	13/265, 4.9% (2.7%-8.4%)	8/158, 5.1% (2.4%-10%)	
Non-Hispanic White	368/423, 87% (83%-90%)	230/265, 87% (82%-91%)	138/158, 87% (81%-92%)	
Country of residence				.81
Canada	11/423, 2.6% (1.4%-4.7%)	7/265, 2.6% (1.2%-5.6%)	4/158, 2.5% (0.81%-6.8%)	
Germany	5/423, 1.2% (0.44%-2.9%)	2/265, 0.8% (0.13%-3.0%)	3/158, 1.9% (0.49%-5.9%)	
United Kingdom	5/423, 1.2% (0.44%-2.9%)	3/265, 1.1% (0.29%-3.5%)	2/158, 1.3% (0.22%-5.0%)	
United States	391/423, 92% (89%-95%)	247/265, 93% (89%-96%)	144/158, 91% (85%-95%)	
Other countries	11/423, 2.6% (1.4%-4.7%)	6/265, 2.3% (0.92%-5.1%)	5/158, 3.2% (1.2%-7.6%)	
Marital status				.96
Divorced	42/398, 11% (7.8%-14%)	27/253, 11% (7.3%-15%)	15/145, 10% (6.1%-17%)	
Married or civil union	237/398, 60% (55%-64%)	151/253, 60% (53%-66%)	86/145, 59% (51%-67%)	
Never married	109/398, 27% (23%-32%)	69/253, 27% (22%-33%)	40/145, 28% (21%-36%)	
Separated	6/398, 1.5% (0.61%-3.4%)	3/253, 1.2% (0.31%-3.7%)	3/145, 2.1% (0.54%-6.4%)	
Widowed	4/398, 1.0% (0.32%-2.7%)	3/253, 1.2% (0.31%-3.7%)	1/145, 0.7% (0.04%-4.4%)	
Missing data	25	12	13	
Employed pre-pandemic	338/396, 85% (81%-89%)	213/252, 85% (79%-89%)	125/144, 87% (80%-92%)	.54
Missing data	27	13	14	
Pre-pandemic annual household income				.68
$10,000 to $35,000	20/396, 5.1% (3.2%-7.8%)	12/252, 4.8% (2.6%-8.4%)	8/144, 5.6% (2.6%-11%)	
$35,000 to less than $50,000	29/396, 7.3% (5.0%-10%)	15/252, 6.0% (3.5%-9.8%)	14/144, 9.7% (5.6%-16%)	
$50,000 to less than $75,000	38/396, 9.6% (7.0%-13%)	25/252, 9.9% (6.6%-14%)	13/144, 9.0% (5.1%-15%)	
$75,000 or more	274/396, 69% (64%-74%)	176/252, 70% (64%-75%)	98/144, 68% (60%-75%)	
Less than $10,000	4/396, 1.0% (0.32%-2.7%)	2/252, 0.8% (0.14%-3.1%)	2/144, 1.4% (0.24%-5.4%)	
Prefer not to answer	31/396, 7.8% (5.5%-11%)	22/252, 8.7% (5.7%-13%)	9/144, 6.2% (3.1%-12%)	
Missing data	27	13	14	
Index SARS-CoV-2 infection time period				.006
Pre-Delta	171/373, 46% (41%-51%)	97/233, 42% (35%-48%)	74/140, 53% (44%-61%)	
Delta	48/373, 13% (9.7%-17%)	27/233, 12% (7.9%-17%)	21/140, 15% (9.7%-22%)	
Omicron	110/373, 29% (25%-34%)	72/233, 31% (25%-37%)	38/140, 27% (20%-35%)	
Post-Omicron	44/373, 12% (8.8%-16%)	37/233, 16% (12%-21%)	7/140, 5.0% (2.2%-10%)	
Missing data	50	32	18	
Hospitalized for COVID-related conditions	40/423, 9.5% (6.9%-13%)	20/265, 7.5% (4.8%-12%)	20/158, 13% (8.1%-19%)	.08
Number of weeks between infection and completing the symptom survey	63, 32-111	54, 26-99	74, 38-118	.003
Missing data	50	32	18	
Financial difficulties caused by the pandemic				< .001
Not at all	125/396, 32% (27%-36%)	94/252, 37% (31%-44%)	31/144, 22% (15%-29%)	
A little	146/396, 37% (32%-42%)	95/252, 38% (32%-44%)	51/144, 35% (28%-44%)	
Quite a bit	66/396, 17% (13%-21%)	36/252, 14% (10%-19%)	30/144, 21% (15%-29%)	
Very much	59/396, 15% (12%-19%)	27/252, 11% (7.3%-15%)	32/144, 22% (16%-30%)	
Missing data	27	13	14	
Do not have health insurance	15/423, 3.5% (2.1%-5.9%)	9/265, 3.4% (1.7%-6.6%)	6/158, 3.8% (1.6%-8.5%)	.83

Table 1 (*Continued*)

	Overall, *N* = 423 *n/N*, % (95% CI)	No Internal Tremors, *N* = 265 *n/N*, % (95% CI)	Has Internal Tremors, *N* = 158 *n/N*, % (95% CI)	*P* Value*
Social support (someone around to help you if you need it)				.77
Never	24/398, 6.0% (4.0%-9.0%)	16/253, 6.3% (3.8%-10%)	8/145, 5.5% (2.6%-11%)	
Rarely	31/398, 7.8% (5.4%-11%)	22/253, 8.7% (5.7%-13%)	9/145, 6.2% (3.1%-12%)	
Sometimes	72/398, 18% (15%-22%)	42/253, 17% (12%-22%)	30/145, 21% (15%-28%)	
Usually	148/398, 37% (32%-42%)	93/253, 37% (31%-43%)	55/145, 38% (30%-46%)	
Always	123/398, 31% (26%-36%)	80/253, 32% (26%-38%)	43/145, 30% (23%-38%)	
Missing data	25	12	13	
Social isolation (how often do you feel isolated from others?)				.04
Hardly ever or never	85/395, 22% (18%-26%)	64/251, 25% (20%-31%)	21/144, 15% (9.5%-22%)	
Some of the time	155/395, 39% (34%-44%)	94/251, 37% (32%-44%)	61/144, 42% (34%-51%)	
Often	155/395, 39% (34%-44%)	93/251, 37% (31%-43%)	62/144, 43% (35%-52%)	
Missing data	28	14	14	
Housing				< .001
I do not have a steady place to live	4/398, 1.0% (0.32%-2.7%)	0/253, 0% (0.00%-1.9%)	4/145, 2.8% (0.89%-7.4%)	
I have a place to live today, but I am worried about losing it in the future	47/398, 12% (8.9%-15%)	21/253, 8.3% (5.3%-13%)	26/145, 18% (12%-25%)	
I have a steady place to live	347/398, 87% (83%-90%)	232/253, 92% (87%-95%)	115/145, 79% (72%-85%)	
Missing data	25	12	13	

CI = confidence interval.
*Wilcoxon rank sum test; Fisher's exact test; Pearson's Chi-squared test.

[95% CI, 39-55] vs. 22% [17-27]), and tinnitus or humming in ears (62% [95% CI, 54-70] vs. 36% [30-42]) (Bonferroni-adjusted $P < .05$ for each; Table S4).

DISCUSSION

In a cross-sectional study of people with long COVID, we found internal tremors were a common symptom, affecting 37% of participants. Participants with internal tremors were more likely to be female but had otherwise similar demographic characteristics compared with those without internal tremors. Importantly, although the 2 groups had similar pre-pandemic comorbidities, participants with internal tremors had, at the time of the survey, worse EQ-VAS health status, and higher rates of new-onset conditions for mast cell disorders and neurologic disorders. Symptoms important for differentiating participants with and without internal tremors included neurologic symptoms such as tremors or shakiness, floaters or flashes of light in vision, tinnitus or humming in ears, and tingling, pins and needles, and numbness. Socioeconomically, participants with internal tremors reported more financial difficulties caused by the pandemic, social isolation, and housing insecurity.

To the best of our knowledge, only 4 prior studies describe people with internal tremors;[3,5,6,18] no quantitative study of people with long COVID has fully described symptoms of internal tremors. Recent studies based on large

Table 2 Health Status and Symptom Severity

	Overall *N* = 423	No Internal Tremors *N* = 265	Has Internal Tremors *N* = 158	*P* Value*
Euro-QoL visual analogue scale (0-100, 100 means best), median (IQR)	49 (32, 61)	50 (35, 62)	40 (30, 60)	.007
Symptom severity on worst days (0-100, 100 means unbearable), median (IQR)	79 (65, 86)	73 (60, 82)	80 (73, 90)	< .001
Missing data	24	11	13	

CI = confidence interval, IQR = interquartile range.
Symptom severity assessed by the question, "How bad your long COVID or other symptoms are (0 to 100) on your worst days?" See full question phrasing in S1 Protocol.
*Wilcoxon rank sum test; Pearson's Chi-squared test.

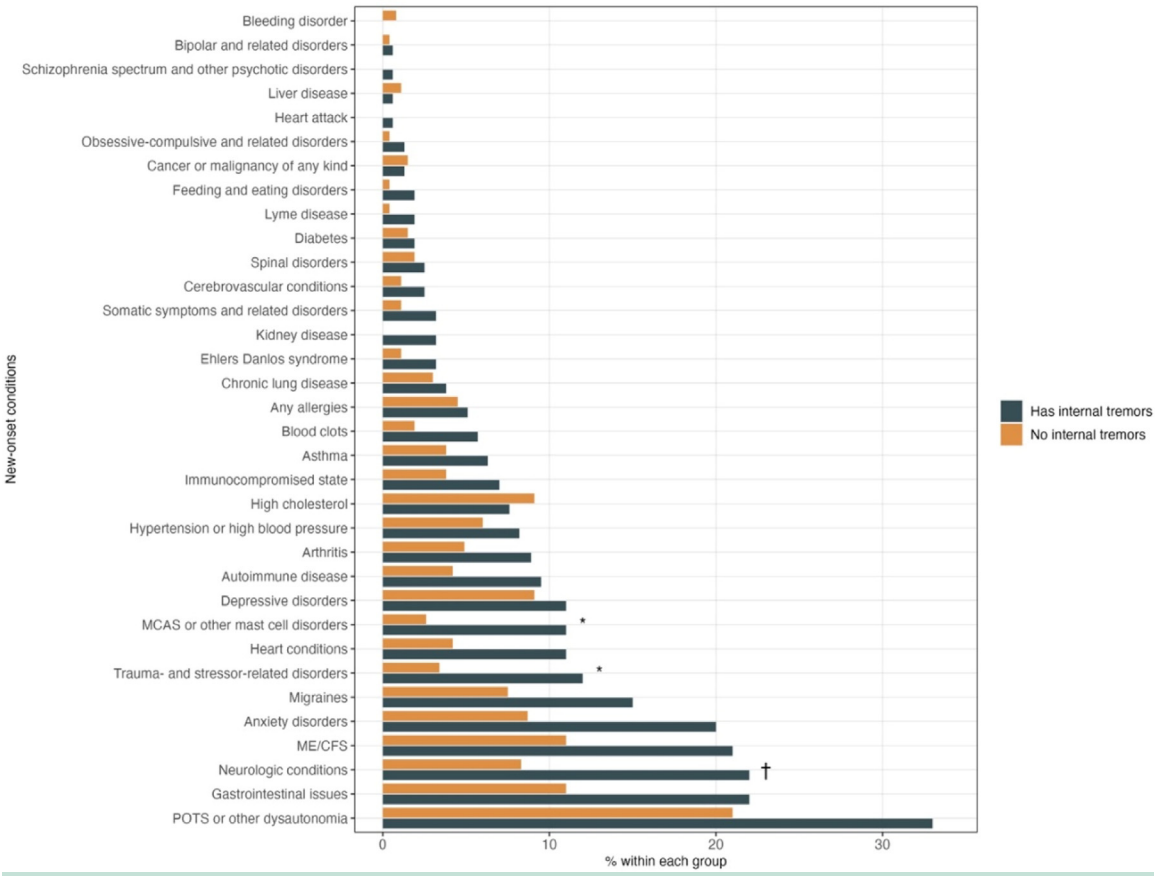

Figure 2 New-onset conditions.
*Bonferroni-adjusted $P < .05$.
†Bonferroni-adjusted $P < .01$.
MCAS = mast cell activation syndrome; ME/CFS = myalgic encephalomyelitis/chronic fatigue syndrome; POTS= postural orthostatic tachycardia syndrome.

prospective cohorts of people with long COVID did not report on symptoms of internal tremors.[10,19] Our findings are consistent with and extend prior findings by showing that compared with others with long COVID, participants with internal tremors had worse quality of life and had significantly higher rates of neurologic symptoms.

Rates of new-onset dysautonomia were higher among participants with internal tremors, with statistical significance before but not after correction. The mechanism of dysautonomia may be related to organ-selective sympathetic denervation,[20] but the pathophysiologic links among dysautonomia, long COVID, and internal tremors have not been established and should be explored in further studies.

Our findings add nuance to the hypothesized associations between ME/CFS and long COVID, which are often discussed together due to overlapping symptomatology and infectious etiopathogenesis.[21-23] Although greater than 70% of participants in this study reported excessive fatigue or exercise intolerance, these hallmark symptoms of ME/CFS were not significantly associated with internal tremors. Our findings are consistent with prior observations of long COVID as a heterogeneous condition with many phenotypes,[24] which may be driven by several mechanisms.[25]

Study Limitations

Study participants were recruited from an online long COVID community and should not be considered representative. Rather, the study provides an opportunity to describe the characteristics of people within the online community who do and do not have internal tremors and vibrations. In addition, conditions and symptoms are based on self-report using a pre-specified checklist, which may be susceptible to recall bias with unclear directionality for under versus overreporting, as well as inaccuracies such as misdiagnoses due to uncertainties surrounding long COVID evaluation and management during early stages of the pandemic.

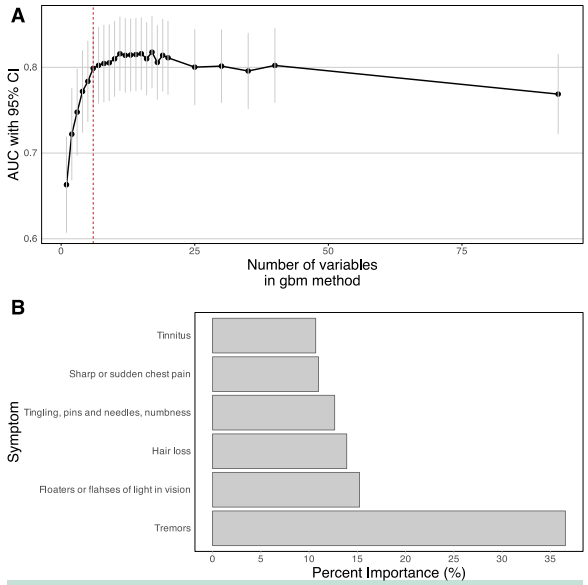

Figure 3 Most important symptoms for differentiating participants with and without internal tremors.
AUC = area under the curve; CI = confidence interval; gbm = gradient-boosting machine.
(**A**) Area under the curve and 95% confidence interval as a function of the number of top variables selected and used in a gradient-boosted tree model. The red line denotes that a model consisting of the top 6 most important variables (AUC = 0.80; 95% confidence interval [0.75-0.84]) was strongly informative in differentiating factors that led to participants experiencing internal tremors relative to other models as marked by the marked drop in AUC between models with 6 and 5 variables.
(**B**) Variable importance values for the 6-variable model and the percent importance of each variable in differentiating participants with and without internal tremors.

CONCLUSIONS

Internal tremors and vibrations are common symptoms among people with long COVID. People with these symptoms had pre-infection characteristics similar to those of others with long COVID, but worse EQ-VAS health status, higher rates of financial difficulties and housing insecurity, and higher rates of new-onset conditions of mast cell disorders and neurologic conditions. Individuals with long COVID symptoms of internal tremors may experience a particularly severe phenotype of long COVID. Clinicians should be aware of internal tremors and vibrations as a long COVID symptom. Further research is needed to clarify the pathophysiology of internal tremors and vibrations and identify potential treatment targets.

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SUPPLEMENTARY DATA

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.amjmed.2024.07.008

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S1 PROTOCOL. HEALTH STATUS AND SYMPTOM SEVERITY QUESTIONS

1. Please choose one point in this 0-100 scale, which can best represent your health today (0 means the worst and 100 means the best) (“slider”).
2. We are trying to get a sense of how bad your long COVID symptoms are when you feel them the most. On the slider below, with 0 being a trivial illness and 100 being unbearable, please let us know what the worst days are like ("slider").

S2 PROTOCOL. PRE-PANDEMIC COMORBIDITIES QUESTIONS

Have you ever been told by a doctor before January 2020 that you have any of the following?

Check all that apply
("multiple choice")

1. Any allergies
2. Arthritis (including rheumatoid arthritis, gout, lupus, or fibromyalgia)
3. Asthma
4. Autoimmune disease (including lupus, scleroderma, etc.)
5. Bleeding disorder (including sickle cell disease or thalassemia)
6. Blood clots
7. Cancer or malignancy of any kind
8. Cerebrovascular conditions affecting blood vessels to or in the brain (including stroke)
9. Chronic lung disease (including emphysema, chronic bronchitis, chronic obstructive pulmonary disease (COPD), or pulmonary fibrosis)
10. Cystic fibrosis
11. Diabetes
12. Ehlers Danlos Syndrome (hypermobile joints)
13. Gastrointestinal issues (including IBS or acid reflux)
14. Heart attack, also called myocardial infarction
15. Heart conditions (including coronary artery disease or cardiomyopathies)
16. Heart failure
17. High cholesterol
18. History of organ transplant (including kidney, liver, heart, or lung)
19. Hypertension or high blood pressure
20. Immunocompromised state (including weakened immune system from blood or bone marrow transplant, immune deficiencies, HIV, use of corticosteroids, or use of other immune-weakening medicines)
21. Kidney disease
22. Liver disease
23. Lyme disease
24. MCAS (mast cell activation syndrome) or other mast cell disorders
25. ME/CFS (myalgic encephalomyelitis/chronic fatigue syndrome)
26. Migraines
27. Neurologic conditions (including seizures, dementia, multiple sclerosis, Parkinson’s, neuropathy, small fiber neuropathy, etc.)
28. Postural orthostatic tachycardia syndrome (POTS) or dysautonomia
29. Spinal disorder(s)
30. Tremors/Internal vibrations
31. Other
32. None of the above

Have you ever been told by a doctor before January 2020 that you have any of the following?

Check all that apply
("multiple choice")

1. Depressive disorders
2. Anxiety disorders
3. Schizophrenia spectrum and other psychotic disorders
4. Bipolar and related disorders
5. Obsessive-compulsive and related disorders
6. Trauma- and stressor-related disorders
7. Feeding and eating disorders
8. Somatic symptoms (excessive thoughts, feelings and behaviors relating to the physical symptoms) and related disorders
9. Other
10. None of the above

S3 PROTOCOL. CURRENT CONDITIONS QUESTIONS

Currently, have you ever been told by a doctor that you have any of the following?

Check all that apply ("multiple choice")

1. Any allergies
2. Arthritis (including rheumatoid arthritis, gout, lupus, or fibromyalgia)
3. Asthma
4. Autoimmune disease (including lupus, scleroderma, etc.)
5. Bleeding disorder (including sickle cell disease or thalassemia)
6. Blood clots
7. Cancer or malignancy of any kind
8. Cerebrovascular conditions affecting blood vessels to or in the brain (including stroke)
9. Chronic lung disease (including emphysema, chronic bronchitis, chronic obstructive pulmonary disease (COPD), or pulmonary fibrosis)
10. Cystic fibrosis
11. Diabetes
12. Ehlers Danlos Syndrome (hypermobile joints)
13. Gastrointestinal issues (including IBS or acid reflux)

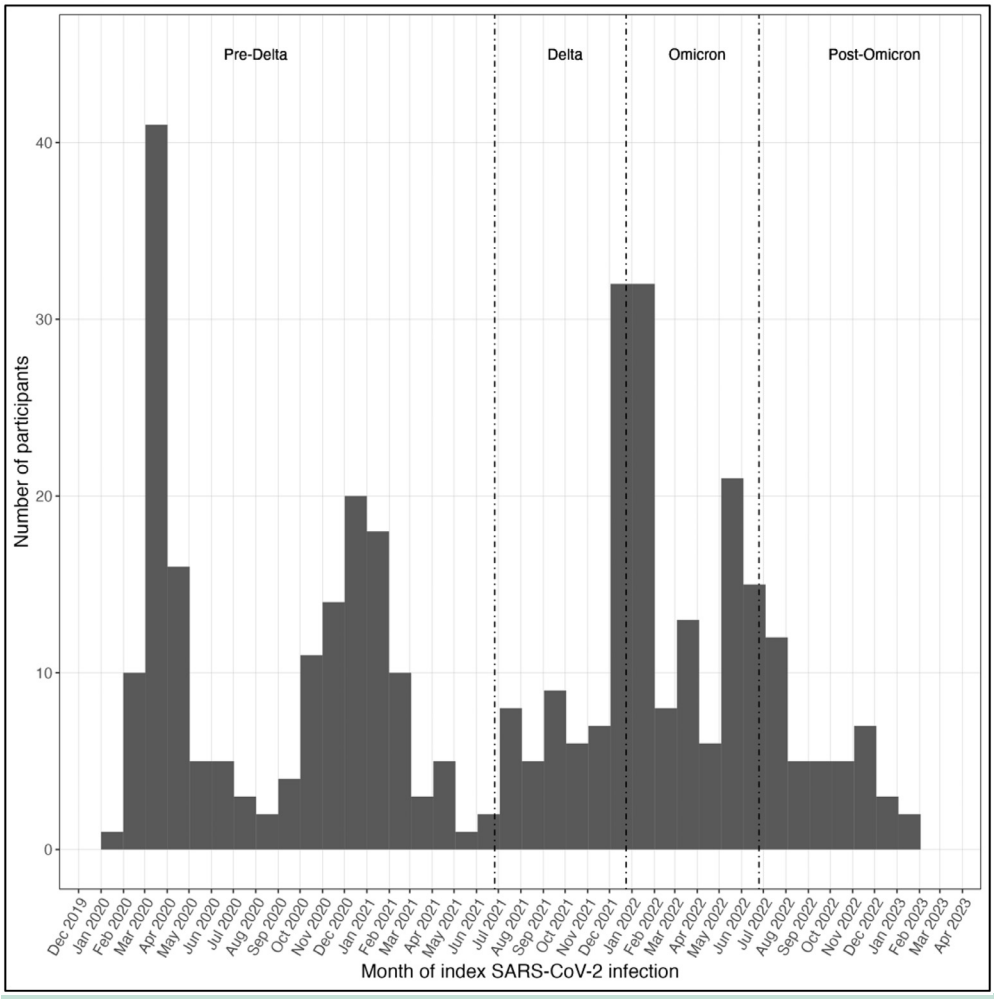

Figure S1 Distribution of SARS-CoV-2 index infection dates.
Self-reported time of index SARS-CoV-2 infection was categorized as pre-Delta (before June 26, 2021), Delta (June 26, 2021-December 24, 2021), Omicron (December 25, 2021-June 25, 2022), and post-Omicron (after June 25, 2022), consistent with time period definitions associated with dominant variants of SARS-CoV-2.

Table S1 Pre-Pandemic Comorbidities

	Overall, *N* = 423	No Internal Tremors, *N* = 265	Has Internal Tremors, *N* = 158	*P* Value*	Adjusted *P* Value†
	n/N, % (95% CI)	*n/N*, % (95% CI)	*n/N*, % (95% CI)		
Any allergies	208/423, 49% (44%-54%)	141/265, 53% (47%-59%)	67/158, 42% (35%-51%)	.032	> .999
Arthritis (including rheumatoid arthritis, gout, lupus, or fibromyalgia)	67/423, 16% (13%-20%)	46/265, 17% (13%-23%)	21/158, 13% (8.6%-20%)	.268	> .999
Asthma	78/423, 18% (15%-23%)	58/265, 22% (17%-27%)	20/158, 13% (8.1%-19%)	.018	.627
Autoimmune disease (including lupus, scleroderma, etc.)	50/423, 12% (9.0%-15%)	35/265, 13% (9.5%-18%)	15/158, 9.5% (5.6%-15%)	.252	> .999
Bleeding disorder (including sickle cell disease or thalassemia)	4/423, 0.9% (0.30%-2.6%)	3/265, 1.1% (0.29%-3.5%)	1/158, 0.6% (0.03%-4.0%)	> .999	> .999
Blood clots	6/423, 1.4% (0.58%-3.2%)	2/265, 0.8% (0.13%-3.0%)	4/158, 2.5% (0.81%-6.8%)	.202	> .999
Cancer or malignancy of any kind	21/423, 5.0% (3.2%-7.6%)	12/265, 4.5% (2.5%-8.0%)	9/158, 5.7% (2.8%-11%)	.593	> .999
Cerebrovascular conditions affecting blood vessels to or in the brain (including stroke)	3/423, 0.7% (0.18%-2.2%)	3/265, 1.1% (0.29%-3.5%)	0/158, 0% (0.00%-3.0%)	.296	> .999
Chronic lung disease (emphysema, chronic bronchitis, chronic obstructive pulmonary disease)	10/423, 2.4% (1.2%-4.4%)	6/265, 2.3% (0.92%-5.1%)	4/158, 2.5% (0.81%-6.8%)	> .999	> .999
Diabetes	11/423, 2.6% (1.4%-4.7%)	7/265, 2.6% (1.2%-5.6%)	4/158, 2.5% (0.81%-6.8%)	> .999	> .999
Ehlers Danlos Syndrome (hypermobile joints)	8/423, 1.9% (0.88%-3.8%)	4/265, 1.5% (0.48%-4.1%)	4/158, 2.5% (0.81%-6.8%)	.479	> .999
Gastrointestinal issues (including IBS or acid reflux)	103/423, 24% (20%-29%)	67/265, 25% (20%-31%)	36/158, 23% (17%-30%)	.563	> .999
Heart attack, also called myocardial infarction	3/423, 0.7% (0.18%-2.2%)	2/265, 0.8% (0.13%-3.0%)	1/158, 0.6% (0.03%-4.0%)	> .999	> .999
Heart conditions (including coronary artery disease or cardiomyopathies)	12/423, 2.8% (1.5%-5.0%)	7/265, 2.6% (1.2%-5.6%)	5/158, 3.2% (1.2%-7.6%)	.768	> .999
High cholesterol	59/423, 14% (11%-18%)	42/265, 16% (12%-21%)	17/158, 11% (6.6%-17%)	.144	> .999
Hypertension or high blood pressure	50/423, 12% (9.0%-15%)	34/265, 13% (9.2%-18%)	16/158, 10% (6.1%-16%)	.405	> .999
Immunocompromised state	13/423, 3.1% (1.7%-5.3%)	12/265, 4.5% (2.5%-8.0%)	1/158, 0.6% (0.03%-4.0%)	.037	> .999
Kidney disease	5/423, 1.2% (0.44%-2.9%)	4/265, 1.5% (0.48%-4.1%)	1/158, 0.6% (0.03%-4.0%)	.655	> .999
Liver disease	3/423, 0.7% (0.18%-2.2%)	2/265, 0.8% (0.13%-3.0%)	1/158, 0.6% (0.03%-4.0%)	> .999	> .999
Lyme disease	25/423, 5.9% (3.9%-8.7%)	14/265, 5.3% (3.0%-8.9%)	11/158, 7.0% (3.7%-12%)	.479	> .999
MCAS (mast cell activation syndrome) or other mast cell disorders	4/423, 0.9% (0.30%-2.6%)	1/265, 0.4% (0.02%-2.4%)	3/158, 1.9% (0.49%-5.9%)	.149	> .999
ME/CFS (myalgic encephalomyelitis/chronic fatigue syndrome)	16/423, 3.8% (2.3%-6.2%)	10/265, 3.8% (1.9%-7.0%)	6/158, 3.8% (1.6%-8.5%)	.990	> .999
Migraines	84/423, 20% (16%-24%)	50/265, 19% (14%-24%)	34/158, 22% (16%-29%)	.509	> .999
Neurologic conditions (including seizures, dementia, multiple sclerosis, Parkinson's, neuropathy, small fiber neuropathy, etc.)	20/423, 4.7% (3.0%-7.3%)	14/265, 5.3% (3.0%-8.9%)	6/158, 3.8% (1.6%-8.5%)	.486	> .999
Postural orthostatic tachycardia syndrome (POTS) or other dysautonomia	13/423, 3.1% (1.7%-5.3%)	5/265, 1.9% (0.70%-4.6%)	8/158, 5.1% (2.4%-10%)	.083	> .999
Spinal disorder(s)	16/423, 3.8% (2.3%-6.2%)	10/265, 3.8% (1.9%-7.0%)	6/158, 3.8% (1.6%-8.5%)	.990	> .999
Tremors/internal vibrations	6/423, 1.4% (0.58%-3.2%)	2/265, 0.8% (0.13%-3.0%)	4/158, 2.5% (0.81%-6.8%)	.202	> .999
Depressive disorders	122/423, 29% (25%-33%)	84/265, 32% (26%-38%)	38/158, 24% (18%-32%)	.093	> .999

Table S1 (*Continued*)

	Overall, *N* = 423	No Internal Tremors, *N* = 265	Has Internal Tremors, *N* = 158	*P* Value*	Adjusted *P* Value†
Anxiety disorders	127/423, 30% (26%-35%)	83/265, 31% (26%-37%)	44/158, 28% (21%-36%)	.451	> .999
Schizophrenia spectrum and other psychotic disorders	1/423, 0.2% (0.01%-1.5%)	1/265, 0.4% (0.02%-2.4%)	0/158, 0% (0.00%-3.0%)	> .999	> .999
Bipolar and related disorders	13/423, 3.1% (1.7%-5.3%)	6/265, 2.3% (0.92%-5.1%)	7/158, 4.4% (2.0%-9.3%)	.249	> .999
Obsessive-compulsive and related disorders	15/423, 3.5% (2.1%-5.9%)	7/265, 2.6% (1.2%-5.6%)	8/158, 5.1% (2.4%-10%)	.193	> .999
Trauma- and stressor-related disorders	46/423, 11% (8.1%-14%)	27/265, 10% (6.9%-15%)	19/158, 12% (7.6%-18%)	.557	> .999
Feeding and eating disorders	20/423, 4.7% (3.0%-7.3%)	13/265, 4.9% (2.7%-8.4%)	7/158, 4.4% (2.0%-9.3%)	.824	> .999
Somatic symptoms (excessive thoughts, feelings and behaviors relating to physical symptoms) and related disorders	7/423, 1.7% (0.73%-3.5%)	5/265, 1.9% (0.70%-4.6%)	2/158, 1.3% (0.22%-5.0%)	> .999	> .999

*Pearson's Chi-squared test; Fisher's exact test.
†Bonferroni correction for multiple testing.CI = confidence interval; IBS = irritable bowel syndrome.

Table S2 Health Status by Internal Tremors Status and Time of Index SARS-CoV-2 Infection

Overall, *N* = 373					
	Pre-Delta, *N* = 171*	Delta, *N* = 48*	Omicron, *N* = 110*	Post-Omicron, *N* = 44*	*P* Value†
EQ-VAS (0-100)	41 (32, 60)	46 (31, 69)	49 (31, 61)	50 (34, 60)	.914
No Internal Tremors, *N* = 233					
	Pre-Delta, *N* = 97*	Delta, *N* = 27*	Omicron, *N* = 72*	Post-Omicron, *N* = 37*	*P* Value†
EQ-VAS (0-100)	45 (35, 61)	59 (38, 69)	50 (32, 62)	49 (34, 60)	.750
Has Internal Tremors, *N* = 140					
	Pre-Delta, *N* = 74*	Delta, *N* = 21*	Omicron, *N* = 38*	Post-Omicron, *N* = 7*	*P* Value†
EQ-VAS (0-100)	40 (30, 60)	35 (31, 55)	41 (30, 58)	55 (35, 60)	.922

Excluding *n* = 50 participants with missing dates of index SARS-CoV-2 infection.
Self-reported time of index SARS-CoV-2 infection was categorized as pre-Delta (before June 26, 2021), Delta (June 26, 2021-December 24, 2021), Omicron (December 25, 2021-June 25, 2022), and post-Omicron (after June 25, 2022), consistent with time period definitions associated with dominant variants of SARS-CoV-2.[10]
EQ-VAS = Euro-QoL visual analogue scale, IQR = interquartile range.
*Median (IQR).
†Kruskal—Wallis rank sum test.

Table S3 New-Onset Conditions

	Overall, *N* = 423 *n/N*, % (95% CI)	No Internal Tremors, *N* = 265 *n/N*, % (95% CI)	Has Internal Tremors, *N* = 158 *n/N*, % (95% CI)	*P* Value*	Adjusted *P* Value†
Any allergies	20/423, 4.7% (3.0%-7.3%)	12/265, 4.5% (2.5%-8.0%)	8/158, 5.1% (2.4%-10%)	.802	> .999
Arthritis (including rheumatoid arthritis, gout, lupus, or fibromyalgia)	27/423, 6.4% (4.3%-9.3%)	13/265, 4.9% (2.7%-8.4%)	14/158, 8.9% (5.1%-15%)	.107	> .999
Asthma	20/423, 4.7% (3.0%-7.3%)	10/265, 3.8% (1.9%-7.0%)	10/158, 6.3% (3.2%-12%)	.231	> .999
Autoimmune disease (including lupus, scleroderma, etc.)	26/423, 6.1% (4.1%-9.0%)	11/265, 4.2% (2.2%-7.5%)	15/158, 9.5% (5.6%-15%)	.027	.914
Bleeding disorder (including sickle cell disease or thalassemia)	2/423, 0.5% (0.08%-1.9%)	2/265, 0.8% (0.13%-3.0%)	0/158, 0% (0.00%-3.0%)	.531	> .999
Blood clots	14/423, 3.3% (1.9%-5.6%)	5/265, 1.9% (0.70%-4.6%)	9/158, 5.7% (2.8%-11%)	.034	> .999
Cancer or malignancy of any kind	6/423, 1.4% (0.58%-3.2%)	4/265, 1.5% (0.48%-4.1%)	2/158, 1.3% (0.22%-5.0%)	> .999	> .999
Cerebrovascular conditions affecting blood vessels to or in the brain (including stroke)	7/423, 1.7% (0.73%-3.5%)	3/265, 1.1% (0.29%-3.5%)	4/158, 2.5% (0.81%-6.8%)	.432	> .999
Chronic lung disease (emphysema, chronic bronchitis, chronic obstructive pulmonary disease)	14/423, 3.3% (1.9%-5.6%)	8/265, 3.0% (1.4%-6.1%)	6/158, 3.8% (1.6%-8.5%)	.665	> .999
Diabetes	7/423, 1.7% (0.73%-3.5%)	4/265, 1.5% (0.48%-4.1%)	3/158, 1.9% (0.49%-5.9%)	.716	> .999
Ehlers Danlos Syndrome (hypermobile joints)	8/423, 1.9% (0.88%-3.8%)	3/265, 1.1% (0.29%-3.5%)	5/158, 3.2% (1.2%-7.6%)	.156	> .999
Gastrointestinal issues (including IBS or acid reflux)	65/423, 15% (12%-19%)	30/265, 11% (7.9%-16%)	35/158, 22% (16%-30%)	.003	.095
Heart attack, also called myocardial infarction	1/423, 0.2% (0.01%-1.5%)	0/265, 0% (0.00%-1.8%)	1/158, 0.6% (0.03%-4.0%)	.374	> .999
Heart conditions (including coronary artery disease or cardiomyopathies)	29/423, 6.9% (4.7%-9.8%)	11/265, 4.2% (2.2%-7.5%)	18/158, 11% (7.1%-18%)	.004	.148
High cholesterol	36/423, 8.5% (6.1%-12%)	24/265, 9.1% (6.0%-13%)	12/158, 7.6% (4.2%-13%)	.602	> .999
Hypertension or high blood pressure	29/423, 6.9% (4.7%-9.8%)	16/265, 6.0% (3.6%-9.8%)	13/158, 8.2% (4.6%-14%)	.389	> .999
Immunocompromised state	21/423, 5.0% (3.2%-7.6%)	10/265, 3.8% (1.9%-7.0%)	11/158, 7.0% (3.7%-12%)	.144	> .999
Kidney disease	5/423, 1.2% (0.44%-2.9%)	0/265, 0% (0.00%-1.8%)	5/158, 3.2% (1.2%-7.6%)	.007	.237
Liver disease	4/423, 0.9% (0.30%-2.6%)	3/265, 1.1% (0.29%-3.5%)	1/158, 0.6% (0.03%-4.0%)	> .999	> .999
Lyme disease	4/423, 0.9% (0.30%-2.6%)	1/265, 0.4% (0.02%-2.4%)	3/158, 1.9% (0.49%-5.9%)	.149	> .999
MCAS (mast cell activation syndrome) or other mast cell disorders	25/423, 5.9% (3.9%-8.7%)	7/265, 2.6% (1.2%-5.6%)	18/158, 11% (7.1%-18%)	< .001	.008
ME/CFS (myalgic encephalomyelitis/chronic fatigue syndrome)	62/423, 15% (11%-18%)	29/265, 11% (7.6%-15%)	33/158, 21% (15%-28%)	.005	.175
Migraines	43/423, 10% (7.5%-14%)	20/265, 7.5% (4.8%-12%)	23/158, 15% (9.6%-21%)	.021	.714
Neurologic conditions (including seizures, dementia, multiple sclerosis, Parkinson's, neuropathy, small fiber neuropathy, etc.)	56/423, 13% (10%-17%)	22/265, 8.3% (5.4%-12%)	34/158, 22% (16%-29%)	< .001	.004
Postural orthostatic tachycardia syndrome (POTS) or other dysautonomia	107/423, 25% (21%-30%)	55/265, 21% (16%-26%)	52/158, 33% (26%-41%)	.005	.184
Spinal disorder(s)	9/423, 2.1% (1.0%-4.1%)	5/265, 1.9% (0.70%-4.6%)	4/158, 2.5% (0.81%-6.8%)	.733	> .999
Depressive disorders	42/423, 9.9% (7.3%-13%)	24/265, 9.1% (6.0%-13%)	18/158, 11% (7.1%-18%)	0.437	> .999
Anxiety disorders	54/423, 13% (9.8%-16%)	23/265, 8.7% (5.7%-13%)	31/158, 20% (14%-27%)	.001	.038
Schizophrenia spectrum and other psychotic disorders	1/423, 0.2% (0.01%-1.5%)	0/265, 0% (0.00%-1.8%)	1/158, 0.6% (0.03%-4.0%)	.374	> .999
Bipolar and related disorders	2/423, 0.5% (0.08%-1.9%)	1/265, 0.4% (0.02%-2.4%)	1/158, 0.6% (0.03%-4.0%)	> .999	> .999
Obsessive-compulsive and related disorders	3/423, 0.7% (0.18%-2.2%)	1/265, 0.4% (0.02%-2.4%)	2/158, 1.3% (0.22%-5.0%)	.559	> .999
Trauma- and stressor-related disorders	28/423, 6.6% (4.5%-9.5%)	9/265, 3.4% (1.7%-6.6%)	19/158, 12% (7.6%-18%)	< .001	.019
Feeding and eating disorders	4/423, 0.9% (0.30%-2.6%)	1/265, 0.4% (0.02%-2.4%)	3/158, 1.9% (0.49%-5.9%)	.149	> .999
Somatic symptoms (excessive thoughts, feelings and behaviors relating to physical symptoms) and related disorders	8/423, 1.9% (0.88%-3.8%)	3/265, 1.1% (0.29%-3.5%)	5/158, 3.2% (1.2%-7.6%)	.156	> .999

*Pearson's Chi-squared test; Fisher's exact test.

†Bonferroni correction for multiple testing.CI = confidence interval; IBS = irritable bowel syndrome.

Table S4 Long COVID Symptoms

	Overall, *N* = 423 *n/N*, % (95% CI)	No Internal Tremors, *N* = 265 *n/N*, % (95% CI)	Has Internal Tremors, *N* = 158 *n/N*, % (95% CI)	*P* Value*	Adjusted *P* Value†
Anxiety	185/423, 44% (39%-49%)	97/265, 37% (31%-43%)	88/158, 56% (48%-64%)	< .001	.012
Confusion	166/423, 39% (35%-44%)	91/265, 34% (29%-40%)	75/158, 47% (40%-56%)	.007	.710
Brain fog; difficulty concentrating or focusing	362/423, 86% (82%-89%)	223/265, 84% (79%-88%)	139/158, 88% (82%-92%)	.279	> .999
Feelings of impending doom	105/423, 25% (21%-29%)	50/265, 19% (14%-24%)	55/158, 35% (28%-43%)	< .001	.023
Memory problems	297/423, 70% (66%-74%)	175/265, 66% (60%-72%)	122/158, 77% (70%-83%)	.015	> .999
Difficulty speaking properly	195/423, 46% (41%-51%)	106/265, 40% (34%-46%)	89/158, 56% (48%-64%)	.001	.106
Suicidal thoughts	60/423, 14% (11%-18%)	27/265, 10% (6.9%-15%)	33/158, 21% (15%-28%)	.002	.217
Abnormally low temperature	54/423, 13% (9.8%-16%)	20/265, 7.5% (4.8%-12%)	34/158, 22% (16%-29%)	< .001	.003
Fevers, including low-grade fevers	80/423, 19% (15%-23%)	40/265, 15% (11%-20%)	40/158, 25% (19%-33%)	.009	.893
Chills but no fever	146/423, 35% (30%-39%)	69/265, 26% (21%-32%)	77/158, 49% (41%-57%)	< .001	< .001
Heat intolerance	197/423, 47% (42%-51%)	101/265, 38% (32%-44%)	96/158, 61% (53%-68%)	< .001	< .001
Cold intolerance	131/423, 31% (27%-36%)	68/265, 26% (21%-31%)	63/158, 40% (32%-48%)	.002	.211
Night sweats	175/423, 41% (37%-46%)	89/265, 34% (28%-40%)	86/158, 54% (46%-62%)	< .001	.002
Trouble falling or staying asleep	303/423, 72% (67%-76%)	171/265, 65% (58%-70%)	132/158, 84% (77%-89%)	< .001	.003
Sleeping more than usual	168/423, 40% (35%-45%)	96/265, 36% (30%-42%)	72/158, 46% (38%-54%)	.057	> .999
Nightmares	73/423, 17% (14%-21%)	32/265, 12% (8.5%-17%)	41/158, 26% (19%-34%)	< .001	.025
Exercise intolerance	333/423, 79% (74%-82%)	199/265, 75% (69%-80%)	134/158, 85% (78%-90%)	.018	> .999
Excessive fatigue	369/423, 87% (84%-90%)	227/265, 86% (81%-90%)	142/158, 90% (84%-94%)	.209	> .999
Burning sensations	116/423, 27% (23%-32%)	50/265, 19% (14%-24%)	66/158, 42% (34%-50%)	< .001	< .001
Tremors or shakiness	161/423, 38% (33%-43%)	59/265, 22% (18%-28%)	102/158, 65% (57%-72%)	< .001	< .001
Tingling, pins and needles, numbness	222/423, 52% (48%-57%)	109/265, 41% (35%-47%)	113/158, 72% (64%-78%)	< .001	< .001
Neuropathy (nerve sensations including pain) anywhere in the body	192/423, 45% (41%-50%)	91/265, 34% (29%-40%)	101/158, 64% (56%-71%)	< .001	< .001
Seizures	5/423, 1.2% (0.44%-2.9%)	3/265, 1.1% (0.29%-3.5%)	2/158, 1.3% (0.22%-5.0%)	> .999	> .999
Abdominal pain	136/423, 32% (28%-37%)	61/265, 23% (18%-29%)	75/158, 47% (40%-56%)	< .001	< .001
Acid reflux or heartburn	123/423, 29% (25%-34%)	62/265, 23% (19%-29%)	61/158, 39% (31%-47%)	< .001	.082
Diarrhea	132/423, 31% (27%-36%)	64/265, 24% (19%-30%)	68/158, 43% (35%-51%)	< .001	.005
Constipation	108/423, 26% (21%-30%)	56/265, 21% (16%-27%)	52/158, 33% (26%-41%)	.007	.684
Nausea/vomiting	138/423, 33% (28%-37%)	72/265, 27% (22%-33%)	66/158, 42% (34%-50%)	.002	.185
Loss of appetite	129/423, 30% (26%-35%)	64/265, 24% (19%-30%)	65/158, 41% (33%-49%)	< .001	.023
Sore throat	129/423, 30% (26%-35%)	76/265, 29% (23%-35%)	53/158, 34% (26%-42%)	.293	> .999
Congested or runny nose	134/423, 32% (27%-36%)	76/265, 29% (23%-35%)	58/158, 37% (29%-45%)	.086	> .999
Palpitations (improper beating of the heart due to electrical impulse problems)	222/423, 52% (48%-57%)	117/265, 44% (38%-50%)	105/158, 66% (58%-74%)	< .001	< .001
Bilateral neck throbbing around lymph nodes	57/423, 13% (10%-17%)	20/265, 7.5% (4.8%-12%)	37/158, 23% (17%-31%)	< .001	< .001
Costochondritis (pain in the cartilage that connects a rib to the breastbone)	105/423, 25% (21%-29%)	47/265, 18% (13%-23%)	58/158, 37% (29%-45%)	< .001	.001
Cough	116/423, 27% (23%-32%)	73/265, 28% (22%-33%)	43/158, 27% (21%-35%)	.941	> .999

Table S4 (*Continued*)

	Overall, *N* = 423 *n/N*, % (95% CI)	No Internal Tremors, *N* = 265 *n/N*, % (95% CI)	Has Internal Tremors, *N* = 158 *n/N*, % (95% CI)	*P* Value*	Adjusted *P* Value†
Coughing up blood	7/423, 1.7% (0.73%-3.5%)	2/265, 0.8% (0.13%-3.0%)	5/158, 3.2% (1.2%-7.6%)	.108	> .999
Cold or burning feeling in lungs	53/423, 13% (9.6%-16%)	26/265, 9.8% (6.6%-14%)	27/158, 17% (12%-24%)	.029	> .999
Difficulty swallowing	74/423, 17% (14%-22%)	32/265, 12% (8.5%-17%)	42/158, 27% (20%-34%)	< .001	.014
Throat pain or discomfort	95/423, 22% (19%-27%)	42/265, 16% (12%-21%)	53/158, 34% (26%-42%)	< .001	.002
Lump in throat	58/423, 14% (11%-17%)	24/265, 9.1% (6.0%-13%)	34/158, 22% (16%-29%)	< .001	.030
Phlegm in back of throat	102/423, 24% (20%-29%)	54/265, 20% (16%-26%)	48/158, 30% (23%-38%)	.020	> .999
Postnasal drip	97/423, 23% (19%-27%)	56/265, 21% (16%-27%)	41/158, 26% (19%-34%)	.254	> .999
Runny nose	74/423, 17% (14%-22%)	40/265, 15% (11%-20%)	34/158, 22% (16%-29%)	.092	> .999
Swollen lymph nodes	82/423, 19% (16%-24%)	41/265, 15% (11%-21%)	41/158, 26% (19%-34%)	.008	.795
Tachycardia (rapid heartbeat) at rest	179/423, 42% (38%-47%)	89/265, 34% (28%-40%)	90/158, 57% (49%-65%)	< .001	< .001
Tachycardia (rapid heartbeat) after standing up	194/423, 46% (41%-51%)	103/265, 39% (33%-45%)	91/158, 58% (49%-65%)	< .001	.018
Wheezing	46/423, 11% (8.1%-14%)	21/265, 7.9% (5.1%-12%)	25/158, 16% (11%-23%)	.012	> .999
Shortness of breath or difficulty breathing	246/423, 58% (53%-63%)	143/265, 54% (48%-60%)	103/158, 65% (57%-72%)	.024	> .999
Bone aches	138/423, 33% (28%-37%)	65/265, 25% (20%-30%)	73/158, 46% (38%-54%)	< .001	< .001
Migraine	129/423, 30% (26%-35%)	62/265, 23% (19%-29%)	67/158, 42% (35%-51%)	< .001	.004
Headache	271/423, 64% (59%-69%)	149/265, 56% (50%-62%)	122/158, 77% (70%-83%)	< .001	.001
Calf cramps	114/423, 27% (23%-31%)	54/265, 20% (16%-26%)	60/158, 38% (30%-46%)	< .001	.008
Pressure at base of head	151/423, 36% (31%-40%)	71/265, 27% (22%-33%)	80/158, 51% (43%-59%)	< .001	< .001
Jaw pain	92/423, 22% (18%-26%)	42/265, 16% (12%-21%)	50/158, 32% (25%-40%)	< .001	.013
Joint pain	177/423, 42% (37%-47%)	88/265, 33% (28%-39%)	89/158, 56% (48%-64%)	< .001	< .001
Kidney pain	35/423, 8.3% (5.9%-11%)	7/265, 2.6% (1.2%-5.6%)	28/158, 18% (12%-25%)	< .001	< .001
Mouth sores or sore tongue	82/423, 19% (16%-24%)	38/265, 14% (10%-19%)	44/158, 28% (21%-36%)	< .001	.064
Muscle or body aches	239/423, 57% (52%-61%)	129/265, 49% (43%-55%)	110/158, 70% (62%-77%)	< .001	.003
Persistent chest pain or pressure	138/423, 33% (28%-37%)	68/265, 26% (21%-31%)	70/158, 44% (36%-52%)	< .001	.007
Painful scalp	63/423, 15% (12%-19%)	23/265, 8.7% (5.7%-13%)	40/158, 25% (19%-33%)	< .001	< .001
Sharp or sudden chest pain	131/423, 31% (27%-36%)	57/265, 22% (17%-27%)	74/158, 47% (39%-55%)	<0.001	< .001
Changed sense of taste	122/423, 29% (25%-33%)	66/265, 25% (20%-31%)	56/158, 35% (28%-43%)	.021	> .999
Changed sense of smell	132/423, 31% (27%-36%)	66/265, 25% (20%-31%)	66/158, 42% (34%-50%)	< .001	.028
Floaters or flashes of light in vision	117/423, 28% (24%-32%)	43/265, 16% (12%-21%)	74/158, 47% (39%-55%)	< .001	< .001
Loss of hearing	37/423, 8.7% (6.3%-12%)	14/265, 5.3% (3.0%-8.9%)	23/158, 15% (9.6%-21%)	.001	.104
Loss or decrease in quality of vision/blurry vision	176/423, 42% (37%-46%)	90/265, 34% (28%-40%)	86/158, 54% (46%-62%)	< .001	.003
Phantom smells	98/423, 23% (19%-28%)	43/265, 16% (12%-21%)	55/158, 35% (28%-43%)	< .001	.001
Phantom tastes	36/423, 8.5% (6.1%-12%)	14/265, 5.3% (3.0%-8.9%)	22/158, 14% (9.1%-21%)	.002	.196
Hallucinations (visual or auditory)	26/423, 6.1% (4.1%-9.0%)	10/265, 3.8% (1.9%-7.0%)	16/158, 10% (6.1%-16%)	.008	.807
Tinnitus or humming in ears	193/423, 46% (41%-51%)	95/265, 36% (30%-42%)	98/158, 62% (54%-70%)	< .001	< .001
Skin bruising	93/423, 22% (18%-26%)	42/265, 16% (12%-21%)	51/158, 32% (25%-40%)	< .001	.008
Change in nails (i.e. white spots, brittleness, change in moons)	83/423, 20% (16%-24%)	35/265, 13% (9.5%-18%)	48/158, 30% (23%-38%)	< .001	.002

Table S4 (*Continued*)

	Overall, *N* = 423 *n/N*, % (95% CI)	No Internal Tremors, *N* = 265 *n/N*, % (95% CI)	Has Internal Tremors, *N* = 158 *n/N*, % (95% CI)	*P* Value*	Adjusted *P* Value†
Tender or itchy rash or chilblains on the toes or foot)	29/423, 6.9% (4.7%-9.8%)	5/265, 1.9% (0.70%-4.6%)	24/158, 15% (10%-22%)	< .001	< .001
Cracked or dry lips	79/423, 19% (15%-23%)	35/265, 13% (9.5%-18%)	44/158, 28% (21%-36%)	< .001	.018
Dental problems (e.g., chipped tooth, tooth loss)	54/423, 13% (9.8%-16%)	26/265, 9.8% (6.6%-14%)	28/158, 18% (12%-25%)	.018	> .999
Discoloration of the skin (for example: purple or blue on the hands or feet, no blistering)	74/423, 17% (14%-22%)	28/265, 11% (7.3%-15%)	46/158, 29% (22%-37%)	< .001	< .001
Dry or peeling skin	76/423, 18% (14%-22%)	35/265, 13% (9.5%-18%)	41/158, 26% (19%-34%)	< .001	.091
Dry scalp or dandruff	61/423, 14% (11%-18%)	30/265, 11% (7.9%-16%)	31/158, 20% (14%-27%)	.019	> .999
Hair loss	167/423, 39% (35%-44%)	79/265, 30% (24%-36%)	88/158, 56% (48%-64%)	< .001	< .001
Itchiness	108/423, 26% (21%-30%)	46/265, 17% (13%-23%)	62/158, 39% (32%-47%)	< .001	< .001
Tender or itchy rash not on foot	44/423, 10% (7.7%-14%)	21/265, 7.9% (5.1%-12%)	23/158, 15% (9.6%-21%)	.031	> .999
Chilblains (itching, bumps, red- to violet-colored patches on the hands or feet)	24/423, 5.7% (3.7%-8.4%)	6/265, 2.3% (0.92%-5.1%)	18/158, 11% (7.1%-18%)	< .001	.008
Constant thirst	111/423, 26% (22%-31%)	46/265, 17% (13%-23%)	65/158, 41% (33%-49%)	< .001	< .001
Changes in voice	81/423, 19% (16%-23%)	46/265, 17% (13%-23%)	35/158, 22% (16%-30%)	.226	> .999
Clogged ears	98/423, 23% (19%-28%)	49/265, 18% (14%-24%)	49/158, 31% (24%-39%)	.003	.299
Dizziness	249/423, 59% (54%-64%)	131/265, 49% (43%-56%)	118/158, 75% (67%-81%)	< .001	< .001
Dry eyes	120/423, 28% (24%-33%)	56/265, 21% (16%-27%)	64/158, 41% (33%-49%)	< .001	.002
Fatigue	361/423, 85% (82%-89%)	219/265, 83% (77%-87%)	142/158, 90% (84%-94%)	.042	> .999
Irregular or skipped menstrual cycles	78/423, 18% (15%-23%)	38/265, 14% (10%-19%)	40/158, 25% (19%-33%)	.005	.462
Menstrual cycles that are heavier or lighter than normal	81/423, 19% (16%-23%)	40/265, 15% (11%-20%)	41/158, 26% (19%-34%)	.006	.575
New allergies	68/423, 16% (13%-20%)	32/265, 12% (8.5%-17%)	36/158, 23% (17%-30%)	.004	.354
Inability to eat or tolerate food	90/423, 21% (18%-26%)	39/265, 15% (11%-20%)	51/158, 32% (25%-40%)	< .001	.002
Swollen hands or feet	78/423, 18% (15%-23%)	36/265, 14% (9.8%-18%)	42/158, 27% (20%-34%)	< .001	.081
Fainting	43/423, 10% (7.5%-14%)	13/265, 4.9% (2.7%-8.4%)	30/158, 19% (13%-26%)	< .001	< .001
Weakened neck	69/423, 16% (13%-20%)	23/265, 8.7% (5.7%-13%)	46/158, 29% (22%-37%)	< .001	< .001

*Pearson's Chi-squared test; Fisher's exact test.
†Bonferroni correction for multiple testing.CI = confidence interval.

Table S5 Variable Importance in the Machine Learning Models When Including All Symptom Variables

Symptom	GBM Percent Importance	XGB Mean Absolute Shapley Value	XGB Gain Percent Importance
Tremors or shakiness	27.45	0.510490907	44.85
Floaters or flashes of light in vision	8.44	0.139807497	10.16
Hair loss	5.27	0.121706726	5.26
Tingling, pins and needles, numbness	4.47	0.166079321	9.82
Tinnitus or humming in ears	3.75	0.120033087	4.98
Sharp or sudden chest pain	3.46	0.073050261	4.94
Abdominal pain	2.98	0.018376863	0.97
Itchiness	2.82	0.013954319	0.78
Migraine	2.46	0	0
Kidney pain	2.23	0.04543798	4.6
Sore throat	2.09	0.014627527	0.68
Painful scalp	1.98	0	0
Dizziness	1.94	0.056787718	2.29
Cough	1.79	0	0
Tender or itchy rash on toes or foot	1.76	0.008380492	1.06
Acid reflux or heartburn	1.72	0	0
Postnasal drip	1.68	0	0
Constant thirst	1.65	0.01901079	0.73
Tachycardia at rest	1.6	0.021019243	0.98
Headache	1.45	0.018371266	0.7
Phantom smells	1.34	0	0
Inability to eat or tolerate food	1.27	0	0
Changes in voice	1.2	0	0
Constipation	1.18	0	0
Costochondritis	1.17	0	0
Calf cramps	1.06	0.016288212	1.09
Trouble falling/staying asleep	1.01	0.022355786	0.72
Neuropathy	0.95	0.038334172	1.46
Wheezing	0.85	0	0
Bilateral neck throbbing	0.81	0	0
Difficulty swallowing	0.68	0	0
Loss of hearing	0.66	0	0
Tachycardia after standing up	0.64	0	0
Mouth sores or sore tongue	0.6	0	0
Feelings of impending doom	0.59	0	0
Phlegm in back of throat	0.59	0	0
Throat pain	0.55	0	0
Cold intolerance	0.51	0	0
Clogged ears	0.51	0	0
Chilblains on hands or feet	0.5	0.009202775	0.86
Fainting	0.49	0	0
Excessive fatigue	0.43	0	0
Heat intolerance	0.41	0	0
Chills	0.34	0	0
Difficulty speaking properly	0.33	0	0
Diarrhea	0.31	0	0
Anxiety	0	0	0
Confusion	0	0	0
Brain fog	0	0	0
Memory problems	0	0	0
Suicidal thoughts	0	0	0
Abnormally low temperature	0	0	0
Fevers	0	0	0
Night sweats	0	0	0
Sleeping more than usual	0	0	0

Table S5 (*Continued*)

Symptom	GBM Percent Importance	XGB Mean Absolute Shapley Value	XGB Gain Percent Importance
Nightmares	0	0	0
Exercise intolerance	0	0	0
Burning sensations	0	0	0
Seizures	0	0	0
Nausea/vomiting	0	0	0
Loss of appetite	0	0	0
Congested or runny nose	0	0	0
Palpitations	0	0	0
Coughing up blood	0	0	0
Cold or burning feeling in lungs	0	0	0
Lump in throat	0	0	0
Runny nose	0	0	0
Swollen lymph nodes	0	0	0
Shortness of breath	0	0	0
Bone aches	0	0	0
Pressure at base of head	0	0	0
Jaw pain	0	0	0
Joint pain	0	0	0
Muscle or body aches	0	0.014623417	0.72
Persistent chest pain or pressure	0	0	0
Changed sense of taste	0	0	0
Changed sense of smell	0	0.014390654	0.69
Loss or decrease in quality of vision/blurry vision	0	0	0
Phantom tastes	0	0	0
Hallucinations	0	0	0
Skin bruising	0	0	0
Change in nails	0	0.013030063	0.69
Cracked or dry lips	0	0	0
Dental problems	0	0	0
Discoloration of skin	0	0	0
Dry skin	0	0	0
Dry scalp	0	0	0
Tender or itchy rash not on foot	0	0	0
Dry eyes	0	0	0
Fatigue	0	0	0
New allergies	0	0	0
Swollen hands/feet	0	0	0
Weakened neck	0	0.01949914	0.97

GBM = gradient-boosting machine using a permutation-based approach; XGB Gain = XGBoost tree machine learning model with gain in accuracy metric.

In this table, symptoms were sorted based on their importance in the GBM method. For each of the 3 methods used, we sorted the variables based on their importance and, using this fixed sorting, progressively excluded those with least importance from the model by evaluating the change in the AUC.

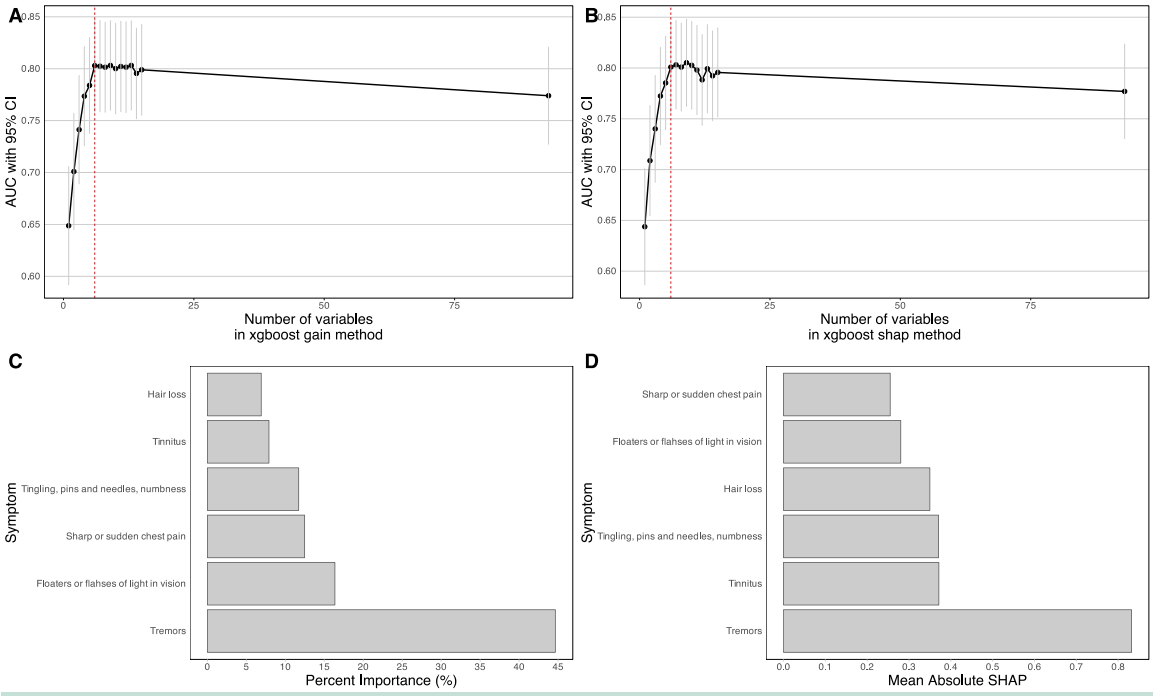

Figure S2 XGBoost model results for symptoms strongly associated with internal tremors.
AUC = area under the curve; CI = confidence interval; SHAP = Shapley value.
(**A**) Model performance as a function of the number of top variables used in XGBoost model with variable importance computed by relative gain. Red line denotes model with 6 variables selected (AUC = 0.80; 95% CI [0.76-0.85]). (**B**) Model performance as a function of the number of top variables used in XGBoost model with variable importance computed by mean absolute Shapley values. Red line denotes model with 6 variables selected (AUC = 0.80; 95% CI [0.76-0.85]). (**C**) Symptoms' importance in differentiating internal tremor symptom status for XGBoost gain model selected in panel A. (**D**) Symptoms' importance in differentiating internal tremor symptom status for XGBoost shap model selected in panel B.

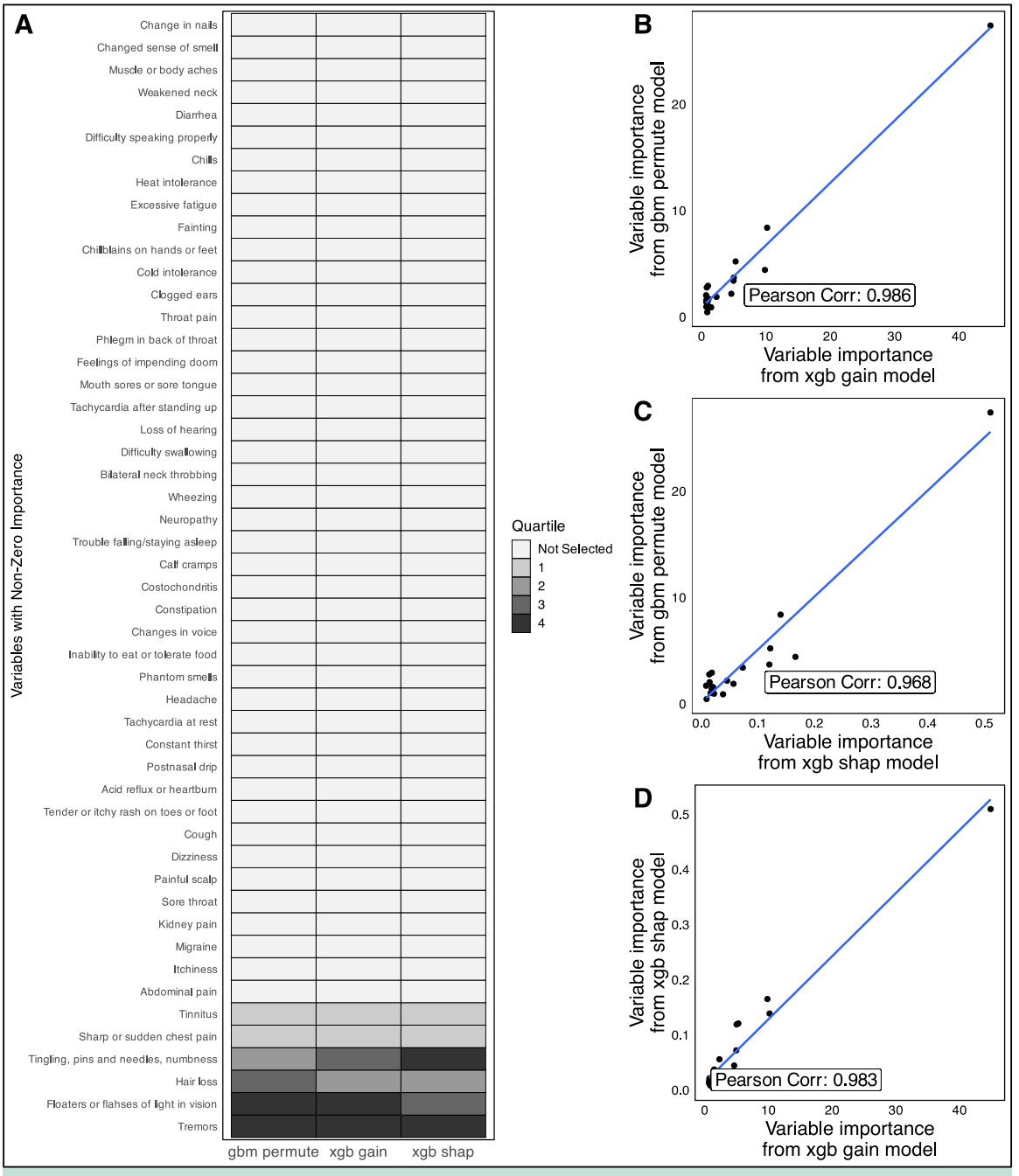

Figure S3 Comparison between symptoms associated with internal tremors across machine learning methods. GBM permute = gradient-boosting machine using a permutation-based approach; XGB gain = XGBoost tree machine learning model with gain in accuracy metric; XGB shap = XGBoost tree machine learning model with Shapley value. (**A**) Comparison between the selected final models for each of the three methods. All variables with non-zero importance are shown and for each of the three models, each variable is classified by their quartile rank in the final model or is not selected. The selected variables are highly concordant across models suggesting that the variables selected are truly important in differentiating patients with and without internal tremors. (**B, C, D**) Correlation between the variable importance metrics for each of the three methods for all variables with non-zero importances. (**B**) Correlation between XGBoost gain and GBM permute is 0.99 with $P < 1.19e\text{-}14$. (**C**) Correlation between XGBoost shap and GBM permute is 0.97 with $P < 1.3e\text{-}11$. (**D**) Correlation between XGBoost gain and XGBoost shap is 0.98 with $P < 2.2e\text{-}16$.

14. Heart attack, also called myocardial infarction
15. Heart conditions (including coronary artery disease or cardiomyopathies)
16. Heart failure
17. High cholesterol
18. History of organ transplant (including kidney, liver, heart, or lung)
19. Hypertension or high blood pressure
20. Immunocompromised state (including weakened immune system from blood or bone marrow transplant, immune deficiencies, HIV, use of corticosteroids, or use of other immune-weakening medicines)
21. Kidney disease
22. Liver disease
23. Long COVID
24. Lyme disease
25. MCAS (mast cell activation syndrome) or other mast cell disorders
26. ME/CFS (myalgic encephalomyelitis/chronic fatigue syndrome)
27. Migraines
28. Neurological conditions (including seizures, dementia, multiple sclerosis, Parkinson's, neuropathy, small fiber neuropathy, etc.)
29. Postural orthostatic tachycardia syndrome (POTS) or dysautonomia
30. Spinal disorder(s)
31. Vaccine injury
32. Other
33. None of the above

Currently, have you ever been told by a doctor that you have any of the following?

Check all that apply ("multiple choice")

1. Depressive disorders
2. Anxiety disorders
3. Schizophrenia spectrum and other psychotic disorders
4. Bipolar and related disorders
5. Obsessive-compulsive and related disorders
6. Trauma- and stressor-related disorders
7. Feeding and eating disorders
8. Somatic symptom and related disorders
9. Other
10. None of the above

S4 PROTOCOL. LONG COVID SYMPTOMS QUESTIONS

Please select all following health conditions that you have had as a result of long COVID. Check all that apply ("multiple choice")

1. Abnormally low temperature
2. Fevers, including low-grade fevers
3. Chills but no fever
4. Heat intolerance
5. Cold intolerance
6. Night sweats
7. Other
8. None of the above

Please select all following health conditions that you have had as a result of long COVID. Check all that apply ("multiple choice")

1. Trouble falling or staying asleep
2. Sleeping more than usual
3. Nightmares
4. Exercise intolerance
5. Excessive fatigue
6. Other
7. None of the above

Please select all following health conditions that you have had as a result of long COVID. Check all that apply ("multiple choice")

1. Burning sensations
2. Tremors or shakiness
3. Internal tremors or buzzing/vibration
4. Tingling, pins and needles, numbness
5. Neuropathy (nerve sensations including pain) anywhere in the body
6. Seizures
7. Other
8. None of the above

Please select all following health conditions that you have had as a result of long COVID. Check all that apply ("multiple choice")

1. Abdominal pain
2. Acid reflux or heartburn
3. Diarrhea
4. Constipation
5. Nausea/vomiting
6. Loss of appetite
7. Other
8. None of the above

Please select all following health conditions that you have had as a result of long COVID. Check all that apply ("multiple choice")

1. Sore throat
2. Congested or runny nose
3. Palpitations (improper beating of the heart due to electrical impulse problems)
4. Bilateral neck throbbing around lymph nodes
5. Costochondritis (pain in the cartilage that connects a rib to the breastbone)
6. Cough
7. Coughing up blood
8. Cold or burning feeling in lungs
9. Difficulty swallowing

10. Throat pain or discomfort
11. Lump in throat
12. Phlegm in back of throat
13. Postnasal drip
14. Runny nose
15. Swollen lymph nodes
16. Tachycardia (rapid heartbeat) at rest
17. Tachycardia (rapid heartbeat) after standing up
18. Wheezing
19. Shortness of breath or difficulty breathing
20. Other
21. None of the above

Please select all following health conditions that you have had as a result of long COVID. Check all that apply ("multiple choice")

1. Bone aches
2. Migraine
3. Headache
4. Calf cramps
5. Pressure at base of head
6. Jaw pain
7. Joint pain
8. Kidney pain
9. Mouth sores or sore tongue
10. Muscle or body aches
11. Persistent chest pain or pressure
12. Painful scalp
13. Sharp or sudden chest pain
14. Other
15. None of the above

Please select all following health conditions that you have had as a result of long COVID. Check all that apply ("multiple choice")

1. Changed sense of taste
2. Changed sense of smell
3. Floaters or flashes of light in vision
4. Loss of hearing
5. Loss or decrease in quality of vision/blurry vision
6. Phantom smells
7. Phantom tastes
8. Hallucinations (visual or auditory)
9. Tinnitus or humming in ears
10. Other
11. None of the above

Please select all following health conditions that you have had as a result of long COVID. Check all that apply ("multiple choice")

1. Skin bruising
2. Change in nails (i.e., white spots, brittleness, change in moons)
3. Tender or itchy rash or chilblains on the toes or foot)
4. Cracked or dry lips
5. Dental problems (e.g., chipped tooth, tooth loss)
6. Discoloration of the skin (for example: purple or blue on the hands or feet, no blistering)
7. Dry or peeling skin
8. Dry scalp or dandruff
9. Hair loss
10. Itchiness
11. Tender or itchy rash not on foot
12. Chilblains (itching, bumps, red- to violet-colored patches on the hands or feet)
13. Other
14. None of the above

Please select all following health conditions that you have had as a result of long COVID. Check all that apply ("multiple choice")

1. Constant thirst
2. Changes in voice
3. Clogged ears
4. Dizziness
5. Dry eyes
6. Fatigue
7. Irregular or skipped menstrual cycles
8. Menstrual cycles that are heavier or lighter than normal
9. New allergies
10. Inability to eat or tolerate food
11. Swollen hands or feet
12. Fainting
13. Weakened neck
14. Other
15. None of the above

Please select all that you have. Check all that apply ("multiple choice")

1. Anxiety
2. Confusion
3. Brain fog; difficulty concentrating or focusing
4. Feelings of impending doom
5. Memory problems
6. Difficulty speaking properly
7. Suicidal thoughts
8. Other
9. None of the above