Improved Sleep in Individuals Using Transcutaneous Electrical Nerve Stimulation for Chronic Pain Management

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Introduction

- Chronic pain is associated with significant sleep disturbance, which has been linked to poor health including cardiovascular disease, diabetes, and obesity[1,2]
- Pharmacological and nonpharmacological options are available to treat chronic pain and associated sleep disturbance[1]
  - Nonpharmacological treatments have a low incidence of adverse events and lack of drug interactions, and can be used alone or in conjunction with pharmacological agents[1]
- Fixed-site, high-frequency transcutaneous electrical nerve stimulation (FS-TENS) is a nonpharmacological, noninvasive treatment that relieves pain. It is applied to a single predetermined location and can be used while a person is active and during sleep
- In a large-scale observational study (N=713), 38.7% of participants using FS-TENS daily for chronic pain reported a reduction in pain interference with sleep by ≥2 points on an 11-point rating scale,[3] which is considered clinically meaningful improvement[4]

Objective

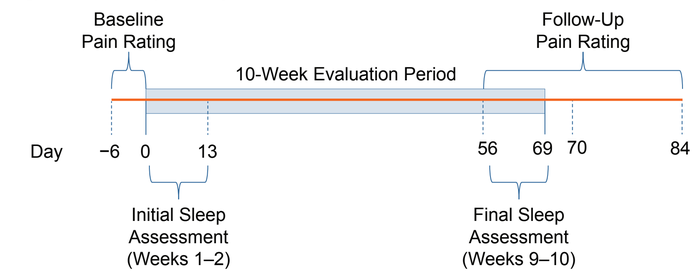
- Evaluate whether objective sleep metrics are improved by FS-TENS use in individuals with chronic pain with and without sleep impairment

Methods

Study Design, Assessments, and Outcomes

- This retrospective, observational, real-world study evaluated the effect of FS-TENS device use on sleep outcomes among persons with chronic pain, with and without sleep impairment, over a 10-week period (**Figure 1**)

Figure 1. Study Design



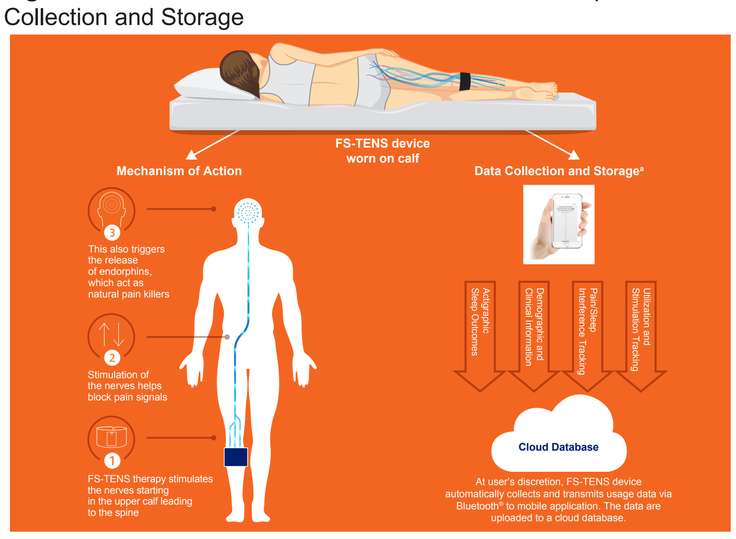
Reproduced with permission from Gozani et al.[5]

- Device utilization (percentage of days with ≥30 minutes of stimulation), sleep utilization (percentage of nights with ≥30 minutes of stimulation during sleep), and mean hours of stimulation per week were electronically tracked by the FS-TENS device
  - Sensation threshold (the current, in milliamps, at which electrical stimulation is first perceived), and stimulation intensity (the ratio of therapeutic current to sensation threshold expressed in decibels) were also captured by the FS-TENS device
- The FS-TENS device collected the following actigraphy-based sleep outcomes data: Total sleep time (TST; total time spent sleeping), sleep efficiency (percentage of total time in bed spent asleep), and the periodic leg movement index (number of periodic leg movements per hour of sleep)
  - Baseline measurements for each participant were calculated as the median of nighttime measurements during weeks 1–2 and follow-up measurements as the median of nighttime measurements during weeks 9–10, with a minimum of 3 nights required for each
- Device users, via a companion smartphone application, rated pain intensity and interference with sleep using the 11-point numerical rating scales (scores 0–10) from the validated Brief Pain Inventory[6]
  - The pain rating closest to day 1 of FS-TENS use was considered the baseline rating, and the rating closest to day 70 was used as the follow-up rating (**Figure 1**)

FS-TENS Device

- The FS-TENS device provided stimulation (60 minutes every other hour) to sensory nerves in the S2-L4 dermatomes (**Figure 2**)

Figure 2. FS-TENS Device: Mechanism of Action and Optional Data Collection and Storage



FS-TENS, fixed-site, high-frequency transcutaneous electrical nerve stimulation.

[a]Data storage on the cloud database is not required for therapeutic use and is subject to local privacy laws and regulations. The mobile device application does not have a diagnostic function.

Study Population

- FS-TENS users who authorized uploading of their device use history and demographic and chronic pain data to the online database were included if they:
  - Provided baseline demographics and pain ratings
  - Had daily or weekly pain for >3 months
  - Wore the device ≥3 nights during weeks 1–2
- Participants were assigned to one of the following study arms based on their baseline TST
  - Acceptable sleep (AS): ≥360 minutes of sleep per night
  - Impaired sleep (IS): <360 minutes of sleep per night

Statistical Analyses

- Change in sleep outcomes from baseline to follow-up was assessed by analysis of variance with sleep status (AS or IS) as independent factor and demographics, pain characteristics, TENS utilization, overnight utilization, and number of nights of device use during baseline and follow-up as covariates
- Differences between the AS and IS groups were analyzed using a 2-sample *t* test with equal variances

Results

Demographics and Baseline Characteristics

- A total of 2975 device users contributed data at baseline: 2272 (76%) in the AS group and 703 (24%) in the IS group
  - A subset of 880 participants (AS: 690/2272 [30.4%]; IS: 190/703 [27.0%]) had actigraphic sleep data at follow-up; thus, 78% of this subset was in the AS group and 22% in the IS group
  - A subset of 649 (AS: 501/649 [77%]; IS: 148/649 [23%]) had pain intensity ratings at follow-up, and 645 (AS: 498/645 [77%]; IS: 147/645 [23%]) had pain interference ratings at follow-up
- The IS group was older, had a higher BMI, had a smaller percentage of persons with pain duration ≥4 years, had a smaller percentage of women, and had greater pain interference with sleep compared with the AS group (**Table 1**)

Table 1. Demographics and Baseline Pain Characteristics

Characteristic	AS Group (N=2272)	IS Group (N=703)
Female gender, n (%)	1375 (60.5)	357 (50.8)
Age, y, mean (SD)	52.8 (14.2)	55.2 (12.6)
BMI, mean (SD)	30.1 (6.5)	31.7 (7.8)
Duration of pain ≥4 y, n (%)	1690 (74.4)	511 (72.7)
No. of pain sites, mean (SD)	4.9 (2.5)	4.9 (2.5)
No. of painful health conditions, mean (SD)	2.8 (1.8)	2.9 (1.8)
Pain frequency, n (%)		
Daily	2197 (96.7)	672 (95.6)
Weekly	75 (3.3)	31 (4.4)
Time of worst pain, n (%)		
All day	1216 (53.5)	368 (52.3)
At night or when sleeping	198 (8.7)	62 (8.8)
Morning	257 (11.3)	90 (12.8)
At rest	73 (3.2)	25 (3.6)
With activity	404 (17.8)	137 (19.5)
Baseline pain intensity, mean (SD)[a]	6.4 (1.9)	6.5 (2.0)
Baseline pain interference with sleep, mean (SD)[a]	5.5 (2.9)	5.9 (2.9)

AS, acceptable sleep; BMI, body mass index; IS, impaired sleep; SD, standard deviation.

[a]Based on 11-point numerical rating scales (scores 0–10).

- Pain sites were similar in the AS and IS groups, with the most common sites being the lower back (AS: 81.9%; IS: 82.1%), legs (AS: 72.1%; IS: 74.3%), hips (AS: 58.5%; IS: 55.2%), feet (AS: 52.6%; IS: 56.6%), shoulders (AS: 55.4%; IS: 53.2%), and neck (AS: 53.8%; IS: 52.9%)

FS-TENS Use

- Overall FS-TENS utilization was similar between groups, but the AS group had higher sleep utilization than the IS group (**Table 2**)
  - Mean sensation threshold was higher in the IS group than the AS group

Table 2. FS-TENS Adherence Over Weeks 1–10

Parameter	AS Group (N=2272)	IS Group (N=703)
Utilization,[a] mean (SD) %	57.6 (31.4)	56.6 (30.9)
Sleep utilization,[b] mean (SD) %	35.5 (28.1)	28.7 (23.9)
Hours of stimulation per week, mean (SD)	32.5 (23.9)	31.2 (23.7)
Sensation threshold,[c] mean (SD), mA	14.8 (13.2)[d]	17.9 (14.6)
Stimulation intensity,[e] mean (SD), dB	5.2 (5.4)[d]	4.5 (5.4)

AS, acceptable sleep; IS, impaired sleep; SD, standard deviation.

[a]Percentage of days with ≥30 minutes of stimulation; [b]Percentage of nights with ≥30 minutes of stimulation during sleep; [c]Current at which electrical stimulation is first perceived; [d]N=2266; [e]Ratio of therapeutic current to sensation threshold.

Effects of FS-TENS on Objective Sleep Metrics

- All sleep metrics at baseline and follow-up were significantly different between groups (**Table 3**)

Table 3. Sleep Metrics at Weeks 1–2 and Weeks 9–10 of FS-TENS Use

Sleep Metric	AS Group	IS Group	*P* Value, AS vs IS[a]
Baseline, mean (SD)[b]	N=2272	N=703	
TST, min	442.7 (56.1)	313.0 (31.0)	<0.001
Sleep efficiency, %	89.2 (5.1)	84.7 (7.6)	<0.001
PLM index score	6.8 (8.2)	10.7 (13.5)	<0.001
Follow-up, mean (SD)[b]	n=690	n=190	
TST, min	433.0 (69.9)	358.0 (69.9)	<0.001
Sleep efficiency, %	89.2 (5.7)	86.9 (6.4)	<0.001
PLM index score	7.2 (9.1)	10.5 (12.1)	<0.001
Change from baseline to follow-up, mean (95% CI)[c]	n=690	n=190	
TST, min	−10.6 (−15.2 to −6.0)	45.1 (36.0 to 54.0)	<0.001
Sleep efficiency, %	−0.15 (−0.60 to 0.30)	1.50 (0.58 to 2.34)	0.002
PLM index score	0.14 (−0.38 to 0.66)	−0.61 (−1.63 to 0.41)	0.203

[a]Comparison of AS vs IS analyzed using 2-sample *t* test with equal variances.

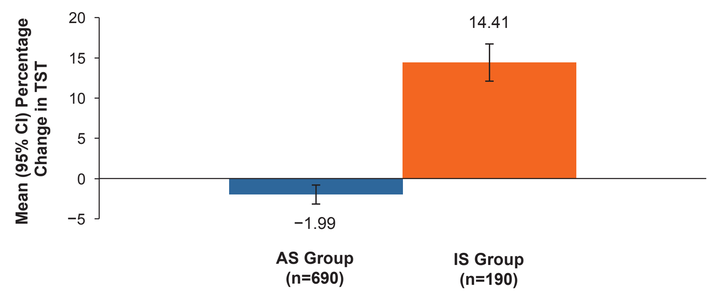
[b]Population means were calculated from individual median values for weeks 1–2 for baseline values and individual median values for weeks 9–10 for follow-up values.

[c]Based on analysis of variance with adjustment for demographics, utilization, overnight utilization, and number of nights of device use during baseline and follow-up.

AS, acceptable sleep; CI, confidence interval; IS, impaired sleep; PLM, periodic leg movement; SD, standard deviation; TST, total sleep time.

- FS-TENS use was associated with increased TST (**Figure 3**, **Table 3**) and sleep efficiency in the IS group but did not substantially improve any of the sleep metrics in the AS group (**Table 3**)

Figure 3. Percent Change in TST From Baseline to Follow-Up[a]



[a]Based on analysis of variance with adjustment for demographics, utilization, overnight utilization, and number of nights of device use during baseline and follow-up.

AS, acceptable sleep; CI, confidence interval; IS, impaired sleep; TST, total sleep time.

Effect of FS-TENS on Subjective Ratings of Pain Intensity and Sleep

- FS-TENS use was associated with similar reductions in pain intensity ratings from baseline to follow-up in the AS group (mean, −0.69; 95% CI, −0.91 to −0.47; n=501) and IS group (mean, −0.70; 95% CI, −1.12 to −0.28; n=148)
- Ratings of pain interference with sleep also decreased in both the AS group (mean, −0.63; 95% CI, −0.88 to −0.38; n=498) and IS group (mean, −0.93; 95% CI, −1.47 to −0.39; n=147) during FS-TENS use

Conclusions

- In this real-world study, people who had sleep impairment related to chronic pain experienced improved sleep (increased TST and sleep efficiency) and a reduction in pain intensity and pain interference with sleep during a period of FS-TENS device use
- Patients with chronic pain but no sleep impairment at baseline did not show objective sleep improvements, but reported subjective improvement in pain ratings and pain interference with sleep after using the FS-TENS device

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Disclosures

Shai Gozani and Xuan Kong are employees of NeuroMetrix, Inc. Dawn Chesher and Taara Madhavan are employees of GlaxoSmithKline Consumer Healthcare.

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