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SLEEP ENHANCEMENT TECHNOLOGY IN 2021: AN UPDATED SURVEY OF APPS

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Introduction: Commercially available smartphone apps that claim to improve sleep quantity and/or quality represent an ever-evolving and fast-growing market. Although a large body of work has validated the performance of sleep tracking technologies, there is little information regarding potential sleep enhancement technologies. Our study systematically surveyed currently available commercial sleep enhancement smartphone apps to provide details to inform both providers and patients alike, in addition to the healthy consumer market.

Methods: We systematically searched the Google Play Store (Android) on 30 JUN 2021 and the App Store (Apple) on 30 JUN 2021 and 26 JUL 2021 in the US using the keyword "sleep." The Android search was conducted via the Google Play Store website. The Apple search was conducted via third-party websites linked to the App Store due to restrictions on searching the App Store online. This survey was conducted using Google Chrome web browsers and is inclusive of all smartphone applications found.

Results: We identified 550 apps: 59.5% on Android (N=327) and 40.5% on Apple (N=223). Ninety-four percent of apps offered a free version. The majority of sleep apps were intended for use during wake (72.7% exclusively during wake; 25.1% during both wake and sleep), with only 2.2% intended to be used during sleep alone. Most apps purport to enhance rather than measure sleep (87.8% versus 0.5%). The vast majority of apps claim to enhance sleep via reductions in sleep latency (92.9%). Reduced sleep latency is primarily achieved using auditory stimuli (74.5%).

Conclusion: Most current sleep apps are designed to be used while awake, prior to sleep, and focus on the enhancement of sleep, rather than measurement, by targeting sleep latency. Given the evidence that supports sleep latency as an important target for sleep promoting interventions and the multitude of available sleep enhancement apps across both Android and Apple platforms, sleep apps could be considered a possible strategy for patients and consumers to improve their sleep, although validation of these apps is required.

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SLEEP APNEA DIAGNOSIS USING TRACHEAL SIGNALS AND OXIMETRY

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Introduction: Diagnosing sleep apnea requires detection of apneas and hypopneas during sleep either via in-laboratory overnight polysomnography (PSG) or portable in-home sleep apnea testing (HSAT). While PSG is the optimal method, it is expensive, inconvenient and often inaccessible for patients. Although HSATs are more convenient and less expensive than PSG, they are not as accurate and have relatively high failure rates because of the nature of the sensors used to measure respiratory variables. We have developed a HSAT, the Patch, that is unique in that it is very simple and reliable because it measures respiratory variables using tracheal motion and sound combined with oximetry to detect respiratory events. In this study we tested the ability of the Patch to detect respiratory events versus simultaneous PSG.

Methods: Participants were adults with a suspected sleep disorder referred to the sleep laboratory at Toronto Rehabilitation Institute for PSG. Simultaneous to the PSG, the Patch, consisting of a module containing a microphone and a 3-D accelerometer that was affixed to participants' suprasternal notch, and a finger oximeter. After filtering the tracheal signals, the envelope of the tracheal motions in the cranial and postero-anterior directions and tracheal sound envelope were extracted. Along with tracheal features, the amplitude and slopes of oxygen desaturations were also extracted and, were fed into a supervised deep neural network model to detect apneas and hypopneas. The total number of detected events was divided by total estimated sleep time to estimate the apnea-hypopnea index (AHI). The performance of the model in diagnosing sleep apnea was evaluated by sensitivity (AHI≥15) and specificity (AHI<15). The relationship between the estimated AHI and PSG-based AHI was quantified using Pearson correlation.

Results: Ninety-nine participants (42 females, age: 48±16 years, body mass index: 29.2±5.2 kg/m2, and AHI: 15.8±19.4 events/hour) completed the study. We found that the Patch had 88.6% sensitivity and 89.1% specificity for diagnosing sleep apnea. Strong agreement was observed between the estimated and reference AHI values ($r = 0.92$, $p < 0.001$).

Conclusion: The Patch is a novel, robust and convenient portable device that provides an accurate means of detecting and quantifying sleep apnea. It has the potential to provide reliable home-based sleep apnea monitoring.

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REM-LIKE NEURAL ACTIVITY IS SUPERIOR TO NREM PARAMETERS FOR PREDICTING NON-SLEEP RESTRICTED VIGILANCE

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Introduction: Currently unknown is whether REM-like neural activity reverses, incurs, or is neutral with respect to its effect on sleep pressure independent from NREM recovery. We investigated the relationship between a novel scalp-EEG measure of REM-like neural activity and next-day performance on the Psychomotor Vigilance Task (PVT) – a sensitive measure of sleep debt. Our EEG measure reflects the oscillatory-theta activity (OTA) that is the hallmark of REM sleep in animal studies. This method preserves amplitude information, isolates OTA from aperiodic theta-band power, and accounts for REM-like activity thought to occur outside of conventionally scored-REM epochs. We compared the PVT-association of OTA, traditionally measured EEG REM-theta, and traditional sleep parameters. To assess REM-like independent effects, we controlled for traditional parameters using a multivariate model.

Methods: Our method uses Irregular-Resampling Auto-Spectral Analysis to remove the aperiodic spectrum, followed by low-band

power normalization to derive the relative oscillatory-theta activity (OTA). The average OTA was then used to predict next-day performance on the PVT. Traditional sleep parameters (sleep efficiency, total sleep time, %NREM, %N3, and delta-band power) were also examined. We combined data from two previously reported in-laboratory studies resulting in a sample size of 42 healthy young adult subjects. Analyses used non-sleep restricted overnight EEG recordings from a frontal channel.

Results: There was a substantial PVT-OTA association (OTA positively correlated with response-time and thus with reduced vigilance) during scored-REM epochs (r=0.44, p=0.003). This was stable irrespective of conventional sleep staging when using all sleep epochs (r=0.48, p=0.001), and OTA during scored-NREM (r=0.35, p=0.02). The effect was also stable after controlling for total sleep time, %NREM, and N3 delta-band power in a multivariate model (all-sleep PVT-OTA: r=0.5, p=0.004). Traditional sleep parameters were not significantly correlated with PVT performance.

Conclusion: OTA was a superior quantitative predictor of reduced next-day vigilance than traditional sleep parameters, and this persisted after controlling for NREM parameters. These findings are consistent with the hypothesis that periods of high REM-like activity are less restorative than other periods and may actually increase homeostatic sleep pressure.

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A MODEL FOR A CHRONIC NAPPING IN OLDER ADULTS AT RISK FOR ALZHEIMER'S DISEASE

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Introduction: Theoretically, napping could have positive effects on health (e.g., by reducing stress and compensating for short night time sleep) or negative effects (e.g., by disrupting nighttime sleep or impairing circadian synchronization). Epidemiologic studies have produced mixed results regarding associations of napping with health. Causality can be better addressed with a randomized controlled trial of daily napping, as described herein.

Methods: Participants were 12 older adults (70.8±4.4 years) with a first degree relative with Alzheimer's Disease. Inclusion criteria included normal cognitive function; stable sleep schedule; stable medication use; and self-reported ease of taking naps, but with napping frequency of ≤2 days per week. Exclusion criteria included having a sleep disorder or high risk of obstructive sleep apnea; hypertension; sleeping pill use > once per week; MI or stroke within the past 3 years. Following a one week baseline involving a stable sleep/nap schedule consistent with usual habits, participants were randomized to one of two 21-day treatments: (1) daily napping (1 h/day begun at 5-7 h after arising) while keeping a stable night sleep schedule consistent with baseline (n=6); (2) a no-napping control treatment in which participants read quietly for 1 h/day at the same time (n=6). Sleep for night sleep and napping (or non-napping) was assessed via self-report, actigraphy, and the Z-machine.

Results: ANOVA revealed a significant increase in napping minutes/day (p=0.01) in the napping treatment (baseline: 14.5±21.1; 21-day average: 42.1±19.1) compared with the control treatment (baseline: 2.2±5.5; treatment: 1.4±3.5). However, reported nighttime sleep duration did not change significantly between the napping (from 7.1±1.2 to 7.4±1.0 h) and the control treatment (7.8±0.7 to 7.8±0.6 h). Actigraphic night sleep changed from 7.3±0.8 to 7.1±0.9 and 7.8±5 to 7.6±0.7 after napping and control, respectively. There were not significant treatment differences (nor notable effect size differences) for depressed mood, sleepiness, PSQI, amyloid beta, nor cardiovascular measures (e.g., blood pressure, flow mediated dilation, pulse wave velocity).

Conclusion: The data indicate that older adults can undergo daily napping without significant impairment in nighttime sleep. Neither benefits nor detrimental effects on health-related variables were shown in this small sample. A more prolonged intervention is needed.

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COMPARISON OF TWO ACTIGRAPHY-BASED ALGORITHMS FOR DETECTING DAYTIME AND NIGHTTIME SLEEP

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Introduction: The Actiware software that comes with Philips Respironics' actiwatches tends to overestimate sleep, due to its poor accuracy in distinguishing immobility from sleep. Re-scoring rules were introduced in the Cole-Webster algorithm to overcome this issue. Previous validation of the two algorithms was based on nighttime sleep, and their performance in daytime sleep detection is unknown. This study aims to test/compare the performance of the two algorithms in detecting daytime sleep and nighttime sleep.

Methods: We analyzed actigraphy and polysomnography data that were simultaneously collected from 25 participants (14 non-shift-workers and 11 shift-workers; age: 30.93±8.96 [mean±SD]; female: 14 [56%]) each in two in-lab visits with scheduled nighttime or daytime sleep. The sleep/wake epochs scored by the Cole-Webster algorithm and Actiware (using medium wake threshold) were compared to those obtained from polysomnography. We conducted linear mixed-effects regression models to compare the sensitivity, specificity, and F1-score (a measure of performance less affected by imbalanced datasets) in detecting daytime and nighttime sleep and between the two algorithms.

Results: The Cole-Webster algorithm (mean±SE: daytime=0.66±0.02, nighttime=0.60±0.02) yielded lower sensitivity than Actiware (daytime=0.96±0.02, nighttime=0.96±0.02; p<0.0001), which was consistent for both daytime and nighttime sleep (daytime/nighttime×algorithm interaction: p=0.2). The Cole-Webster algorithm (daytime=0.91±0.04, nighttime=0.94±0.05) yielded higher specificity than Actiware (daytime=0.45±0.04, nighttime=0.56±0.05; p<0.0001), which was consistent for both daytime and nighttime sleep (daytime/nighttime×algorithm interaction: p=0.2). Both sensitivity and specificity did not differ between daytime and nighttime sleep (p>0.05). F1 scores of the Cole-Webster algorithm were lower (daytime=0.77±0.02, nighttime=0.74±0.02) than those of Actiware (daytime=0.92±0.02, nighttime=0.97±0.02; p<0.0001) for both daytime and nighttime sleep. There was a significant daytime/nighttime×algorithm interaction on F1 score (p=0.02). Specifically, the Cole-Webster algorithm performed better in scoring daytime than nighttime sleep,