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A New Advanced Implementation Results of Comprehensive Statistical Analysis for Recent Smartphone Sleep-Tracking Applications

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Abstract—
Background: Sleep disorders and lack of sleep are serious health problems that must be accurately monitored and closely followed-up before the cumulative long-term effects of sleep deprivation and sleep disorders have been associated with a wide range of deleterious health consequences including an increased risk of hypertension, diabetes, obesity, depression, heart attack, and stroke. Therefore, in these recent years of thriving technologies especially in the fields of Smartphones, biometric sensors, Artificial Intelligence, Programming and App developing; leading to thousands of downloadable apps from different stores (Google play, and Apple store) that offer a stable, controllable, and scalable options for sleep tracking apps utilization at general population level since it became an important target of health and fitness app developers. Moreover, the recent sleep tracking apps have many features and functionalities including smart alarms, sleep aids, sleep cycles, and sleep analysis.
Objective: This study aims to comprehensively survey, review and analyze most recent smartphones' sleep tracking apps in the period from February – to- June 2023 scouting and exploring their technical features and functionalities in order to comprehensively explore their effectiveness in sleep tracking activity of users.
Methods: This study has surveyed the Apple Store and Google Play as the two major stores for most popular sleep tracking apps. The following keywords were used in our search for applications: sleep apps, sleep monitoring, sleep tracking, sleep analysis, sleep quality, sleep coaching, and sleep statistics. Titles, descriptions, and keywords of the selected applications were thoroughly checked and reviewed. First all publicly available smartphones' apps in stores were included. Then, apps used for other purposes than sleep tracking were excluded. Moreover, apps that are not intended for self-management sleep tracking such as baby sleep tracking apps were excluded during the apps screening and filtering process. Furthermore, the apps that have the same technical features and/or functionalities were excluded for duplication, along with the low usage and low ratings apps during the apps eligibility filtering process. Finally, the remaining apps were rated individually for consistency with the well-known American Psychiatric Association (APA) app evaluation model taken to consideration that each store was analyzed separately.
Results: a total of 157 most recent sleep-tracking related apps were included at first in our study which took place during the period from February – to - end of June 2023 focusing on 24 major technical features of sleep-tracking apps, 32 apps (20.38%) were excluded from the study due to irrelevant main design and implementation purposes, while another 9 apps (5.73%) were excluded for not supporting self-management sleep tracking, then another 12 apps (7.64%) were excluded due to low usage and low rating during study period. Moreover, 21 apps (13.37%) did not meet the designed requirement values of APA-based statistical model of the study, finally 83 apps (52.86%) satisfied all the applications inclusion criteria, technical features of the study, and designed statistical model values.
Conclusions: Even though there are several hundreds of smartphones' sleep-tracking applications that were approved, this statistical and analytical study evaluates and examines the 24 content analysis and major technical features in 83 of the more recent with users' most highly rated apps in Apple and Google play stores with several advantages and beneficial features, including smart alarms and sleep aids. However, a review of apps that met the inclusion requirements revealed that sleep-tracking applications can utilize more improvements in technical features design and implementation, along with privacy for users' data sharing.

Keywords—*sleep analysis, sleep apps, sleep coaching, sleep monitoring, sleep quality, sleep statistics, sleep tracking, Smartphone applications.*

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I. Introduction

LEEPis a natural and biological need for humans that occupies between 20% and 40% of the day for humans [9], and it is extensively considered an influential factor leading to numerous health problems. For instance, sleep disorders such as short sleep duration, wakefulness, snoring, sleep apnea, parasomnias, and restless leg patterns [1]. In addition; sleep disturbance is widely spread and affects 33% - 45% of adults [2]. Furthermore, smartphones and applications tools have been prevalent and very common in popularity, with 92% ownership as first quarter of 2023 compared to only 35% in 2011 for instance [3]. As microelectronic sensors along with Artificial Intelligence (AI) technologies continuously evolving many smartphones' applications utilizing a built-in microelectronic sensor device to measure users' movements during their sleep called "accelerometer", then measured data can be used in an algorithm to estimate sleep time and sleep quality [6]. Hence, smartphone sleep-trackers have been developed as a self-management strategy for people with sleeping disorders. Apple Store and Google Play are the major mobile app stores in the world, they have over 3.61 million and 2.4 million apps, respectively [4]. This analytical study also found health behavior tracking such as activity and sleep are two digital devices' most widely tracked behaviors since global estimates of sleep show that sleep difficulties are reported by 15-43% of adults sampled, which addressing that poor sleep health is an international issue [5].

A study in 2021 [8] mentioned that; "sleep quality" is a measure of how well an individual can sleep which is considered a self-satisfaction with all aspects of the sleep experience which differs from "sleep quantity". Whereas; sleep quantity measures how much sleep an individual gets each night; both measures are important. According to study in [5] most healthy both male and female adults from age 20-to-45 years; need between seven and nine hours a night to wake up feeling well-rested, but it depends on exactly what happens during those hours regardless of any mental dysfunctions. Which means quality of sleep ensures to get the essential physical, mental, and emotional benefits [9]. However; sleep quality as an important measure in this study, it should be stated that there are five characteristics generally assessed to measure sleep quality which are; sleep latency, sleep waking, Wakefulness after sleep onset (WASO), and Total-Sleep-Time (TST) and Time-in-Bed (TiB) which are also crucial to calculate sleep efficiency [40]; all of which determine whether sleep quality is good or not, and therefore are taken to consideration of this study as supporting technical features and inclusion / exclusion criteria of sleep tracking apps under study.

A study conducted on 2022 [7] stated that; sleep tracking and management applications on a smartphone have been supported to help people with sleep disturbance to achieve better situations of sleep control and better sleep quality issues. With increased smartphones spread and power on a global scale; the term "Electronic Health" (eHealth) became one of the most interesting terms which is defined as "the ability of people to use emerging information and communications technologies to improve or enable health and healthcare" [12]. Furthermore, rapid and large-scale development in Mobile Health (mHealth) technologies allows users to self-monitor their sleep patterns, symptoms, and behavioral data and support them taking applicable conduct on a daily basis [7]. Most of the available sleep-tracking applications are accelerometer-based in which the decision to use raw-data accelerometers is motivated by the improved comparability of output across different sensor brands, and better control over all steps in data processing, which can employ built-in mobile detectors similar to microphones and light sensors to gain sleep data [41]. Sleep tracking apps use smartphones erected accelerometers to record and interpret sleep data each night [5]. These apps generally track movements during sleep, record sound, wake sleepers up during light stages of their sleep cycle and give perceptivity to help the user interpret the data [13]. Sleep apps are generally accessible, affordable, and salutary for the user overall sleep quality [7]. Furthermore; Sleep health application may be valuable for user self-management and improvement of sleep hygiene. In addition, they may help increase awareness and promote help seeking regarding sleep-related issues. However, the severe lack of validation studies raises concerns around their use and limits their function as alternatives to standard clinical tools. Moreover, assessment of available applications is necessary to guide physician recommendations of sleep tracker apps for patient use [13]. A study in [11] stated that mobile phone intervention could devaluate sleep diseases and ameliorate sleep quality. With a three-piece test set up by [11], the results show that 16 eligible studies were evaluated to examine the impact of mobile phone interventions on sleep disorders and sleep quality. These included one case study, three pre-post studies, and 12 randomized controlled trials. The studies were categorized as (1) conventional mobile phone support and (2) utilizing mobile phone apps. Based on the results of sleep outcome measurements, 88% (14/16) studies showed that mobile phone interventions have the capability to attenuate sleep disorders and to enhance sleep quality, regardless of intervention type. However, the utmost apps (almost 76%) cannot distinguish and record snoring noises from colorful disturbing noises in real-life situations.

II. Problem Statement and Objectives of the Study

A content analysis of smartphones applications must be performed and conducted based on the information available on the apps developers' websites along with written descriptions of sleep apps in the

Apple and Google Play stores, taken to consideration that any analysis study based only on these written descriptions will limit the study design that might entail purchasing, downloading, and using the sleep apps available. Therefore, the scope of this study aims to analyze the same information on the apps developers' websites and Apple – Google Play stores that are available to consumers when considering an app purchase. Also this study emphasizes 24 of the common technical features among the most recent smartphones sleep-tracking apps. In addition, the study conducts a comprehensive analysis designed utilizing a statistical model based on the American Psychiatric Association (APA) application evaluation model [20] which is used for the goal of evaluation process is to employ a hierarchical rating system and embedded rubric to familiarize APA members, patients, and other providers with important information upon any application selection, and how this differs from choosing more traditional therapeutic interventions, such evaluations include important considerations and choosing the correct app for a particular situation will hopefully result in better clinical decision-making, and improved patient outcomes. In conclusion this study aims to review and analyze Smartphones' (iOS and Android) sleep apps to explore their technical features and functionalities in order to find out about their effectiveness in tracking users' sleep activity utilizing classification of the 24 common technical features of most recent sleep-tracking apps, and using a statistical model based on the American Psychiatric Association (APA) Application evaluation model as inclusion / exclusion criteria. Therefore; for achieving the study main objective it is been a necessity to subdivide it into five specific objectives; Firstly, to thoroughly examine and explore smartphones' applications related to sleep more recently available on the Apple store and google play store. Secondly, to analyze the technical features and discover the more common sleep app features. Thirdly, to build a classification of features. Fourthly, to build a Statistical model based on American Psychiatric Association (APA) App evaluation model to determine and evaluate technical rating for using the sleep-tracking app. Finally, to promote the developers to design better sleep apps regarding technical features utilizing the new and evolving technologies in microelectronic sensors and software engineering.

III. METHODOLOGY AND STEPS

Apps selection and systematic Search criteria

This study focused on the most recent Apple iTunes and Android Google Play Stores for sleep related apps searching, as these are the most popular and used apps on smartphones during the period from February– to – end of June 2023 using the following keywords and search strings to find the applications: Smartphones sleep apps; sleep monitoring; sleep tracking; sleep analysis; sleep quality; sleep coaching; and sleep statistics. At this point, a total of 157 smartphone' applications that were available or recently deployed for public commercial level in app stores related to sleep tracking and monitoring during the study period were included. In this round, any smartphones' apps that weren't designed and deployed just for sleep related issues were excluded from the study. Apps belonging to the Apple iTunes and Android Google Play stores were identified, shared across both stores.

Applications Filtering and Technical Features extraction

In this step, all the included smartphones' applications from the previous step of apps searching and selection were double-checked for duplication in both iTunes and Google Play stores for any duplicated apps to be excluded. Furthermore, each smartphone sleep app was thoroughly examined either through the app store or the app developers' website to explore each technical feature provided by the app to the user/consumer and how it works to help the users. Through this level, a major 24 common technical features of the most recent sleep related apps became clear and can be easily classified by the author into five categories or dimensions representing the purpose of the examined sleep apps.

Apps Evaluation and Statistical Analysis

A statistical model was designed by the study author utilizing the American Psychiatric Association (APA) application evaluation model which is used for the goal of APA App Advisor's evaluation process is to employ a hierarchical rating system and embedded rubric so that APA members, patients, and other providers, become familiar with important information that should be considered when selecting an app, and how this differs from choosing more traditional therapeutic interventions [20]. Evaluations include important considerations and choosing the correct app for a particular situation will hopefully result in better clinical decision-making, and improved patient outcomes. The APA application evaluation-based statistical model is designed in this study to add more technical feature extraction methodology for selecting sleep-tracking apps from the two major stores (Apple and Google Play stores) as clarified in Multimedia Appendix 3 of this study. Each app was rated separately for its consistency with the designed statistical APA app evaluation-based model which includes 37 objective questions based on major five classes of consideration of evaluating an application: (1) Access and Background, (2) Privacy and Security, (3) Clinical Foundation, (4) Usability, and (5) Data Integration towards Therapeutic Goal. These characteristics were evaluated to gain a broader understanding of

the significant features of each app category in comparison against a control group [21] [24].

Applications Screening and Eligibility

Exclusion Criteria

As stated previously, a total of 157 apps related to sleep-tracking were firstly included in our study which took place during the period from February - to - end of June 2023 focusing on 24 major technical features of sleep-tracking apps brightened up through exploring information available on the apps stores and developers' websites, 32 apps (20.38%) were excluded from the study either due to irrelevant main implementation purpose or due to duplication, while another 9 apps (5.73%) were excluded for not supporting self-management sleep tracking, such as baby sleep tracking apps: baby feeding & sleep tracker, Baby sleep diary tracker, Baby Tracker, Huckleberry Sleep Baby Tracker, Little Winks Sleep Tracker, Baby sleep tracker, Baby tracker - feeding, sleep. Then another 12 apps (7.64%) were excluded due to low usage and low rating during study period, after that 21 apps (13.37%) did not meet the designed requirement values of the APA-based statistical model of the study. In the event of a duplication, we included the Apple Store app, as it had all the required information about the app including its date of release.

Inclusion Criteria

Each smartphone sleep-related application during the study period was thoroughly searched and examined by browsing through available information in both the Apple iTunes and Android Google Play stores and the app developers' websites. Data for each app was extracted and collected: app name, price, rating, number of reviews, author or developer name, technical features, and source (link to app webpage). Appendix 1 provides full details of our sample applications. After four phases of app filtering and examination process; begins with irrelevant main implementation purpose other than sleep-tracking and duplicated apps elimination (1st exclusion phase), then not supporting self-management sleep tracking apps elimination (2nd exclusion phase), after that low usage and low rating apps elimination during study period (3rd exclusion phase), and finally apps elimination for not achieving the designed requirement values of APA-based statistical model of the study (4th exclusion phase). Therefore, an aggregate of 83 (52.86%) sleep-tracking apps remaining to be thoroughly examined and analyzed. Figure 1 shows the flowchart of the app selection process emphasizing the inclusion and exclusion phases and criteria.

After the author researched all apps; technical features were determined and collected based on the most popular Apple iTunes and Android Google Play stores' sleep-related apps. Then all the components and gathered information about the technical features of the most recent sleep tracking apps were put in ascending order in one table. Similar goal-oriented technical features are linked and categorized together in one dimension or category that represents the purpose/ goal of the technical feature, and the technical categories or dimensions are highlighted and given a title. For example, the attribute "User can set the alarm for bedtime and wake up time" is under the heading (Notifications feature). All features have been grouped into categories, each representing a different purpose served by the app. Moreover, Parts and related apps were checked repeatedly by the author to assure that there is no lack of information gathering or technical feature grouping.

IV. RESULTS

Consumers' Statistics and Reviews

The information about users' ratings and commentaries were gathered and obtained from the smartphones app stores on a scale of 1 to 5. Whereas; 13 (8%) Apple iTunes store apps and 5 (3%) Android Google Play apps are not included in the ratings. For apps with available ratings, the average rating for Apple iTunes store apps was 4.7, and the average rating for Android Google Play apps was 4.3.

Extracted and Classified Technical Features of the Included Sleep-tracking Apps

After conducting an open statistical analysis as shown in Multimedia Appendix 2 for the descriptions of remaining included 83 applications; an aggregate of 24 technical features were extracted. Table 1 presents the main technical features, with the associated number and percentage of examined apps, and examples of applications that support these technical features, the table is arranged in a descending order. Furthermore, each technical feature is described in detail in the following sections.

TABLE I

MAIN TECHNICAL FEATURES OF THE INCLUDED APPS WITH EXAMPLES

Technical features (number of Technical features: m=24)	Number of Apps: (n=83), n (%)	Selected app example
1.Smart alarm	76 (91.56%)	**Alarm Sleep**
2.Sleep Coaching / Tips	61 (73.49%)	**Sleep Cycle**

3.Sleep Recording & Info representation	57 (68.67%)	**SleepScore**
4.Sleep sounds	56 (67.46%)	**Sleep sounds**
5.Timer	53 (63.85%)	**Cycle alarm timer**
6.Sleep duration	48 (57.83%)	**PrimeNap**
7.Sleep statistics	46 (55.42%)	**Sleep Analyser**
8.Stress Level Monitoring	44 (53.01%)	**SleepWell**
9.Sleep Efficiency (TST-to-TiB ratio)	43 (51.80%)	**Sleep Central**
10.Meditation	40 (48.19%)	**Meditation & Relaxation**
11.Accessibility & Exporting Data	39 (46.98%)	**Sleep++**
12.Music	37 (44.58%)	**Relaxing music sleep**
13.Natural sounds	35 (42.16%)	**Natural sounds**
14.Sleep stories	32 (38.55%)	**Sleepiest**
15.Light sleep	31 (37.35%)	**SleepScore**
16.Heart rate	30 (36.14%)	**Tracker sleep**
17.Deep sleep	30 (36.14%)	**Better sleep**
18.Sleep Note	28 (33.73%)	**Sleep theory-sleep better**
19.Bedtime reminder	25 (30.12%)	**Bedtime sleep**
20.Sleep talking record	22 (26.5%)	**Sleep recording**
21.Snoring	22 (26.5%)	**Snore Lab**
22.REM	21 (25.30%)	**REM: auto sleep tracker**
23.Breathing	21 (25.30%)	**Pillow**
24.Movement	20 (24.10%)	**Sleep Bot**

The first and most popular technical feature in our review is the Smart Alarm, developed in more than n= 76 (91.56%) applications. This feature allows waking up at a specific time and is sensitive to any sound and noise during sleep. The primary function of this feature is to wake people up from their deep sleep or nap, and it is sometimes used as a reminder. Allows the user to choose alarm ringtones and in some cases, can download music and set it as the alarm tone for waking up [13].The second most common technical feature is Sleep Coaching and/or Sleep Tips. It was developed in more than n= 61 (73.49%) applications. Sleep coaching apps can provide personalized tips and guidance to help you improve your sleep habits. These apps can track your sleep patterns, provide sleep-related education and offer customized sleep plans based on your goals and preferences. [44].The third most common technical feature is Sleep Recording & Info representation. It was developed in more than n= 57 (68.67%) applications. This feature allows the app to record sleep habits, sounds, and analytics and then represent them in a clear understandable tables and graphs [13].The fourth most popular technical feature is Sleep sounds feature, with n = 56 (67.46%) of applications. It carries several sounds, including nature, rain, and calm music. This feature works on good sleep and has been developed by several developers [13].The fifth common technical feature is the Timer feature, with n = 53 (63.85%) of the included applications. It measures the time of sleep start and time of waking-up and hence it helps measuring sleep duration [14]. The sixth common technical feature is Sleep duration, with n = 48 (57.83%) of the included apps. This intelligent feature determines the time you need to go to bed and the time you need to wake up, along with information on a regular and healthy sleep pattern [14].The Sleep statistics feature is supported, with n = 46 (55.42%) applications, it provides graphs for each night separately. It detects sleep stages and analyzes them comprehensively daily. This feature is based on the principle that sleep is not a one-track process but is instead a multiple wave consisting of peaks - which is a stage closer to awakening - and bottoms, which is the stage of deep sleep, and this process is repeated throughout the sleep period. It works by calculating these waves to find out the quality of sleep you got during the last night [13].Stress Level Monitoring feature is supported, with n = 44 (53.01%) applications, it provides a defined two different stress scores, the daily stress score estimating the acute stress level of the previous day and the long-term stress score, which is the accumulated stress over the last days and weeks and which estimates the chronic stress level of a person [43].Sleep Efficiency feature which is supported with n = 43 (51.80%) applications, it refers to the percentage of time a person sleeps, in relation to the amount of time a person spends in bed. The percentage is calculated by dividing Total-Sleep-Time (TST) by Time-in-Bed (TiB) (TST-to-TiB ratio). Normal sleep efficiency is considered to be 80% or greater. For example, if a person spends 8 hours in bed (from 10 p.m. to 6 a.m), at least 6.4 hours or more should be spent sleeping to achieve an 80% or greater sleep efficiency. Most healthy and young adults have sleep efficiencies above 90% [13]. The tenth common feature is Meditation, with n = 40 (48.19%) of apps. In practice, meditation before bed stimulates deep sleep and high-quality sleep. It helps in discovering new techniques and mechanisms aimed at relaxing and emptying the brain of all thoughts. Meditation before bed calms the body. Meditation helps generate the same physiological effects that occur in the early stages of sleep [15].Accessibility and

Exporting Data is also a common feature included in our study with n = 39 (46.98%) of the included apps. whereas sleep app ownership is increasing exponentially, due to their accessibility and ease-of-use. Moreover, sleep apps may increase engagement with healthcare professionals, which may place additional strain on under-pressure sleep services [14].Music, with n = 37 (44.57%), which are the attributes of a piece of music that can be used to describe and analyze it. Some familiar music features include melody, harmony, rhythm, timbre, and shape. Music features also have more specific characteristics, such as certain chord progressions, instruments, and rhythmic patterns, and these features can be used to classify and understand the different musical styles, genres, and emotions conveyed by the music. Music is a common self-strategy that many people use as an aid when they are having trouble sleeping [13].The Natural sounds feature is supported by the n = 35 (42.16%) of the applications, which are quiet or refined and monotonous sounds. The sounds of nature, such as sea waves or autumn leaves, simulate familiar sounds that give an atmosphere of relaxation. Inconvenience and distant sounds are confusing, so many sounds of nature rely on tinnitus masks to cover up tinnitus and any disturbing sounds, which was evident in a report by the American Tinnitus Association (ATA), which explained the importance of using white noise applications to get a reasonable premium. From sleeping [14].The Sleep stories feature is supported by the n = 32 (38.55%) applications. It stimulates creativity and develops imagination, and promotes psychological and emotional maturity to be able to sleep well. Improving communication skills and increasing focus and discipline are beneficial and healthy habits [14].The Light sleep, and Deep sleep features are supported by n = 31 (37.35%) and n = 30 (36.14%) respectively of the included apps. Light sleep is a tool that will help you adjust the brightness level on your smartphone screen to avoid damaging your eyes in situations where the lighting is not appropriate (e.g., when you are browsing your phone at night before going to sleep), which may help you sleep better [14].The Heart rate futures is supported by n= 30 (36.14%) apps. It analyzes heart and respiratory rate variance based on sleep movements to better understand your sleep behavior. You'll also get data based on your sleep patterns, the ratio of light sleep to the comforter [15].The Sleep Note feature is supported by n= 28 (33.73%) apps. It enables users to take notes and gives tips to overcome sleep disturbances. There are some examples of those tips that you can keep track of in Sleep Diary. The time you go to sleep, the time you sleep, it helps you review your daily habits [15].The Bedtime reminder feature is supported by n = 25 (30.12%) apps. This feature does not track your sleep quality in the main form. Still, it offers useful features, such as giving reminders before bedtime and automatically setting the alarm for you, and the ability to customize your sleep schedule on certain days of the week [15].The Sleep talking record feature is supported by n = 22 (26.50%) of the applications. It records annoying sounds only, puts them in different audio tracks and sorts them in a timetable for easy browsing, and saves them on the smartphone without needing continuous recording throughout your sleep. It automatically records when a sound occurs, thanks to intelligent technology that records exactly what you say while you are asleep and dreaming [13].The Snoring tracking feature is also supported by n = 22 (26.50%) of the applications. It enables you to analyze your sleep quality and detect if any problems impede your proper sleep. It only records snoring moments or disturbing sounds [13] [16].The Rapid-Eye-Movement (REM) feature is supported by n = 21 (25.30%) applications. Sleep tracking technology that is now generally available cannot accurately measure REM sleep, as researchers in sleep tracking laboratories measure sleep stages with more sophisticated scientific equipment that usually includes devices sensors attached to a person's face and neck; to measure eye and brain activity, and other scientific variables used in the measurement [13] [15].The Breathing feature is also supported by n = 21 (25.30%) of the applications. It helps to advise users and remind them of correct breathing methods. It also allows deep breathing exercises to get rid of sleep problems, in addition to straightforward lessons that teach the user about the benefits and importance of deep breathing [14] [15].The Movement feature is supported by n = 20 (24.10%) apps. It monitors sleep cycles in addition to monitoring your movement during the day [13].

As stated in a previous section, the major extracted 24 common technical features of the most recent sleep related apps became clear and can be easily classified by the author into five categories or dimensions representing the purpose of the examined sleep-related apps. Therefore, after feature extraction and analysis of all identified technical features (n = 24), as shown in Figure 3. These categories include; sleep cycle, notifications, sleep aids, vital signs and sleep disorders. The categories for each type contains a set of extracted technical features. The purpose is explained in the following section.

As shown in Figure 2. for the sleep cycle category, 6 of the 24 extracted technical features were found. The data generated from these apps helped their users improve healthy sleep habits. You view statistics of data collected about sleep in an app. The report includes total sleep time, number of awakenings in the night, and awake times. It also has a summary of your sleep stages. The technology also works to monitor sleep and record sounds made during sleep. It also determines sleep state to detect the time of falling asleep and waking up automatically and if the user is in a light sleep or a deep sleep. Detailed sleep data can be synchronized and displayed to give its users a peaceful sleep.

As for the notifications category, 6 of 24 technical features were found to be relevant. It, turn, periodically reminds you of information from certain specific apps. It enables users to set sleep reminders for a

custom time and also lets you perform more actions automatically when they are absorbed. It works with a timer, stopwatch, and ring reminders for bedtime and wake-up times.

As for sleep aid category, 6 of 24 technical features were found to be relevant. helping to reduce distractions and increase focus through meditation practice. Natural sounds help calm the mind, thus improving sleep patterns. Music and meditation produce more focus, better sleep, and less stress. It greatly facilitates the achievement of deep meditation, relaxation, and concentration. It also improves mental and physical health.

As for sleep disorders category, 4 of the 24 technical features were found to be relevant. The data generated from these apps helped their users change the way they sleep. And maintain their health by recording the moments of snoring and movement and placing them in different audio tracks, and sorting them in a timeline.

Finally, for vital signs category, 2 of the 24 technical features were found to be relevant. The data generated from these apps helped its users track measurements such as blood oxygen, heart rate, sleep time, and breathing rate. He analyzes them into a timeline that details sources of sleep disturbance, such as coughing, snoring, or sleep interruption by lighting.

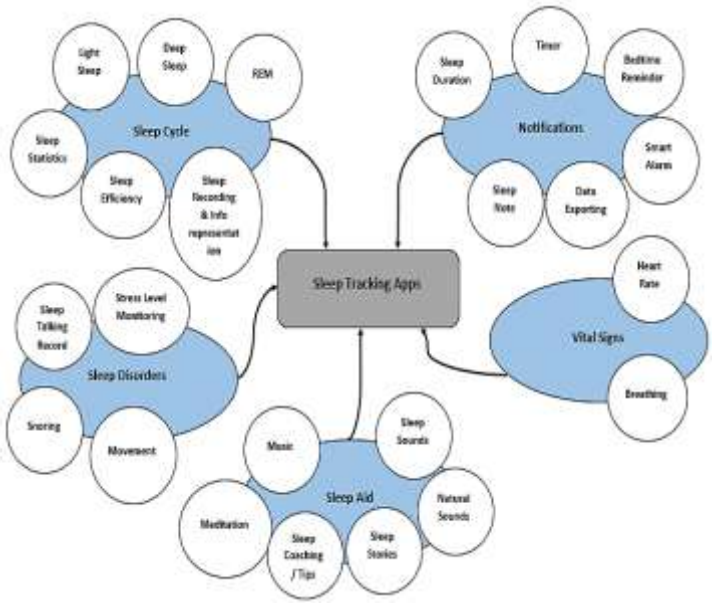

Fig. 2. Extracted Technical Features Classification into Categories representing applications' purposes.

V. IMPLEMENTATION OF STATISTICAL ANALYSIS BASED ON APA APPLICATION EVALUATION MODEL OF THE INCLUDED SLEEP-TRACKING APPS

a statistical model utilizing the American Psychiatric Association's (APA) application evaluation model has been implemented by the author to add more technical feature extraction methodology for selecting sleep-tracking apps from the two major Apple iTunes and Android Google Play stores. Each app was rated separately for its consistency with the designed statistical APA app evaluation-based model which includes 37 objective questions based on major five classes of consideration of evaluating an application: (1) Access and Background, (2) Privacy and Security, (3) Clinical Foundation, (4) Usability, and (5) Data Integration towards Therapeutic Goal. These characteristics were evaluated to gain a broader understanding of the significant features of each app category in comparison against a control group by sub-dividing each of the five major classes into sub-categories (objective questions) to furtherly evaluate each app functionality and consistency as an exclusion / inclusion criterion. Moreover, thorough clarification is shown in the Excel sheet designed the author in Multimedia Appendix 3 of this study. Table 2 below shows the five major classes of consideration and the related evaluation questions associated with each class based on the APA Application Evaluation model, along with the average (between 0 and 1) of each APA related question as an evaluation result, and the percentage of impact of each of the five classes of APA application evaluation model. The numeric data (answers for the sub-divided related questions of each major class) have been acquainted or retrieved either from the app developers' website or the Apple store and Google Play stores, and/or been statistically calculated from the data-sheets of the applications under study.

VI. DISCUSSION

Principal Findings and Statistical Results

This comprehensive statistical study shows that sleep-tracking smartphones apps differ in terms of the type of developer and background, major core 24 common technical features, purposes of use, privacy and security, accessibility, clinical foundation, and data integration towards therapeutic goal. This study reveals various apps developed by multiple developers and authors, and analyzes the most common technical features as sleep data, calculating vital signs such as heart rate and breathing, detecting sleep disorders, and working to improve sleep quality. With the pervasive nature of smartphones, the use of health-related apps, including sleep analysis apps, will increase [13]. Several studies have found that sleep is linked to several health outcomes, including mood and blood pressure [4][6].

This study has focused on sleep-tracking smartphones apps because they are accessible and inexpensive, making them more attractive to most people. Sleep apps have many features, but after analyzing them in the Apple iTunes and Android Google Play stores, we found that the most popular features are smart alarms, sleep coaching, sleep sounds, and Timers. One major attraction for users when downloading sleep apps is the smart alarm, which reportedly wakes the user at the optimal time [13]. smart alarm feature in 76 apps helps users wake up, refresh and invigorate in the morning at the perfect sleep cycle (light stage). Several "smart alarms" assume that sleep cycles are 90 minutes long.

Sleep quality and quantity are important factors for measuring sleep. Sleep tracking apps can collect data to measure the quality and quantity of users' sleep. Detection of sleep disorders is one of the crucial functions offered by mobile applications; conditions in the early stage are much easier to treat than those later [2]. As the result of this study show in Table 1. the sleep Duration feature in 48 apps, which tracks the sleep cycle by listening to sounds and analyses those sounds with the help of ever-evolving machine learning algorithms, presents the results and helps users to understand sleep with unique data analysis and graphs. Progressing multiple times through the sleep cycle, composed of four separate sleep stages, is vital to getting high-quality sleep. Understanding the sleep cycle helps to explain certain sleep disorders which can impact a person's sleep and health [14]. In stage 1 (Light Sleep): the brain slows down, the body has some muscle tone, and breathing is regular. Stage 2 (Light Sleep): heart rate and body temperature both decrease. Stage 3 (Deep Sleep): brain waves at this stage, called delta waves, are at their slowest of the night. REM sleep feature in 21 apps; during REM sleep, brain activity is similar to awake, with loss of muscle tone except for the eyes, which move rapidly, breathing irregularly, and heart rate speed up [15]. This study found no correlation between the polysomnogram findings and the sleep apps under study such as Sleep Cycle, Sleep Score, Pillow concerning sleep efficiency, light sleep percentage, deep sleep percentage, or sleep latency. Some smartphone meditation apps can help users measure sleep quality [2], [3]. The meditation feature in 40 apps in study results enables users to relieve stress, and meditation before bed stimulates deep sleep and high-quality sleep since it helps discover new techniques and mechanisms to relax and empty the brain of all thoughts [20].There were 22 of the included apps in this study record snoring during users' sleep. These apps use the smartphone's built-in microphone to register during the night. Recording snoring during sleep may benefit clinicians examining patients who don't know about chronic snoring. Habitual snoring is an increased risk factor for CVD and may indicate obstructive sleep apnea. Although the apps are not intended for screening, their use in identifying snoring in specific populations could be helpful [13]. Nevertheless, 28 apps in this study can record sleep notes about sleep quality, any reasons for difficulty falling asleep, habits that may affect sleep, such as drinking coffee, eating late or exercising at night, and mood upon waking. Take brief notes about sleep, then discover how these factors affect sleep quality. Sleep doctors recommend using a sleep diary to collect information about a patient's sleep patterns. This is particularly critical for patients with hypersomnia due to poor sleep hygiene, insomnia, circadian disturbances, or phase shift [13]. Moreover, this study has revealed that a percentage of 66.11% of the total 83 included apps achieve accessibility and trusted background sources regarding the Accessibility and Background class of consideration in the APA application evaluation model, while 80.87% of the included apps achieve Privacy and Security section of the APA application evaluation model. Moreover, a percentage of 97.25% is achieved by the study included apps in the class of Clinical Foundation of the APA application evaluation model, and a percentage of 100% is achieved by the study included apps in the class of Usability in the APA application evaluation model. Finally, a percentage of 95.33% is achieved by the study included apps in the last Data Integration towards Therapeutic Goal class of APA application evaluation model.

Limitations

While 83 apps were included and analyzed in this study, it is possible that some apps that met the inclusion criteria were missed. Our research study for health apps related to sleep tracking was limited to the

major app stores Apple iTunes and Android Google Play. However, these stores are the largest global platforms for app distribution. Furthermore, the quality of these apps was not examined and rated Mobile apps also collect and manage users' sleep data, so data privacy becomes a common concern. In addition, this study did not explore the specific written reviews of users; only the star ratings were provided without taking the written user comments into account it is unclear what factored into users' ratings. For instance, a user may have enjoyed the content of an app but experienced a technical fault and therefore decided to give the app a lower rating. Last, we did not directly explore the aesthetics or marketing of sleep apps in the Google Play store and Apple App Store, and future research should explore how these factors influence use of particular apps over others. The apps were not downloaded, thus more potential information regarding the app may be missing. Finally, short battery life is also a limitation of sleep apps, especially those that fit small sensors.

Comparison with Prior Work

This statistical study has collected and analyzed recent smartphones apps in the two major app stores (Apple iTunes and Android Google Play store) in the period from February – to- end of June 2023. During the study period the author has focused on the most common technical features regarding sleep tracking apps which have been found to be 24 technical features, then a thorough statistical analysis is conducted by the author to determine the importance, impact, and frequency of these technical features in sleep-tracking apps during the recent time of the study. Exclusion and inclusion criteria of included apps have been designed by the author concerning the technical features been analyzed, the irrelevancy of app main implementation purpose (other than sleep-tracking), low star-rating or usage of apps in the developer's website, and duplication of apps from the same developer with similar features. Moreover, this study designed and conducted a specific and accurate content and review statistical analysis of the included apps based on the American Psychiatric Association (APA) application's evaluation model classes of consideration and related questions, all information has been collected and reviewed from the apps developers' websites.

VII. CONCLUSION

In conclusion, smartphones are an integral part of today's society specially with continuous growth of AI, Programming, and microelectronic sensors technologies; leading to sleep-tracking applications have become very popular and easy to use. This analytical study only searched the two major app stores, the Apple iTunes and Android Google Play stores for sleep related apps as these stores considered the world's largest platforms for app distribution. Technology has increased awareness of sleep and its effects on health and functional outcomes, and mobile apps have become a popular tool for delivering sleep therapies. However, there is little evidence that the information provided by these apps is correct to support their usefulness. Multiple developers have developed sleep apps to measure and analyze sleep data, calculate vital signs, and detect sleep disorders. This study evaluated 83 apps and found that sleep-wake detection is unreliable enough to evaluate sleep efficiency and sleep quality since only 14 apps of 83 apps under study (16.86%) used sleep-wake detection technical feature, compared to sleep mapping feature which is used in most of the apps under study (72 apps – 86.75%). The most popular aspects of sleep apps are intelligent alarms, sleep sounds, and timers. Apps that monitor sleep can collect information about users' sleep patterns, including their duration and quality, and provide services such as detecting sleep disorders. Although 83 apps were examined for this study, some of them likely met the requirements for inclusion. Users' sleep data is collected and managed by mobile apps as well, so data privacy becomes a common issue. In addition, only star ratings were provided in this search; No specific written user reviews have been screened. It is unclear what influenced user ratings without considering written user comments. For example, a user may have liked the app's content but had a technical problem, so he gave the app a lower rating.

Finally, this study designed and conducted a specific and accurate content and review statistical analysis of the included smartphones applications based on the American Psychiatric Association (APA) application's evaluation model classes of consideration and related questions. Future studies should investigate how these factors influence the use of certain apps over others. We did not specifically examine the aesthetics or marketing of sleep apps in the Google Play Store or the Apple App Store. As the apps are not downloaded, more details may not be available. Sleeping apps should undergo a rigorous validation study and give more autonomy to their users over how their data is shared.

Based on this study we found that most apps include intelligent alarm clock function and sleep recording function, but sleep-related physiological signal recording function accounts for a small proportion; that is the reason this study strongly recommends the app developers to focus and improve sleep-related physiological signal recording function in most of their apps through utilizing sensors, AI, and machine learning new and advancing technologies.

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