REVIEW ARTICLE

Smartphones and Consumer Devices in Management of Obstructive Sleep Apnea

Kamaldeep Singh[1], Arpit Jain[2], Ishita Panchal[3], Hritik Madan[4], Salil Chaturvedi[5], Anastas Kostojchin[6], Ambreen Shahzadi[7], Muzammil M Khan[8], Shobhit Piplani[9]

Received on: 04 November 2022; *Accepted on:* 02 January 2023; *Published on:* 29 April 2023

Abstract

Aim: To review various consumer-level technologies for management and continuing case of obstructive sleep apnea (OSA) patients.

Background: Recent advancements in wearable and smartphone technology have created new ways to assess sleep health, including OSA. Obstructive sleep apnea leads to continuous upper airway obstruction during sleep, producing episodes of apnea–hypopnea, sleep fragmentation, nonrestorative sleep, and excessive daytime somnolence, leading to long-term cardiopulmonary complications. This review sheds light on the use of modern smartphone-based sleep-tracking applications and consumer devices in the management of OSA.

Results: Rapid advancements in mHealth technologies have enabled users to self-monitor and visualize their sleeping patterns, symptoms, and behavioral data, enabling them to take everyday precautions. Various available options include plethysmography, actigraphy, pulse-oximetry, ambulatory ECG recorders, body temperature sensors, sound analysis, and cardiorespiratory coupling.

Conclusion: Due to limitations in precision and standards, such tools may not be recommended for clinical populations or as diagnostic tools. Future research should focus on analyzing the effect of these interventions on persons who already have good sleep quality or who use the applications but skip days. In addition, comprehensive studies measuring behavioral changes in various age, gender, and comorbidity groups are warranted.

Clinical significance: While technological aids help in better management, it is vital to develop efficient methods for integrating wearables' data into patient-care pathways. Restrictive IT infrastructures, privacy, data protection, and data ownership arguments prevent widespread integration of consumer wearables into clinical workflows.

Keywords: Obstructive sleep apnea, Review, Sleep medicine, Smartphone, Telemonitoring, Wearable sleep technology.

Indian Journal of Sleep Medicine (2022): 10.5005/jp-journals-10069-0108

Background

A minimum of 10% of the average public suffers from obstructive sleep apnea (OSA), a major and widespread health issue, yet many people with mild-to-severe conditions go misdiagnosed.[1] Obstructive sleep apnea is extremely common in adults (14% in men and 5% in women), especially with mild–moderate severity, and is growing more common as a result of rising obesity rates in industrialized countries.[2] Global estimates of prevalence put it at 1 billion, with figures of the population in broad prevalence in some nations topping 50%.[3] This offers a diagnostic issue because the currently recommended test, nightly polysomnography (PSG) in a sleep laboratory, is labor- and financially intensive.[4] Continuous upper airway obstruction (UAO) during sleep, which causes bouts of apnea and hypopnea and causes sleep fragmentation, nonrestorative sleep, and excessive daytime somnolence (EDS), is what contributes to OSA.[1] Intermittent hypoxia (IH) is brought on by the interruption of airflow and is considered a primary pathogenic mechanism for the negative sequelae of OSA,[1] including cardiovascular issues and mortality rates.[5] With the help of cutting-edge technology, deeper data may be obtained from more complex algorithms and systems.

The evaluation of anomalies in sleep patterns in medical settings has been benefited by technology. The gold standard for identifying sleep disturbances in many diseases is PSG, which records the biophysiological aspects of sleep, such as brain signals, eye movements, muscle movement, and heartbeat.[6] Polysomnography is not generally accessible or practical for most patients, though. Recent developments in wearable technology and mobile software have opened up new avenues for psychiatric symptom tracking and intervention, as well as for the evaluation of sleep patterns.[7] A person's everyday routine does not include prior technology like PSG or actigraphy, but cell phones are common

[1]Department of Cardiology, Government Medical College and Hospital, Chandigarh, Haryana, India

[2]Department of Emergency Medicine, All India Institute of Medical Sciences, Delhi, India

[3]Department of Medicine, Jawaharlal Nehru Medical College, Belagavi, Karnataka, India

[4]Department of Medicine, Adesh Medical College and Hospital, Ambala, Haryana, India

[5,8,9]Department of Medicine, Albert Einstein College of Medicine, Jacobi Medical Center, Bronx, New York, United States of America

[6,7]Department of Medicine, Icahn School of Medicine at Mount Sinai, Bronx, New York, United States of America

Corresponding Author: Arpit Jain, Department of Emergency Medicine, All India Institute of Medical Sciences, Delhi, India, Phone: +91 9999685429, e-mail: dr.arpitjain@protonmail.com

How to cite this article: Singh K, Jain A, Panchal I, *et al*. Smartphones and Consumer Devices in Management of Obstructive Sleep Apnea. Indian J Sleep Med 2022;17(4):103–107.

Source of support: Nil

Conflict of interest: None

and can open up new options to measure activities without being intrusive.[8] In addition, cell phones provide built-in sensors (such as an accelerometer and a microphone) that make it easier to collect data, creating innovative options for passively monitoring patients in their natural environments. Smartphones have become more frequently used in research recently to measure subjects' behavior in realistic scenarios. Much of the existing literature has concentrated on assessing various aspects of sleep in the general population, including sleep onset and wake-up times, sleep midpoint and length, interruptions, chronotype, and activity rhythms.[9] This review aims to determine the utilization of novel smartphone-based sleep-tracking applications in the diagnosis and management of OSA. Such an avenue may open new doors to managing this condition and providing timely treatment as well as better data tracking.

Results

Sleep Tracking by Smart Wearable Devices

"Smart" wearable gadgets are useful because they do not involve particular consumer activities and quietly gather information over days or longer using a small number of sensors that are directly incorporated into a gadget worn on the wrist or finger.[10] Actigraphy and photoplethysmography are both performed using a variety of sensors and software-based pattern recognition. These techniques help gather data on movement and heart rate, from which secondary information, such as heartbeat variability and breathing regulation of the pulse amplitude, can be extracted. Some of these data streams have been utilized to perform sleep staging using proprietary algorithms without relying on the gold standard EEG. These data streams are used to predict sleep–wake cycle times. It makes sense that wakefulness can be determined by movement sensing. While REM sleep is frequently accompanied by more erratic heart rates and deep sleep by prominent respiratory sinus arrhythmia, the amount and consistency of pulse rate fluctuations help distinguish between light and deep non-REM sleep.[11] The incorporation of skin temperature readings seems to enhance the ability to detect the start of sleep.[12] Although these surrogate measures are correlated with several EEG-based sleep metrics, the accuracy varies depending on the parameter (for example, REM vs. light sleep), and person-specific factors can also affect misclassification (e.g., underlying psychiatric variations, mobility difficulties, and sleep disturbances). As a result, to make the best use of metrics from these devices, it is crucial to fully comprehend their meaning and prediction power. In some circumstances, this may also imply using population-specific thresholds to establish normal values (e.g., the proportion of N3 time or sleep length on average). In other instances, some measurements could show to be ineffective at forecasting disease risk or impairment. On the other hand, in some situations, such measurements might show to be superior to the current clinical instruments. It may be possible to produce new predictive data for cardiac events by focusing on heart rate measures that capture autonomic cardiac regulation, which is typically ignored in current professionally performed sleep studies, for example, and using data gathered over extended periods.[13] Consumer wearable technology could be a useful supplement to sleep evaluation instruments. Wearables are multimodal gadgets with an accelerometer and a heart monitor, and they are sometimes referred to as sleep trackers. They fall under the category of actigraphy since they graphically and chronologically capture human action. The data gathered can be interpreted using a variety of potential algorithms to reveal information on sleep function. Since they involve less effort from participants, these devices have demonstrated more adherence than questionnaires in their goal to be impartial in their measurement.[14] They are considerably cheaper than PSG and enable the daily gathering of information on a more accurate ecological environment, ignoring the first inversion of the purchase, which is rapidly dropping as the market expands.[15,16]

In previously conducted research, participants evaluated components of the applications' potential to influence behavior after using them. These included perceptions of a change in behavior as well as awareness, knowledge, attitudes, and an intention to change. The majority of participants said the applications helped spread awareness and information about good sleep hygiene. In addition, they thought that using sleep monitors might encourage people to take action to solve their sleep issues, such as consulting doctors. Participants generally concurred that the usage of sleep trackers may influence sleep hygiene either favorably or unfavorably. Despite the paucity of data about app-related behavioral change, a prior study discovered that the app "Sleep Cycle" was useful in raising awareness of children's sleep issues.[17]

To diagnose OSA, Tseng et al.'s Android Application employed 17 decision rules taken from the Microsoft Decision Trees algorithm.[18] In addition, the suggested application can recommend a referral to a medical service. The authors introduced a smart adjustable cushion for actual OSA diagnosis. The smartphone receives the SpO_2 signal from the pillow, which is connected to a pulse oximeter for sensing it. The smart pillow then receives an adjustment command from the smartphone based on the patient's condition.[19] A full IoT-based PSG for the house was introduced by Lin et al.[20] A wireless multifunctional recorder, which is battery operated, compact, and transportable, is the main component of the suggested system. Bluetooth® technology is used to link the tiny recorder to a Java virtual machine on a computer. The biosignals that were captured are sent through this link to a Java-based PSG recording application, which then converts them into European data format. Following the experiment, the suggested system demonstrated its dependability and practical application. The creators then pioneered the "DeepQ Tricorder", an innovation that allowed for OSA diagnosis at home.[21]

Validity of Wearable Devices

Wearable technology has many potential uses, but it is still a commercial product that was created by nonmedical individuals. Depending on the algorithm utilized, their interpretation varies greatly, and they exhibit precision problems. According to several studies, wearables have not yet attained sufficient psychometric qualities, discouraging their usage in therapeutic settings. In a recent policy statement on consumer sleep technology, the American Academy of Sleep Medicine emphasizes the necessity for these devices to be validated before being used in clinical settings.[22] The majority of wearable device validation studies conducted in the past used healthy individuals. Before using wearable technology in healthcare, it must first be validated in clinical populations because the diagnosis may be less reliable when there are sleep disorders and other illnesses present. Only a few studies have included patients with sleep problems in their sample, mainly in pediatric populations. The first wearable device validation study in individuals with sleep apnea has just been published in academic journals.[23] A parallel exaggeration of total sleep time (TST) and a high sensitivity at the cost of specificity were documented in earlier Fitbit device validation trials.[24]

For instance, a 2017 study indicated that the Fitbit Flex device's accuracy was significantly worse in individuals with sleeplessness compared to good sleepers. A later investigation discovered that the Jawbone device's overall accuracy in assessing sleep in those with suspected central hypersomnolence was poor.[25] The goal of the study was to assess how well two sleep trackers – Withings Pulse O_2 (W) and Jawbone Up (U) – measure various aspects of sleep in people with OSA.[23] Every patient who had their OSA examined in the sleep lab received overnight PSG. Polysomnography was used in conjunction with two consumer-level sleep monitors (U and W) and one actigraph [Bodymedia SenseWear Pro Armband (SWA)], totaling three devices. Out of 36 patients who underwent evaluation, 22 (17 men) had OSA (mean apnea–hypopnea index: 37 ± 23/h). Actigraph (SWA) and sleep tracker (U and W) single comparisons were conducted. In comparison to PSG, SWA equally accurately measured TST, and wake after sleep onset (WASO), while U and W accurately assessed time in bed (TIB) and light sleep. With the exception of WASO as determined by SWA, intraclass correlations showed low validity for all metrics and devices. It is probable that as more readings are taken, the accuracy of sleep monitors improves. The PSG must be completed in a hospital setting, so it is challenging to evaluate sleep over a period of multiple nights. Contrarily, doing this is simple with wearable technology. Future research should examine if the accuracy of these tools improves with time. If that is the situation, wearable technology may be employed to continuously monitor sleep with acceptable accuracy.[4]

Integrating Information from Wearables into Clinical Settings

It is necessary to find efficient ways to integrate wearables' data on sleep into patient care pathways while also empowering patients to participate in data collecting.[10] An illustration of how sleep-tracking metrics continuously acquired by smart wearable gadgets may eventually enter the clinical setting is the extensive use of heart rate and rhythm monitoring by many mobile applications in the cardiology setting.[10] The majority of heart rate and rhythm assessment applications were initially created for consumer-initiated self-tracking of health and lifestyle but quickly found their way into the professional setting, similar to how sleep evaluation applications were. Recent updates to the practical advice for using electronic devices for arrhythmias, from timely identification to management and clinical application, have been made available to cardiology associations. The definition of practical clinical scenarios and the incorporation of meaningful information in treatment pathways discovered in the field of cardiology should also be taken into account. Other difficulties include the incorporation of actionable information in diagnosis pathways learned in the field of sleep medicine. Multiple specialties may present unique difficulties in the sleep use case. The application of digital technologies, cloud-based analysis, and data exchange has the potential to lessen the fragmentation of the healthcare system.[10]

Consumer wearables cannot yet be widely integrated into clinical processes due to several factors, including rigid IT infrastructures, privacy concerns, data protection worries, and continuous debates about data ownership. Large amounts of information for health professionals, unauthorized recordings, and recordings sent outside of business hours can further add to the burden and create legal ambiguity. In addition, wearables and associated software that promote or maintain a healthy lifestyle without having anything to do with the identification, mitigation, treatment, or prevention of a disease or illness are not regarded as medical devices. Although the FDA does not presently oversee these devices, new organizations other than professional associations may be required to guarantee that the interests of the public are addressed.[10]

Discussion

Self-management apps for smartphones have been recommended as a way of assisting persons with sleep disturbances to improve their level of sleep control and outcomes related to sleep quality. Quick development in mHealth technologies has made it possible for users to self-monitor and envision their sleeping habits, symptoms, and behavioral data and help them take appropriate measures on a potentially daily basis.[26] This is made possible by an increase in mobile smartphone ownership on a global scale. The majority of the currently accessible sleep tracking apps are accelerometer-based and can collect sleep data using mobile built-in sensors like accelerometers, microphones, and ambient light detectors. However, mobile accelerometer functions using arbitrary and variable algorithms, unlike the accelerometry employed in conventional sleep assessment instruments (such as actigraphy). Getting little sleep has negative effects on one's health,[27] but most adults do not follow the suggested sleeping habits. Users of mobile phone technology can monitor their actions, think back on them, and self-evaluate their performance in relation to goals of healthy behavior or adherence to a treatment plan.[24]

Individuals who used digital healthcare apps seemed to have good short-term effects and better healthcare experiences, according to a Chinese survey conducted in 2018.[28] Sleep apps are among the most popular mobile health applications. According to a survey, sleep apps are highly popular and frequently used in China, with the most popular app collecting more than 8000 comments. It was observed that usability and functionality had a substantial impact on app popularity. People liked multipurpose apps that could play the music that would help them go asleep, provide knowledge about sleep, and act as a smart alarm clock to assist them to wake up at the right time. Some apps allowed users to speak with a doctor for advice. This is the mobile health apps' most preferred feature, per an online survey. However, the study found no correlation between functionality and usability and the scientific domain. This implies that multifunctional apps were not necessarily superior to other apps.[29] Researchers are focusing on refining algorithms, enhancing device design, and integrating numerous devices to increase diagnostic effectiveness to boost sleep monitoring apps. It has been hypothesized that portable monitoring could speed up diagnosis and track the results of OSA treatment.[22–24]

Wearables' ability to provide multiple-night recordings at a reasonable cost and in natural settings is one of their key advantages. Numerous studies have shown that a single-night PSG causes a 20–50% misdiagnosis of the diagnosis of sleep apnea. Data from several nights will lessen misclassification brought on by nonrepresentative sleep on a single night and enable tracking of environmental and health changes to be taken into consideration, thereby improving health outcomes on a wide scale. When night-to-night fluctuation is described, triggers or circumstances that affect OSA severity can be found. If the wearable device's measurement errors are random and unrelated to the signal, multiple-night recordings might also significantly minimize measurement inaccuracies by increasing the signal-to-noise ratio.

Clinical Significance

The collaboration between technology developers and healthcare providers is essential. The accuracy of sleep detection is influenced by numerous nonclinical factors. The software that processes the data is as crucial as the precision of the sensors. In addition, the algorithms utilized can have a significant impact on how raw data is interpreted.[10] The proprietary algorithms used by Fitbit wearables and other commercial sleep trackers are not disclosed by the maker, nor is it possible to examine the device's raw data. Notably, one of the biggest problems came up when attempting to apply the ideas of gentle and profound sleep to the three sleep stages identified by PSG. The use of this system in both clinical and research settings would be significantly enhanced by a wearable device model that is more in line with accepted evaluation techniques and hence better suited to deliver directly comparable results. Sleep trackers have generally gotten better over time, and as technology advances, they should become more dependable. New possibilities for the identification and treatment of numerous illnesses are being made possible through e-health. Different physiological functions can be evaluated using commercially available activity monitors, and tracking is one of the most clinically applicable uses.

Sleep health applications might not be advised for use in clinical populations or as diagnostic tools due to limits in accuracy and dependability.[10] Sleep tracking applications were used by participants in the existing literature to learn more about the amount and quality of sleep that is advised. Our future work should also focus on directly assessing the changes in sleep habits, and how those applications affect people who already have high sleep quality or individuals who use the apps but skip certain days. A thorough investigation that measures the behavioral changes caused by apps among various age and gender groups as well as patients with several common ailments is also necessary to maximize usability across various cohorts.

Although mobile technology has great potential for delivering health interventions, we are still learning a lot about sleep tracking. Future studies are required to better encourage people who are at risk for health problems, such as those who have been diagnosed with chronic conditions or who have poor overall health, to think about using mobile-based solutions for documenting, analyzing, and optimizing their sleep health. Smartwatches can capture information on the length, types, and qualities of your sleep. Self-care and self-monitoring may be on the rise, even as doctors may see their patients' sleeping patterns at home. Caretakers can even identify sleep apnea if they combine this technology with digital oxygen saturation. These details might help identify the symptoms earlier. In addition, it also assists managing care of physical ailments by understanding their own health.

Acknowledgments

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors have no conflicts of interest to declare.

Orcid

Kamaldeep Singh https://orcid.org/0000-0003-0933-6996
Arpit Jain https://orcid.org/0000-0001-7625-1189
Hritik Madan https://orcid.org/0000-0003-2773-7160
Muzammil M Khan https://orcid.org/0000-0003-1324-3637
Shobhit Piplani https://orcid.org/0000-0002-8920-7280

References

1. O'Mahony AM, Garvey JF, McNicholas WT. Technologic advances in the assessment and management of obstructive sleep apnoea beyond the apnoea-hypopnoea index: A narrative review. J Thorac Dis 2020;12(9):5020–5038. DOI: 10.21037/jtd-sleep-2020-003.
2. Franklin KA, Lindberg E. Obstructive sleep apnea is a common disorder in the population – A review on the epidemiology of sleep apnea. J Thorac Dis 2015;7(8):1311–1322. DOI: 10.3978/j.issn.2072-1439.2015.06.11.
3. Benjafield AV, Ayas NT, Eastwood PR, et al. Estimation of the global prevalence and burden of obstructive sleep apnoea: A literature-based analysis. Lancet Respir Med 2019;7(8):687–698. DOI: 10.1016/S2213-2600(19)30198-5.
4. Kapur VK, Auckley DH, Chowdhuri S, et al. Clinical practice guideline for diagnostic testing for adult obstructive sleep apnea: An American Academy of Sleep Medicine Clinical Practice Guideline. J Clin Sleep Med 2017;13(3):479–504. DOI: 10.5664/jcsm.6506.
5. Lam JCM, Mak JCW, Ip MSM. Obesity, obstructive sleep apnoea and metabolic syndrome. Respirology 2012;17(2):223–236. DOI: 10.1111/j.1440-1843.2011.02081.x.
6. Baglioni C, Nanovska S, Regen W, et al. Sleep and mental disorders: A meta-analysis of polysomnographic research. Psychol Bull 2016;142(9):969–990. DOI: 10.1037/bul0000053.
7. Torous J, Keshavan M. A new window into psychosis: The rise digital phenotyping, smartphone assessment, and mobile monitoring. Schizophr Res 2018;197:67–68. DOI: 10.1016/j.schres.2018.01.005.
8. U.S. Smartphone Use in 2015. Pew Research Center. https://www.pewresearch.org/internet/2015/04/01/us-smartphone-use-in-2015/ (accessed 05.09.2022).
9. Aledavood T, Lehmann S, Saramäki J. Social network differences of chronotypes identified from mobile phone data. EPJ Data Sci 2018;7(1):46. DOI: 10.1140/epjds/s13688-018-0174-4.
10. Baumert M, Cowie MR, Redline S, et al. Sleep characterization with smart wearable devices: A call for standardization and consensus recommendations. Sleep 2022. DOI: 10.1093/sleep/zsac183.
11. Stein PK, Pu Y. Heart rate variability, sleep and sleep disorders. Sleep Med Rev 2012;16(1):47–66. DOI: 10.1016/j.smrv.2011.02.005.
12. Altini M, Kinnunen H. The promise of sleep: A multi-sensor approach for accurate sleep stage detection using the oura ring. Sensors (Basel) 2021;21(13):4302. DOI: 10.3390/s21134302.
13. Zhang L, Wu H, Zhang X, et al. Sleep heart rate variability assists the automatic prediction of long-term cardiovascular outcomes. Sleep Med 2020;67:217–224. DOI: 10.1016/j.sleep.2019.11.1259.
14. Moreno-Pino F, Porras-Segovia A, López-Esteban P, et al. Validation of fitbit charge 2 and fitbit alta HR against polysomnography for assessing sleep in adults with obstructive sleep apnea. J Clin Sleep Med 2019;15(11):1645–1653. DOI: 10.5664/jcsm.8032.
15. Ibáñez V, Silva J, Cauli O. A survey on sleep assessment methods. PeerJ 2018;6:e4849. DOI: 10.7717/peerj.4849.
16. Dunn J, Runge R, Snyder M. Wearables and the medical revolution. Per Med 2018;15(5):429–448. DOI: 10.2217/pme-2018-0044.
17. Patel P, Kim JY, Brooks LJ. Accuracy of a smartphone application in estimating sleep in children. Sleep Breath 2017;21(2):505–511. DOI: 10.1007/s11325-016-1425-x.
18. Tseng MH, Hsu HC, Chang CC, et al. Development of an intelligent app for obstructive sleep apnea prediction on android Smartphone using data mining approach. In: Proceedings of the IEEE 9th International Conference on Ubiquitous Intelligence and Computing and 9th

International Conference on Autonomic and Trusted Computing; 2012. pp. 774–779. DOI: 10.1109/UIC-ATC.2012.89.

19. Zhang J, Zhang Q, Wang Y, et al. A real-time auto-adjustable smart pillow system for sleep apnea detection and treatment. In: Proceedings of the 12th International Conference on Information Processing in Sensor Networks–IPSN ’13, ACM Press; 2013. p. 179. DOI: 10.1145/2461381.2461405.
20. Lin CT, Prasad M, Chung CH, et al. IoT-based wireless polysomnography intelligent system for sleep monitoring. IEEE Access 2018;6:405–414. DOI: 10.1109/ACCESS.2017.2765702.
21. Chang EY, Wu MH, Tang KFT, et al. Artificial Intelligence in XPRIZE DeepQ Tricorder. In: Proceedings of the 2nd International Workshop on Multimedia for Personal Health and Health Care. ACM; 2017. pp. 11–18. DOI: 10.1145/3132635.3132637.
22. Khosla S, Deak MC, Gault D, et al. Consumer sleep technology: An American Academy of Sleep Medicine Position Statement. J Clin Sleep Med 2018;14(05):877–880. DOI: 10.5664/jcsm.7128.
23. Gruwez A, Bruyneel AV, Bruyneel M. The validity of two commercially-available sleep trackers and actigraphy for assessment of sleep parameters in obstructive sleep apnea patients. PLoS One 2019;14(1):e0210569. DOI: 10.1371/journal.pone.0210569.
24. Mantua J, Gravel N, Spencer RMC. Reliability of sleep measures from four personal health monitoring devices compared to research-based actigraphy and polysomnography. Sensors (Basel) 2016;16(5):646. DOI: 10.3390/s16050646.
25. Kang SG, Kang JM, Ko KP, et al. Validity of a commercial wearable sleep tracker in adult insomnia disorder patients and good sleepers. J Psychosom Res 2017;97:38–44. DOI: 10.1016/j.jpsychores.2017.03.009.
26. Choi YK, Demiris G, Lin SY, et al. Smartphone applications to support sleep self-management: Review and evaluation. J Clin Sleep Med 2018;14(10):1783–1790. DOI: 10.5664/jcsm.7396.
27. St-Onge MP, Grandner MA, Brown D, et al. Sleep duration and quality: Impact on lifestyle behaviors and cardiometabolic health: A scientific statement from the American Heart Association. Circulation 2016;134(18):e367–e386. DOI: 10.1161/CIR.0000000000000444.
28. Lu C, Hu Y, Xie J, et al. The use of mobile health applications to improve patient experience: Cross-sectional study in Chinese public hospitals. JMIR Mhealth Uhealth 2018;6(5):e126. DOI: 10.2196/mhealth.9145.
29. Li H, Zhang T, Chi H, et al. Mobile health in China: Current status and future development. Asian J Psychiatry 2014;10:101–104. DOI: 10.1016/j.ajp.2014.06.003.