The Impact of Portable Smart Terminals (PTS) on the Sleep Quality of 18- to 25-Year-Olds During the COVID-19 Pandemic, and the Effect of Walking on the Improvement of Sleep Quality

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| **Article Info** |  | **ABSTRACT** |
| ***Article history:***  Received month dd, yyyy  Revised month dd, yyyy  Accepted month dd, yyyy |  | In order to reduce the risk of contracting COVID-19, people go out less or even stay at home, the use of PST by teenagers has increased, and physical activity has decreased significantly. Hence, this article is dedicated to studying the impact of PST on young people’s sleep quality and the effect of walking on improving sleep quality during the COVID-19 pandemic. A survey was conducted on the daily walking steps, sleep quality, and the use of PST among 312 ordinary young people aged 18-25. The control group (156 people) kept their original lifestyle, while the experimental group (156 people) walked 10,000 steps a day for 30 days. The outcome of this study found that during the COVID-19 outbreak, 88% of respondents used PST for more than 4 hours. The detection rate of sleep disorders among adolescents accounted for 39% of the total respondents. Compared with the control group, the sleep duration and sleep quality of the adolescents in the exercise group were significantly improved (P<0.05). In conclusion, during the COVID-19 pandemic, the more time young people spend on PST daily, the less time they spend on physical activities and the worse their sleep quality. Appropriately increasing the number of walking steps can reduce the adverse effects of PST and help improve the sleep quality of adolescents. |
| ***Keywords:***  COVID-19 Pandemic  Portable Smart Terminal  Walking  Sleep Quality  Young Adults |
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1. **INTRODUCTION**

During the COVID-19 pandemic, in order to reduce the risk of virus infection, people reduced leaving their homes. Additionally, the use of PST by teenagers increased during this time [1]. Overall, intelligent terminal refers to the built-in computer system equipment, which comprises of both hardware and software. However, "PST" refers to all portable devices such as smart phones, tablet computers, handheld computers, mobile audio-visual equipment, etc. These days, there is noticeable addiction among young people towards PST which could gradually ruin their physical health and deteriorate their physical function. Especially young people aged 18 to 25 years old who are in the process of adolescence/ adulthood transition are more vulnerable to gain weight and decline in physical function. Thus, individual health behavioral patterns developed during this transition often persist into later life, potentially influencing themselves, their partners and/or their children lifestyle. Generally, 18 to 25-year-olds are chosen due to the immense amount of time spent on PST [2].

Furthermore, it is noteworthy that sleep quality is one of the key indicators when evaluating quality of life and a person’s physical and mental health [3]. Accordingly, poor sleep quality is proven to negatively affect the health and academic achievements of young people [4]. Therefore, physical activities are recognized to result in various benefits to people's health and overall well-being [5], yet so, most young people do not reap its benefits due to inadequate physical activities [6]. On the whole, the lack of physical activities is the known risk factor for non-communicable diseases among young people [7]. Thus, the “10,000 Steps” campaign initiated by the government provides a clear and prescriptive idea concerning the required daily physical activity 'dose’ [8]. Though, the lockdown period during the COVID-19 pandemic had a negative impact on physical activity levels among the young people [9]. The 10,000 Steps program which is practical and fun could change people’s sedentary lifestyle and improve their health [10].

At present, there is sufficient evidence concerning screen time surveys among teenagers during the COVID-19 pandemic in the United States, Germany, Canada, Spain, Italy, and India [1], [2], [9], [11], [12], [13]. These researches on the effect of physical activity towards sleep quality has been relatively sufficient [14], [15]. Focusing in on China which is the most populous country in the world, it has been one of most affected countries due to COVID-19. Therefore, this study investigated the screen time, physical activity level, and sleep quality of young Chinese people aged 18-25 during the COVID-19 pandemic. Based on this, the impact of PST on the physical activity and sleep quality of young people was discussed, and further suggestions for improving the sleep quality of young people were put forward. It is of great significance for the improvement of young people's lifestyle and the promotion of their health.

1. **LITERATURE REVIEW**

Statistics estimate that globally PST has 3.484 billion active users and who spend an average of nearly 136 minutes on PST [16]. Such prolific PST usage and its subsequent effect on human lives are being progressively scrutinized on academia and the mainstream media. Researchers are mainly focusing on the bad effect of PST usage [17] towards individual health and psyche [18].

Additionally, the association between extreme or problematic PST usage and sleep-related issues are one such individual-level concern that has drawn attention over the last five years or so. Such interest can be attributed to scholars' recognition that the gradual integration of PST into human lives has led to the blurring of boundaries between daytime and nocturnal PST usage [19], [20], especially within periods of sleep latency. Past studies deduced that such nocturnal PST usage can have detrimental effects on individuals' health and well-being, especially during the Covid-19 pandemic [21].

Furthermore, [22] posit that the inclusion of walking exercise may substantially increase individuals' sleep period. They also implied that tiredness from physical labour or exercise may further shorten the onset of sleep. Moreover, the prolonged absence of walking or any exercise for that matter are postulated to be adversely linked with weakened cognitive processes, for instance, poor academic performance [23] and reduced daytime functioning [24], [25]. Thus, prior literature also suggests that without walking exercises various physiological issues may arise especially during the Covid-19 Pandemic, such as obesity, and indicators of mental illness, such as anxiety, depression, or low self-esteem [26].

Ultimately, previous research has suggested that the nighttime use of PST has adverse effects on sleep and may result in the development of sleep-related problems [19], [25]. Exceeded sleep time, psychological arousal, and impeded production of the hormone melatonin are among the three major negative association between nocturnal PST usage and sleep [27]. Similarly, [22], [28], [29], 30] and [31] posit that the offset of the sleep period because of nocturnal PST usage may significantly shorten a persons' sleep time. They also suggested that sleep deprivation can lead to various damaging health effects on young people, be it physically, emotionally, or mentally.

1. **METHODS AND MATERIALS**

**3.1. Research Subjects**

From February to March 2020, 398 volunteers were recruited in Xiangtan City, Hunan Province, China. Among the 398 volunteers, 86 were not able to participate in the experiment because they were unable (n=35), busy (n=23), could not be contacted (n=17), and on medication (n=6), suffering from diseases (n=4), or physically disabled (n=3). Overall, 312 young people were selected for the research, they comprised of 164 males and 148 females, with an average age of 21.47±1.30 years old. Baseline data were obtained through questionnaires and the Pittsburgh Sleep Quality Index (PSQI) scale was used to assess their sleep quality [32]. The research met the requirements of the university’s ethics committee (approval code: 202001243). Also, all participants voluntarily participated in the experiment and have signed an informed consent letter.

**3.2. Study Design**

The application timing software records the participants’ usage of PST. In addition, the Huawei Band 3 Pro recorded the levels of all participants’ daily walking and sleep related indicators (total sleep duration, deep sleep time, etc.) for 30 days. The values are averaged to measure their daily PST usage, physical activity and sleep conditions. After 30 days, a stratified sampling method was utilised to measure sleep duration and sleep quality index. The 312 participants were divided into two groups, 156 participants were placed in the experimental group and the other 156 participants in the control group. There was no significant difference (P>0.05) of sleep duration and sleep quality index between the two groups before the experiment. The control group maintained the original lifestyle, while the experimental group walked 10,000 steps per day under the guidance of professionals for 30 days. All participants used PST daily, had their daily average number of steps walked tracked and their sleep related indicators recorded. After the experiment, PSQI scale was used to reassess their sleep quality.Additionally, IBM SPSS Statistics 25.0 was utilised for statistics analysis, Independent Samples T Test for Inter-group comparison, Paired-Samples T Test for fore-and-aft comparison and Spearman's correlation coefficient for correlated analysis(α=0.05).

**3.3. Test Index**

**3.3.1. Duration of Use on PST**

In order to record the daily PST usage of participants precisely, a professional application timing software was utilised to record their use of PST, which is more reliable than the traditional questionnaire [33]. Also, to scientifically measure participants’ daily use of PST, the data for 30 consecutive days was collected and averaged.

* + 1. **Physical Activities and Sleep Duration**

To obtain accurate data pertaining participants’ daily physical activity and sleep, the commercially available wearable device, Huawei Band 3 Pro was used to track their daily steps and their daily sleep related indicators (the total length of sleep, deep sleep duration, etc.). The device adopts HUAWEI TruSleepTM 2.0 scientific sleep technology which was developed in collaboration with the Centre for Dynamical Biomarkers (CDB) of Harvard Medical School to monitor overall sleep conditions more accurately. Additionally, the built-in low-power-consuming independent GPS accurately records walking steps, calories consumption and walk trajectory. Therefore, it can accurately record the participants’ daily walk and sleep related data. Hence, it is recommended that commercial wearable devices be integrated into future research on young adults [34].

* + 1. **Sleep Quality Assessment**

PSQI was devised in 1989 by Dr. Buysse, a psychiatrist at the University of Pittsburgh. The PSQI is the gold standard questionnaire for assessing subjective sleep quality and has been validated in both clinical and non-clinical populations [35], [36]. There is evidence that the PSQI scale is also applicable for the evaluation of Chinese people’s sleep quality [37]. Thus, PSQI was used to assess the sleep quality of participants during the COVID-19 pandemic. Overall, the Cronbach’s alpha for internal consistency of this questionnaire was determined to be 0.872 [38]. It consists of 19 self-evaluation and 5 preceptor-evaluation items, among which the 19th self-evaluation item and 5 preceptor-evaluation items are not taken into scoring. Also, there are 7 components for the 18 scored items and each component is scored on a scale of 0 to 3. The scores of each component are accumulated and portrayed as the total PSQI score, ranging from 0 to 21. The higher the score, the worse the sleep quality. Whereby, if the total score is higher than or equals to 8, it means the sleep quality is poor. If the score is between 4 and 7, the sleep quality is medium. However, if the score is less than or equals to 3, it’s considered to be good sleep quality [39].

1. **RESULTS AND DISCUSSION**

At present, when PSTs are rapidly developing and is highly popular, they become an indispensable part of today’s young adults (18 to 25 years old). Also, because PST has evolved from a basic communication function to a device that replaces the computer. Young adults used PSTs for a long period of time and frequently [40]. Thus, it is evident that the vast majority of young people on average use PST for more than 4 hours per day and accounts for 88.14% of the participants. However, during the COVID-19 pandemic, 20.20% of them use PST for more than 8 hours per day (Table 1). Calculated via the 24 hours a day measure, almost all the young adults’ free time is occupied by PST, with exception for sleeping, eating, working or studying. Therefore, the lack of physical activity gradually affects the physical and mental health of young adults.

Commonly, to adopt a safe, practical and effective way of exercising, walking has proven to be most suitable for all people [41]. However, in recent years, due to the rapid developments of PST, young adults are focused on the prolonged usage of PSTs which ultimately leads to lesser physical activities and a decline in overall physical fitness [42]. Thus, according to [43], it is believed that 10,000 steps per day can maintain an ideal level of health and fitness. Moreover, based on the findings of this study, during the COVID-19 pandemic, most 18 to 25-year-olds on average walked only 2000 to 6000 steps per day, this statistic is accounted by 67.63% of all participants. Yet, only 2.88% of all 18 to 25-year-old participants attained an average daily walking of 10,000 steps, and sadly, 10.90 % participants walked lesser than 2000 steps per day (Table 1), indicating that their daily physical activities were seriously insufficient.

On the whole, sleep is a spontaneous and reversible resting state of the higher vertebrate in a cycle. It is manifested via a decrease in the body's responsiveness to external stimuli and a temporary interruption of consciousness. It is noteworthy that humans spend about one-third of their life in sleep. Therefore, humans are always in an alternating state of awake and asleep, which is one of our biological rhythms. Generally, sleep plays the role of eliminating fatigue, protecting the brain, enhancing immunity, promoting growth, delaying aging and balancing the mental state [44], [45], [46], [47]. Therefore, poor sleep quality (too little or too much sleep) has been proven as a risk factor for obesity, diabetes, cardiovascular disease, depression and mortality [48], [49]. Hence, the National Sleep Foundation recommends that young adults sleep 9 hours a night to achieve optimal health and development [50]. However, the results of this study show that during the COVID-19 pandemic, most young adults (18 to 25-year-olds) sleep on average about 4 to 6 hours a day. But only 5.45% of 18 to 25-year-olds sleep for 8 hours, and about 12.50% young adults sleep for lesser than 4 hours a day (Table 1).Since sleep is of much importance to young adults' learning, memory, and performance; adequate sleep can strengthen the immune system, which helps fight infection. Based on a previous study, male young adults who slept ≥8.5 hours had the lowest average depression/anxiety risk. Nonetheless, shorter sleep duration among young adults is related to increased depression and suicidal intentions [51]. Thus, poor sleep quality may be one of the causes of psychological problems such as anxiety and depression in young adults.

Furthermore, previous studies have shown that deep sleep is particularly important throughout the sleep cycle [52]. Whereby, during deep sleep, human cerebral cortical cells are in a state of full rest, which plays an extremely important role in stabilizing the mood, balancing mental health and restoring energy [53], [54]. Table 1 shows that the young adults (18 to 25 years old) with daily deep sleep of only 2 to 3 hours accounted to 46.47% of all participants. Only 17.95% of the participants attained deep sleep for more than 3 hours (Table 1). It shows that young people (18 to 25 years old) with short deep sleep hours cannot effectively restore their physical condition. It often manifests as daytime sleepiness, which is not conducive to normal learning [55]. Additionally, since PSTs emit light in the blue spectrum, it results in a reduction in melatonin secretion, which subsequently reduces deep sleep, or creates difficulty to enter a deep sleep state and has non-restorative sleep [56], [57]. At the same time, studies have shown that the use of PST may lead to reverse stimulation of sleep preparation [58]. Therefore, for 18 to 25-year-olds, reducing the use of PST before going to bed may be one important way to promote good sleep.

Besides, based on PSQI, if the total score is larger than or equal to 8, the sleep quality is poor. If between 4 and 7, the sleep quality is medium (more than 5 means problematic sleep, which requires clinical detection) [39]. If the score is lesser than or equals to 3, it is considered as good sleep quality. The higher the total PSQI score, the lower the sleep quality level and the more obvious the sleep problem. The results show that only 1.60% of the young adults (18 to 25-year-olds)' PSQI score was below 3 while those with scores of more than 5 accounted for 84.61% of the total participants. Their sleep disorder (score≧8) detection rate was 39.10% (Table 1). [59] believes that sleep dysfunction brings more problems, for more people who do not realize that poor sleep quality has a complex relationship with overall physical health, including many mutual interactions among neurological, physiological, psychological and behavioural factors. Thus, if no treatment is attained for sleep disorders, it can essentially be life-threatening [59]. Additionally, sleep disorders are associated with neurocognitive dysfunction, including attention deficits, impaired cognitive ability, depression, anxiety, stress and poor impulsive control, which leads to reduced physical activity and poor academic performance [60].

Table 1. Description of the usage time, physical activity, sleep duration and sleep quality of young people's portable smart terminals(n=312)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | Number | Percentage (%) | Mean ± SD |
| Daily Time Spent on Portable Intelligent Terminals | |  |  | 7.63±4.14 |
|  | Below 2 hours | 9 | 2.88 |  |
|  | 2 – 4 hours | 28 | 8.97 |  |
|  | 4 – 6 hours | 103 | 33.01 |  |
|  | 6 – 8 hours | 109 | 34.94 |  |
|  | 8 – 10 hours | 50 | 16.03 |  |
|  | Above 10 hours | 13 | 4.17 |  |
| Walking (Steps) |  |  |  | 6536.08±1423.29 |
|  | Below 2000 | 34 | 10.90 |  |
|  | 2000 – 4000 | 116 | 37.18 |  |
|  | 4000 – 6000 | 95 | 30.45 |  |
|  | 6000 – 8000 | 39 | 12.50 |  |
|  | 8000 – 10000 | 19 | 6.09 |  |
|  | Above 10000 | 9 | 2.88 |  |
| Sleep Duration |  |  |  | 7.29±3.16 |
|  | Below 4 hours | 39 | 12.5 |  |
|  | 4 – 6 hours | 176 | 56.41 |  |
|  | 6 – 8 hours | 80 | 25.64 |  |
|  | 8 – 10 hours | 14 | 4.49 |  |
|  | Above 10 hours | 3 | 0.96 |  |
| Deep Sleep Duration |  |  |  | 2.32±1.03 |
|  | Below 30 minutes | 9 | 2.88 |  |
|  | 30 – 60 minutes | 27 | 8.65 |  |
|  | 1 – 2 hours | 75 | 24.04 |  |
|  | 2 – 3 hours | 145 | 46.47 |  |
|  | 3 – 4 hours | 50 | 16.03 |  |
|  | Above 4 hours | 6 | 1.92 |  |
| Overall PSQI score |  |  |  | 6.86±2.32 |
|  | Below 3 | 5 | 1.60 |  |
|  | 4 – 5 | 43 | 13.78 |  |
|  | 6 – 7 | 142 | 45.51 |  |
|  | Above 8 | 122 | 39.10 |  |

Table 2 shows that the length of PST usage among 18 to 25-year-olds is negatively correlated with their sleep duration; whereby, the longer the PST usage, the shorter the sleep length. Thus, the average daily walking duration for the young adults was positively correlated with the average sleep duration, with a correlation coefficient of 0.84, p<0.05. These findings show that the higher the average steps walked, the longer the average daily sleep length. Thus, the amount of average daily walking is one of the effective indicators for daily physical activity. Also, walking increases energy consumption, which increases fatigue, and makes them fall asleep fast and sleep longer.

Furthermore, the length of PST usage among young adults is positively correlated with the sleep quality index. This shows that the longer the usage of PST, the higher the sleep quality index. It indicates that the use of PST among young adults has a bad influence on sleep quality. Additionally, the longer they use PST, the worse their sleep quality turns out. One possible reason is that the PST owned by most 18 to 25-year-olds are mainly smart phones or tablet computers. Therefore, only a few young adults have portable smart wearable devices. Also, most of the young adults use smartphones and tablet computers to increase their screen time, which leads to a decrease in their overall physical activity level and affect their sleep quality.

On the other hand, most young adults aged 18 to 25 must do intense work or study during the day and are relatively free only at night. Therefore, 9:00-11:00 pm is a relatively peak period for young people to use PST. However, the use of PST can lead to increased excitement in the sympathetic nervous system of young adults, which in turn affects time for sleep and quality [61]. Overall, the results of this study identified that the average number of steps for 18 to 25-year-olds was negatively correlated with the PSQI, r=-0.97, p≦0.01 (Table2). Also, walking promotes young adults’ energy consumption, which increases the fatigue of their body, reduces sympathetic excitability, increases parasympathetic excitability, reduces the secretion of thyroxine, adrenaline and norepinephrine, and increases serotonin secretion, which help the body to fall into the state of sleep. Therefore, the more steps young people take each day, the lower the sleep quality index and the better the sleep quality. In summary, the impact of PST on sleep quality may be produced through the mediating effect of physical activity.

Table 2. Correlations among usage time of portable smart terminals, walking volume and sleep quality (n=312)

|  |  |  |
| --- | --- | --- |
|  | Sleep Duration (hour) | Sleep Quality Index |
| Length of Use of Portable Intelligent Terminals (hour) | - 0.92\* | 0.87\* |
| Walk Amount (step) | 0.84\* | - 0.97\*\* |

Note : \*: P <0.05; \*\*: P <0.01

The participants were divided into two groups: control group (n = 156) and experimental group (n = 156). Young adults in the control group kept their original lifestyle unchanged, whereas the young adults in the experimental group exercised no less than 10,000 steps a day under the guidance of professionals. Therefore, the average sleep time of young people in the experimental group was 7.29 ± 3.16 hours before exercise and 8.26 ± 3.38 hours after exercise (Table 3). The sleep length of 18 to 25-year-olds walking 10,000 steps per day increased significantly compared with their sleep length before exercise. This shows that the walking of 10,000 steps daily can effectively increase the sleep duration of these young adults. Also, compared with the control group, the sleep length of participants in the experimental group after doing exercise significantly increased (p<0.05), indicating that walking had a great impact on the sleep duration of 18 to 25-year-olds (Table 3). Thus, it is established that appropriate walking can promote the consumption of energy, generate appropriate fatigue, help to fall asleep, and improve sleep duration.

Eventually, under strict control of other conditions, for participants who walked 10,000 steps daily, their sleep quality index decreased significantly compared with that before exercise (p<0.01), Also, compared with the control group, the sleep quality index of the experimental group was significantly lesser (p<0.01), indicating that 10,000 steps per day can effectively improve the sleep quality of young adults (Table 3). Ultimately, after about 1 month of walking exercise, the self-control of young adults had improved and their dependence on PST had significantly reduced. It is proven by the phenomenon of going to bed early, falling asleep fast, sleeping well, and feeling spirited after waking up.

Table 3. Comparative analysis of daily sleep duration and sleep quality indicators after 30 days of walking for in adolescents (Mean ± SD)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Groups | N | Before the Experiment | After the Experiment |
| Daily sleep duration (hour) | Control group | 156 | 7.31 ± 3.17 | 7.18 ± 2.96 |
| Experimental group | 156 | 7.28 ± 3.14 | 8.26 ± 3.38 \*# |
| Sleep Quality Index | Control group | 156 | 6.85 ± 2.30 | 6.74 ± 3.41 |
| Experimental group | 156 | 6.87 ± 2.31 | 5.93 ± 2.03 \*\*## |

Note : Values are (Mean ± SD); \*: Significant difference compared to the control group, p<0.05; \*\*: Significant and large difference compared to the control group, p<0.01; #: Significant difference compared to pre-experimental data, p<0.05; ##: Significant and large difference compared to pre-experimental data, p<0.01.

1. **CONCLUSION**

Conclusively, the daily 10,000-step exercise recommended does help young adults fall asleep and improve their sleep length and quality. Especially during the COVID-19 pandemic, most young people used PST for more than 4 hours a day and their average daily walks were relatively low. Therefore, the longer the usage of PST, the shorter the sleep time and the inferior the sleep quality. This may be related to two factors: one is the use of a PST before going to bed, which will increase central excitability and decrease melatonin secretion, resulting in bad sleep quality. The second is the mediating effect of physical activity, whereby the increase in PST usage will reduce physical activity, thereby affecting the quality of sleep. Hence, this study suggests that young adults should reduce PST usage and increase their physical activity time. These initiatives will help young adults fall asleep, increase the total length of sleep and deep sleep, and improve the quality of sleep.

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