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A. Green, Y. Dagan & A. Haim

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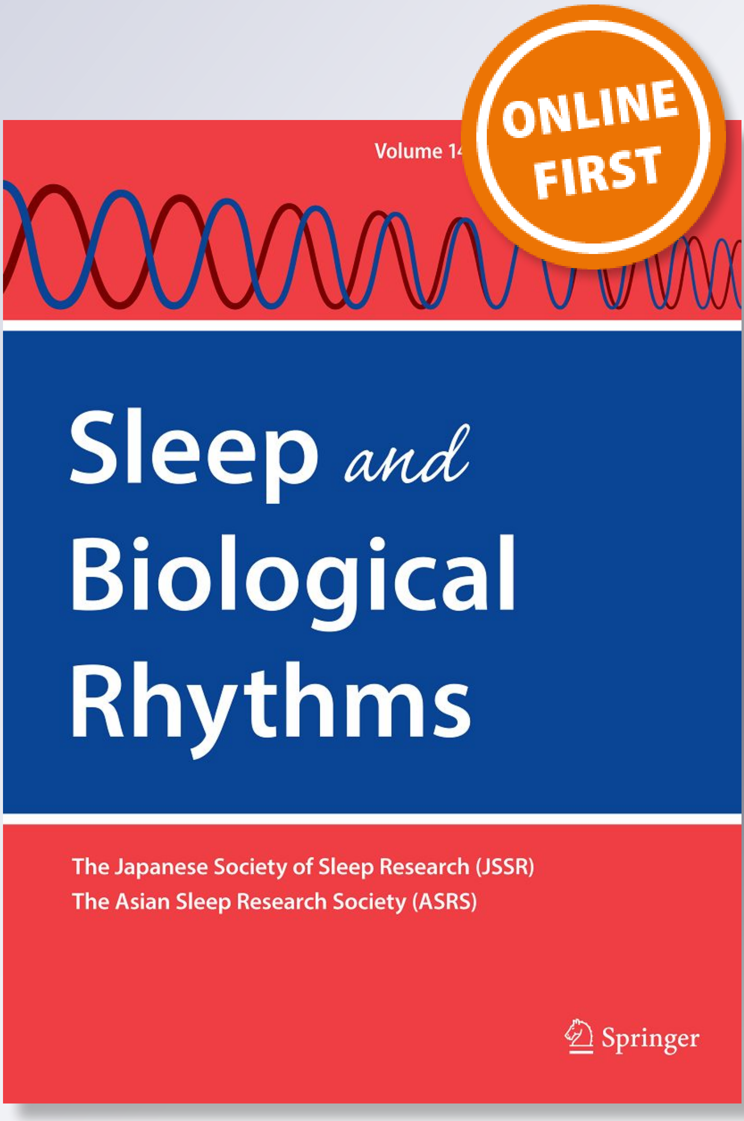

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ORIGINAL ARTICLE

Exposure to screens of digital media devices, sleep, and concentration abilities in a sample of Israel adults

A. Green[1,2] · Y. Dagan[1,2,3,4] · A. Haim[1]

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Abstract

A major consequence of the invasion of digital media devices with screens equipped with light-emitting diode (LED) into bedrooms exposes the users to ongoing short wavelength (SWL) lighting during the evening and at night when under natural conditions, long wavelength are dominant. Results of several studies reveal a negative physiological, behavioral, and functional outcome of the exposure to SWL artificial light at night (ALAN) from digital media screens. The aims of our study are to assess the relationships between digital media usage, sleep patterns, subjective sleepiness, and attention abilities in adult Israeli citizens compared with Israeli adolescents. We recruited 280 adult participants using convenience sample method, 49% males and 51% females with an age range of 18–82. The participants filled out self-reporting novel and original questionnaires as follows: demographic, general health evaluation, sleep habits, and difficulties by the Pittsburgh Sleep Quality Index (PSQI) and the Karolinska Sleepiness Scale (KSS), prevalence, and usage patterns of digital media devices. Smartphones are the most used digital media device in the evening and after bedtime (the time one gets to sleep in bed). Israeli adults used smartphones for 30 min and TV for about 15 min after bedtime. We noted that excessive exposure to these devices at nighttime was associated with longer sleep latency ($r=0.192$, $p<0.01$) and decreased sleep hours ($r=-0.143$, $p<0.05$). Moreover, we found a negative correlation between attention abilities in the morning and the usage time of digital media at nighttime ($r=-0.155$, $p<0.01$). Exposure to digital screens at evening and nighttime was positively correlated with subjective sleepiness on the KSS ($r=0.135$, $p<0.05$, and $r=0.261$, $p<0.01$). To the best of our knowledge, this study is the first to explore the association between digital media screens usage, sleep, and concentration abilities in the Israeli adult.

Keywords Digital screen · Sleepiness · Concentration · Smartphone · Israel · Adult

Introduction

The last decade witnessed a dramatic growth in the availability and affordability of digital media devices such as televisions, desktop and laptop computers, tablets, video gaming consoles, and smartphones. These electronic devices have become more portable, multi-functional, and useful for various everyday tasks, such as communication, reading, writing, working, playing, entertainment, and social media. In the "2011 Sleep in America" poll, 97% of the participants reported that they had at least one electronic media device in their bedroom [1]. These findings are not exclusive to the American population; surveys from other countries report similar habits of having digital media in the bedroom, among both adults and adolescents [2–6]. Moreover, the usage duration of these devices has been increasing rapidly, especially in the evening and at night shortly before the onset of sleep. Overall, 90% of the "2011 Sleep in America" participants reported using a digital media device in their bedroom in the hour before sleep [1]. The use of digital media devices close to sleep time is very concerning. Several studies in the past few years have reported the negative effects of exposure to screens of digital media devices on sleep. It was noted that

✉ A. Green
amitg@assuta.co.il

1 The Israeli Center for Interdisciplinary Research in Chronobiology, University of Haifa Mount Carmel, 3498838 Haifa, Israel

2 The Sleep and Fatigue Institute, Assuta Medical Center, 96 Yigal Alon Street, 67891 Tel Aviv, Israel

3 The Research Institute of Applied Chronobiology, The Academic College of Tel-Hai, 1220800 Tel Hai, Israel

4 The Department of Human Biology, University of Haifa, Mount Carmel, 3498838 Haifa, Israel

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they decrease sleep efficiency, sleep time, and deep slow wave sleep (SWS) and rapid eye movement (REM) sleep, and increase sleep latency and wakening after sleep onset (WASO) [7–10].

A major consequence of the invasion of digital media devices equipped with light-emitting diode (LED) screens into bedrooms is the exposure of users to ongoing short wavelength (SWL) light emitted from digital screens in the evening and at night, while SWL lighting is the environmental signal for daytime to our biological clock. Results of several studies reported on negative physiological outcomes of the exposure to artificial light at night (ALAN) from digital media screens. Light from electronic screen devices can alter melatonin (MLT) secretion [7, 11, 12], thermoregulation [13]. It can also have an impact on sleep physiology and sleepiness measures [7, 13, 14], cognitive performance [15], and mood [16].

Studies carried out mainly among children and adolescents, tested the relationship between digital media watching screen habits, sleep and its health consequences. From the results of these studies, it was noted that in both tested population, increased exposure time to digital screens in the evening and at night is associated with increased reports of sleep problems. The reports included decreased sleep time, decreased sleep efficiency, and increased sleep onset latency [2, 17–21]. At present, only one study has explored this association in Israeli adolescents. Shochat et al. [6] reported poor sleep quality patterns related to excessive digital media usage and daytime sleep-related problems. Fewer studies worldwide have examined such relationships in adult populations [8, 22, 23], and similar research has not yet examined Israeli adults.

The aims of this survey are to assess the relationships between exposure to screens of digital media devices, sleep patterns, and daily function such as subjective sleepiness and attention abilities in adult Israel population. Recent studies carried out in sleep laboratories revealed major differences in physiological, sleep architecture, sleep efficiency, and cognitive variables after exposure to light emitted from computer screens at evening and nighttime [7, 9, 15]. We assumed that we would find similar effects in the Israeli adult population. We explore the differences and similarities of the use of digital screen devices and sleep in adult Israelis compared with Israeli adolescents. We hypothesized that we would find: (1) positive associations between exposure time to digital media screens in the evening and at night accompanied by sleep difficulties; (2) positive correlation between exposure time to digital media screens in the evening and at night associated with subjective sleepiness and concentration difficulties; and (3) differences between weekdays and weekend days in the pattern of usage of digital devices.

Methods

Participants

Participants included 280 adults, 137 males (49%) and 143 females (51%), with an age range of 18–82 (mean ± SD, 37.0 ± 14.3). Marital status: married (47%) or single (43%), and (5%) were divorced, in a relationship (4%), or widowed (1%). The majority of the participants had an academic education (55%), one-third graduated high school (33%), and the rest were either professional (11%) or had an elementary school education (2%). Almost all the participants were employed (91%), and the rest (9%) were either pensioners or unemployed. Only 14% of the participants reported that they worked night shifts. All of the participants were Hebrew-speaking residents of the state of Israel. We sampled participants in universities and shopping centers from the north and center parts of Israel. We controlled the sample to get a similar proportion of age and gender values to the general population. Participants completed the questionnaires in the presence of a research assistant. The response rate to the survey was 93%. The institutional ethical review board at the University of Haifa approved the study.

Measured variables

We used the following self-reporting questionnaires: demographic, general health, sleep patterns and difficulties, as well as prevalence and exposure patterns to digital media screens.

1. *Demographic* We asked the participants to report their age, gender, family status, education, and employment status including shift work.
2. *General health* The subjective general health evaluation was measured with the question "Please rate how do you assess your health condition?" on a five-point Likert scale with numbers and a description: 1 = "not good," 2 = "fine," 3 = "good," 4 = "very good," and 5 = "excellent." We asked the participants to report chronic sickness, prescription and non-prescription medications, height and weight, visual and sight condition ("Do you wear glasses? Do you suffer from cataracts?"). To measure their concentration and attention, we asked them to evaluate their level of concentration in the morning ("Please rate your level of concentration in the morning.") on a nine-point Likert scale. All of the numbers have valid point values, but only the odd numbers have descriptions: 1 = "extremely poor concentration", 3 = "not able to concentrate," 5 = "neutral, neither unable

to concentrate or concentrate," 7 = "able to concentrate" and 9 = "extremely good concentration."

3. *Sleep* The Pittsburgh Sleep Quality Index (PSQI) was applied to evaluate sleep timing, sleep onset latency, sleep duration, sleep difficulties, and sleep quality. The PSQI is a self-reporting questionnaire that assesses sleep quality over a 1-month time interval. The PSQI consists of 19 individual items comprising seven components that produce one global score. The PSQI is a standardized sleep questionnaire for clinicians and researchers to use with ease and for multiple populations, used in many research and clinical settings to diagnose sleep disorders [24, 25]. We used the Karolinska Sleepiness Scale (KSS) to assess sleepiness and tiredness. It is a nine-point Likert scale; all of the numbers have valid point values, but only the odd numbers have descriptions: 1 = "extremely alert," 3 = "alert," 5 = "neither alert nor sleepy," 7 = "sleepy", and 9 = "extremely sleepy" [26, 27].
4. *Exposure to screens of digital media devices* We asked the participants about the presence and usage habits of digital media devices equipped with a screen (for example, TV, computer, tablet, smartphone, etc.) and reported whether they had a TV, computer, tablet, and smartphone in their homes and bedrooms. They reported the duration of exposure to digital screens of any digital media device for different time periods of the day, beginning in the morning until bedtime or sleep during weekdays and on weekends. We asked the participants to report on their exposure time to screens of digital devices the mean time in minutes of each separate time period, so we could calculate the exposure summation (sum) for the different periods: early morning, before work or school, during work or study time, after work or study, until bedtime, and after bedtime. Digital media usage for all devices (TVs, computers, smartphones, and tablets) were computed for the summation (sum) of each four time periods of the day (sum-morning, sum-day, sum-evening, and sum-night) reflecting the summation time in minutes to overall exposure time of digital media screens devices in each time segment of the day. We also computed an additional "sum-total," a summation of the "sum-evening" and "sum-night" variables.

Statistical analysis

We found no gender differences; thus, we performed all analyses using the total sample of females and males. Paired *t* tests were conducted to assess differences in usage time of digital media devices between weekdays and weekend. Correlations were calculated between the variables in the study using Pearson and Spearman coefficients. We calculated partial correlations between the variables in the study adjusting for potential confounding variables: age, marital status, gender, occupation and education. We report only those correlation coefficients that where significant under the partial correlation test. We performed all statistical analyses using SPSS version 22 (SPSS Inc., Chicago, IL, USA).

Results

Exposure to screens of digital devices and usage patterns

141 participants (51%) reported that they had TVs in their bedrooms, and 106 (38%) reported they had computers in their bedrooms. Almost the entire sample had smartphones, 273 participants (98%), and 100 (36%) reported they owned tablets. As can be seen in Table 1, smartphones were the most used digital media device in the evening and after bedtime (the time one gets to sleep in bed), followed by TV, computers, and tablets. This pattern of using digital devices in the evening and after bedtime was similar on weekdays

Table 1 Mean exposure time in minutes and to screens of digital media devices on weekdays and weekends in the evening and after bedtime and sum-evening and sum-after bedtime

	Weekdays		Weekend	
	Evening	After bedtime	Evening	After bedtime
Smartphone	93 (± 102.5)	29 (± 55.5)	81 (± 105.0)	31 (± 60.3)
TV	74 (± 77.0)	17 (± 50.8)	80 (± 74.7)	17 (± 35.7)
Computer	67 (± 83.7)	8 (± 32.6)	43 (± 73.2)	14 (± 87.2)
Tablet	6 (± 6.9)	2 (± 4.4)	4 (± 16.2)	2 (± 13.0)
Sum	199 (± 187.1)*	46 (± 87.5)**	227 (± 252.3)*	79 (± 130.9)**

*$t_{(231)} = -2.25$, $p < 0.05$

**$t_{(271)} = -4.59$, $p < 0.01$

The mean exposure time in minutes and (± SD) to screens of digital media devices (smartphones, TVs, computers, and tablets) on weekdays and weekends in the evening and after bedtime and sum-evening and sum-after bedtime. (*) and (**) are the paired *t* test and significant values comparing sum-evening in weekdays with weekend and sun after bedtime in weekdays with weekend and weekends. We revealed significant differences in the usage time of digital devices between weekdays and weekends; according to our survey, there is a greater tendency to use digital media devices in weekends day compare with weekdays.

Sleep

According to the PSQI answers, the mean bedtime was 00:39 h (±11.02 min), the mean time to fall asleep was 25.8 min (±28.3 min), the mean wakeup hour was 07:00 h (±27.1 min), and the mean sleep hours were 6.59 h (±1.42 min). Table 2 presents the percentage frequency distribution of the sleep complaints and sleep evaluation in the PSQI questionnaire.

Associations between exposure to screens of digital media devices and self-health evaluation and concentration in the morning

Figures 1 and 2 present the frequencies distribution of self-health evaluation and levels of concentration in the morning in the participants sample.

Weekdays

Correlation analysis yielded significant negative correlation between subjective health evaluations and the use of smartphones in the evening ($r = -0.141$, $p < 0.05$) and after bedtime ($r = -0.130$, $p < 0.05$). We discovered a significant negative correlation between concentration in the morning and the usage time of computers in the evening ($r = -0.149$, $p < 0.05$) and watching TV in the evening ($r = -0.266$, $p < 0.01$). In addition, we found a significant negative correlation for using smartphones after bedtime and concentration in the morning ($r = -0.156$, $p < 0.05$).

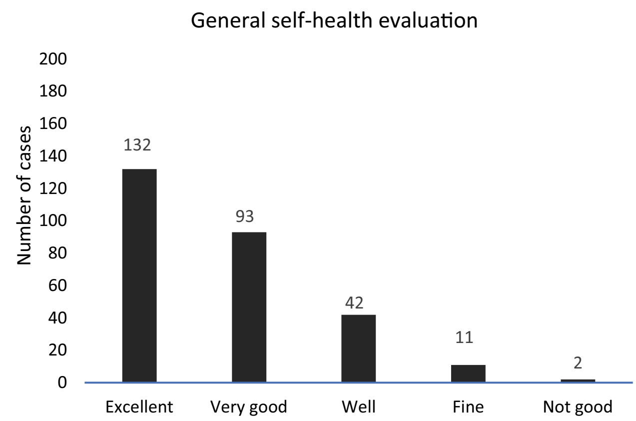

Fig. 1 Frequencies distribution of self-reported health evaluation ($n = 280$)

Weekends

We noted non-significant coefficient correlations between concentration in the morning and all other variables.

Table 2 Percentage frequency distribution of each complaint in the PSQI questionnaire ($n = 280$)

	Not during past month	Less than once a week	Once or twice a week	Three or more times a week
Cannot get to sleep within 30 min	43.6	19.0	17.6	19.8
Wake up in the middle of the night or early morning	26.5	23.5	19.5	30.5
Have to get up to use the bathroom	43.2	20.1	12.5	24.2
Cannot breathe comfortably	70.8	9.9	8.8	10.6
Cough or snore loudly	68.3	9.7	7.5	14.2
Feel too cool	61.5	19.8	13.6	5.1
Feel too hot	60.4	23.0	10.4	6.3
Had bad dream	59.1	27.1	10.4	3.4
Have pain	74.4	13.2	7.1	5.3
Other reason	62.5	7.5	10.6	19.4
During the past month, how often have you taken medicine to help your sleep?	90.9	4.2	1.9	3.0
During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?	67.7	19.7	10.0	2.6
During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	34.7	30.6	24.3	10.4
	Very good	Fairly good	Fairly bad	Very bad
During the past month, how would you rate your sleep quality overall?	21.4	51.8	19.9	6.9

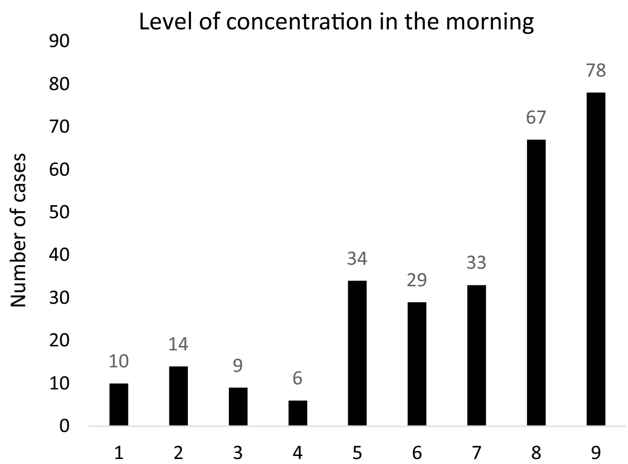

Fig. 2 Frequencies distribution of level of concentration in the morning ($n = 280$). Frequencies distribution of level of concentration in the morning. 1—extremely poor concentration, 3—not able to concentrate, 5—neutral, neither unable to concentrate or concentrate, 7—able to concentrate, and 9—extremely good concentration

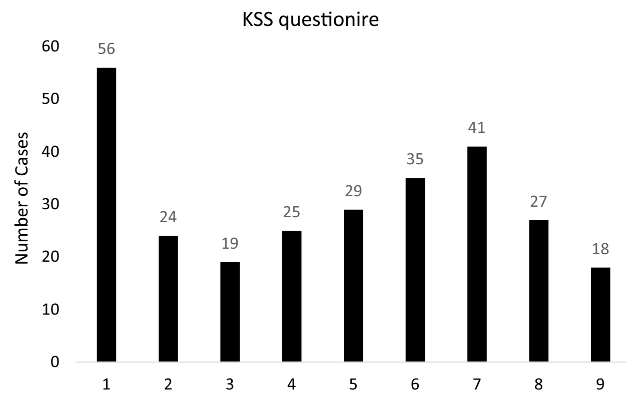

Fig. 3 Frequency distribution of subjective sleepiness in the KSS questionnaire ($n = 274$). Frequency distribution of subjective sleepiness in the KSS questionnaire. 1—Extremely alert, 3—alert, 5—neither alert nor sleepy, 7—sleepy, and 9—extremely sleepy

Associations between exposure time to screens of digital media devices and sleep habits, sleep complaints, sleep quality, and subjective sleepiness

Weekdays

Correlation analysis revealed a significant positive correlation between time to fall asleep and the use of TV after bedtime ($r = 0.296$, $p < 0.01$), using smartphones in the evening ($r = 0.159$, $p < 0.05$) and after bedtime ($r = 0.172$, $p < 0.05$). These findings indicate that excessive exposure to these devices is associated with longer sleep latency. We observed a significant negative correlation between the sleep complaint "Cannot get to sleep within 30 min" in the PSQI questionnaire and the usage time of smartphones in the evening ($r = 0.208$, $p < 0.01$) and using smartphones after bedtime ($r = 0.193$, $p < 0.01$). We did not discover significant correlations, for all other sleep complaints in the PSQI questionnaire, with exposure to screens of any other digital media device. The sleep quality rating was positively associated with smartphone usage in the evening, meaning that extensive use of smartphones in the evening correlated with bed sleep quality reports ($r = 0.160$, $p < 0.05$).

Almost half of the sample reported subjective sleepiness in the morning according to the KSS questionnaire (see Fig. 3). We noted a significant positive correlation, between subjective sleepiness using the KSS with the following variables; TV watching after bedtime ($r = 0.171$, $p < 0.05$), computer usage in the evening ($r = 0.165$, $p < 0.05$), computer usage after bedtime ($r = 0.269$, $p < 0.01$), smartphone use in the evening ($r = 0.270$, $p < 0.01$), and smartphone use after bedtime ($r = 0.258$, $p < 0.01$).

Weekends

We noted positive significant correlation between ranks using the KSS and use of these devices on weekends, TV use after bedtime ($r = 0.204$, $p < 0.01$), smartphone use in the evening ($r = 0.215$, $p < 0.01$), and smartphone use after bedtime ($r = 0.222$, $p < 0.01$).

Associations between summation of exposure to screens of digital media device, sleep, and concentration

Weekdays

Correlation coefficient analysis of the computed variables of sum-evening and sum-night (after bedtime) variables revealed significant correlation coefficients. Sum-evening was found to positively correlate with subjective sleepiness under the KSS ($r = 0.135$, $p < 0.05$) and with complaints in the PSQI "Cannot get to sleep within 30 min" item ($r = 0.175$, $p < 0.01$). Sum-night was discovered to negatively correlate with subjective concentration ability in the morning ($r = -0.155$, $p < 0.01$), and sleep hours ($r = -0.143$, $p < 0.05$). A positive significant correlation was noted between sum-night and the following variables; time to fall asleep ($r = 0.192$, $p < 0.01$), "Cannot get to sleep within 30 min" PSQI item ($r = 0.159$, $p < 0.01$), and subjective sleepiness using the KSS ($r = 0.261$, $p < 0.01$).

Weekends

Correlation analysis yielded significant coefficients for KSS ranks and sum-night on weekends ($r = 0.217$, $p < 0.01$) and sum-evening weekends ($r = 0.167$, $p < 0.01$), reflecting that an increase in time exposure to digital media screens is associated with an increase in subjective sleepiness in the KSS.

Mediation analysis

Correlation analysis yielded significant positive correlation coefficient between sum-evening and subjective sleepiness using the KSS ($r=0.200$, $p<0.01$). Thus, the total time of exposure to all types of screens in the evening positively correlated with subjective sleepiness in the morning. Mediation analysis revealed that the variable "time to fall asleep" in the PSQI questionnaire mediated this correlation. This means that sum-evening increases time to fall asleep ($r=0.170$, $p<0.01$), which in turn increases subjective sleepiness ($r=0.100$, $p<0.01$). For more information, see Fig. 4. In addition, we discovered a significant negative correlation coefficient between sum-evening and subjective concentration in the morning ($r=-0.100$, $p<0.01$). Thus, the total time of exposure to all types of screens in the evening, negatively correlated with concentration in the morning. Mediation analysis revealed that the variable "time to fall asleep" in the PSQI questionnaire mediated this correlation. This means that sum-evening increases time to fall asleep ($r=0.170$, $p<0.01$), which in turn decreases concentration abilities in the following morning ($r=-0.117$, $p<0.01$), see Fig. 5.

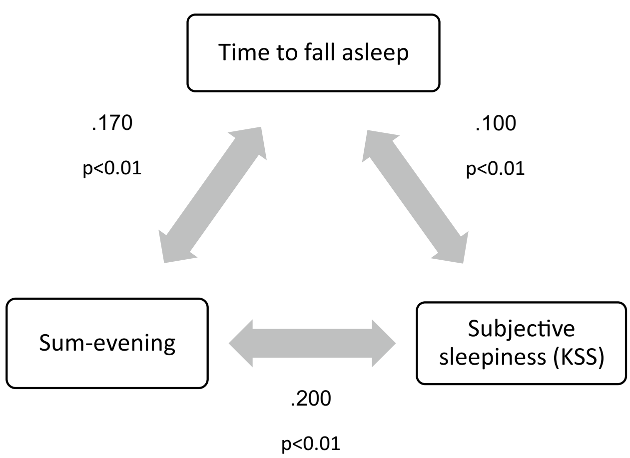

Fig. 4 Association between sum-evening and subjective sleepiness in the KSS mediated by the time to fall asleep. The total time of exposure time to all types of screens in the evening positively correlated with subjective sleepiness in the morning ($r=0.200$, $p<0.01$). The variable "time to fall asleep" in the PSQI questionnaire mediated this correlation; this means that sum-evening increases time to fall asleep ($r=0.170$, $p<0.01$), which in turn increases subjective sleepiness ($r=0.100$, $p<0.01$)

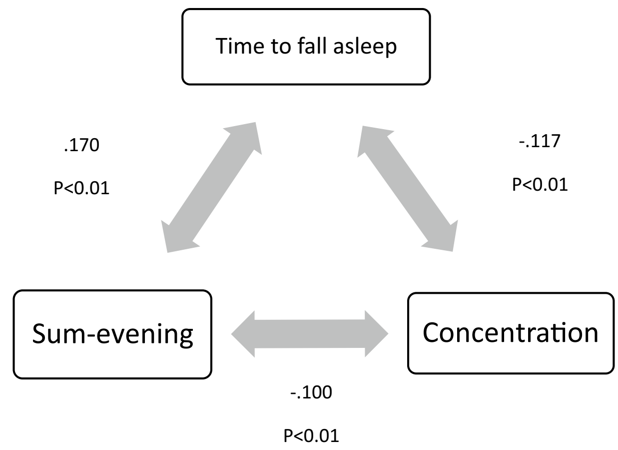

Fig. 5 Association between sum-evening and concentration in the morning is mediated by the time to fall asleep. The total time of exposure to all types of screens in the evening, negatively correlated with concentration in the morning ($r=-0.100$, $p<0.01$). The variable "time to fall asleep" in the PSQI questionnaire mediated this correlation; this means that sum-evening increases time to fall asleep ($r=0.170$, $p<0.01$), which in turn decreases concentration abilities in the following morning ($r=-0.117$, $p<0.01$)

Discussion

Recently, results of studies carried out in a sleep laboratory revealed major differences in physiological, sleep architecture, and cognitive variables between exposure to short (blue) and long (red) wavelength computer screens under acute and chronic conditions [9, 28]. As we carried out the recent studies, only on 19 participants, the survey using questionnaires gave us an opportunity, to test our hypothesis on a larger population scale. To the best of our knowledge, these are the first studies to explore the association between exposure to screens of digital media devices, sleep, and concentration abilities in the Israeli adult population. Our present results indicate that Israelis tend to go to sleep late (00:39 h) and sleep an average 6.59 h at night. One-quarter of the adults rated their sleep quality as bad and the most common complaints were "difficulty to fall asleep" and "waking after sleep onset" (WASO). Almost half of the studied participants suffered from subjective sleepiness in the morning. Smartphones are the most common digital media devices in Israel; 98% of the adult Israeli population owns this device. TVs and computers are very accepted devises in Israeli bedrooms, while tablets are less common. Smartphones are the most used digital media device in the evening and after bedtime, followed by TV, computers, and tablets. The presence and the exposure time to screens of digital media devices are associated with a decrease in subjective health, prolonged sleep latency, an increase in the time of waking during sleep, an increase in concentration difficulty, and subjective sleepiness in the morning.

Our results in adults are equivalent to those in adolescents in Israel regarding the presence of TV and computers in bedrooms. Nevertheless, smartphone was the most available digital media device; 98% of the participants reported owning one. In 2010, smartphones were not as available as today, which may explain why Shochat et al. [6] study did not report on the prevalence of this device. The modern smartphone is a multi-functional device used for multiple purposes: communication, music, entertainment, playing games, work, etc. In addition, a smartphone is by definition a portable device moved from room to room and accompanies the user everywhere. Therefore, it is possible that the traditional distinction between living room and bedroom is not relevant, since one can use smartphone anytime, anywhere, and for many purposes. Main support for this idea comes from our data, showing that the smartphone is the most used digital media device in the evening and after bedtime.

In both studies, ours on adults and in that of Shochat et al. [6] on adolescents, there were positive correlations between exposure time to screens of digital media, late bedtime and subjective sleepiness in the morning. Our results are in line with the previous reports, that exposure to screens of digital media devices in the evening and night led to prolonged sleep latency, and in the morning after, led to subjective sleepiness and difficulties with attention and concentration [7, 9, 15].

The results of our study on adults are in line with the previous reports from around the globe (United States, Belgium, Korea, and Japan) reporting that TVs and computers are pervasive in bedrooms [8]. While Israeli adults sleep an average of 6.5 h, American adults sleep 7.5 h. Israelis tend to go to sleep late and wake up late (00:39–07:00 h, respectively) compared with Americans, who go to sleep and wake up earlier (23:00–06:15 h, respectively). These differences in sleep patterns recorded in adults are in line with the previous research on adolescents, which noted that Israeli adolescents are shorter sleepers compared with adolescents from other countries and tend to go to bed late [29].

A major exclusive result of our study is the usage time of digital media after bedtime when participants are in bed. Israeli adults used smartphones for 30 min and TV for about 15 min after bedtime according to our survey. In contrast, 90% of Americans reported using a digital media device in the bedroom in the hour before sleep [1]. The discovery that Israelis tend to use digital media for a prolonged duration after bedtime may imply that bedtime and sleep time are different actions. Usually, when one goes to bed and turns off the light, we think he/she is going to sleep. Our findings suggest that going to bed and going to sleep are distinct actions. Participants reported that they used digital media for lengthy time after bedtime.

As hypothesized, we revealed positive correlations between exposure to screens of digital media and variables as TVs, smartphones, and tablets usage after bedtime and subjective reports of the time to fall asleep, reflecting the possible influence of excessive exposure to SWL from digital media screens on sleep latency. Green et al. [9] used an experimental study design and discovered that 2 h of exposure to computer screens before bedtime increased sleep latency and decreased sleep efficiency. Furthermore, in this study, we noted an association between smartphone usage in the evening and after bedtime and difficulties in falling asleep at night. Our results are in line with the previous studies [1, 6] which reported that using digital media technology before and after bedtime significantly correlated with difficulty in falling asleep. Finally, we revealed that smartphone usage in the evening is associated with negative sleep quality reports. We assume that a major factor affecting sleep patterns, quality, and difficulty in falling asleep is the exposure to SWL emitted from the light-emitting diodes (LED) screens of digital media devices, known as an efficient suppressor of pineal melatonin secretion, as reported in the previous studies [7, 9, 14].

Since people usually use digital media devices in their daily routines, we should assess the overall exposure time to them. We computed two variables that reflect the general exposure time to screens of all digital devices in the evening and at night. The "sum-evening" and "sum-night" computed variables are associated with excessive reports of subjective sleepiness in the morning. In adults, Gradiser et al. [1] reported that frequent nappers (napping > 3 times in the prior 2 weeks) are more likely to use interactive devices before bedtime, reflecting sleepiness and difficulty staying awake. Several studies have reported that excessive daytime sleepiness is associated with exposure to screens of digital media devices in adolescents [19, 20].

One important outcome of this study is the association between exposure duration to screens of digital media devices in the evening and at night and difficulties with concentration and attention the following morning. Green et al. [9] suggested the possibility of a "chain reaction" of physiological and behavioral changes emerging from exposure to digital media screens in the evening and at night, such as reduced melatonin secretion, thermoregulation dysfunction, and lower sleep quality and quantity. According to Green et al. [9], these changes directly or indirectly lead to deficit outcomes of greater sleepiness and inattention at the following morning. The idea of possible "chain reaction" supported by the mediation role of sleep latency on the association between exposures to screens of digital media devices in the evening and night, and subjective sleepiness and decreased concentration in the morning after.

Unfortunately, the penetration of digital media devices screens into bedrooms might be partially responsible for health difficulties in addition to the above-mentioned sleep difficulties. We revealed that excessive exposure to digital media screens in the evening and after bedtime is associated with a decrease in the subjective health state. We assume that these results are in line with the previous reports of negative physiological outcomes due to exposure to artificial light at night (ALAN). Studies have reported a wide range of effects emerging from ALAN exposure (indoor and outdoor) on the human circadian clock, such as the suppression of melatonin secretion, changes in body temperature regulation, circadian dysfunction, and other sleep disorders [30–35]. Moreover, circadian dysfunction caused by chronic ALAN exposure affects cardiovascular, metabolic, and immune system functions and increases risk for breast and prostate cancers [36, 37]. Our results emphasize the subjective health perspective emerging from exposure to ALAN sources as screens of digital media devices and their association to human health.

There are some major limitations to this study: first, our sample was not random, and we used the convince sample method. In addition, our sample is relatively small, limiting the ability to test relationships that are more complex and decrease the generalization ability of the study. Despite the small sample size, we found some significant key results in the adult Israeli population. We assessed concentration abilities using one question in the survey, to validate our preliminary results, further studies should explore the effects of ALAN from digital media screens on concentration and attention abilities. We based our study on retrospective subjective reports rather than prospective diaries; objective measures such as using actigraphy to evaluate sleep measures.

The prevalence of digital media screens into Israeli bedrooms (sleeping habitats) is high, and the exposure duration to SWL emitted from such screens in the Israeli adult population in the evening and at night is common, especially during the hours before bedtime or sleep. Our results suggest that using digital media devices in the evening and at night is associated with sleep difficulties and presumably as an outcome in the following morning greater sleepiness, attention, and concentration dysfunction.

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Compliance with ethical standards

Ethical approval The institutional ethical review board at the University of Haifa approved the study. Approval Number: 039/17. Date: 29.1.2017.

Informed consent Informed consent was obtained from all individual participants included in the study.

Conflict of interest Green Amit, Prof. Dagan Yaron, and Prof. Haim Abraham declare that they have no conflict of interest.

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