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Adolescents with a smartphone sleep less than their peers

--Manuscript Draft--

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Abstract:	Many studies have shown that the use of electronic media is related to sleep disturbance, but few have examined the impact of Smartphones. The objective of this study was to assess longitudinally whether acquiring a Smartphone had an effect on adolescents' sleeping duration. The study included 591 adolescents observed at baseline (T0, Spring 2012; mean age: 14.3 years, 288 females) and two years later (T1). They were divided into Owners (those owning a Smartphone at T0 and T1; N=383), New Owners (those owning a Smartphone at T1 but not at T0; N=153), and Non-owners (those not owning a Smartphone at any time-point; N=55). Groups were compared on sleep duration, sleep problems, and socio-demographic variables. Overall, all three groups decreased their sleeping time between T0 and T1. At T0, Owners of a Smartphone were found to sleep significantly less than Non-owners and New-owners, especially on schooldays, and to report significantly more sleeping problems. At T1, New-owners and Owners showed no differences on sleep duration or sleeping problems. Conclusion: The results emphasize that owning a Smartphone tends to entail sleep disturbance. Therefore, adolescents and parents should be informed about the potential consequences of Smartphone use on sleep and health.

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Concerne : Lorem Ipsum

Dear Dr Toelen,
Thank you for giving us the opportunity to submit a revised version of our manuscript. We have addressed the comments of the reviewers as follows:

Overall impression:

The manuscript is well written, starts with a hypothesis and is interesting for a general pediatric audience. The English is moderate to excellent (there are a few typographical and grammatical errors that need revising before accepting the paper). The assessment of the strengths and limitations of the study are very accurate.

We thank the Reviewer for these comments. A native English-speaker has reviewed and corrected the manuscript.

Minor comments:

Change title into statement: Adolescents with a smartphone sleep less than their peers.

We have changed the title (Line 1).

Line 116-120 should be included in the 'Results' section, not the M&M section.

If we understand it correctly, the Reviewer would like us to include the following part in the Results section

Compared to the other respondents, those who initially agreed to be contacted again were more likely to be females, younger, and to belong to the highest school track. Similarly, compared to the other respondents who initially agreed to be contacted again, the 621 respondents of the last wave were more likely to be females, younger, to belong to the highest school track, and to have a good emotional wellbeing

From our point of view, this is part of the explanation of the attrition rate that goes from line 114 to line 124 and changing it to Results would not add to its understanding. So we have decided to leave it as it was, but we are open to discussing it and to change the whole part (lines 114-124) to Results if needed.

Line 128-137 should be part of the 'Statistical Analysis' section rather than M&M.

We have changed it as indicated (Lines 170-179).

Line 147 replace 'sex' with the more neutral 'gender' (as in the other places in the text).

We have changed it (Line 148).

Member of the Editorial Board (comments not in order of importance!):

We come to the conclusion that the paper is suitable for publication provided you revise it taking into account the referees' comments and criticisms.

We thank the Member of the Editorial Board for this comment.

We look forward to hearing from you,

Prof. JC Surís, on behalf of all authors

Adolescents with a smartphone sleep less than their peers

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Running title: Adolescents and Smartphones

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ABSTRACT

Many studies have shown that the use of electronic media is related to sleep disturbance, but few have examined the impact of Smartphones. The objective of this study was to assess longitudinally whether acquiring a Smartphone had an effect on adolescents' sleeping duration. The study included 591 adolescents observed at baseline (T0, Spring 2012; mean age: 14.3 years, 288 females) and two years later (T1). They were divided into Owners (those owning a Smartphone at T0 and T1; N=383), New Owners (those owning a Smartphone at T1 but not at T0; N=153), and Non-owners (those not owning a Smartphone at any time-point; N=55). Groups were compared on sleep duration, sleep problems, and socio-demographic variables. Overall, all three groups decreased their sleeping time between T0 and T1. At T0, Owners of a Smartphone were found to sleep significantly less than Non-owners and New-owners, especially on schooldays, and to report significantly more sleeping problems. At T1, New-owners and Owners showed no differences on sleep duration or sleeping problems. *Conclusion*: The results emphasize that owning a Smartphone tends to entail sleep disturbance. Therefore, adolescents and parents should be informed about the potential consequences of Smartphone use on sleep and health.

Key words: Adolescence; Smartphone; Electronic media use; Sleep duration; Sleeping problems; Longitudinal study

ABBREVIATIONS

ESPAD: European School Project on Alcohol and Other Drugs

T0: Time 0 (baseline)

T1: Time 1 (follow-up)

WHO-5: World Health Organization Five Well-Being Index

WHAT IS KNOWN

- The use of electronic media plays an important role in the life of adolescents.
- Smartphone use is increasing among young people and allow them to be connected almost anytime anywhere.

WHAT IS NEW

- Adolescents owning a Smartphone sleep less hours on schooldays than their peers.
- After acquiring a Smartphone, adolescents decrease their sleeping time on schooldays.
- Smartphones seem to have an important impact on youths' sleep duration.

INTRODUCTION

The use of electronic media plays an important role in adolescent life. Moreover, there is a large body of evidence [1-5] indicating that television, computers and mobile phones are related to sleep disturbance, primarily shortened duration and delayed timing [6]. According to Gamble et al. [7], among 11-17 year old Australians, mobile phones are more frequently used in bed than any other electronic device, which can directly interfere with sleep. As a small device, adolescents can use it very discretely if needed, even when they are supposed to be asleep.

Several studies have focused on mobile phone use in bed. Arora et al. [8] observed, among adolescents aged 11-13 years, a significant reduction of schoolday sleep duration with bedtime mobile phone use. According to the National Sleep Foundation [9; 10] the appropriate sleep duration for adolescents aged 14-17 years should be between 8 and 10 hours. Below this range, lack of sleep may affect health and well-being.

Currently, there is an increase of teenage Smartphone owners in many Western countries. According to Madden et al. [11], 37% of 12-17 year old teens in the United Stated owned a Smartphone in 2012, while they were 23% in 2011. The authors highlighted that half of Smartphone owners reported using their mobile phone as their primary mode of online connection. In Switzerland, we observe the same trend. The number of 12-19 year-old Smartphone owners increased from 47% in 2010 to 97% in 2014. Among them, 87% used it daily or more than once a week to access the Internet [12].

Smartphone offers some of computers' functionalities (accessing the Internet, playing games) as well as that of watching TV. It provides an Internet connection potentially anytime and almost everywhere. Furthermore, new applications have been developed, allowing free communication such as texting, sharing pictures, watching TV or videos. Calamaro et al. [13] found that shorter sleep duration was related to media multi-tasking (using phones in addition to TV and other electronic devices) among 12-18 year-old adolescents in the United Sates. New functionalities offered by Smartphones, allowing multi-tasking (watching TV, playing video

games, texting, etc.) and their daily use in bed and before sleep may highly impact the quality and quantity of sleep.

To our knowledge, there have been few studies that have examined the relationship between owning a Smartphone and sleep duration. Among these, a recent cross sectional research [14] led in Switzerland emphasized that the possession of a Smartphone was associated with a high media use in bed before sleeping. The authors compared two groups of 12-17 year-olds: those with a Smartphone and those with a conventional mobile phone. Those who had a Smartphone were more likely to go to bed later, although there were no differences regarding sleep duration between these two groups.

To date most studies on mobile phone use are cross sectional, but longitudinal research is necessary to better understand the potential consequences of using a Smartphone on sleep duration. In order to fill this gap, the objective of the present study is to compare longitudinally the evolution of sleeping time among adolescents acquiring a Smartphone for the first time compared to adolescents already owning a Smartphone and adolescents not owning one. We hypothesize that acquiring a Smartphone is associated with reduced sleeping time and with more sleeping problems.

MATERIALS AND METHODS

Procedure / Study population

Data were obtained from the *ado@internet.ch* survey, a longitudinal study based on a representative sample of students in the French-speaking part of Switzerland. In spring 2012 all 8th graders (N=3367; mean age 14.2 years) in a random sample of 35 schools were invited to participate in the study. After data cleaning, the final sample of the first wave included 3067 youths (50.3% females). The baseline questionnaire was filled in online in the school's computer science room. At the end of the questionnaire, participants were asked whether they would agree to leave their email address in order to be contacted biannually during 2 years to continue the study and 2035 of them (64.4%) agreed to it. For each subsequent wave, consenting

participants were contacted via e-mail and given a web-link where to answer the online questionnaire. The sample of the last wave of the study (spring 2014) included 621 youths (308 females) with a mean age of 16.2 years. This high attrition was mainly caused by the fact that contrarily to the initial wave, the following waves were performed out of the school context. Compared to the other respondents, those who initially agreed to be contacted again were more likely to be females, younger, and to belong to the highest school track. Similarly, compared to the other respondents who initially agreed to be contacted again, the 621 respondents of the last wave were more likely to be females, younger, to belong to the highest school track, and to have a good emotional wellbeing. On the other hand, there was no significant difference regarding sleep problems. To account for the attrition observed throughout the whole study, longitudinal weights were computed to make sure that the sample remained representative of the whole population under study, i.e. similar to the initial sample of 3367 respondents. For this paper, we focused on the 621 youths who responded to the first (T0) and last (T1) waves.

Our final sample consisted of 591 adolescents (288 females) divided into Owners (those owning a Smartphone at T0 and T1; N=383; 64.8%), New Owners (those owning a Smartphone at T1 but not at T0; N=153; 25.9%), and Non-owners (those not owning a Smartphone at any time-point; N=55; 9.3%).

Measures

To assess sleep duration, students were asked to indicate how many hours on average they slept during schooldays and during weekends/vacation. Minutes are given on a decimal scale. Sleep problems were assessed by the following question: "*over the last six months have you ever had sleep problems*?". There were five possible answers dichotomised as "at least once a week" (at least once a week, most days) and other (never, less than monthly, about once a month).

To assess the type of devices used to access the Internet other than the Smartphone, there were two possible answers: personal computer and tablet. Other covariates included

demographic data (gender, age, nationality [Swiss/other]), family structure (parents together/other), residence (rural/urban), academic track (pre high-school, extended requirements, basic requirements) and socioeconomic status. In Switzerland there is an early screening leading to three tracks at school. Only the first two tracks give access to studies beyond compulsory school (High school, University), whereas the third one (basic requirements) is focused on apprenticeship. To measure socioeconomic status, we used the question of the European School Project on Alcohol and Other Drugs (EPSAD) survey (www.espad.org) asking: "Compared to other families in Switzerland, you think that the financial situation of your family is..." with seven possible answers divided into three categories: below average, average, and well/very above average. Finally, for emotional well-being, we used the World Health Organization Five Well-Being Index (WHO-5), with a score below 13/25 indicating poor well-being [15].

Statistical analyses

We first analysed the relationship between the three groups (Smartphone Owners, New-owners, and Non-owners) and each covariate measured at T0 and/or T1. We used chi-square tests for categorical variables and ANOVAs followed by Sidak tests (the exact version of the Bonferonni test which allows multiple comparisons between groups) for continuous variables. Then we analysed the number of sleeping hours for each group of Smartphone owners both at T0 and T1, differentiating between sleep time on schooldays and on weekends/vacations. We used again ANOVAs followed by Sidak tests for that purpose. All calculations were done with STATA 13.0 (StataCorp, College Station, Texas). The type I error was set to 5% for all analyses.

The three groups are unbalanced, but the statistical software we used for the computations (Stata) employs the correct formula for computing the sum of squares in this case. Moreover, the main issue related to unequal group size in one-way ANOVA is that a rejection of the equal variance hypothesis would lead to possibly more adverse consequences than in the

case of a balanced design. However, using the Brown and Forsythe robust test for the equality of variance, we verified that the equality of variances was acceptable for all of our variables. We did not include adolescents who reported owning a Smartphone at T0 but not at T1 anymore for two reasons: first because of the small number of respondents (N=30) that would have resulted in underpowered statistical calculations; and second because we did not know whether the reason for not having a Smartphone anymore was voluntary or involuntary (for instance theft or loss).

The study was approved by the Ethics Committee of the Canton of Vaud.

RESULTS

At the bivariate level there were no differences between groups in age, gender, nationality, family structure, academic achievement, socioeconomic status or well-being (Table 1). Nevertheless, Smartphone owners were more likely to live in an urban area. Moreover, a change was observed between T0 and T1 regarding the devices other than the Smartphone used to access the Internet. At T0, Smartphone Owners were more prone to also use a computer to access Internet, while no difference between the three groups was observed at T1. On the other hand, Smartphone Owners were more prone to also use a tablet to access Internet at T1, when no difference between the three groups was observed at T0. Globally, the use of a computer to access Internet stayed quite stable between T0 and T1, while the use of tablets decreased dramatically.

Regarding sleep problems, at T0, Smartphone Owners were more likely to have sleep problems than Non-owners and New-owners (P=<0.001). However, there were no differences in sleep problems between groups at T1. Regarding sleep duration, a statistically significant difference was observed between Owners and Non-owners at T0 both on schooldays (Owners: 7.81±0.10 hours; Non-owners; 8.61±0.12 hours; P=.001) and on weekend/vacations (Owners: 9.48±.016 hours; Non-owners; 10.20±0.24 hours; P=.045), and between Owners and New-owners on schooldays (Owners: 7.81±0.10 hours; New-owners: 8.23±0.12 hours; P=0.020). As

expected, there were no differences between Non-owners and New-owners on schooldays or on weekends/vacation (Table 2).

At T1, the only statistically significant difference was observed between Owners and Non-owners on schooldays (Owners: 7.28±.09 hours; Non-owners: 8.0±.20 hours; P=0.002).

DISCUSSION

The aim of the present study was to examine whether acquiring a Smartphone had an effect on adolescents' sleep duration. Overall, adolescents who owned a Smartphone were significantly more likely to have shorter sleep duration than Non-owners. As recommended by the National Sleep Foundation [9; 10] the appropriate sleep duration for adolescents aged 14-17 should be between 8 to 10 hours. Below this range, lack of sleep may affect health and well-being. Several studies [16; 17] have shown that reducing sleep duration, even by a single hour may have a negative impact on youth's development, to the extent that sleep seems to be essential during brain maturation, which characterizes the period of adolescence. In this context, our results highlighted that Non-owners slept the number of hours recommended by the National Sleep Foundation. However, as soon as adolescents owned a Smartphone, they slept less than advised. Even if overall all three groups reduced their sleep time from T0 to T1, New-owners reduced more their sleep time from T0 to T1 on schooldays (8.23 vs 7.54) and to a lesser extent on weekends (9.82 vs 9.63), reaching the sleeping time of Owners of a Smartphone at both T0 and T1. Similarly, the prevalence of sleeping problems increased between T0 and T1 among New-owners to reach the prevalence observed among Owners of a Smartphone. These results indicate that acquiring a Smartphone has indeed an impact on sleep, confirming our hypothesis.

Two main mechanisms have been described to explain media use impact on sleep disturbance. First, media use in the evenings may increase mental, emotional or physiological arousal associated with playing computer games or social interactions (through texting, Facebook, etc.) making it more difficult to fall asleep [14]. Second, exposure to the bright light

from screens may suppress melatonin and consequently delay the circadian rhythm [2; 17]. In view of the widespread use of Smartphones among adolescents in Switzerland and given the difference in sleep duration between New-owners, Owners and Non-owners demonstrated in this article, it becomes necessary to reflect upon possible strategies to rationalize their use. Therefore, on the one hand, adolescents and parents should be better informed about the potential consequences on sleep and health. On the other hand, health professionals may screen for adolescents' Smartphone use, especially those complaining of tiredness or sleep problems.

Even if New-owners of a Smartphone reduced their sleeping time between T0 and T1 more than both other groups, we should be cautious in the interpretation of the results, because Non-owners were also at the limit of the sleep duration range recommended by NSF. This suggests that other factors, not assessed in this current study, such as shifting family and peer relationships, increased academic demands or part-time employment [6; 18] may also impact on sleep duration. Second, a moderator variable may interfere with the relationship between Smartphone and sleep disturbance. For example, we suggest that Non-owners may have parents with stricter rules about many aspects of their lives including an earlier bedtime. According to Bartel et al. [18], adolescents with parent-set bedtime benefit from longer sleep duration and experience less fatigue.

The strength of our study is that it is based on longitudinal data which confirm that acquiring a Smartphone may entail sleep disturbance. However, several limitations need to be mentioned. First of all, the size of our sample is relatively small and representative of a small part of Switzerland only. Moreover, measures on sleep duration did neither assess whether Smartphones were used before bedtime or after turning lights off, nor the frequency of Smartphone use. Further research may employ time use diaries to capture sleep duration and time spent using phone more accurately. Similarly, measures on sleep problems were broad questions which did not permit to identify specificities in sleep problems such as sleep onset

latency, night waking, sleep quality, etc. Finally, we did not have data regarding Smartphone use rules at home, which could influence our results.

To summarize, our findings emphasize that having a Smartphone may interfere with sleep among adolescents, specifically shorter sleep duration. Due to the success of Smartphone use among adolescents and its implications on health, further studies are needed to examine in detail the relationship between Smartphone use and sleep disturbance. In the meanwhile, parents and adolescents should be made aware of the possible consequences of excessive Smartphone use.

DISCLOSURE

Funding: The *ado@internet.ch* study was financed by the Service of Public Health of the canton of Vaud and by the Swiss National Science Foundation (FNS 105319_140354). André Berchtold is partly supported by the National Centre of Competence in Research LIVES funded by the Swiss National Science Foundation.

Conflict of interest: The authors declare that they have no conflict of interest.

COMPLIANCE WITH ETHICAL STATEMENT

ETHICAL APPROVAL

The study protocol was approved by the Ethics Committee of the Canton of Vaud.

AUTHORS' CONTRIBUTION

Angélick Schweizer analyzed the data, drafted the initial manuscript and approved the final manuscript as submitted.

André Berchtold conceptualized and designed the study, collected and analyzed the data, critically reviewed and revised the manuscript and approved the final manuscript as submitted.

Yara Barrense-Dias conceptualized and designed the study, critically reviewed and revised the manuscript and approved the final manuscript as submitted.

Christina Akre conceptualized and designed the study, critically reviewed and revised the manuscript and approved the final manuscript as submitted.

JC Suris conceptualized and designed the study, collected and analyzed the data, critically reviewed and revised the manuscript and approved the final manuscript as submitted.

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Table 1. Bivariate analysis comparing the three groups of Smartphone Owners, New-owners, and Non-owners with all factors measured at T0 and/or T1. The far-right column provides the p-value corresponding to a chi-square test for categorical factors, and to a one-way ANOVA for numerical ones.

	Owners (n=383)	**New-owners (n=153)**	**Non-Owners (n=55)**	**p-value**
T0				
Mean age (years ± SD)	14.3± 0.04	14.08 ± 0.08	14.55± 0.37	0.924
Gender (female)	49.1%	51.4%	39.1%	0.469
Nationality (Swiss)	83.5%	87.2%	91.6%	0.348
Residence (urban)	53.0%	39.3%	38.8%	0.045
Family structure (parents together)	70.0%	75.6%	63.6%	0.460
Socioeconomic status				0.501
Well/very above average	37.5%	28.4%	38.1%	
Average	57.0%	65.8%	58.1%	
Below average	5.4%	5.7%	3.7%	
Devices to access the Internet (other than Smartphone)				
Personal computer	63.8%	44.5%	31.8%	<0.001
Tablet	30.8%	42.0%	28.2%	0.105
Academic achievement				0.058
Pre high-school	32.6%	52.6%	40.5%	
Extended requirements	32.4%	31.3%	35.7%	
Basic requirements	34.9%	16.0%	23.8%	
Emotional wellbeing (poor)	14.5%	9.8%	7.6%	0.239
Sleep problems (yes)	35.2%	19.8%	15.4%	<0.001
T1				
Family structure (parents together)	68.6%	76.4%	66.7%	0.432
Devices to access the Internet (other than Smartphone)				
Personal computer	49.6%	48.4%	54.1%	0.861
Tablet	22.0%	13.7%	7.0%	0.007
Emotional wellbeing (poor)	14.6%	14.23%	22.7%	0.598
Sleep problems (yes)	33.7%	33.6%	23.4%	0.485

Table 2: Sleep duration across the three groups. The p-values refer to a Sidak test following a one-way ANOVA.

Dependent variables		**P value**
Sleeping hours on schooldays T0 (mean ± SD)		
Owners vs Non-owners	7.81±0.10 vs 8.61±0.12	0.001
Owners vs New-owners	7.81±0.10 vs 8.23±0.12	0.020
New-owners vs Non-owners	8.23±0.12 vs 8.61±0.12	0.241
Sleeping hours on weekends/vacation T0 (mean ± SD)		
Owners vs Non-owners	9.48±0.16 vs 10.2±0.24	0.045
Owners vs New-owners	9.48±0.16 vs 9.82±0.19	0.441
New-owners vs Non-owners	9.82±0.19 vs 10.2±0.24	0.552
Sleeping hours on schooldays T1 (mean ± SD)		
Owners vs Non-owners	7.28±.09 vs 8.0±.20	0.002
Owners vs New-owners	7.28±09 vs 7.54±09	0.104
New-owners vs Non-owners	7.54±.09 vs 8.0±.20	0.075
Sleeping hours on weekends/vacation T1 (mean ± SD)		
Owners vs Non-owners	9.28±0.12 vs 9.44±0.3	0.944
Owners vs New-owners	9.28±0.12 vs 9.63±0.12	0.099
New-owners vs Non-owners	9.63±0.12 vs 9.44±0.3	0.914

Adolescents with a smartphone sleep less than their peers ~~Adolescents with a smartphone sleep less than their peers~~

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ABSTRACT

Many studies have shown that the use of electronic media is related to sleep disturbance, but few have examined the impact of Smartphones. The objective of this study was to assess longitudinally whether acquiring a Smartphone had an effect on adolescents' sleeping duration. The study included 591 adolescents observed at baseline (T0, Spring 2012; mean age: 14.3 years, 288 females) and two years later (T1). They were divided into Owners (those owning a Smartphone at T0 and T1; N=383), New Owners (those owning a Smartphone at T1 but not at T0; N=153), and Non-owners (those not owning a Smartphone at any time-point; N=55). Groups were compared on sleep duration, sleep problems, and socio-demographic variables. Overall, all three groups decreased their sleeping time between T0 and T1. At T0, Owners of a Smartphone were found to sleep significantly less than Non-owners and New-owners, especially on schooldays, and to report significantly more sleeping problems. At T1, New-owners and Owners showed no differences on sleep duration or sleeping problems. *Conclusion*: The results emphasize that owning a Smartphone tends to entail sleep disturbance. Therefore, adolescents and parents should be informed about the potential consequences of Smartphone use on sleep and health.

Key words: Adolescence; Smartphone; Electronic media use; Sleep duration; Sleeping problems; Longitudinal study

ABBREVIATIONS

ESPAD: European School Project on Alcohol and Other Drugs

T0: Time 0 (baseline)

T1: Time 1 (follow-up)

WHO-5: World Health Organization Five Well-Being Index

WHAT IS KNOWN

- The use of electronic media plays an important ~~part~~ role in the life of adolescents.
- ~~The use of~~ Smartphone~~s~~ use is increasing among young people and ~~they alow~~allow them to be connected almost anytime anywhere.

WHAT IS NEW

- Adolescents owning a Smartphone sleep less hours on schooldays than their peers.
- After acquiring a Smartphone, adolescents decrease their sleeping time on schooldays.
- Smartphones seem to have an important impact on youths' sleep duration.

INTRODUCTION

The use of electronic media plays an important ~~part~~ role in adolescent life. Moreover, there is a large body of evidence [1-5] indicating that television, computers and mobile phones are related to sleep disturbance, primarily shortened duration and delayed timing [6]. According to Gamble et al. [7], among ~~Australians~~ 11-17 year old Australians, mobile phones are more frequently used in bed than any other electronic device~~s~~, which can directly interfere with sleep. As a small device, adolescents can use it very discretely if needed, even when they are supposed to be asleep.

Several studies have focused on mobile phone use in bed. Arora et al. [8] observed, among adolescents aged 11-13 years, a significant reduction ~~on~~ of schoolday~~s'~~ sleep duration with bedtime mobile phone use. According to the National Sleep Foundation [9; 10] the appropriate sleep duration~~,~~ for adolescents aged 14-17~~,~~ years should be between 8 and 10 hours. Below this range, lack of sleep ~~duration~~ may affect health and well-being.

Currently, there is an increase of teenage Smartphone owners ~~among teens~~ in many Western countries. According to Madden et al. [11], 37% of 12-17 year old ~~American~~ teens in the United Stated ~~aged 12-17~~ owned a Smartphone in 2012, while they were 23% in 2011. The authors highlighted that half of Smartphone owners reported using their mobile phone as their primary mode of online connection. In Switzerland, we observe the same trend. The number of 12-19 year-old Smartphone owners increased from 47% in 2010 to 97% in 2014. Among them, 87% used it daily or more than once a week to access the Internet [12].

Smartphone offers some of computers' functionalities (accessing the Internet, playing games) as well as that of watching TV. It provides an Internet connection potentially anytime and almost everywhere. Furthermore, new applications have been developed, allowing free communication such as texting, sharing pictures, watching TV or videos. Calamaro et al. [13] found that shorter sleep duration was related to media multi-tasking (using phones in addition to TV and other electronic devices) among 12-18 year-old ~~US~~ adolescents in the United Sates.

New functionalities offered by Smartphones, allowing multi-tasking (watching TV, playing video games, texting, etc.) and their daily use in bed and before sleep may highly impact the quality and quantity of sleep.

To our knowledge, there have been few studies that have examined the relationship between owning a Smartphone and sleep duration. Among these, a recent cross sectional research [14], led in Switzerland, emphasized that the possession of a Smartphone was associated to with a high media use in bed before sleeping. The authors compared two groups of 12-17 year-olds: , adolescentsthose with a Smartphone and adolescents those with a conventional mobile phone. Those who possessed had a Smartphone were more likely to go to bed later, although there were no differences regarding sleep duration between these two groups.

To date mMost studies to date on mobile phone use are cross sectional, but longitudinal research is necessary to better understand the potential consequences of using a Smartphone on sleep duration. In order to fill this gap, the objective of the present study is to compare longitudinally the evolution of sleeping time among adolescents acquiring a Smartphone for the first time as compared to adolescents already owning a Smartphone and adolescents not owning one. We hypothesize that acquiring a Smartphone is associated with a reduced sleeping time and with more sleeping problems.

MATERIALS AND METHODS

Procedure / Study population

Data were obtained from the *ado@internet.ch* survey, a longitudinal study based on a representative sample of students in the French-speaking part of Switzerland. In spring 2012 all 8th graders (N=3367; mean age 14.2 years) in a random sample of 35 schools were invited to participate in the study. After data cleaning, the final sample of the first wave included 3067 youths (50.3% females). The baseline questionnaire was filled in online in the school's computer science room. At the end of the questionnaire, participants were asked whether they would

agree to leave their email address in order to be contacted biannually during 2 years to continue the study and 2035 of them (64.4%) agreed to it. For each subsequent wave, consenting participants were contacted via e-mail and given a web-link where to answer the online questionnaire. The sample of the last wave of the study (spring 2014) included 621 youths (308 females) with a mean age of 16.2 years. This high attrition was mainly caused by the fact that contrarily to the initial wave, the following waves were performed out of the school context. Compared to the other respondents, those who initially agreed to be contacted again were more likely to be females, younger, and to belong to the highest school track. Similarly, compared to the other respondents who initially agreed to be contacted again, the 621 respondents of the last wave were more likely to be females, younger, to belong to the highest school track, and to have a good emotional wellbeing. On the other hand, there was no significant difference regarding sleep problems. To account for the attrition observed throughout the whole study, longitudinal weights were computed to make sure that the sample remained representative of the whole population under study, i.e. similar to the initial sample of 3367 respondents. For this paper, we focused on the 621 youths who responded to the first (T0) and last (T1) waves.

Our final sample consisted of 591 adolescents (288 females) divided into Owners (those owning a Smartphone at T0 and T1; N=383; 64.8%), New Owners (those owning a Smartphone at T1 but not at T0; N=153; 25.9%), and Non-owners (those not owning a Smartphone at any time-point; N=55; 9.3%). ~~The three groups are unbalanced, but the statistical software we used for the computations (Stata) employs the correct formula for computing the sum of squares in this case. Moreover, the main issue related to unequal group size in one-way ANOVA is that a rejection of the equal variance hypothesis would lead to possibly more adverse consequences than in the case of a balanced design. However, using the Brown and Forsythe robust test for the equality of variance, we verified that the equality of variances was acceptable for all of our variables. We did not include adolescents who reported owning a Smartphone at T0 but not at T1 anymore for two reasons: first because of the small number of respondents (N=30) that~~

~~would have resulted in underpowered statistical calculations; and second because we did not know whether the reason for not having a Smartphone anymore was voluntary or involuntary (for instance theft or loss).~~

Measures

To assess sleep duration, students were asked to indicate how many hours on average they slept during schooldays and during weekends/vacation. Minutes are given on a decimal scale. Sleep problems were assessed by the following question: "*over the last six months have you ever had sleep problems*~~"~~?". There were five possible answers dichotomised as "at least once a week" (at least once a week, most days) and other (never, less than monthly, about once a month).

To assess the type of devices used to access the Internet other than the Smartphone, there were two possible answers: personal computer and tablet. Other covariates included demographic data [(~~sex~~ gender, age, nationality [(~~S~~Swiss/other]), family structure (parents together/other), residence (rural/urban), academic track (pre high-school, extended requirements, basic requirements) and socioeconomic status. In Switzerland there is an early screening leading to three tracks at school. Only the ~~two~~ first two tracks ~~enable to pursue~~give access to studies beyond compulsory school (High school, University), whereas the third one (basic requirements) is focused on apprenticeship. To measure socioeconomic status, we used the question of the European School Project on Alcohol and Other Drugs (EPSAD) survey (www.espad.org) asking: "Compared to other families in Switzerland, you think that the financial situation of your family is..." with seven possible answers divided into three categories: below average, average, and well/very above average. Finally, for emotional well-being, we used the World Health Organization Five Well-Being Index (WHO-5), with a score below 13/25 indicating poor well-being [15].

Statistical analyses

We first analysed the relationship between the three groups (Smartphone Owners, New-owners, and Non-owners) and each covariate measured at T0 and/or T1. We used chi-square tests for categorical variables and ANOVAs followed by Sidak tests (the exact version of the Bonferonni test which allows multiple comparisons between groups) for continuous variables. Then we analysed the number of sleeping hours ~~of sleeping time~~ for each group of Smartphone owners ~~at~~ both at T0 and T1, differentiating between sleep time on schooldays and on weekends/vacations. We used again ANOVAs followed by Sidak tests for that purpose. All calculations were done with STATA 13.0 (StataCorp, College Station, Texas). The type I error was set to 5% for all analyses.

The three groups are unbalanced, but the statistical software we used for the computations (Stata) employs the correct formula for computing the sum of squares in this case. Moreover, the main issue related to unequal group size in one-way ANOVA is that a rejection of the equal variance hypothesis would lead to possibly more adverse consequences than in the case of a balanced design. However, using the Brown and Forsythe robust test for the equality of variance, we verified that the equality of variances was acceptable for all of our variables. We did not include adolescents ~~reporting~~ who reported owning a Smartphone at T0 but not at T1 anymore for two reasons: first because of ~~due to~~ the small number of respondents (N=30) that would have resulted in underpowered statistical calculations~~;~~, and second~~to the fact~~ because ~~that~~ we did not know whether the reason for not having a Smartphone anymore was voluntary or involuntary (for instance theft or loss).

The study was approved by the Ethics Committee of the Canton of Vaud.

RESULTS

At the bivariate level there were no differences between groups in age, gender, nationality, family structure, academic achievement, socioeconomic status or well-being (Table 1). Nevertheless, Smartphone owners were more likely to live in an urban area. Moreover, a change was observed between T0 and T1 regarding the devices other than the Smartphone

used to access the Internet. At T0, Smartphone Owners ~~of a Smartphone~~ were more prone to also use a computer to access Internet, while no difference between the three groups was observed at T1. On the other hand, Smartphone Owners ~~of a Smartphone~~ were more prone to also use a tablet to access Internet at T1, when no difference between the three groups was observed at T0. Globally, the use of a computer to access Internet stayed quite stable between T0 and T1, while the use of tablets decreased dramatically.

Regarding sleep problems, at T0, Smartphone Owners ~~of a Smartphone~~ were more likely to have sleep problems than Non-owners and New-owners (P=<0.001). However, there were no differences in sleep problems between groups at T1. Regarding sleep duration, a statistically significant difference was observed between Owners and Non-owners at T0 both on schooldays (Owners: 7.81±0.10 hours; Non-owners; 8.61±0.12 hours; P=.001) and on weekend/vacations (Owners: 9.48±.016 hours; Non-owners; 10.20±0.24 hours; P=.045), and between Owners and New-owners on schooldays (Owners: 7.81±0.10 hours; New-owners: 8.23±0.12 hours; P=0.020). As expected, there were no differences between Non-owners and New-owners on schooldays or on weekends/vacation (Table 2).

At T1, the only statistically significant difference was observed between Owners and Non-owners on schooldays (Owners: 7.28±.09 hours; Non-owners: 8.0±.20 hours; P=0.002).

DISCUSSION

The aim of the present study was to examine whether acquiring a Smartphone had an effect on adolescents' sleep duration. Overall, adolescents who owned a Smartphone were significantly more likely to have shorter sleep duration than Non-owners. As recommended by the National Sleep Foundation [9; 10] the appropriate sleep duration~~,~~ for adolescents aged 14-17~~,~~ should be between 8 to 10 hours. Below this range, lack of sleep may affect health and well-being. Several studies [16; 17] have shown that reducing sleep duration, even by a single hour may have a negative impact on youth's development, to the extent that sleep seems to be essential during brain maturation, which characterizes the period of adolescence. In this

context, our results highlighted that Non-owners slept the number of hours recommended by the National Sleep Foundation. However, as soon as adolescents owned a Smartphone, they slept less than advised. Even if overall all three groups reduced their sleep time from T0 to T1, New-owners reduced more their sleep time from T0 to T1 on schooldays (8.23 vs 7.54) and to a lesser extent on weekends (9.82 vs 9.63), ~~joining~~ reaching the sleeping time of Owners of a Smartphone at both T0 and T1. Similarly, the prevalence of sleeping problems increased between T0 and T1 among New-owners to ~~join~~ reach the prevalence observed among Owners of a Smartphone. These results indicate that acquiring a Smartphone has indeed an impact on sleep, confirming our hypothesis.

Two main mechanisms have been described to explain media use impact on sleep disturbance. First, media use in the evenings may increase mental, emotional or physiological arousal associated with playing computer games or social interactions (through texting, Facebook, etc.) making it more difficult to fall asleep [14]. Second, exposure to the bright light from screens may suppress melatonin and consequently delay the circadian rhythm [2; 17]. In view of the widespread use of Smartphones among adolescents in Switzerland and given the difference in sleep duration between New-owners, Owners and Non-owners demonstrated in this article, it becomes necessary to reflect upon possible strategies to rationalize their use. Therefore, on the one hand, adolescents and parents should be better informed about the potential consequences on sleep and health. On the other hand, health professionals may screen for adolescents' Smartphone use, especially those complaining of tiredness or sleep problems.

Even if New-owners of a Smartphone reduced ~~more~~ their sleeping time between T0 and T1 more than both other groups, we should be cautious in the interpretation of the results, because Non-owners were also at the limit of the sleep duration range recommended by NSF. This suggests that other factors, not assessed in this current study, such as shifting family and peer relationships, increased academic demands or part-time employment [6; 18] may also

impact on sleep duration. Second, a moderator variable may interfere with the relationship between Smartphone and sleep disturbance. For example, we suggest that Non-owners may have parents with stricter rules about many aspects of their lives including an earlier bedtime. According to Bartel et al. [18], adolescents with parent-set bedtime ~~obtain~~ benefit from longer sleep duration and experience less fatigue.

The strength of our study is that it is based on longitudinal data~~,~~ which confirm that acquiring a Smartphone may entail sleep disturbance. However, several limitations need to be mentioned. First of all, the size of our sample is relatively small and representative of a ~~single~~ small part of Switzerland only. Moreover, measures on sleep duration did neither assess whether Smartphones were used before bedtime or after turning lights off, nor the frequency of Smartphone use. Further research may employ time use diaries to capture sleep duration and time spent using phone more accurately. Similarly, measures on sleep problems were broad questions which did not permit to identify specificities in sleep problems such as sleep onset latency, night waking, sleep quality, etc. Finally, we did not have data regarding Smartphone use rules at home, which could influence our results.

To summarize, our findings emphasize that having a Smartphone may interfere with sleep among adolescents, specifically shorter sleep duration. Due to the success of Smartphone use among adolescents and its implications on health, further studies are needed to examine in detail the relationship between Smartphone use and sleep disturbance. In the meanwhile, parents and adolescents should be made aware of the possible consequences of excessive Smartphone use.

DISCLOSURE

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Conflict of interest: The authors declare that they have no conflict of interest.

COMPLIANCE WITH ETHICAL STATEMENT

ETHICAL APPROVAL

The study protocol was approved by the Ethics Committee of the Canton of Vaud.

AUTHORS' CONTRIBUTION

Angélick Schweizer analyzed the data, drafted the initial manuscript and approved the final manuscript as submitted.

André Berchtold conceptualized and designed the study, collected and analyzed the data, critically reviewed and revised the manuscript and approved the final manuscript as submitted.

Yara Barrense-Dias conceptualized and designed the study, critically reviewed and revised the manuscript and approved the final manuscript as submitted.

Christina Akre conceptualized and designed the study, critically reviewed and revised the manuscript and approved the final manuscript as submitted.

JC Suris conceptualized and designed the study, collected and analyzed the data, critically reviewed and revised the manuscript and approved the final manuscript as submitted.

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340 Table 1. Bivariate analysis comparing the three groups of Smartphone Owners, New-owners,
341 and Non-owners with all factors measured at T0 and/or T1. The far-right column provides the p-
342 value corresponding to a chi-square test for categorical factors, and to a one-way ANOVA for
343 numerical ones.

	Owners (n=383)	**New-owners (n=153)**	**Non-Owners (n=55)**	**p-value**
T0				
Mean age (years ± SD)	14.3± 0.04	14.08 ± 0.08	14.55± 0.37	0.924
Gender (female)	49.1%	51.4%	39.1%	0.469
Nationality (Swiss)	83.5%	87.2%	91.6%	0.348
Residence (urban)	53.0%	39.3%	38.8%	0.045
Family structure (parents together)	70.0%	75.6%	63.6%	0.460
Socioeconomic status				0.501
Well/very above average	37.5%	28.4%	38.1%	
Average	57.0%	65.8%	58.1%	
Below average	5.4%	5.7%	3.7%	
Devices to access the Internet (other than Smartphone)				
Personal computer	63.8%	44.5%	31.8%	<0.001
Tablet	30.8%	42.0%	28.2%	0.105
Academic achievement				0.058
Pre high-school	32.6%	52.6%	40.5%	
Extended requirements	32.4%	31.3%	35.7%	
Basic requirements	34.9%	16.0%	23.8%	
Emotional wellbeing (poor)	14.5%	9.8%	7.6%	0.239
Sleep problems (yes)	35.2%	19.8%	15.4%	<0.001
T1				
Family structure (parents together)	68.6%	76.4%	66.7%	0.432
Devices to access the Internet (other than Smartphone)				
Personal computer	49.6%	48.4%	54.1%	0.861
Tablet	22.0%	13.7%	7.0%	0.007
Emotional wellbeing (poor)	14.6%	14.23%	22.7%	0.598
Sleep problems (yes)	33.7%	33.6%	23.4%	0.485

344

345 Table 2: Sleep duration across the three groups. The p-values refer to a Sidak test following a
346 one-way ANOVA.

Dependent variables		**P value**
Sleeping hours on schooldays T0 (mean ± SD)		
Owners vs Non-owners	7.81±0.10 vs 8.61±0.12	0.001
Owners vs New-owners	7.81±0.10 vs 8.23±0.12	0.020
New-owners vs Non-owners	8.23±0.12 vs 8.61±0.12	0.241
Sleeping hours on weekends/vacation T0 (mean ± SD)		
Owners vs Non-owners	9.48±0.16 vs 10.2±0.24	0.045
Owners vs New-owners	9.48±0.16 vs 9.82±0.19	0.441
New-owners vs Non-owners	9.82±0.19 vs 10.2±0.24	0.552
Sleeping hours on schooldays T1 (mean ± SD)		
Owners vs Non-owners	7.28±.09 vs 8.0±.20	0.002
Owners vs New-owners	7.28±09 vs 7.54±09	0.104
New-owners vs Non-owners	7.54±.09 vs 8.0±.20	0.075
Sleeping hours on weekends/vacation T1 (mean ± SD)		
Owners vs Non-owners	9.28±0.12 vs 9.44±0.3	0.944
Owners vs New-owners	9.28±0.12 vs 9.63±0.12	0.099
New-owners vs Non-owners	9.63±0.12 vs 9.44±0.3	0.914

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Adolescents with a smartphone sleep less than their peers

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