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Adolescents with a smartphone sleep less than their peers

--Manuscript Draft--

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Abstract:	<p>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.</p>	



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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

[Click here to view linked References](#)

1 **Adolescents with a smartphone sleep less than their peers**

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26 **ABSTRACT**

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

42

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

45

46 **ABBREVIATIONS**

47 ESPAD: European School Project on Alcohol and Other Drugs

48 T0: Time 0 (baseline)

49 T1: Time 1 (follow-up)

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

51

52 **WHAT IS KNOWN**

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

56 **WHAT IS NEW**

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

60

61 INTRODUCTION

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

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

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

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

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

89 To our knowledge, there have been few studies that have examined the relationship
90 between owning a Smartphone and sleep duration. Among these, a recent cross sectional
91 research [14] led in Switzerland emphasized that the possession of a Smartphone was
92 associated with a high media use in bed before sleeping. The authors compared two groups of
93 12-17 year-olds: those with a Smartphone and those with a conventional mobile phone. Those
94 who had a Smartphone were more likely to go to bed later, although there were no differences
95 regarding sleep duration between these two groups.

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

103 **MATERIALS AND METHODS**

104 **Procedure / Study population**

105 Data were obtained from the ado@internet.ch survey, a longitudinal study based on a
106 representative sample of students in the French-speaking part of Switzerland. In spring 2012 all
107 8th graders (N=3367; mean age 14.2 years) in a random sample of 35 schools were invited to
108 participate in the study. After data cleaning, the final sample of the first wave included 3067
109 youths (50.3% females). The baseline questionnaire was filled in online in the school's computer
110 science room. At the end of the questionnaire, participants were asked whether they would
111 agree to leave their email address in order to be contacted biannually during 2 years to continue
112 the study and 2035 of them (64.4%) agreed to it. For each subsequent wave, consenting

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

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

130 **Measures**

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

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

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

151 **Statistical analyses**

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

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

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

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

173 **RESULTS**

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

184 Regarding sleep problems, at T0, Smartphone Owners were more likely to have sleep
185 problems than Non-owners and New-owners ($P < 0.001$). However, there were no differences in
186 sleep problems between groups at T1. Regarding sleep duration, a statistically significant
187 difference was observed between Owners and Non-owners at T0 both on schooldays (Owners:
188 7.81 ± 0.10 hours; Non-owners; 8.61 ± 0.12 hours; $P = .001$) and on weekend/vacations (Owners:
189 9.48 ± 0.16 hours; Non-owners; 10.20 ± 0.24 hours; $P = .045$), and between Owners and New-
190 owners on schooldays (Owners: 7.81 ± 0.10 hours; New-owners: 8.23 ± 0.12 hours; $P = 0.020$). As

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

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

195 **DISCUSSION**

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

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

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

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

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

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

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

251

252 **DISCLOSURE**

253 **Funding:** The ado@internet.ch study was financed by the Service of Public Health of the
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257 **Conflict of interest:** The authors declare that they have no conflict of interest.

258

259 **COMPLIANCE WITH ETHICAL STATEMENT**

260 **ETHICAL APPROVAL**

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

262

263 **AUTHORS' CONTRIBUTION**

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

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

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

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

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

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275

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- 326

327 Table 1. Bivariate analysis comparing the three groups of Smartphone Owners, New-owners,
 328 and Non-owners with all factors measured at T0 and/or T1. The far-right column provides the p-
 329 value corresponding to a chi-square test for categorical factors, and to a one-way ANOVA for
 330 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

331

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

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

334

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

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26

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27 **ABSTRACT**

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

43

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

46

47 **ABBREVIATIONS**

48 ESPAD: European School Project on Alcohol and Other Drugs

49 T0: Time 0 (baseline)

50 T1: Time 1 (follow-up)

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

52

53 **WHAT IS KNOWN**

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

57 **WHAT IS NEW**

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

61

62 INTRODUCTION

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

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

75 Currently, there is an increase of teenage Smartphone owners ~~among teens~~ in many
76 Western countries. According to Madden et al. [11], 37% of 12-17 year old American teens in
77 the United States ~~aged 12-17~~ owned a Smartphone in 2012, while they were 23% in 2011. The
78 authors highlighted that half of Smartphone owners reported using their mobile phone as their
79 primary mode of online connection. In Switzerland, we observe the same trend. The number of
80 12-19 year-old Smartphone owners increased from 47% in 2010 to 97% in 2014. Among them,
81 87% used it daily or more than once a week to access the Internet [12].

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

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

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

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

106 MATERIALS AND METHODS

107 Procedure / Study population

108 Data were obtained from the ado@internet.ch survey, a longitudinal study based on a
109 representative sample of students in the French-speaking part of Switzerland. In spring 2012 all
110 8th ~~-~~ graders (N=3367; mean age 14.2 years) in a random sample of 35 schools were invited to
111 participate in the study. After data cleaning, the final sample of the first wave included 3067
112 youths (50.3% females). The baseline questionnaire was filled in online in the school's computer
113 science room. At the end of the questionnaire, participants were asked whether they would

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

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

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

143 **Measures**

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

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

164 **Statistical analyses**

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

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

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

186 RESULTS

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

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

197 Regarding sleep problems, at T0, Smartphone Owners ~~of a Smartphone~~ were more
198 likely to have sleep problems than Non-owners and New-owners ($P < 0.001$). However, there
199 were no differences in sleep problems between groups at T1. Regarding sleep duration, a
200 statistically significant difference was observed between Owners and Non-owners at T0 both on
201 schooldays (Owners: 7.81 ± 0.10 hours; Non-owners; 8.61 ± 0.12 hours; $P = .001$) and on
202 weekend/vacations (Owners: 9.48 ± 0.016 hours; Non-owners; 10.20 ± 0.24 hours; $P = .045$), and
203 between Owners and New-owners on schooldays (Owners: 7.81 ± 0.10 hours; New-owners:
204 8.23 ± 0.12 hours; $P = 0.020$). As expected, there were no differences between Non-owners and
205 New-owners on schooldays or on weekends/vacation (Table 2).

206 At T1, the only statistically significant difference was observed between Owners and
207 Non-owners on schooldays (Owners: 7.28 ± 0.09 hours; Non-owners: 8.0 ± 0.20 hours; $P = 0.002$).

208 **DISCUSSION**

209 The aim of the present study was to examine whether acquiring a Smartphone had an
210 effect on adolescents' sleep duration. Overall, adolescents who owned a Smartphone were
211 significantly more likely to have shorter sleep duration than Non-owners. As recommended by
212 the National Sleep Foundation [9; 10] the appropriate sleep duration, 7 for adolescents aged 14-
213 17, 7 should be between 8 to 10 hours. Below this range, lack of sleep may affect health and well-
214 being. Several studies [16; 17] have shown that reducing sleep duration, even by a single hour
215 may have a negative impact on youth's development, to the extent that sleep seems to be
216 essential during brain maturation, which characterizes the period of adolescence. In this

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

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

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

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

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

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

264

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

271

272 **COMPLIANCE WITH ETHICAL STATEMENT**

273 **ETHICAL APPROVAL**

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

275

276 **AUTHORS' CONTRIBUTION**

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

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

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

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

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

287

288

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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

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