Emotions relating to romantic love – further disruptors of adolescent sleep

Liisa Kuula[1], PhD, Timo Partonen[2], MD, PhD, Anu-Katriina Pesonen[1], PhD

[1]*SleepWell Research Program, Faculty of Medicine, University of Helsinki, Helsinki, Finland*

[2]*National Institute for Health and Welfare, Department of Public Health Solutions, Helsinki, Finland*

Corresponding author:

Liisa Kuula, SleepWell Research Program, Faculty of Medicine, PO BOX 21 (Haartmaninkatu 3 B), 00014 University of Helsinki, Helsinki, Finland, tel. +358 40 7546308, fax: NA. Email: liisa.kuula-paavola@helsinki.fi

Funding: This work was supported by the Academy of Finland under Grant 12871741.

Abstract

Objective

Early-stage romantic involvement may resemble hypomania in its manifestation on behavioral, physiological, and psychological levels. Previous research suggests that self-reported sleep duration may diminish as a result of falling in love during adolescence. We investigated how feelings of infatuation are related to subjective and objective measures of sleep duration, quality and timing.

Methods

1374 adolescents (66% girls; mean age 16.9, SD=0.6 years) selected from the population register responded to online questionnaires regarding romantic love, mental wellbeing, and sleep behavior. A subsample (n=309) underwent a week-long actigraphy measurement (GENEActiv Original). We compared the sleep duration, quality and timing of those who reported being in the early stages of love to those who were not.

Results

11% of all participants reported being in the early stages of romantic love. Those girls and boys who were in love had higher scores of depression and anxiety than others. Girls who were in love reported poorer sleep quality, later sleep timing and shorter sleep duration both on weekdays (mean difference 32 minutes, $p \leq 0.001$) and at weekends (15 minutes, $p=0.037$) than those who were not in love. Actigraphy measurements were similar (sleep duration mean difference 27 minutes, $p=0.04$).

Conclusions

We conclude that romantic love is one further cause for short or poor quality sleep in girls, and may relate to symptoms of depression and anxiety in both sexes. However, feelings of infatuation contain important developmental lessons.

Keywords: love; adolescence; sleep; insomnia; actigraphy; depression

Introduction

Falling in love is an emotional disruption at any age, but for adolescents the feelings might be overwhelming [1]. In addition to being a positive feeling, romantic love may cause stress, negative affect, and influence wellbeing in many areas of the adolescent life, especially if the feeling is not reciprocal [2]. Indeed, love in young women has been associated with heightened levels of anxiety [3], depressive symptoms [2, 4, 5] as well as acute increases in cortisol levels after simply being asked to reflect on their romantic relationship and partners [6].

Love may be defined in many ways, and it may also carry different meanings to different people. Typically, for research purposes, a useful taxonomy distinguishes between infatuation which precedes the early stages of love, and attachment which tends to build up as a slower form of love [7]. Infatuation is an overwhelming passion towards one person whereas attachment is a more stable emotional bond [7]. Love may also include different phases depending on how long the feelings have lasted. Infatuation and early stage love are thought to be more prevalent in early months (1-8 months) of love, whereas longer duration (8-17 months) represents a different phase of love [8]. In this study we focus on emotions relating to early-stage romantic love or infatuation which include some emotional turmoil, that is, emotions relating to hypomania, feelings of exhilaration, intrusive thinking, and the craving for emotional union [3, 9].

During adolescence the brain and body change at an accelerated pace, and typically the behavioral and emotional development lags behind physical pubertal maturation. While bodies transform rapidly, the social and psychological progress towards adulthood is far slower. In addition to other physical changes resulting from pubertal maturation, the adolescent brain goes through dramatic development, including pruning and myelination [10]. The prefrontal cortex is among the last areas of the brain

to complete development, typically only during the early adulthood years [11]. With weaker prefrontal cortical regulation and dramatic developmental changes in reward circuitry of the brain[12], adolescence tends to be a period which lacks emotional and executive control. These shortcomings may lead to further distress when combined with powerful romantic emotions or sexual desires and budding relationships [13, 14]. Romantic relationships during adolescence have been reported to be linked to both poorer [15, 16] and better mental wellbeing [17, 18]. Specifically, these associations have been different between girls and boys: girls seem to experience more adverse effects of being in a relationship than boys [15, 18].

Hormonal changes, triggered by brain and body developments, are strongly involved in the intense feelings of sexual attraction and falling in love. During puberty, the volume of circulating sex hormones in the body rises, and while testosterone and estrogen are associated with heightened sexual urges, oxytocin and vasopressin are implicated in attachment and bonding [19]. During the early phases of falling in love, changes have been reported in the secretion of testosterone (increased in females, decreased in males) [20], as well as increased nerve growth factor (NGF)[21]. Furthermore, these changes seem to diminish as a function of time since love onset: in the previous studies neither testosterone nor NGF levels remained elevated after a one-year follow-up [20, 21].

This combination of changes in the adolescent body, endocrine glands, and brain leads a typically developing teenager into a situation where they are very likely to fall in love rapidly, not be ready for the emotions, and experience distress related to this. Early-stage romantic involvement may resemble hypomania in its manifestation on behavioral, physiological and psychological levels. While behavior, emotions, and neural development go through changes during adolescent years, sleep is one of the most

powerful markers to manifest these changes [22]. Typically, sleep schedules shift towards later times, and sleep duration shortens [23, 24]. Biological and social pressure both play a part in this, but it is not yet known how romantic love influences this development. One previous study in 107 adolescents suggested that self-reported sleep may diminish as a result of falling in love during adolescence [25]. That study found that those adolescents who reported being in love (56% of the sample) also reported 1.12 hours less sleep daily than the control group, but also improved subjective sleep quality, and lower daytime sleepiness. Given that these evaluations may be biased due to a hypomanic state of self-report, it is important to investigate the effects of romantic love using objective measures of sleep.

At this point of development, there are considerable differences between sexes. The pace of pubertal maturation alone differs between males and females [26], possible leading female adolescents to relationships at an earlier age than male adolescents. Furthermore, previous literature suggests that emotions relating to early stages of love, and possible adverse implications are sex-specific [15, 20]. As the biological changes relating to sex hormones as well as social and psychological maturation seem to be different in both pace and mechanism, our study focuses on investigating these phenomena separately for girls and boys.

For the purposes of investigating love from an infatuation angle rather than mature or stable love, we studied sleep in adolescents who were experiencing emotional turmoil relating to early stage love, and also whether they were currently in a relationship. This way we were able to investigate the potential differences between fulfilling love-related emotions versus being in a non-reciprocal situation where the feelings might be more consuming.

Hypotheses

The distress following intense feelings, and the difficulties in coping with these, may be manifested as insomnia symptoms or shorter sleep duration. We hypothesized that there is difference in sleep pattern between those adolescents who reported being in love and those who did not. Specifically, we expected to find shorter sleep duration, later sleep timing, and poorer sleep quality in those adolescents who report being in love. Additionally, we hypothesized to find shorter sleep duration, later sleep timing and poorer sleep quality in those who were experiencing love-related emotional turmoil but were not in a relationship compared to those who were in relationships. Furthermore, we explored whether anxiety or depressive symptoms would attenuate the possible association.

Methods

Participants

The SleepHelsinki! study is a population-based cohort study initiated in autumn 2016. We used the Finnish Population Register Centre to identify all adolescents born between 1.1.1999 and 31.12.2000 (n=10,476) who resided in Helsinki, the capital city of Finland, and whose native language was registered as Finnish (72% of the total sample). The register thus included 7539 adolescents (3789 born in 1999, and 3750 born in 2000), of whom 50% were males. In September 2016 we sent invitation letters to all registered adolescents to participate in the SleepHelsinki! study, which consisted of an online survey primarily targeting sleep, health and behavior. The estimated time for filling in the questionnaire was 30 minutes. The survey also served as a screening tool for the next phases of the SleepHelsinki! study, which aimed at testing new intervention tools for

adolescents with a delayed sleep phase (ClinicalTrials.gov Identifier: NCT02964598).

Altogether, 1411 adolescents (19% of the initial cohort) responded to the online survey during autumn 2016 (from late September to early December, 2016), with valid responses from 1374 (18%) participants. The age of the respondents did not differ from the initial cohort mean age ($t(7537)=0.95$, $p=0.34$), but the respondents were more often females (34% males)($X^2=(1,1374)=171$, $p < 0.0001$). All respondents signed an electronic consent form, and for the subsequent study phases targeting on the intervention, all participants signed further consent. Ethical permission was obtained from The Hospital District of Helsinki and Uusimaa Ethics Committee for gynaecology and obstetrics, pediatrics and psychiatry (Decision number 50/13/03/03/2016).

Out of the 1374 adolescents (66% girls; mean age 16.9, SD=0.6 years) who provided valid responses to the baseline questionnaires, we invited a subsample (552 invited, completed n=309, 70% girls) who underwent a week-long actigraphy recording period (GENEActiv Original, Activinsights, Kimbolton, UK) (mean time between baseline questionnaire and actigraphy measurements 7.2 months, SD=4.1 months). The baseline questionnaire contained questions about the adolescents' sleep behavior and also a question regarding their emotional turmoil relating to being in the early stages of romantic love (later referred to as 'love status'), and a question regarding their romantic relationship situation (later referred to as 'relationship status'). In the current study, we compared the sleep of those who reported being in the early stages of love to those who were not, as well as different groups which were formed based on their love and relationship status. Girls and boys were analyzed separately due to theoretical assumptions based on previous reports [15, 20, 26], and differences in initial measures.

The subsample with actigraphy measurement data was compared to the rest of the

sample who had filled in the online survey (n=1065). The comparisons regarding age, sex, socio-economic status, depressive symptoms, anxiety, relationship status, and sleep behavior are presented in Table 1.

Questions measuring sleep and love

Total sleep duration, and chronotype (sleep midpoint) for both school nights (weekdays) and free nights (weekends) were derived from responses to the Münich Chronotype Questionnaire (MCTQ)[27] which is a validated method for sleep assessment. Chronotype was estimated using the midpoint between sleep onset and sleep offset on nights when adolescents do not have school the next day, which reflects the timing of the individuals' circadian clock.

Subjective sleep quality was assessed using the Pittsburgh Sleep Quality Inventory (PSQI), which is a validated questionnaire which assesses sleep quality and disturbances over a 1-month time interval [28]. We used the global score as a measure of subjective sleep quality.

Love and relationship status were detected using two questions (in Finnish): "Love can be a powerful feeling, especially in the beginning. Are you currently experiencing the emotional turmoil which relates to the early stages of falling in love?" and "Are you in an exclusive romantic relationship?" The response options for both questions were binary (Yes I am / No I am not).

The emotional turmoil relating to being in the early stages of love is referred to as "being in love" for the sake of readability.

Sleep actigraphy measurements

The participants included in the objective measurements were instructed to wear the GENEActiv Original actigraph (Activinsights, Kimbolton, UK) for a minimum of one week, and they were given a sleep log booklet to fill in alongside the actigraphy measurement period. Data were treated meticulously: nights were excluded from analyses if they were considered to contain atypical events or phenomena. The detailed procedure for exclusions and data cleaning has been described previously [29]. All actigraphy measurements were analyzed by taking into consideration both recorded activity and self-reported sleep timing information. For sleep behavior analyses regarding all measured days as well as weekdays and weekends separately, we derived assumed sleep duration from the actigraphy data, and calculated sleep midpoint by adding half of the assumed sleep duration to sleep onset based on actigraphy data.

Potential covariates and background variables

We investigated whether levels of depression or anxiety might explain some of the associations between sleep behavior and emotions relating to love. Thus, we included scores estimating depressive and anxiety symptoms as covariates in Model 2. Symptoms of depression were evaluated using a sum score from Beck depression inventory-II [30] (BDI-II), and anxiety levels were evaluated using the 7-item GAD [31]. BDI-II scores were available from 1261 (67% girls) and GAD scores from 1353 (67% girls) participants. Both scores were available from 1246 participants (67% girls).

As an overall indicator of the sample's socio-economic status (SES), we classified parental education into three groups. Participants were asked to report the highest educational attainment of their parents, and the highest report was selected as the basis for classifying participants' SES as (1) lower (2) middle, or, (3) upper. Lower SES

included minimum compulsory educational attainment. Education attained beyond this (i.e. vocational school, technical college) was classified as middle level SES. SES was classified as upper level if either parent had a university-level degree.

Statistics

We used SPSS version 25.0 for all statistical analyses (SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.). T-tests were used to compare continuous variables in preliminary inspection of the data and chi square (χ^2) tests were used for comparing categorical measures, such as parental education. Covariates' correlations were analyzed using Pearson correlations in order to detect how they were associated to sleep duration, timing, and quality. Sleep duration and timing regarding both self-reports and actigraphy measurements were investigated both pooled (all days) and separately for weekdays and weekends. In order to compare group differences between (1) those who were experiencing emotions relating to love, and those who were not, as well as (2) four different groups of adolescents who differed regarding their relationship status and love status, we used one-way ANOVAs and ANCOVAs.

The initial comparisons (Model 1; no covariates) between love status groups and relationship status groups were done using ANOVAs; we report means or mean differences (MD), 95% Confidence intervals, R^2 values, and p-values for these comparisons. The potential covariates included depression and anxiety scores, which were initially analyzed with T-tests to study whether they were significant confounders in our sample. For adjusted Model 2 ANCOVA analyses, we report results after controlling for depressive and anxiety symptoms, and, regarding the actigraphy measures, time between filling in the initial questionnaire and initiating actigraphy measurement.

Additionally, possible sex interaction effects were investigated by using the interaction term 'Sex*Love status'.

Results

Initial analyses

The sample characteristics are presented in Table 1.

Of all participants 11% reported being in the early stages of romantic love. Girls and boys differed significantly from each other in several aspects as was expected at this developmental phase. Girls were more likely to be in a romantic relationship (χ^2 (1, 1360) =11.23, p<.001), but both girls and boys were as likely to be in love (χ^2 (1, 1360) =0.47, p=0.49). Regarding self-reported sleep variables, girls had poorer sleep quality as indicated by higher scores in PSQI (t(1372)=6.61, p<.001), earlier sleep midpoint during weekdays and weekends (t(1365)=-6.76), t(1365)=-6.37, respectively, p-values <.001), and shorter total sleep duration during weekdays (t(1365)=-2.40, p=0.017). In actigraphy sleep measures (recorded on average 7.2 months after responding to the questionnaire) sleep duration was longer regarding all nights and weekend nights for girls (t(307)=2.49, p=0.013, t(275)=2.32, p=0.021, respectively) compared to boys. Girls' sleep midpoint was earlier regarding all measured nights (t(307)=-3.07, p=0.002), weekday nights (t(307)=-2.69, p=0.008), and weekend nights (t(275)=-2.26, p=0.025). Regarding depressive and anxiety symptoms, girls had higher scores in both BDI-II and GAD (t(1259)=9.67, t(1351)=11.92, respectively, both p-values <.001). The sex*love status interaction effects were significant regarding self-reported weekday and weekend sleep midpoints (F(1,1349)=6.51, p=.011 and F(1,1349)=7.61, p=.006, respectively), but no other interactions were significant (all p-values >.08). Parental education was not a

differentiating characteristic between in-love and not-in-love participants (all p-values >.08), and was thus not included as a covariate.

Depression and anxiety symptoms: associations with sleep

BDI-II and GAD scores were highly correlated with each other (girls r=.77, p≤.001; boys r=.76, p≤.001). In girls, the BDI-II score correlated with all of the self-reported sleep measures except for weekend sleep duration: higher estimates of depressive symptoms were related to later sleep timing, shorter sleep duration and poorer sleep quality (r> .24, all p-values <.001). In girls, higher GAD scores were related to all self-reported measures of sleep timing, duration, and quality (r>.12, all p-values <.001).

Regarding girls' actigraphy measurements, BDI-II scores were not related to any of the sleep measures. GAD scores in girls correlated significantly with weekend and all days' sleep duration, sleep midpoint during all measurement days, weekdays, and weekends (r>.14, all p-values <.04).

The correlations were similar in boys: BDI-II score correlated with all of self-reported sleep measures except weekend sleep duration. Later self-reported sleep timing, shorter sleep duration and poorer sleep quality correlated significantly with depressive symptoms (r>.15, p<.001) and GAD scores (r>.14, p<.003). Boys' actigraphy measurements correlated with depression symptoms only regarding weekday sleep midpoint (r=.23, p=.03), and did not correlate with GAD scores.

Love and relationship status: associations with depression and anxiety

Out of all of the participants, 11% reported being in the early stages of romantic

love. Table 2 disseminates the portions of adolescents who were also in a relationship. There was a significant difference between the proportions of girls and boys in these groups (χ^2 (4,1374)=11.94, p=0.018), which emphasizes the differences at this developmental phase.

Both depression and anxiety scores differed significantly according to love status: girls in love had higher mean BDI-II scores than others (15.3 vs. 12.3, p=0.012), and boys' BDI-II scores differed similarly (11.1 vs. 6.5, p<.001). GAD score differences replicated these associations: for girls the mean scores were 6.1 vs. 5.0 (p=0.019), and for boys 3.8 vs. 2.2 (p=0.001). BDI-II and GAD scores were added as covariates in Model 2 analyses (significance regarding associations with all sleep measures shown in Tables 3 and 4).

To further investigate the cause of the depressive and anxiety symptoms in those who reported being in the early stages of love, we examined whether being in a relationship would differentiate between these associations. We found an overall significant difference between all the groups' depressive scores (amount of participants belonging to the groups presented in Table 2) (F(4,1256)=7.67, p<0.0001), and that the greatest differences in respondents were between those girls who reported being both in love and in a relationship (BDI-II mean score=16.7) as compared to those who were neither in love nor in a relationship (mean=12.0)(F(4,840)=3.93, p=0.004).

In boys the overall differences were quite similar (F(4,411)=4.38, p=0.002), with those boys who were neither in love nor in a relationship having the lowest BDI-II scores (mean=6.3), but those boys who reported being in love but not in a relationship reporting the highest scores (mean BDI-II score=11.3).

Regarding anxiety symptoms and their distribution according to love and relationship status, both sexes' scores were similar to depressive symptoms. Overall differences between groups were significant ($F(4,1348)=9.31$, $p<0.0001$). Girls not in love nor in a relationship had the lowest anxiety scores (mean=4.8), and girls who were in love and in a relationship had the highest (mean=6.6) ($F(4,895)=3.96$, $p=0.003$). In boys, those who were neither in love nor in a relationship had the lowest GAD scores (mean=2.0), but those boys who reported being in love but not in a relationship reporting the highest scores (mean=3.9) ($F(4,448)=5.21$, $p<0.0001$).

Being in love: associations with subjective and objective sleep measurements in girls

Table 3 presents differences in sleep measures between those girls who reported being in love and those who did not. Those girls who stated being in the early stages of love reported shorter sleep duration both on weekdays (mean difference 31 minutes, $p\leq0.001$) and at weekends (15 minutes, $p=0.037$) than those who were not in love. Sleep timing differed significantly: those girls who reported being in love, also reported having a later weekday (MD 14 minutes) and weekend (MD 30 minutes) sleep midpoint. Additionally, they reported poorer sleep quality as indicated by a higher PSQI score. Model 2 analyses remained significant regarding self-reported weekend sleep midpoint and weekday sleep duration (p-values <0.008).

During the actigraphy measurement period (on average 7.2 months later), the mean difference between the two groups in sleep duration was 27 minutes ($p=0.039$). This difference was no longer significant in Model 2, suggesting either a temporary effect, or one that is dependent on either anxiety or depressive symptoms.

Being in love: associations with subjective and objective sleep measurements in boys

Table 4 presents differences in sleep measures between those boys who reported being in love and those who did not. Boys' sleep quality as estimated by PSQI score was 0.9 points poorer in those boys who reported being in love; other measures did not differ significantly according to self-report about being in love (all p-values>0.42) in initial Model 1 analyses. The PSQI result did not survive further adjustments. However, in Model 2 analyses, boys' self-reported midpoint differences became significant: those boys who reported being in love had earlier sleep midpoints on weekdays (11 minutes) and at weekends (21 minutes).

Relationship & love status: associations with subjective and objective sleep measurements

As there seemed to be some joint association between negative affect and being in love and in a relationship, we ran the sleep analyses over the four groups (Not in love, not in a relationship; Not in love, in a relationship; In love, not in a relationship; In love, in a relationship) in order to examine how the groups might differ regarding sleep. We found that relationship status seemed to be associated with poorer subjective sleep measures in girls, regarding sleep quality, duration, and timing: the girls who were not in love, nor in a relationship had better quality sleep (PSQI mean=7.9, SD=3.3) compared to those who were in love and in a relationship (PSQI mean=9.0, SD=2.5) ($F(4,908)=2.58$, $p=0.036$). A similar pattern was found also in other subjective sleep measures, such that those girls who were in love and in a relationship had the latest sleep midpoint over weekdays (3:31 vs. 3:07, $F(4,904)=3.24$, $p<.001$) and weekends (6:15 vs. 5:24, $F(4,904)=5.69$, $p<.001$) and shortest weekday sleep duration (6.23h vs. 7:18h, $F(4,904)=6.44$, $p<.001$). The associations regarding sleep midpoint both on weekdays and at weekends survived

controlling for depressive and anxiety symptoms, suggesting these were not the causes for late sleep midpoint.

We were unable to detect any initial differences in boys' sleep according to relationship status in Model 1 (all p-values >.13), but after controlling for depressive and anxiety symptoms (Model 2), self-reported weekend sleep midpoint differed such that those boys who were in love and in a relationship had the earliest sleep midpoint over weekends (4:58 vs. 6:26 for those boys who those who were not in love but in a relationship; MD=1:01 for boys not in love nor in a relationship ($F(4,408)=3.21$, $p=0.013$)). None of the actigraphy measures differed between these four groups in girls or boys.

Discussion

This study found a significant difference in sleep duration between those adolescent girls who reported being in the early stages of love, and those who did not. This difference was found using both self-reports and objective measures of sleep duration, though the strongest associations were found in self-reported measures of sleep timing, duration and quality. Girls who reported being in love also had later sleep midpoint and poorer sleep quality, as well as higher anxiety and depression scores than those who were not in the early stages of love.

Our findings suggest that falling in love is a powerful disruptor of girls' sleep in this phase of development. Adolescence is a turbulent time in many aspects, including neural development [10], hormone secretion levels [32], social and emotional issues, as well as sleep behavior. As normative development during the teenage years is considered to include some level of sleep disruption, the cause behind these problems is often

overlooked. While diminishing sleep duration may result from positive emotions, romantic feelings may also be related to depressive feelings and anxiety symptoms [5, 33]. Our study suggested that depressive symptoms may be associated with being in love, and they may partially explain the association between love and sleep both in girls and boys. The findings related to self-reported sleep quality or weekend sleep duration, as well as actigraphy measured sleep duration did not survive controlling for depressive symptoms.

Romantic love per se might be disruptive for sleep, but since depressive symptoms have been suggested to relate to unhappy or unfulfilled romantic feelings [2], we further investigated the role of relationship status on sleep. Involvement in romantic relationships during adolescence can be considered developmentally healthy [1], but previous studies have not addressed how this reflects on sleep. In explorative analyses we considered the joint associations of being in love and being in a relationship, and compared sleep measures between the combinations of these statuses. When we distinguished between possible unhappy infatuations from the effects of being in a stable relationship, we found that those girls who were in love and also in a relationship had the poorest sleep quality, the shortest weekday sleep duration and the latest sleep midpoint on both weekdays and weekends. This would suggest that being in a relationship is a further disturber of sleep in adolescent girls, and that the sleep disrupting effects of romantic love are not primarily caused by unhappy rumination on unfulfilled infatuations.

In boys the findings were less prominent, and did not survive controlling for anxiety or depressive symptoms. Only after controlling for mental wellbeing scores, boys' self-reported sleep midpoint was earlier in those who were in love – this may suggest a possible protective effect of being in love on sleep timing. This was further

emphasized when observing the sleep of those boys who were both in love and in relationships. Weekend sleep midpoint difference was almost 1.5h earlier in those boys who were in love and in relationships compared to those who were not in the early stages of love, but were in relationships. However, this latter group was relatively small in numbers, so the results may not be universally applicable.

One pathway for sex-specific findings at this developmental phase is the earlier pubertal maturation of girls. This may lead to romantic relationships at a younger age but with partners that are older. On a speculative level, older relationship partners may then have some influence on bedtimes.

During this time period of critical emotional and social development, being in love may cause problems in sleep behavior, but these problems are likely to be temporary in nature, and thus probably do not represent a threat to future healthy sleep behavior. In this study, the actigraphy measurements were completed several months after the adolescents filled in the baseline questionnaire. Adolescent development is rapid on physical, psychological and social levels, and it is likely that the participants' lives have already changed during the months since the initial report of being in love. It is plausible to assume that a more immediate measurement would have yielded more robust results in the objective measurements; this remains a topic of investigation for future studies.

The findings in this study were similar to those previous reports which have emphasized the effect of early stage romantic love on hormones or brain function during adolescence [6, 21]. It seems that females are more affected with the turbulence involved in this, but no previous report has thus far shown that this effect is true regarding sleep in addition to other biological aspects. While there is no evident explanation for this sexual dimorphism, pubertal maturation and sleep disruption markers (such as insomnia

symptoms) are extremely differentiated along the entire human developmental pathways and thus it is not surprising that this association replicates this separation between the sexes.

In summary, adolescent romantic relationships have the potential to be healthy experiences that teach emotion regulation as well as reciprocity in relationships. While it seems impossible to protect adolescents from problems in sleep, the individual problems should be observed carefully in order to detect whether romantic love is a positive or disruptive force. This is an especially important aspect in relation to mental wellbeing, as our study replicates previous findings [5] which have suggested that romantic love may be associated with higher risks of experiencing anxiety and depressive symptoms in adolescents. A recent study also reported associations between romantic love and elective alteration in immune cell gene regulation, suggesting vital changes in somatic health as well as psychological well-being [34]. Future studies are needed to investigate what is sleep's role in this finding.

Strengths and limitations

This study included a large sample of Finnish adolescents living in Helsinki. Our sample included a relatively large sample of adolescents who reported being in love, and as a major strength, we were able to analyze sleep using both questionnaire scores and objective measurements. Thus, this study is the first to report differences in sleep behavior according to love status using objectively measured sleep. However, as a limitation, the subsample does not fully represent the original cohort, and was measured later than the original questionnaire sample. The actigraphy sample differed from the original questionnaire sample in some regards: in the actigraphy sample, levels of depression and anxiety were significantly higher than in the original questionnaire. This may indicate a

greater emphasis of overall mental well-being on sleep, as both depression and anxiety influence sleep. As a further limitation we only had a single-item measure of being in love, which does not cover the entire range of romantic love, infatuation, or limerence. These aspects require further investigation. We, however, did have information on the adolescents' relationship status which enabled us to compare how emotions relating to love were associated to sleep measures under these different situations.

Conclusions

During adolescence, romantic love may be one further cause for shorter sleep duration in girls. While the mechanism remains unclear, feelings of romantic love contain important lessons in a developmental context, and may require processing time in the evening. This may lead to shorter sleep duration and poorer sleep quality, but these issues are likely to be transient states of behavior.

References

1. Collins, W.A., D.P. Welsh, and W. Furman, *Adolescent romantic relationships.* Annu Rev Psychol, 2009. **60**: p. 631-52.
2. Stoessel, C., et al., *Differences and similarities on neuronal activities of people being happily and unhappily in love: a functional magnetic resonance imaging study.* Neuropsychobiology, 2011. **64**(1): p. 52-60.
3. Bajoghli, H., et al., *In Iranian female and male adolescents, romantic love is related to hypomania and low depressive symptoms, but also to higher state anxiety.* Int J Psychiatry Clin Pract, 2013. **17**(2): p. 98-109.

4. Davila, J., et al., *Romantic and sexual activities, parent-adolescent stress, and depressive symptoms among early adolescent girls.* J Adolesc, 2009. **32**(4): p. 909-24.

5. Starr, L.R., et al., *Love hurts (in more ways than one): specificity of psychological symptoms as predictors and consequences of romantic activity among early adolescent girls.* J Clin Psychol, 2012. **68**(4): p. 403-20.

6. Loving, T.J., E.E. Crockett, and A.A. Paxson, *Passionate love and relationship thinkers: experimental evidence for acute cortisol elevations in women.* Psychoneuroendocrinology, 2009. **34**(6): p. 939-46.

7. Langeslag, S.J. and J.W. van Strien, *Regulation of Romantic Love Feelings: Preconceptions, Strategies, and Feasibility.* PLoS One, 2016. **11**(8): p. e0161087.

8. Fisher, H.E., et al., *Intense, Passionate, Romantic Love: A Natural Addiction? How the Fields That Investigate Romance and Substance Abuse Can Inform Each Other.* Front Psychol, 2016. **7**: p. 687.

9. Fisher, H.E., *Lust, attraction, and attachment in mammalian reproduction.* Hum Nat, 1998. **9**(1): p. 23-52.

10. Casey, B.J., R.M. Jones, and T.A. Hare, *The adolescent brain.* Ann N Y Acad Sci, 2008. **1124**: p. 111-26.

11. Petanjek, Z., et al., *Extraordinary neoteny of synaptic spines in the human prefrontal cortex*. Proc Natl Acad Sci U S A, 2011. **108**(32): p. 13281-6.

12. Galvan, A., *Adolescent development of the reward system*. Front Hum Neurosci, 2010. **4**: p. 6.

13. Braams, B.R., et al., *Longitudinal changes in adolescent risk-taking: a comprehensive study of neural responses to rewards, pubertal development, and risk-taking behavior.* J Neurosci, 2015. **35**(18): p. 7226-38.

14. Suleiman, A.B., et al., *Becoming a sexual being: The 'elephant in the room' of adolescent brain development.* Dev Cogn Neurosci, 2017. **25**: p. 209-220.

15. Soller, B., *Caught in a bad romance: adolescent romantic relationships and mental health.* J Health Soc Behav, 2014. **55**(1): p. 56-72.

16. Miller, B., *What Are the Odds:An Examination of Adolescent Interracial Romance and Risk for Depression.* 2017. **49**(2): p. 180-202.

17. Davila, J., et al., *Romantic competence, healthy relationship functioning, and well-being in emerging adults.* 2017. **24**(1): p. 162-184.

18. Ciairano, S., et al., *Dating, sexual activity, and well-being in Italian adolescents.* J Clin Child Adolesc Psychol, 2006. **35**(2): p. 275-82.

19. de Boer, A., E.M. van Buel, and G.J. Ter Horst, *Love is more than just a kiss: a neurobiological perspective on love and affection.* Neuroscience, 2012. **201**: p. 114-24.

20. Marazziti, D. and D. Canale, *Hormonal changes when falling in love.* Psychoneuroendocrinology, 2004. **29**(7): p. 931-6.

21. Emanuele, E., et al., *Raised plasma nerve growth factor levels associated with early-stage romantic love.* Psychoneuroendocrinology, 2006. **31**(3): p. 288-94.

22. Carskadon, M.A., *Sleep in adolescents: the perfect storm.* Pediatr Clin North Am, 2011. **58**(3): p. 637-47.

23. Gradisar, M., G. Gardner, and H. Dohnt, *Recent worldwide sleep patterns and problems during adolescence: a review and meta-analysis of age, region, and sleep.* Sleep Med, 2011. **12**(2): p. 110-8.

24. Ohayon, M.M., et al., *Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: developing normative sleep values across the human lifespan.* Sleep, 2004. **27**(7): p. 1255-73.

25. Brand, S., et al., *Romantic love, hypomania, and sleep pattern in adolescents.* J Adolesc Health, 2007. **41**(1): p. 69-76.

26. Sisk, C.L. and D.L. Foster, *The neural basis of puberty and adolescence.* Nat Neurosci, 2004. **7**(10): p. 1040-7.

27. Roenneberg, T., A. Wirz-Justice, and M. Merrow, *Life between clocks: daily temporal patterns of human chronotypes.* J Biol Rhythms, 2003. **18**(1): p. 80-90.

28. Buysse, D.J., et al., *The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research.* Psychiatry Res, 1989. **28**(2): p. 193-213.

29. Kuula, L., et al., *Poor sleep and neurocognitive function in early adolescence.* Sleep Med, 2015. **16**(10): p. 1207-12.

30. Beck, A.T., R.A. Steer, and G.K. Brown, *Beck depression inventory-II.* San Antonio, 1996. **78**(2): p. 490-8.

31. Spitzer, R.L., et al., *A brief measure for assessing generalized anxiety disorder: the GAD-7.* Arch Intern Med, 2006. **166**(10): p. 1092-7.

32. Paus, T., et al., *Sexual dimorphism in the adolescent brain: Role of testosterone and androgen receptor in global and local volumes of grey and white matter.* Horm Behav, 2010. **57**(1): p. 63-75.

33. Bajoghli, H., et al., *"I love you more than I can stand!" - romantic love, symptoms of depression and anxiety, and sleep complaints are related among young adults.* Int J Psychiatry Clin Pract, 2014. **18**(3): p. 169-74.

34. Murray, D.R., et al., *Falling in love is associated with immune system gene regulation.* Psychoneuroendocrinology, 2019. **100**: p. 120-126.

Table 1. Characteristics and comparisons of the sample based on questionnaire data and an actigraphy subsample 7.2 months later.

	Questionnaire sample	Actigraphy sample	
	Mean (SD)/ N (%)	Mean (SD)/ N (%)	p
N (%)	1374	309	
Age	16.8 (0.58)	17.5 (0.68)	0.6
Sex: Female/Male (% male)	913/461 (34)	215/94 (30)	0.2
Parent education			0.9
Lower	29 (2)	6 (2)	
Middle	321 (23)	69 (22)	
Upper	981 (71)	221 (72)	
Grade point average	8.65 (0.92)	8.65 (0.93)	0.9
Depression score (BDI)	10.7 (9.98)	12.5 (10.75)	.001
Anxiety score (GAD)	4.2 (4.24)	4.9 (4.38)	.001
In love	151 (11)	36 (12)	0.7
In a relationship	262 (19)	66 (21)	0.3
Sleep questionnaire scores:			
Weekday sleep midpoint (MCTQ)	3:15 (0:46)	3:34 (0:56)	<.001
Weekend sleep midpoint (MCTQ)	5:40 (1:21)	6:12 (1:24)	<.001
Sleep duration, weekdays	7:17 (1:11)	6:47 (1:21)	<.001
Sleep duration, weekends	9:15 (1:15)	9:12 (1:16)	<.001
Pittsburgh Sleep Quality Index	7.7 (3.1)	8.6 (3.4)	<.001
Actigraphy measurements:			
Sleep duration, all days	NA	7:42 (1:06)	NA
Sleep duration, weekdays	NA	7:26 (1:15)	NA
Sleep duration, weekends	NA	8:28 (1:31)	NA
Sleep midpoint, all days	NA	4:43 (1:15)	NA
Sleep midpoint, weekdays	NA	4:20 (1:17)	NA
Sleep midpoint, weekends	NA	5:52 (1:38)	NA
Nights measured	NA	6.5 (1.9)	NA

*p refers to significance in differences between measurement subsample groups using T-tests for continuous variables and $\chi 2$ tests for categorical variables. Abbreviations: M=mean; SD=standard deviation; MCTQ=Munich ChronoType Questionnaire; BDI=Beck's Depression Inventory II; GAD=Generalized Anxiety Disorder; NA=not available.

Table 2. Prevalence of romantic love and being in a relationship (p=0.018 for differences between girls and boys using $\chi 2$ test).

Status	Girls N (%)		Boys N (%)	
In love, in relationship	41	(4.5)	13	(2.8)
In love, not in relationship	62	(6.8)	34	(7.4)
Not in love, in relationship	156	(17.1)	52	(11.3)
Not in love, not in relationship	642	(70.3)	358	(77.7)
No response	12	(1.3)	4	(0.9)

Table 3. Mean differences in girls' sleep measures according to self-reports of being in love.

	In love vs. Not in love	95 % CI for MD	R^2	p^1/p^2
Questionnaire measures				
Weekday sleep midpoint (MCTQ)	3:21-3:07	0:04, 0:22	0.01	.003/ .06
Weekend sleep midpoint (MCTQ)	5:57-5:27	0:15, 0:46	0.02	.0001/ .008
Sleep duration, weekdays	6:45-7:17	0:17, 0:46	0.02	.0001/ .006
Sleep duration, weekends	9:02-9:17	-0:00, -0:30	0.01	.037/ .08
Pittsburgh Sleep Quality Index	8.82-7.96	0.20, 1.53	0.01	.011/ .87
Actigraphy measures 7.2 months later				
Sleep duration, all days	7:25-7:52	-0:01, -0:51	0.02	.039/ .19
Sleep duration, weekdays	7:18-7:34	-0:43, 0:12	0.01	.28/ .71
Sleep duration, weekends	8:09-8:42	-1:12, 0:07	0.01	.11/ .30
Sleep midpoint, all days	4:23-4:36	-0:41, 0:16	0.00	.40/ .13
Sleep midpoint, weekdays	4:06-4:13	-0:38, 0:22	0.00	.62/ .25
Sleep midpoint, weekends	5:37-5:45	-0:51, 0:34	0.00	.70/ .31

Abbreviations: MD=mean difference; MCTQ=Munich ChronoType Questionnaire. 95% CI refers to 95% confidence interval for the MD, and p^1 refers to significance between MD between groups (Model 1), p^2 refers to significance after controlling for depressive symptoms, anxiety symptoms, and, for the actigraphy measures: time passed after filling in baseline questionnaire (Model 2).

Table 4. Mean differences in boys' sleep measures according to self-reports of being in love.

	In love vs. Not in love	95 % CI for MD	R^2	p^1/p^2
Questionnaire measures				
Weekday sleep midpoint (MCTQ)	3:19-3:27	-0:23, 0:07	0.00	.29/ .018
Weekend sleep midpoint (MCTQ)	5:50-6:01	-0:37, 0:16	0.00	.43/ .018
Sleep duration, weekdays	7:15-7:24	-0:30, 0:12	0.00	.42/ .64
Sleep duration, weekends	9:10-9:15	-0:28, 0:19	0.00	.73/ .96
Pittsburgh Sleep Quality Index	7.68-6.78	0.07, 1.72	0.01	.033/ .25
Actigraphy measures 7.2 months later				
Sleep duration, all days	7:22-7:28	-1:00, 0:48	0.00	.83/ .81
Sleep duration, weekdays	6:55-7:16	-1:27, 0:45	0.00	.53/ .82
Sleep duration, weekends	8:37-8:06	-0:42, 1:44	0.01	.40/ .40
Sleep midpoint, all days	5:44-4:59	-0:13, 1:43	0.03	.13/ .61
Sleep midpoint, weekdays	5:22-4:34	-0:11, 1:47	0.03	.11/ .66
Sleep midpoint, weekends	6:49-6:08	-0:43, 2:03	0.01	.34/ .79

Abbreviations: MD=mean difference; MCTQ=Munich ChronoType Questionnaire. 95% CI refers to 95% confidence interval for the MD, and p^1 refers to significance between MD between groups (Model 1), p^2 refers to significance after controlling for depressive symptoms, anxiety symptoms, and, for the actigraphy measures: time passed after filling in baseline questionnaire (Model 2).