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FAKULTÄT FÜR PSYCHOLOGIE

THE ROLE OF SLEEP IN THE PSYCHOLOGICAL FUNCTIONING OF ADOLESCENTS

A Cumulative Dissertation

submitted to the Department of Psychology of the University of Basel in partial fulfillment of the requirements for the degree of Doctor of Philosophy

by

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Abstract

Adolescents’ sleep is related to psychological functioning. The present cumulative dissertation examined three main issues: First, whether parents’ sleep patterns are associated with their adolescent children’ sleep patterns using objective assessment of sleep, and whether adolescents’ sleep is associated with their psychological well-being. Second, whether regular physical activity is associated with increased sleep quality and improved psychological functioning. Third, whether interrelations between sleep patterns and subjective psychological well-being persist across one year (three time points), testing for influences in both directions.

The main findings of the cumulative dissertation can be summarized as follows: First, our findings show for the first time the existence of relationships between adolescents’ objective and subjective sleep and well-being and parents’ objective and subjective sleep and well-being. These relationships were apparent regardless of whether subjective or objective sleep data were considered. The overall pattern of results strongly indicates that adolescent’ sleep and well-being and family functioning are related. Second, we could show that thirty minutes of running in the morning during weekday for 3 consecutive weeks impacted positively on objective and subjective sleep and psychological functioning in healthy adolescents compared with control subjects. Third, our findings suggest that sleep duration is predictive of subjective psychological well-being across 6 months.

To summarize, and based on our data, we can say, that sleep is important for adolescents and also for their parents because of the bi-directional interaction (Kalak et al., 2012). Adolescents should be encouraged to have regular moderate-to-vigorous exercise, even if only for 30 minutes a day, as this can improve their psychological functioning and their subjective and objective sleep quality (Kalak et al., 2012), while sufficient sleep duration has an effect on subjective well-being six months later (Kalak et al., 2014).

Synopsis of own studies in the context of existing research

1 Introduction: The role of sleep in the psychological functioning of adolescents

Acute (Kaneita et al., 2007) and chronic (Roberts, Roberts, & Duong, 2008) sleep disturbances in adolescence has been associated with poor psychological and cognitive functioning and poor physical health. Accordingly, there is a wealth of studies, which reports an association between poor sleep (i.e., insufficient and not restoring sleep) and dimensions of psychological functioning, such as a reduction in quality of life, daily functioning (Banks & Dinges, 2007), decreased performance and social withdrawal (Linton, 2004), low subjective well-being, poor mood, sensitivity to stress, increased mental arousal (an increased level of inner tension, i.e., attention, alertness and responsiveness, efficiency, orientation, emotional processing are impaired) (Dahl & Lewin, 2002; Talbot, McGlinchey, Kaplan, Dahl, & Harvey, 2010; Walker & van der Helm, 2009). Moreover, poor sleep is associated with decreased affective consolidation and emotional regulation (Brand & Kirov, 2011; Gujar, McDonald, Nishida, & Walker, 2011; Gujar, Yoo, Hu, & Walker, 2011; Nishida, Pearsall, Buckner, & Walker, 2009; Riemann et al., 2010; Walker, 2009; Yoo, Gujar, Hu, Jolesz, & Walker, 2007). Other studies show that poor sleep is associated with decreased optimism (Lemola et al., 2011), depression, anxiety disorder, emotional problems (Alfano, Ginsburg, & Kingery, 2007; Carotenuto et al., 2012; Nixon et al., 2008), and a range of adaptive and persistent behavior problems (Lavigne et al., 1999).

There is also a wealth of studies, which reports an association between poor sleep and dimensions of cognitive functioning such as impaired memory consolidation, processing, recall, deletion, concentration and efficiency (Esposito et al., 2013; Owens, Spirito, McGuinn, & Nobile, 2000; Touchette et al., 2007). In addition, poor sleep is associated with low achievement in school (Dewald, Meijer, Oort, Kerkhof, & Bogels, 2010), including unfavorable effects on learning and academic performance (Curcio, Ferrara, & De Gennaro, 2006; Dewald et al., 2010; Gruber, Wiebe, Wells, Cassoff, & Monson, 2010; Lund, Reider, Whiting, & Prichard, 2010; Perkinson-Gloor, Lemola, & Grob, 2013; Schabus et al., 2006).

Other studies show that poor sleep in adolescence increases risks to physical health such as obesity and cardiovascular diseases (Al-Hazzaa, Musaiger, Abahussain, Al-Sobayel, & Qahwaji, 2012; Narang et al., 2012). Notably, even after accounting for the differential rate of affective disorders, poor sleep in adolescence elevates suicide risk (Bernert & Joiner, 2007; Goldstein, Bridge, & Brent, 2008; Liu & Buysse, 2006; Wong & Brower, 2012). Furthermore, in terms of a self-medication, adolescents with poor sleep attempt both to induce sleep using for example alcohol and cannabis, and to reduce sleepiness with caffeine or so-called energy drinks (Gromov & Gromov, 2009; Shibley, Malcolm, & Veatch, 2008).

Additionally, chronic sleep disturbances in adolescence increase the risk of psychological dysfunction in adulthood, including the risk of behavior problems (Clinkinbeard, Simi, Evans, & Anderson, 2011; Gregory & O'Connor, 2002), depression and anxiety (Gregory et al., 2005) as well as an adverse impact on cognitive development (Blunden, Lushington, Kennedy, Martin, & Dawson, 2000; Gozal & Pope, 2001). This means, for example, that if sleep disorders remain untreated in adolescence, the probability of suffering from depression in adulthood increases, independently from the fact that adolescents with depression, but without sleep disorders, have a greater risk of continuing to suffer from depression in adulthood (Aronen & Soininen, 2000; Bernert & Joiner, 2007).

Cross-sectional (Kaneita et al., 2007; Lund et al., 2010) and longitudinal studies (Fricke-Oerkermann et al., 2007) have shown that sleep disturbances during the development in adolescence can persist over time and reduce subjective sleep quality (Brand & Kirov, 2011; Pesonen et al., 2014), which again may compromise adolescents’ psychological functioning and physical health at long-term (Kaneita et al., 2009; Roberts et al., 2008; Touchette et al., 2012).

Complaints about poor sleep and daytime sleepiness are common among adolescents, and poor sleep in adolescence has become a significant public mental and physical health problem (Aronen, Paavonen, Fjallberg, Soininen, & Torronen, 2000; Laberge et al., 2001; Owens et al., 2000; Paavonen et al., 2000). Although older adolescents of 15 to 16 years still require approximately 9 hours of sleep per night, if compared to younger adolescents of around 10 to 11 years (Carskadon et al., 1980; Mercer, Merritt, & Cowell, 1998; Moore & Meltzer, 2008), a wealth of studies shows that average sleep duration decreases significantly across adolescence (Bonnet & Arand, 1995; Colrain & Baker, 2011; Mercer et al., 1998; Moore & Meltzer, 2008; Perkinson-Gloor, Lemola, & Grob, 2013; Rajaratnam & Arendt, 2001). In this regard, in a cross-sectional survey of a large sample of college students (*n* = 1125; 17 to 24 years old), over 60% of respondents were categorized as poor-quality sleepers with short sleep duration (Lund et al., 2010). Remarkably, over 25% of adolescents reported sleep disturbances (Archbold, Pituch, Panahi, & Chervin, 2002; Aronen et al., 2000; Owens et al., 2000; Paavonen et al., 2000), and round 20% of children with sleep disturbances also display sleep disturbances in adulthood (Fricke-Oerkermann et al., 2007). Further, we know that around 50% of all psychiatric disorders develop during adolescence (Paus, Keshavan, & Giedd, 2008), while 25% of toddlers (Mindell, 1993), 50% of schoolchildren (Kahn et al., 1989), and 33% of the adolescence (Morrison, McGee, & Stanton, 1992) suffer from sleep disorders, suggesting therefore an association between poor sleep and poor mental health during childhood and adolescence. Though, surprisingly, only 16% of parents recognize sleep disorders in their children (Liu, Liu, Owens, & Kaplan, 2005).

The period of adolescence (the World Health Organization defined this period of gradual transition between childhood and adulthood as running from 10 to 20 years) is marked by a huge number of asynchronous changes (Paus et al., 2008; Pinyerd & Zipf, 2005; Spear, 2000). These include dramatic and distinct physical changes (e.g., secondary sex characteristics develop, changes in height and weight), changes in hormonal status (e.g., dramatic increase in secretion of growth hormones) and alterations in neural network regulation marking puberty and maturation (Giedd et al., 1999; Paus et al., 2008; Pinyerd &

Zipf, 2005). But there are also numerous changes in other areas including social changes (e.g., relative independence from parents and peers, increase in responsibility), emotional changes (e.g., feeling embarrassed in front of members of the opposite sex, becoming overly sensitive about appearance), behavioral changes (e.g., decrease in activity levels), and cognitive changes (e.g., increase academic demands).

Adolescents additionally have to face new challenges and assume greater responsibility for a range of issues. That means, they have challenges and have to take responsibility for their academic and vocational careers (e.g., committing to academic work in their evenings). And they have to face challenges and responsibilities in peer and intimate relationships. Furthermore, physical, emotional, and financial independence from parents and siblings increases. And, they have to face challenges and responsibilities with respect to use of psychoactive substances, extra-curricular employment, and leisure-time activities; and again many of these matters relate to evening activities such as sports, social contacts, participation in cultural events, music and learning (cf. Spear, 2000).

There are several factors, which may influence adolescents' sleep, and these factors may theoretically interact with each other and adversely affect again psychological, cognitive and physiological functioning. The interaction between sleep and health during adolescence is significant but it is also complex (cf. Brand & Kirov, 2011). In brief, these possible influencing factors can be divided into psychiatric reasons (e.g., depression, substance abuse) (Kotagal & Pianosi, 2006; Millman 2005), physiological reasons (e.g., sleep apnea, nocturnal enuresis) (Camhi, Morgan, Pernisco, & Quan, 2000), circadian rhythm (e.g., secretion of melatonin) and sleep phase preference (e.g., advanced or delayed sleep phase) (Crowley, Acebo, & Carskadon, 2007), socio-cultural reasons (e.g., leisure time activities in the evenings) (Wolfson et al., 2003), employment beside school time (Millman, 2005), homework requirements and screen time (e.g., internet, mobile) (Eliasson, Eliasson, King, Gould, & Eliasson, 2002), decrease parenting control to setting bedtimes (Wolfson, & Carskadon, 1998), and psychological factors (e.g., all those factors, which may lead to subjective stress and poor sleep, most probably via increased psychophysiological arousal) (Harvey, 2000, 2002).

It is likely that dealing with all these challenges and responsibly issues is potentially stressful (Grant, Compas, Thurm, McMahon, & Gipson, 2004; Spear, 2009), and may be associated with poor sleep (Dewald, Meijer, Oort, Kerkhof, & Bogels, 2014; El-Sheikh, Buckhalt, Keller, & Granger, 2008). On the flip side, it seems likely that adolescents with favorable sleep will deal more successfully with these challenges, compared to those with poor sleep (El-Sheikh, Tu, Erath, & Buckhalt, 2014).

In summary, sleep plays a crucial role in adolescents' well-being and development, and the relationship between sleep on the one hand and psychological and social functioning and physiological well-being on the other is likely to be reciprocal, with negative feedback from one to the other persisting over time (Brand & Kirov, 2011; Colrain & Baker, 2011; Harvey, 2000, 2002; Jan et al., 2010; Ringli & Huber, 2011).

Based on this background, the purpose of the following studies was three-fold:

- To examine whether parents' sleep patterns are associated with their adolescent children' sleep patterns, and whether adolescents' sleep is associated with their psychological well-being. There has to date been no research using objective measurements of sleep characteristics among adolescents (El-Sheikh, 2011, for extensive overview).
- To examine whether regular physical activity is associated with increased sleep quality and improved psychological functioning. There is currently very little research on sleep among adolescents; most previous studies have used questionnaires, which call for a subjective assessment, while objective sleep measurement remains rare (Brand, Beck, Gerber, Hatzinger, & Holsboer-Trachsler,

2010a, 2010c; Dworak et al., 2008).

- To examine whether interrelations between sleep patterns and subjective psychological well-being persist across one year (three time points), testing for influences in both directions. Although there are numerous studies of the relationship between sleep and mental health, there are very few longitudinal studies focusing on the relationship between sleep duration and positive aspects of functioning such as psychological well-being (Fredriksen, Rhodes, Reddy, & Way, 2004; Wong et al., 2013).

2 Own studies

2.1 Sleep and family

Kalak, N., Gerber, M., Kirov, R., Mikoteit, T., Pühse, U., Holsboer-Trachsler, E., & Brand, S. (2012). The relation of objective sleep patterns, depressive symptoms, and sleep disturbances in adolescent children and their parents: A sleep-EEG study with 47 families. *Journal of Psychiatric Research, 46,* 1374-1382 (IF 2012: 4.66).

Background of the first study

Among the many factors that can affect sleep during adolescence, the role of the family environment is still poorly understood. In recent years, a growing body of research has emphasized the interdependence between children’s sleep and family environment (El-Sheikh, 2011, for extensive overview). Martin, Hiscock, Hardy, Davey, and Wake (2007) investigated the families of 5107 infants and 4983 children aged between 4 and 5 years and assessed both children’s and parents’ sleep and psychological functioning using questionnaires and sleep logs. They concluded that these children’s sleep problems were strongly associated with their parents’ mental health, particularly that of their mothers irrespective of whether they reported a history of health problems. Smedje, Broman, and

Hetta (1998) asked 367 mothers and 273 fathers about the sleep of their 5 to 6 year old children using questionnaires. Parents who reported sleep problems in their children had more sleep problems of their own. The authors interpreted this as an effect of children's sleep problems on parental sleep. In another cross-sectional study of 20,778 Chinese families, parents of 5 to 11 year old children were asked about the latter's sleep; children's shorter sleep duration was associated with parents' shorter sleep duration (Li et al., 2010). Likewise, Zhang, Wang, and Huang (2010) examined parental reports from 4470 families on the sleep of their school-aged children (7 to 11 years). Their results revealed similarities between parents' and children's sleep and wake patterns, although children's sleep-wake patterns were influenced more strongly by the mother-child relationship than by the father-child relationship. Last, Meltzer and Mindell (2007) surveyed 47 mothers of children aged from 3 to 14 years. A key finding from this questionnaire-based study was that children's sleep disruptions were highly associated with mothers' poor sleep and poor mental status. In summary, although the evidence is largely correlational, research on the sleep of infants, toddlers and children suggests that children's poor sleep has a negative impact on parents' and particularly mothers' sleep. However, whereas a growing body of evidence indicates that sleep characteristics in young children and their parents are associated, research on the relationship between parents' and adolescents' sleep remains limited. Lemola, Schwarz, and Siffert (2012) showed in a sample of 176 eleven years olds that a large difference in sleep duration between weekdays and weekends mediated a relation between inter-parental conflict and early adolescent aggression; irregular sleep seemed to be a vulnerability factor for aggression in early adolescence. Similarly, Tynjälä, Kannas, Levälahti, and Välimaa (1999) found that the self-reported sleep patterns of 4187 adolescents aged between 11 and 15 years were associated with their quality of life including their relationships with parents and peers. The main finding, however, was that a positive home atmosphere was the principal factor favoring high quality sleep. This finding held irrespective of gender or age. Likewise, Vignau et al. (1997) examined the prevalence and correlates of sleep problems in 763 16-year-old students as assessed by self-report questionnaires. A key finding was that sleep problems were highly related to various personal issues and particularly to poor family climate. These findings suggest that quality of family life is related to adolescents' sleep. Further, Bernert Merrill, Braithwaite, Van Orden, and Joiner (2007) investigated the association between stress in family life and sleep problems in 115 undergraduates aged 17 to 22 years, using self-reported questionnaires. They showed that familial stress was highly related to increased insomnia and poor academic achievement in late adolescence. Last, in two previous studies (Brand et al., 2009a, 2009b), we were able to show that mothers' and adolescents' sleep quality, both subjectively assessed, were associated, with parenting style being a mediating factor.

To summarize, there is compelling evidence that children's sleep is related to parents' sleep and mental health. This observation holds true not only for infants and children (Bernert et al., 2007; Li et al., 2010; Martin et al., 2007; Smedje et al., 1998), but also for early (Lemola et al., 2012; Li et al., 2010; Zhang et al., 2010), middle (Vignau et al., 1997) and late adolescence (Bernert et al., 2007; Brand et al., 2009a, 2009b).[1]

2.1.1 Why new research?

One major limitation of the research so far published is the source of evidence on sleep quality. In the majority of studies, information about parents' and children's sleep was obtained either from parents or from their children, and exclusively by questionnaire. Moreover, research focusing on adolescents remains limited. To the best of our knowledge, no study has so far examined the relationship between children's and parents' sleep architecture via objective sleep-EEG evaluation of entire families. Nor have parents and their

[1] Following Steinberg (1966) adolescence is subdivided in early adolescence (10 to 14 years old), middle adolescence (15 to 18 years old), and late adolescence (19 to 21 years old).

adolescent children been tested for their sleep concomitantly and separately.

To address these limitations, this study aimed at extending and improving upon previous research by (1) evaluating adolescents' and parents' sleep objectively using sleep-EEG and (2) assessing adolescents' and parents' sleep separately, with a focus on middle adolescence. Given the relative lack of work in which sleep variables have been objectively assessed, we believe that the results of the present study may be a valuable contribution the current literature. Additionally, given the strong possibility that health professionals will encounter adolescents' issues and concerns surrounding sleep complaints alongside difficulties in relations with their parents, results may be of value in family counseling and treatment of adults' and adolescents' sleep complaints. This is crucial as family conditions have been identified as protective factors that foster resilient adaptation among adolescents, particularly if they are exposed to adversity and stressful life circumstances (Cicchetti, 2010; Luthar, Shoum, & Brown, 2006; Lyssenko, Rottmann, & Bengel, 2010; Masten, 2004; Masten et al., 1999; Sameroff and Rosenblum, 2006; Tiet et al., 1998).

2.1.2 Our hypotheses

The following three hypotheses were formulated. First, following Li et al. (2010) and Zhang et al. (2010), we hypothesized that adolescents' sleep, measured by sleep-EEG (sleep continuity and sleep architecture), would be related to parents' sleep. Second, consistent with other findings (Bernert et al., 2007; Brand et al., 2009a, 2009b; Tynjälä et al., 1999; Vignau et al., 1997; Zhang et al., 2010), we expected that sleep objectively assessed in this way (by sleep-EEG), would be associated with subjective measures of sleep (using the Insomnia Severity Index: ISI), and with psychological well-being (using the Depression Scale and self-perceived and parents' perceived family climate), among adolescents and also their mothers and fathers. Third, in line with previous studies (Brand et al., 2009a, 2009b) and information from the Swiss Federal Statistical Office (2009), we expected that mothers' sleep patterns and psychological functioning would be more closely associated with family functioning than would those of fathers or the adolescent members of the families.

2.1.3 How we tested our hypotheses

One hundred and sixty-six complete datasets were obtained from 47 mothers (mean age: 49.45 ± 4.04 years), 39 fathers (mean age: 50.81 ± 5.12 years), and 80 adolescents (overall mean age: 16.28 ± 2.00 years; 36 females [45%]). The majority of adolescents lived with both parents (81.25%), some with their mothers only (16.25%), and a few (2.5%) with their fathers only.

Participants were recruited by advertisements in local high schools and by word-of-mouth in the German-speaking part of North-Western Switzerland. Only adolescents between 12 and 20 years were included in the study. Inclusion criteria for all participants were: at least one parent was employed, and adolescents were attending regular school programs. Exclusion criteria were: any past (6 months) or current medical or psychiatric disorder or complaint, including the intake of any sleep-, or mood-altering medication; shift or weekend work (parents; older adolescents). Each family member independently completed a series of questionnaires related to sleep and psychological functioning. All family members undertook one night home-based sleep-EEG recording. The sleep-EEG recordings were exclusively performed during school-week nights. Experienced lab personal applied the sleep-EEG, a one-channel sleep-EEG device (Fp2-A1; electrooculogram; electromyogram; SOMNOwatch®; Somnomedics, Randersacker, Germany). These simple though powerful devices have been shown to provide reliable data (Brand et al., 2010a, 2010c; Hornung et al., 2008). Sleep polygraphs were visually analyzed by two experienced sleep lab experts following standard procedures (Rechtschaffen & Kales, 1968).

2.1.4 Our results

First, our results indicate that adolescents' and parents' objective sleep patterns were associated. In more detail, adolescents' sleep continuity was associated with mothers' sleep continuity. Greater total sleep time (TST), prolonged sleep onset latency (SOL), increased sleep efficiency (SE), and number of awakenings after sleep onset (WASO) among adolescents were significantly related to mothers' TST, prolonged SOL, increased SE, and greater numbers of WASO. A similar pattern of associations was observed between adolescent' and fathers' sleep continuity variables, though correlations did not consistently reach statistical significance.

As for sleep architecture, adolescents' decreased light sleep and increased slow wave sleep was significantly associated with mothers' decreased light sleep and increased slow wave sleep, though single sleep states and rapid eye movement (REM)-sleep were not significantly associated. Again, similar but non-significant correlations were found between adolescents' and fathers' sleep architecture.

Second, the general pattern of results indicates that good sleep quality measured objectively was associated with better subjective sleep and psychological functioning. In more detail, sleep continuity variables (shorter SOL, higher SE, a lower number of WASO) in adolescents and mothers were associated with better psychological functioning (low subjective sleep disturbances, fewer depressive symptoms and more positive family climate). For fathers, these positive associations were less pronounced.

As for sleep architecture, sleep stages among adolescents and their mothers, including both shorter light sleep and more slow wave sleep, were associated with better subjective sleep (low sleep disturbances) and psychological functioning (fewer depressive symptoms, and an increased family climate). For mothers, increased REM-sleep was related to fewer sleep disturbances and a better family climate.

Third, the sleep patterns and psychological functioning of mothers was more closely *associated with family functioning than those of fathers or adolescents.* In more detail, among mothers increased subjective sleep disturbances were associated with more marked depressive symptoms and with a poorer family climate. The direction of these associations in adolescents and fathers were similar (associations were in the same direction), but for adolescents these were not as strong as for the mothers; for fathers the associations did not reach statistical significance.

As regards sleep continuity, the general pattern of results indicates that good sleep continuity variables (shorter SOL, higher SE, a lower number of WASO) in mothers were associated with a more positive family climate. Again, for adolescence these were less strong than for mothers and for fathers they were even less pronounced.

As regards family climate, for adolescence these associations were less strong and for fathers not statistically significant. Increased REM-sleep in mothers was related to a better family climate. For adolescents and fathers there were no statistically significant associations.

2.1.5 Conclusions

The pattern of the results suggests first that there may be a bi-directional association between family climate, family functioning and adolescents' sleep and well-being and second that mothers' and adolescent children's sleep and well-being are particularly closely associated. These findings add to the existing literature in an important way in that we were able to show that parents' and adolescents' subjective, and especially objective sleep and psychological well-being are interrelated.

The relationship between sleep quality and well-being was apparent regardless of whether subjective or objective sleep data were considered. The overall pattern of results strongly indicates that adolescents' sleep and well-being are sensitive to family functioning, thus pointing to parental social support as key to successful adaptation. Future research might assess broader samples, possibly including families from a wider range of socio-economic, ethnic and cultural backgrounds. Further, both cross-sectional and longitudinal study designs, along with interventions to modify the sleep of family members, might shed light on the extent to which improving sleep could positively impact on family climate and well-being.

The strength of this study is that it is the first to have documented objectively the existence of relationships between adolescents' sleep and well-being and parents' sleep and well-being. Healthy family members completed a series of questionnaires related to sleep and psychological functioning and all family members underwent home-based sleep-EEG recording on the same night.

2.1.6 Limitations

First, mothers were generally housewives and therefore more involved in the daily lives of their children. Future studies might examine whether our results reflect a mother-specific phenomena or instead one of differential child care responsibilities. Second, unfavorable first night effects are possible in first sleep-EEG application (Agnew, Webb, & Williams, 1966); an adaptation night would have been necessary for child participants. However, given that all participants slept in a familiar environment, these effects should be minimal. Third, the present study used a cross-section design which precludes conclusive causal inferences. Moreover, rapid changes in physiology and behavior are hallmarks of adolescence (Ge, Conger, & Elder, 2001); a longitudinal study could shed more light on the progress of this complex mutual interaction. Fourth, participants were recruited by word-of-mouth recommendation in high schools and consequently the sample does not reflect a representative cross-section of adolescents with respect to educational level, socio-economic status, or ethnic origins. Fifth, our data might potentially be biased because only adolescents and parents who were willing and able to fill in the questionnaires and to undergo sleep-EEG registration for one night participated in the study. A positive selection bias cannot be excluded. Sixth, to avoid lack of statistical power, we did not examine differences between male and female adolescents. Future research might therefore include larger samples. Seventh, we applied classical inferential statistics assuming independence of observations. However, due to family structure and concomitant sleep assessment, one might argue that the data were not independent. Eighth, because of the familial vulnerability of some psychiatric disorders (Dashevsky & Kramer, 1998), and because neither participants nor their parents were thoroughly screened for psychiatric disorders, we cannot exclude the possibility that the sleep difficulties assessed are merely bi-products of such disorders. Therefore, future research should include independent screening of parents and children for psychiatric disorders. Last, the study design allowed no exploration of neuroendocrine functioning or possible genetic factors (hereditability estimates of 40% have been proposed for sleep duration; Dhal, 1996; Gottlieb, O'Connor, & Wilk, 2007; Heath, Kendler, Eaves, & Martin, 1990). Nevertheless, it seems that psychological and environmental factors are more likely to shape adolescents' sleep than genetic factors. For instance, there is evidence for a non-genomic transmission of parental behavior and stress responsiveness (Champagne & Meaney, 2001). Last, EEG spectral analyses were not performed; therefore, future research examine whether the present pattern of results can be replicated and extend by including data from EEG spectral analyses.

2.2 Sleep and physical activity

Kalak, N., Gerber, M., Kirov, R., Mikoteit, T., Yordanova, J., Pühse, U., Holsboer-Trachsler, E., & Brand, S. (2012). Daily morning running for 3 weeks improved sleep and psychological functioning in healthy adolescents compared with controls. *Journal of Adolescent Health, 51,* 615-622 (IF 2012: 3.33).

Background of the second study

Exercise appears to be a simple and inexpensive method for addressing sleep loss and daytime sleepiness. Although there have been studies of both young and elderly adults (e.g., Loprinzi & Cardinal, 2011), relevant research on adolescents is scarce, and studies have predominantly involved cross-sectional designs (Liu, Uchiyama, Okawa, & Kurita, 2000; Tynjälä et al., 1999). In previous studies, we have been able to show a relation between exercising and better improved subjective and objective sleep in both adolescent elite athletes (Brand et al., 2010a, 2010d) and moderately exercising adolescents (Brand et al., 2010c), when compared with control subjects.

2.2.1 Why new research?

A limitation is that findings have been derived from cross-sectional group-comparison designs, whereas intervention studies do allow stronger conclusions regarding the direct effects of exercising. In this respect, Dworak et al. (2008) were able to show that acute bouts of exercise led to improvement in objectively recorded sleep. Additionally, there is evidence that regular exercise is associated with improved psychological functioning in adolescents (Brand et al., 2010c, 2010d; Pfeiffer et al., 2006; Stein, Fisher, Berkey, & Colditz, 2007), and that exercising buffers the effects of family conflicts on depressed mood (Sigfusdottir, Asgeirsdottir, Sigurdsson, & Gudjonsson, 2011), while sports participation has been shown to be a protective factor with respect to depression and suicidal ideation, mediated by its impact on self-esteem and social support (Babiss & Gangwisch, 2009). Additionally, there is also evidence that the implementation of regular exercise as a therapeutic intervention leads to positive psychological outcomes; regular exercising improved self-esteem in children and adolescents (Ekeland, Heian, & Hagen, 2005), and walking regularly for 30 to 45 minutes during weekdays for 12 consecutive weeks led to complete psychiatric remission in half of patients suffering from therapy-resistant major depressive disorders, as compared with control subjects (Mota-Pereira et al., 2011). Thus, there is reason to expect that exercise interventions can improve sleep and psychological functioning.

2.2.2 Our hypotheses

The following two hypotheses were formulated. First, we expected a positive impact on sleep of a moderate-to-vigorous exercise training program (here, moderate-to-vigorous exercise was defined as planned and continuous running without interruption at a speed such that conversation is not possible) (Brand et al., 2010a; Dworak et al., 2008) as compared to a control condition. Second, following previous research (Brand et al., 2010a, 2010c, 2010d; Dworak et al., 2008; Pfeiffer et al., 2006; Stein et al., 2007), we anticipated an improvement in psychological functioning (such as stress perception, curiosity, somatosensory amplification, mood, concentration, and sleepiness) in exercising adolescents as compared with control subjects.

2.2.3 How we tested our hypotheses

Fifty-one adolescents (mean age: 18.30 ± 0.89 years; 27 females [53%]) from a high school in the canton of Basel-Landschaft, a district in the German-speaking northwestern part of Switzerland, took part in the study; they were randomly assigned either to a running or to a control group. The running group went running every morning for 30 minutes at moderate intensity during the five school weekdays for three consecutive weeks. Sleep electroencephalographic patterns (sleep-EEG recordings) were performed at home using a three-channel EEG device (Fp2-A1, C3-A2, C4-A1; electrooculogram; electromyogram; SOMNOwatch®; Somnomedics, Randersacker, Germany). Sleep polygraphs were visually analyzed by two experienced raters following the standard procedures (Rechtsschaffen & Kales, 1968).

Raters were completely blind as to participants' group assignments. The SOMNOwatch® device provides assessment of TST, sleep period time, SOL, SE, stages 1 to 4 (minutes and %), light sleep (stages 1 and 2), slow-wave sleep (stages 3 and 4), REM sleep, REM sleep latency, and number and times of WASO.

Psychological functioning (see later in the text) was assessed in both groups before and after the 3-week period, to compare possible effects of regular running (running differed from jogging in that running speed was such that talking was more difficult). All participants also kept a sleep log for 3 weeks.

The control group remained on the school's running track, remained seated, followed school activities, and completed homework. They could speak and interact with each other, but they were not allowed to use electronic devices.

As in a previous study (Brand et al., 2010c), we tested whether perceived stress, coping strategies, somatosensory perception, and curiosity and exploratory behavior changed in a positive direction over time.

2.2.4 Our results

Our results indicate first, that a moderate-to-vigorous exercise training program had a positive impact on adolescents' sleep, whether assessed subjectively or objectively, when compared to a control group. In more detail, subjective sleep quality (based on the daily sleep log) increased significantly over time and was also significantly higher in the running group than in the control group. Moreover, both sleepiness during the day (daily log) and subjective sleep disturbances (based on ISI) decreased significantly over time compared to the control group. Objective sleep continuity improved (sleep onset latency decreased) in the running group compared with the control group (TST, WASO, SE did not improved significantly over time). Objective sleep architecture improved (slow-wave sleep increased, and REM latency became longer) after daily running for 3 weeks for 30 minutes at a time in the running group compared to the control group (light sleep, and REM sleep did not improve significantly over time).

Second, regular exercise had a positive influence on aspects of measured psychological functioning in the running group compared with the control group. In more detail, concentration during the day, pain perception/somatosensory amplification, mood in the morning and in the evening improved over time following the intervention. However, perceived stress, positive and negative coping strategies, curiosity and exploratory behavior did not improve.

2.2.5 Conclusions

In summary, our own research provides evidence that thirty minutes of moderate-to-vigorous running in the morning during weekdays for three consecutive weeks impacted positively on objective and subjective sleep and psychological functioning among healthy adolescents compared to control subjects. Notably, objective and subjective improvements were observed within three weeks on both subjective and objective measures. Moderate, but regular physical exercise such as running should be promoted as both a remedy and preventative measure for poor sleep and poor psychological functioning. Running is inexpensive and easy to implement during school schedules.

The strength of this three week longitudinal design is the inclusion of both subjective and objective sleep assessment together with a series of questionnaires related to psychological functioning of healthy adolescents randomly assigned to one of the two study conditions, namely a running or control group.

2.2.6 Limitations

First, as in all studies of exercising effects, confounders, such as exposure to daylight and social contracts, may have biased results. However, we note that social contacts, exposure to daylight, and eating at school were equivalent in the two conditions; therefore, these possible confounders could be ruled out. Second, it is unclear to what extent the intervention was successful because it took place in the mornings rather than during the day or in the evening; there is little research on possible time of day effects and results are inconclusive

(Buxton, Lee, L'Hermite-Baleriaux, Turek, & Van Cauter, 2003; Cain, Rimmer, Duffy, & Czeisler, 2007). More specifically, there is no such research with respect to adolescents. Third, results may potentially be biased because they are based on data from particularly healthy and motivated adolescents willing to complete questionnaires and to undergo sleep-EEG registration. Thus, the participants in this study might not be representative of adolescents as a whole (Kaneita et al., 2007; Roberts et al., 2008). In this respect, we also note that our participants, with on average around seven hours sleep per night, were far from sleeping for the recommended nine hours per night. Fourth, we did not assess individual fitness, nor did we assess running objectively. However, it was our firm intention to arrange a study design close to a practicable and easy-to-implement intervention. Finally, the relevant dimensions may be linked by further as-yet unidentified variables, such as the release of adenosine, secretion of cortisol, or melatonin or issues related to motivation and volition. Given these limitations, future research should (a) compare exercise interventions at different times of day, (b) assess the impact of exercise intervention based on objectively assessed physiological parameters, and (c) assess neurobiological variables, such as cortisol, melatonin, and BDNF (brain-derived neurotrophic factor).

2.3 Sleep and psychological well-being

Kalak, N., Lemola, S., Brand, S., Holsboer-Trachsler, E., & Grob, A. (2014). Sleep duration and subjective psychological well-being in adolescence: a longitudinal study in Switzerland and Norway. *Neuropsychiatric Disease and Treatment, 10,* 1199-1207. (IF 2014: 1.81).

Background of the third study

As noted in the introduction, older adolescents those aged 15 to 16 years, still require approximately nine hours of sleep on average per night as do younger adolescents, those around 10 to 11 years of age (Carskadon et al., 1980; Mercer et al., 1998; Moore & Meltzer, 2008). However, numerous studies show that average sleep duration decreases significantly across adolescence (Bonnet & Arand, 1995; Iglowstein, Jenni, Molinari, & Largo, 2003; Lemola et al., 2012; Perkinson-Gloor et al., 2013; Rajaratnam & Arendt, 2001). Several factors may be responsible for this decrease, including physical maturation, psychological factors, and social factors, such as a decline in supervision by parents together with the growing importance of peer relations, and issues related to education and training involving pressures concerning academic achievement, homework, vocational issues, and extracurricular activities (Astill, Van der Heijden, Van Ijzendoorn, & Van Someren, 2012; Brand & Kirov, 2011; Colrain & Baker, 2011; Mercer et al., 1998; Moore & Meltzer, 2008).

2.3.1 Why new research?

The pattern of published evidence suggests that sufficient sleep during adolescence is related to adolescents' psychological well-being. Although there are numerous studies of the relationship between sleep and poor mental health, longitudinal studies focusing on the relationship between sleep duration and positive aspects of functioning, such as psychological well-being, are scarce (Wong et al., 2013). A notable exception is a 3-year longitudinal study of 2259 students aged 11 to 14 years showing that depressive symptoms and low self-esteem were predicted by short sleep (Fredriksen et al., 2004). Positive psychological well-being involves both cognitive and affective aspects (Grob et al., 1991). Cognitive aspects include evaluations of whether one's life is on the right track and whether one has a positive attitude toward one's future. Affective aspects include whether one experiences positive emotions and joy in life as well as an absence of negative affect and symptoms of mental distress (Grob et al., 1991).

2.3.2 Our hypotheses

The present study extends upon previous research in two respects. First, we studied interrelations between sleep schedules and subjective psychological well-being (SPW) across three measurement time points to allow testing for causal effects in both directions. The measurement points were each separated by 6 months (data were collected in May, November, and again in the following May). Second, we tested whether associations between sleep duration and SPW differ between age groups (10 to 11 year olds; 12 to 13 year olds; and 14 to 15 year olds). Sleep duration and SPW were assessed in two large samples of adolescents from Switzerland and Norway. Although both countries are examples of Western cultures, they, for instance, differ markedly with regard to day length in May and November, differences which may be associated with sleep patterns and SPW (Laberge et al., 2000).

2.3.3 How we tested our hypotheses

In total, 2703 adolescents provided data for at least one measurement time point. A total of 1601 adolescents (overall mean age, 13.05 ± 1.49 years; 829 females [51.8%]) from two different European countries (Switzerland and Norway), and from a socioeconomically diverse sample provided complete data across all three waves of measurement. The two nations did not differ with regard to the probability of having complete data or gender distribution. The mean age of the Swiss sample was around four months higher than the Norwegian sample. The grades sampled were from fourth to ninth; these school years are compulsory in both countries. Socioeconomic statuses were split between a third upper class, a third middle class, and a third working class. The majority of adolescents lived with both parents (80%), some with their mothers only (18%), and a few (2%) with their fathers only.

Participants were recruited by advertisements in the local schools in the canton of Bern, located in the German-speaking part of Switzerland, and in Bergen (Norway). The first wave of the investigation took place in early summer (May, T1), followed by further waves after 6 months in early winter (November, T2), and again 6 months later in the following early summer (May, T3). Each assessment took place in the classroom during a school lesson.

The present study used items from the Bern well-being questionnaire for adolescents (BFW/J)-subscale (Grob et al., 1991). The items were combined to build a score for subjective psychological well-being. The aggregated score had good internal consistency.

Sleep duration on weekdays was assessed using two items asking for time in bed before school days and time of getting up on school days. The participants had to fill in the respective clock times. Sleep duration was calculated as the difference between bedtime and getting up time.

2.3.4 Our results

Our results indicate first that sleep duration prospectively (six months but not twelve months) predicted subjective psychological well-being while there was no evidence for the reverse relationship. In more detail, generally the stabilities of sleep duration and subjective psychological well-being from baseline to six months and 12 months later were (very) high. Among the crossed lagged paths (the paths between the constructs of sleep duration and subjective psychological well-being across time points) only that from sleep duration at baseline to subjective psychological well-being six months later were significant, indicating a positive relation between sleep duration at baseline and subjective psychological well-being six months later. This positive relation held true for all three age groups.

Second, sleep duration and subjective psychological well-being differed between age groups (age categories: 10 to 11 year olds; 12 to 13 year olds; and 14 to 15 year olds). In more detail, sleep duration and subjective psychological well-being differed between age groups, and cross-sectional and longitudinal analyses revealed that sleep duration was associated with subjective psychological well-being. Moreover, with age sleep duration and concurrent subjective psychological well-being decreased. The decline in sleep duration in both countries (Switzerland and Norway) and in all age groups (age categories: 10 to 11 year olds; 12 to 13 year olds; and 14 to 15 year olds) involved a considerably stronger decrease in the period from November (baseline) to May (six months later) than from May to the following November (twelve months on from baseline).

2.3.5 Conclusions

The strength of this study is the large sample size that allowed study of three different age groups separately, and its longitudinal design. Adolescents' sleep duration plays an important role in their subjective psychological well-being. We note that while the 10 to 13 year old adolescents on average still had the recommended sleep duration of nine hours on weekday nights (Carskadon et al., 1980; Hense et al., 2011), sleep duration was on average shorter for the 14 to 15 year olds despite their need for the same amount of sleep as their younger peers (Carskadon et al., 1980). We believe that both adolescents' and parents' education in sleep hygiene should be promoted, especially for older adolescents, because of the dramatic changes that characterize adolescence, but also because we could show that sleep duration is predictive of subjective psychological well-being six months later. The findings offer further support for the importance of healthy sleep patterns during adolescence.

2.3.6 Limitations

First, objective measurement (e.g., accelerometer) would add to the study, allowing comparisons with subjective measurements. Second, we did not include subjective sleep quality to our analyses. Sleep duration is not necessarily associated with subjective sleep quality yet sleep quality and psychological functioning are known to be associated (Brand, et al., 2009b). A related limitation is that we did not assess other possibly important sleep variables such as sleep debt or circadian preference that would have allowed a more comprehensive picture of adolescents' sleep habits and circadian rhythms. Third, subjective psychological well-being could have been defined and measured differently. More specifically, future research might include additional dimensions of subjective psychological well-being, such as optimism (Lemola et al., 2011), satisfaction with life (Brand et al., 2010b), and mental toughness (Brand et al., 2014). Fourth, as no measure of depressive disorder was included, it was not possible to test whether the associations would also have held if any participants with clinically relevant depression had been excluded. Finally, applying an intervention design to improve sleep would allow investigation of the causal relationship between sleep duration and psychological functioning.

3 Discussion and outlook for future research

To summarize, and based on our data, we can say, that sleep is important for adolescents and also for their parents because of the bi-directional interaction (Kalak et al., 2012). Adolescents should be encouraged to have regular moderate-to-vigorous exercise, even if only for 30 minutes a day, as this can improve their psychological functioning and their subjective and objective sleep quality (Kalak et al., 2012), while sufficient sleep duration has an effect on subjective well-being six months later (Kalak et al., 2014).

Three main issues were addressed in our empirical studies:

- Whether adolescents' sleep pattern and psychological functioning is associated with those of their parents.
- Whether daily morning running for three weeks improves sleep and psychological functioning in healthy adolescents compared with controls.
- Whether shorter sleep duration in adolescents is predictive of lower subjective psychological well-being 6 months and 12 months later or whether lower subjective psychological well-being is predictive of shorter sleep duration.

The main findings of our research can be summarized as follows:

First, our findings suggest that adolescents' objective sleep is related to parents' objective sleep. Our results are in line with a wealth of previous research showing that young children's and their parents' sleep are associated (Li et al., 2010; Zhang et al., 2010). Furthermore, with our data, we were able to extend the current literature by showing this pattern holds in mid adolescence and, importantly, showing this on the basis of an objective assessment of sleep.

Second, we found that, adolescents', mothers' and fathers' objective sleep is related to their subjective sleep and psychological well-being (although not all these links were fully confirmed). Our pattern of results is in line with previous research showing that children's subjective sleep and psychological well-being are related to parents' subjective sleep and psychological well-being (parental strain, negative family atmosphere, high family stress; Bernert et al., 2007; Brand et al., 2009a, 2009b; Vignau et al., 1997; Tynjälä et al., 1999; Zhang et al., 2010). Our results fit well with numerous studies indicating an interdependence (a) of these psychological dimensions with sleep, and (b) across family members. Importantly, we were able to extend the current literature to subjective sleep and well-being in mid adolescence, even if the direction of influence remains uncertain.

Third, based on our data, mothers' sleep, as rated by them and as measured by sleep-EEG, appears to be more closely related to adolescents' sleep and psychological well-being than is fathers' sleep. Our data are in line with the Swiss Federal Statistical Office (SFSO, 2009) and previous studies (Brand et al., 2009a, 2009b), showing that mothers perceive themselves more responsible for family functioning than do fathers. Our results are also consistent with recent data from the SFSO report (2009), according to which mothers of children under seven years and in a relationship were generally housewives and responsible for family functioning. Many studies have shown that sleep disturbances are related to psychological disturbances (Baglioni, Spiegelhalder, Lombardo, & Riemann, 2010; Riemann et al., 2010) and, importantly, this association holds true irrespective of age (Fricke-Oerkermann et al., 2007; Roberts et al., 2008). However, with respect to adolescence, family context as a possible influencing factor has not been taken sufficiently into account. In this regard, the present results indicate that family environment seems to be related to both good quality sleep and normal psychological functioning during adolescence, and also appears to confirm the critical role of mother’s behavior. However, it remains unclear whether the emergence of sleep disturbances increases family problems or vice versa.

Fourth, we found that, moderate-to-vigorous exercise has a favorable impact on adolescents’ sleep, compared with control subjects. Participants in a running group reported improved sleep quality, and objectively assessed sleep improved, in that deep sleep increased, SOL decreased, and REM sleep latency became longer over time. Thus, the present findings echo those of the numerous studies that have confirmed an association between exercise and sleep (Brand et al., 2010a, 2010c, 2010d; Dworak et al., 2008; Youngstedt, 2005). Importantly, the present results add to the literature in demonstrating the impact of moderate exercise, namely, running for 30 minutes in the morning for only three weeks.

Fifth, our findings show, that regular exercise has a positive influence on psychological functioning, but this was only partly confirmed. Whereas no changes were observed in perceived stress and coping or in curiosity and exploratory behavior, running was related to decreased pain perception. The lack of any association between exercising and stress is in marked contrast to the many studies demonstrating a positive influence of exercise on stress management (Gerber & Pühse, 2008, 2009; Puterman et al., 2010). The following are possible explanations for this difference: (a) the time interval of three weeks was too short to induce the relevant changes; (b) trait (as compared with state) characteristics, such as curiosity, perception of stress, and coping strategies, are relatively stable over time and therefore more difficult to modify; (c) perception of stress and coping did change but in ways too subtle to be captured by the questionnaires used; (d) participants were particularly healthy and this would result in ceiling effects. By contrast, the experience and appraisal of bodily sensations and its cognitive-emotional elaboration (i.e., the somatosensory amplification of pain) is much more adaptable and sensitive to situation-specific conditions (Tajet-Foxell & Rose, 1995). Our results suggest that pain threshold increased as a function of exercise, and this pattern of results is in accord with previous findings (Brand et al., 2010c; Tajet-Foxell & Rose, 1995).

Sixth, regarding the relationship between sleep duration and subjective psychological well-being, our findings echo evidence from numerous studies that have confirmed an association between adolescents' sleep duration and subjective psychological well-being (Baglioni et al., 2010; Haario, Rahkonen, Laaksonen, Lahelma, & Lallukka, 2013; Kaneita et al., 2007; Lund et al., 2010; Olds, Blunden, Petkov, & Forchino, 2010; Riemann et al., 2010). Our findings indicate that sleep duration is a longitudinal predictor of subjective psychological well-being. The findings show that affect regulation is compromised by short sleep (Talbot et al., 2010). However, the size of the effect was weak when subjective psychological well-being at baseline was controlled. Moreover, the effect was not consistent across all measurement time points.

Seventh, our findings do not indicate that subjective psychological well-being is a longitudinal predictor of sleep duration. The pattern of results extends upon previous findings in showing that the relationship between sleep duration and subjective psychological well-being across one year is very similar in the three age groups of very early adolescents (10 to 11 year olds), late early adolescents (12 to 13 year olds), and early middle adolescents (14 to 15 year olds).

Appendix: Current and planned studies

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The relation of objective sleep patterns, depressive symptoms, and sleep disturbances in adolescent children and their parents: A sleep-EEG study with 47 families

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ABSTRACT

Objectives: Numerous studies have shown that the sleep and well-being of children and their parents are closely related. Previous studies have relied on subjective sleep data and have focused mostly on younger preadolescent children. The aim of the present study was therefore to investigate the relationship between the sleep patterns of adolescents and those of their parents using objective assessment of sleep.
Methods: Forty-seven families took part in this study. The sample comprised 80 adolescents (age: 16.3 ± 2.0 years; 44 males/36 females), 47 mothers (age: 49.5 ± 4.0 years), and 39 fathers (age: 50.8 ± 5.1 years). All participants individually completed questionnaires related to psychological functioning and sleep. Sleep-EEGs were assessed for all family members in their homes.
Results: Adolescents' and parents' objective sleep patterns were associated. In particular, the sleep continuity and architecture of adolescents and their mothers were strongly related. Additionally, significant relationships between objectively assessed sleep patterns, subjective sleep disturbances, depression scores and family climate held true for equally adolescents and mothers. Also, substantial links were found between adolescents' and parents' subjective sleep disturbances, depressive symptoms, and perceived family climate.
Conclusion: The present findings document objectively for the first time the existence of relationships between adolescents' sleep and well-being and parents' sleep and well-being. These relationships were apparent regardless of whether subjective or objective sleep data were considered. The overall pattern of results strongly indicates that adolescents' sleep and well-being and family functioning are related.

1. Introduction

Sufficient and restoring sleep is essential for psychological well-being, cognitive processes, and a range of adaptive behavioural functions (Diekelmann and Born, 2010; Owens, 2000; Stein et al., 2001; Walker, 2009). Since the period of adolescence is accompanied by dramatic changes in physiology and neural networks (Giedd et al., 1999; Paus et al., 2008), sleep and sleep regulation play a crucial role in adolescents' well-being and development (Brand and Kirov, 2011; Colrain and Baker, 2011; Jan et al., 2010; Kirov and Brand, 2011; Ringli and Huber, 2011). However, poor sleep in adolescence has become a significant public mental and physical health problem (Aronen et al., 2000; Laberge et al., 2000; Owens et al., 2000; Paavonen et al., 2000). Cross-sectional (Kaneita et al., 2007; Lund et al., 2010) and longitudinal studies (Fricke-Oerkermann et al., 2007; Roberts et al., 2008; Wong and Brower, 2012) have shown that acute and chronic sleep loss during development persist over time, with negative effects on adolescents' physical and mental health. At the same time poor psychological well-being may itself negatively impact on adolescents' sleep (Baglioni et al., 2010; Riemann et al., 2010). In other words, the association between sleep and psychological functioning is likely to be bi-directional.

Among the many factors that can affect sleep during adolescence, the role for family environment is still poorly understood. In recent years a growing body of research has emphasized the interdependence between children's sleep and family environment (El-Sheikh, 2011, for extensive overview). Martin et al. (2007)

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investigated families of 5107 infants and 4983 children aged between 4 and 5 years and assessed both children's and parents' sleep and psychological functioning using questionnaires and sleep logs. They concluded that these children's sleep problems were strongly associated with parents' mental health, particularly that of mothers irrespective of whether they reported a history of health problems. Smedje et al. (1998) asked 367 mothers and 273 fathers about the sleep of their 5–6 year old children using questionnaires. Parents who reported sleep problems in their children had increased sleep problems of their own. The authors interpreted this as an effect of children's sleep problems on parental sleep. In another cross-sectional study of 20,778 Chinese families, parents of 5–11 year old children were asked about the latter's sleep; children's shorter sleep duration was associated with parents' shorter sleep duration (Li et al., 2010). Likewise, Zhang et al. (2010) examined parental reports from 4470 families on the sleep of their school-aged children (7–11 years). Their results revealed similarities between parents' and children's sleep and wake patterns, although children's sleep–wake patterns were influenced more strongly by the mother–child relationship than by the father–child relationship. Last, Meltzer and Mindell (2007) recruited 47 mothers of children aged from 3 to 14 years. A key finding from this questionnaire-based study was that children's sleep disruptions were highly associated with mothers' poor sleep and poor mental status.

In summary, although the evidence is largely correlational, research on the sleep of infants, toddlers and children suggests that children's poor sleep has a negative impact on parents' and particularly mothers' sleep.

However, whereas a growing body of evidence indicates that sleep characteristics in young children and their parents are associated, research on the relationship between parents' and adolescents' sleep is limited. Lemola et al. (2012) showed in a sample of 176 eleven years olds that a large difference in sleep duration between weekdays and weekends mediated a relation between inter-parental conflict and early adolescent aggression; irregular sleep seemed to be a vulnerability factor for aggression in early adolescence. Similarly, Tynjälä et al. (1999) showed that self-reported sleep patterns of 4187 adolescents aged between 11 and 15 years were associated with their quality of life including their relationships with parents and peers. The main finding, however, was that a positive home atmosphere was the principal factor favouring high quality sleep. This finding held irrespective of gender or age. Likewise, Vignau et al. (1997) examined the prevalence and correlates of sleep problems in 763 16-year-old students as assessed by self-reported questionnaires. A key finding was that sleep problems were highly related to various personal issues and particularly to poor family climate. These findings suggest that quality of family life is related to adolescents' sleep. Further, Bernert et al. (2007) investigated the association between stress in family life and sleep problems in 115 undergraduates aged 17–22 years, using self-reported questionnaires. They showed that familial stress was highly related to increased insomnia and poor academic achievement in late adolescence. Last, in two previous studies (Brand et al., 2009a, 2009b), we were able to show that mothers' and adolescents' sleep quality, both subjectively assessed, were associated with parenting style being a mediating factor.

To summarize, there is compelling evidence that children's sleep is related to parents' sleep and mental health. This observation holds true not only for infants and children (Bernert et al., 2007; Li et al., 2010; Martin et al., 2007; Smedje et al., 1998) but also for in early[2] (Lemola et al., 2012; Li et al., 2010; Zhang et al., 2010), middle (Vignau et al., 1997) and late adolescence (Bernert et al., 2007; Brand et al., 2009a, 2009b). However, one major limitation of the research so far is the source of evidence on sleep quality. In the majority of studies, information about parents' and children's sleep was obtained either from parents or from their children, and exclusively by questionnaire. Moreover, research focussing on adolescents remains limited. To the best of our knowledge, no study has so far examined the relationship between children's and parents' sleep architecture via objective sleep-EEG evaluation of entire families. Nor have parents and their adolescent children been tested for their sleep concomitantly and separately.

To address these limitations, the present study aimed at extending and specifying previous research by (1) evaluating adolescents' and parents' sleep objectively by means of sleep-EEG and (2) assessing adolescents' and parents' sleep separately, with a focus on middle adolescence. Given the relative lack of objectively measured sleep variables, we believe that the results of the present study may be a valuable contribution the current literature. Additionally, given the strong possibility that health professionals will encounter adolescents' issues and concerns surrounding sleep complaints alongside difficulties with parents, results may be of value in family counselling and treatment of adults' and adolescents' sleep complaints. This is crucial as family conditions have been identified as protective factors that foster resilient adaptation among adolescents, particularly if they are exposed to adversity and stressful life circumstances (Cicchetti, 2010; Luthar et al., 2006; Lyssenko et al., 2010; Masten, 2004; Masten et al., 1999; Sameroff and Rosenblum, 2006; Tiet et al., 1998).

The following three hypotheses were formulated. First, following Li et al. (2010) and Zhang et al. (2010), we hypothesized that adolescents' sleep, measured by sleep-EEG (sleep continuity and sleep architecture) would be related to parents' sleep. Second, consistent with other findings (Bernert et al., 2007; Brand et al., 2009a, 2009b; Tynjälä et al., 1999; Vignau et al., 1997; Zhang et al., 2010), we expected that sleep objectively assessed in this way (by sleep-EEG), would be associated with subjective measures of sleep (using the Insomnia Severity Index: ISI), psychological well-being (using the Depression Scale and self-perceived and parents' perceived Family Climate), among adolescents and also their mothers and fathers, Third, in line with previous studies (Brand et al., 2009a, 2009b) and information from the Swiss Federal Statistical Office (2009), we expected that mothers' sleep patterns and psychological functioning would be more closely associated with family functioning than those of fathers or adolescents.

2. Methods

2.1. Participants

A total of 52 families were recruited for the study. Five families dropped out during the course of the study, for work-related reasons, and other participant refusal. The final sample consisted of 47 families. One hundred and sixty six complete datasets were obtained from 47 mothers (mean age: 49.45 $\pm$ 4.04 years), 39 fathers (mean age: 50.81 $\pm$ 5.12 years), and 80 adolescents (overall mean age: 16.28 $\pm$ 2.00 years; males ($n = 44$): 16.32 $\pm$ 1.97 years; females ($n = 36$): 16.22 $\pm$ 2.12 years). The majority of adolescents lived with both parents ($n = 65$; 81.25%), a few with their mothers only ($n = 13$; 16.25%), and just 2 (2.5%) with their fathers only. Detailed information about family constitution is presented in Table 1.

2.2. Procedure

Participants were recruited by advertisements in local high schools and by word-of-mouth in the German-speaking part of

[2] Adolescence is subdivided as follows: 10–14 years old = early adolescence, 15–18 years old = middle adolescence, and 19–21 years old = late adolescence (Steinberg, 1996).

Table 1
Family constitution and BMI.

Mean number of adolescents per family	1.6 (±0.4)
Minimum number of children attending grammar school per family	1 (62.5%)
Married	52 (60.47%)
Cohabiting	12 (13.95%)
Widowed	1 (1.16%)
Single	3 (3.49%)
Unknown	18 (20.93%)
BMI of mother	23.87 (±4.55)
BMI of father	25.22 (±3.22)
BMI of male adolescents	20.84 (±2.29)
BMI of females adolescents	20.33 (±2.66)

Notes: Adolescents $N = 80$, Mother $N = 47$, Father $N = 39$.

North-Western Switzerland between November 2009 and January 2010. Only adolescents between 12 and 20 years were included in the study. Inclusion criteria for all participants were: at least one parent was employed, and adolescents were attending regular school programs. Exclusion criteria were: any past (6 months) or current medical and psychiatric disorders and complaints, including the intake of any sleep-, or mood-altering medicaments; shift or weekend work (parents; older adolescents).

All participants were informed about the purpose of the study and gave written informed consent. For adolescents aged below 18 years informed consent was obtained from their parents. Each family member independently completed a series of questionnaires related to sleep and psychological functioning as described below. All participants could complete the questionnaires within 60 min. All family members undertook one night home-based sleep-EEG recording. The sleep-EEG recordings were exclusively performed during school-week nights. The study was approved by the local ethics committee, and the entire study was performed in accordance with the ethical standards laid down in the Declaration of Helsinki.

2.3. Materials

2.3.1. Sleep-EEG recordings

For the purpose of this study, all family members were assessed on the same night in their usual environment; that is, sleep-EEG recordings were performed at the families' homes. Participants were asked to go to bed at their usual time. Mean bedtime was 10:46 pm ± 50 min, and mean time in bed was 7.17 h ± 1.16 (adolescents: mean = 7.28 h ± 1.5; mothers: mean = 6.54 h ± 0.98; fathers: mean = 7.16 h ± 0.77). Experienced lab personal applied the sleep-EEG, a one-channel sleep-EEG device (Fp2-A1; electromyogram; electrooculogram; Somnowatch®; Randersacker, Germany). These simple though powerful devices have been shown to provide reliable data (Brand et al., 2010; Hornung et al., 2008). Sleep polygraphs were visually analysed by two experienced sleep lab experts according to standard procedures (Rechtschaffen and Kales, 1968). A total of 166 sleep-EEG recordings were analysed. Of these, 25 (15.1%) were independently analysed by both raters; inter-rater-reliability was Kappa = .95. Sleep parameters were analysed according to the definitions in the standard program described by Lauer et al. (1991). The sleep-EEG records parameterized total sleep time (TST; h), sleep period time (SPT; h), sleep onset latency (SOL; min), sleep efficiency (SE; %), number of awakenings after sleep onset (WASO; nr), stages 1–4, light sleep (stages 1–2), slow wave sleep (stages 3–4), and REM (rapid eye movement) sleep (m and % in each case).

2.4. Self-assessment of sleep complaints

To ensure comparability with previous studies standardized questionnaires were used. Both parents and adolescents were asked to complete the questionnaires concurrently and separately.

2.4.1. Sleep complaints (Insomnia Severity Index: ISI)

The ISI (Bastien et al., 2001) assesses sleep complaints and consists of seven items. Reliability and validity of this instrument has been established previously for adults (Morin et al., 2011), and use with adolescents has been satisfactory (Brand et al., 2010; Wadsworth et al., 2011). Typical items are: "In the last two weeks, how much did you suffer from the following disturbances: difficulties falling asleep, difficulties maintaining sleep, early morning awakening, increased daytime sleepiness?"; "How much does sleep disturbance have a negative impact on your daily performance?" Answers were given on a 5-point rating scale ranging from 0 (= not at all) to 4 (= very much). For "How satisfied are you with your sleep?" answers were given on a 5-point Likert scale ranging from 0 (= very satisfied) to 4 (= very dissatisfied). Higher scores are taken as indicative of insomnia (Cronbach's alpha = .84).

2.5. Additional sleep-related aspects of psychological functioning

2.5.1. Depressive symptoms (Depression Scale: DS)

The Depression Scale (von Zerssen, 1976) consists of 16 items focussing on depressive symptoms such as decreased mood, lack of satisfying social and leisure activities, suicidal ideation, and hopelessness. Previous studies have shown that the DS has satisfactory psychometric properties for adults (Witte et al., 1995) and for adolescents (e.g., Brand et al., 2010). Answers are given on a 4-point rating scale ranging from 1 (= not at all true) to 4 (= definitively true). Higher scores reflect more pronounced depressive symptoms (Cronbach's alpha = .93).

2.5.2. Family climate (FC)

This self-administered questionnaire consists of two items and asked about general family climate. Answers are given on a 7-point rating scale ranging from 1 (= not at all) to 7 (= totally). Higher scores reflect a more positive family climate.

2.6. Statistical analysis

Univariate analyses of variance (ANOVAs) were performed with family members (adolescents vs. mothers vs. fathers) as a between-subjects factor and sleep variables (extracted from sleep-EEG) as dependent variables.

Pearson's correlations were calculated between objective and subjective sleep variables and psychological functioning. In preliminary analyses, age and employment status were introduced as further variables; only age ($r = .24^*$) was related to any other psychological dimension. The statistics were processed using SPSS (Statistical Package for the Social Sciences) 19.0 for Windows.

3. Results

First, adolescent's and parent's objective sleep were compared. Second, associations between subjective sleep disturbances, depressive symptoms, and family climate were compared to each other. Finally, associations between sleep-EEGs, and subjective sleep disturbances, depressive symptoms, and family climate were examined.

3.1. Objective sleep variables in adolescents and parents; differences

Table 2 provides an overview of the objective sleep variables, listed separately for adolescents, mothers and fathers, and the relationship between adolescents and parents.

Results indicate that, compared to both mothers and fathers, adolescents had a shorter light sleep duration ($F(2, 69) = 8.75$, $p = .00$) but more slow wave sleep ($F(2, 69) = 11.58$, $p = .00$). Adolescents also had a longer TST, a longer SOL, a higher sleep efficiency, and shorter REM-sleep time as compared to fathers and mothers ($F(2, 69) < 3.90$, $p < .03$). For all other variables, no statistically significant mean differences were found ($F(2, 69) > 1.5$, $p > .35$).

3.2. Objective sleep variables in adolescents and parents; associations

Table 2 also provides an overview of the correlations between adolescents' sleep-EEGs and parents' sleep-EEGs, separately for mothers and fathers.

Adolescents' sleep continuity was associated with mothers' sleep continuity: adolescents' increased TST, prolonged SOL, increased sleep efficiency, and number of awakenings after sleep onset were significantly associated with mothers' TST, prolonged SOL (see Fig. 1), increased sleep efficiency, and greater numbers of awakenings after sleep onset (see Fig. 2). A similar pattern of associations was observed between adolescents' and fathers' sleep

Table 2
Correlations between objective sleep dimensions (derived from sleep-EEG) separately for adolescents, mothers and fathers.

Sleep-EEG		M (SD)	Mother	Father
			Pearson's correlations	Pearson's correlation
Total sleep time TST (h)	Adolescents	07:03 (1:18)	.38*	.36*
	Mother	06:18 (0:55)	–	.45**
	Father	06:41 (0:50)	–	–
Sleep onset latency (SOL; min)	Adolescents	8.57 (8.25)	.70**	.28
	Mother	7.80 (4.02)	–	–.11
	Father	8.21 (4.98)	–	–
Sleep efficiency (SE, %)	Adolescents	93.74 (5.17)	.35*	–.19
	Mother	91.55 (5.12)	–	.28
	Father	90.12 (9.64)	–	–
Awakening after sleep onset (WASO, number)	Adolescents	5.82 (4.47)	.62**	.41*
	Mother	9.00 (6.57)	–	.13
	Father	9.47 (4.81)	–	–
Stage 1 (min)	Adolescents	9.00 (6.00)	.18	–.31
	Mother	14.00 (13.25)	–	–.10
	Father	22.03 (16.12)	–	–
Stage 1 (%)	Adolescents	2.38 (1.55)	.18	–.35
	Mother	3.70 (2.86)	–	–.12
	Father	5.63 (4.09)	–	–
Stage 2 (min)	Adolescents	196.24 (47.31)	.35*	.10
	Mother	203.51 (39.05)	–	.38*
	Father	200.21 (29.00)	–	–
Stage 2 (%)	Adolescents	46.38 (8.32)	.34*	.15
	Mother	54.12 (9.04)	–	.29*
	Father	50.19 (6.86)	–	–
Stage 3 (min)	Adolescents	30.01 (13.20)	.25	.26
	Mother	34.01 (17.32)	–	–.16
	Father	46.15 (29.32)	–	–
Stage 3 (%)	Adolescents	7.06 (2.60)	.28	–.23
	Mother	9.31 (4.36)	–	–.12
	Father	9.59 (2.50)	–	–
Stage 4 (min)	Adolescents	95.23 (33.00)	.25	–.18
	Mother	39.00 (21.51)	–	–.21
	Father	46.23 (24.32)	–	–
Stage 4 (%)	Adolescents	23.10 (9.18)	.29	.12
	Mother	10.52 (5.10)	–	.02
	Father	11.24 (5.10)	–	–
Light sleep (min)	Adolescents	206.23 (50.32)	.34*	.19
	Mother	218.36 (42.39)	–	.01
	Father	222.31 (26.01)	–	–
Light sleep (%)	Adolescents	48.88 (8.93)	.36*	.00
	Mother	57.80 (8.73)	–	.32
	Father	55.81 (5.28)	–	–
Slow wave sleep (min)	Adolescents	125.22 (40.12)	.29	–.29
	Mother	74.32 (33.12)	–	–.32
	Father	84.36 (32.12)	–	–
Slow wave sleep (%)	Adolescents	30.17 (9.77)	.32*	.06
	Mother	19.83 (8.18)	–	–.06
	Father	20.78 (6.22)	–	–
REM (min)	Adolescents	93.41 (25.13)	.10	–.28
	Mother	85.13 (21.33)	–	–.11
	Father	93.43 (25.09)	–	–
REM (%)	Adolescents	21.54 (3.97)	.06	–.09
	Mother	22.36 (3.86)	–	–.11
	Father	23.40 (5.37)	–	–

Notes: Light sleep = stages 1 and 2; Slow wave sleep = stages 3 and 4; REM = rapid eye movement; * = $p < .05$, ** = $p < .01$.

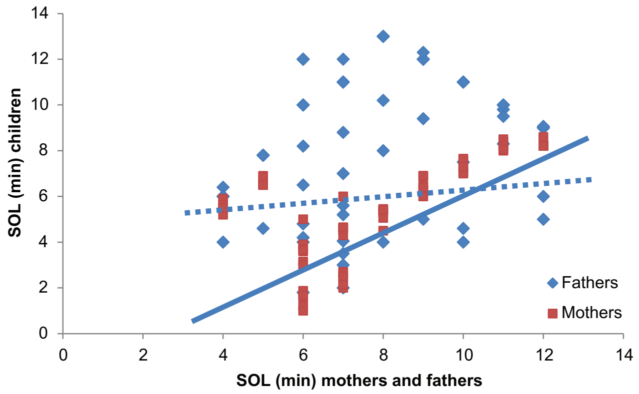

Fig. 1. Children's sleep onset latency (SOL) was associated with mothers ($r = .70^{**}$; continuous line), but not with fathers' sleep onset latency ($r = .28$, dotted line). $* = p < .05$, $** = p < .01$.

continuity variables, though correlations did not consistently reach statistical significance. The latter observation also held for the association between mothers' and fathers' sleep. Thus, while the correlations found were of practical relevant magnitude, they remained under the set alpha-level of $p < .05$.

As for sleep architecture, adolescents' decreased light sleep and increased slow wave sleep was significantly associated with mothers' decreased light sleep and increased slow wave sleep, though single sleep states and REM-sleep were not significantly associated (except stage 2). No significant correlations were found between adolescents' and fathers' sleep architecture (Table 2).

Statistically significant correlations between mothers' and fathers' sleep architecture were only found for stage 2 (min and %). No others correlations coefficients were significant (Table 2).

3.3. Association between sleep disturbances (Insomnia Severity Index; ISI), depressive symptoms (DS), and family climate (FC)

Table 3 provides the correlation matrix between adolescents', mothers', and fathers' psychological functioning (sleep disturbances, depressive symptoms and family climate).

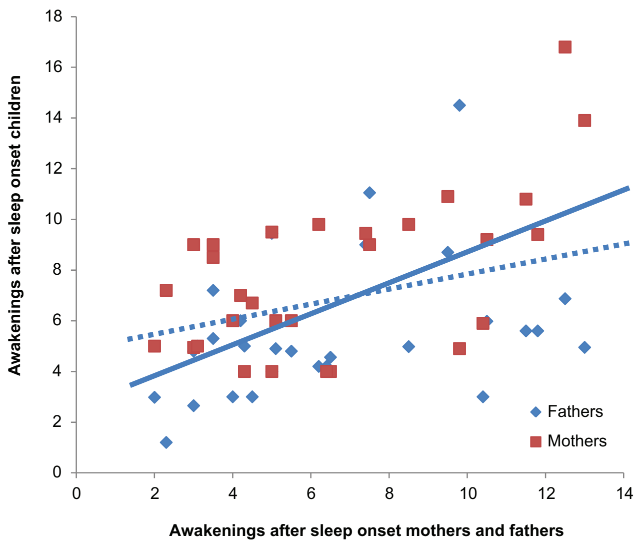

Fig. 2. Children's awakenings after sleep onset correlated with both mothers' ($r = .41^{*}$, continuous line) and fathers' awakenings after sleep onset ($r = .28^{*}$; dotted line). $* = p < .05$.

Among adolescents and mothers, increased sleep disturbances were associated with increased depressive symptoms and with a poorer family climate. The direction of these associations in fathers was similar (associations were in the same direction) but did not reach statistical significance.

Adolescents' and mothers' psychological functioning was not significantly related to fathers' psychological functioning.

3.4. Associations between sleep-EEGs, subjectively perceived sleep disturbances (Insomnia Severity Index; ISI), depressive symptoms (DS), and family climate (FC)

Table 4 reports the correlation matrix between objective sleep variables and subjective ratings (sleep disturbances, depressive symptoms, and family climate) separately for adolescents, mothers and fathers (Table 5).

The general pattern of results indicate that favourable sleep continuity variables (shorter SOL, higher sleep efficiency, a lower number of awakenings) in adolescents and mothers were associated with more favourable psychological functioning (low sleep disturbances, fewer depressive symptoms and a more positive family climate). For fathers, these favourable associations were less pronounced (Table 4; Fig. 3).

As for sleep stages, among adolescents and their mothers, both shorter light sleep and more slow wave sleep were associated with more favourable psychological functioning (low sleep disturbances, fewer depressive symptoms, and an increased family climate). A similar pattern of results was found for fathers, though correlations coefficients were less pronounced compared to adolescents and mothers. Increased REM-sleep in mothers was related to decreased sleep disturbances and a better family climate. In adolescents and fathers, REM-sleep was not associated with psychological functioning. Adolescents' objective sleep continuity and architecture were related to mothers' subjective psychological well-being (depressive symptoms $r < .30$, $p > .05$), and significantly related to mothers' perceptions of family climate ($r = .32$, $p < .05$).

Adolescents' objectively assessed sleep continuity and architecture were significantly related to family climate as subjectively assessed by mothers: sleep onset latency: $r = -.35$, $p < .05$; sleep efficiency: $r = .32$, $p < .05$; number of awakenings: $r = -.31$, $p < .05$; and light sleep: $r = -.29$, $p < .05$.

4. Discussion

The key findings of the present family-study are that, first, objective evidence was provided for the existence of a relationship between the sleep patterns of parents and their adolescent offspring. We showed that adolescents' objectively evaluated sleep continuity and architecture were associated with parents' sleep-EEG parameters of sleep continuity and architecture, and especially with those of mothers. Second, objectively assessed poor sleep continuity, elevated light sleep and decreased slow wave sleep were related to subjectively reported sleep disturbances, depression, and poor family climate both among adolescents and their mothers. Third, adolescents' and parents' subjective sleep disturbances, depressive symptoms and family climate were interrelated. The present data add to the existing literature in an important way in that we were able to show that parents' and adolescents' sleep and psychological well-being were interrelated irrespective of whether objective or subjective assessments were considered.

Three hypotheses were formulated and each of these is examined in turn.

With the first hypothesis, we expected that adolescents' objective sleep would be related to parents' objective sleep, and the

Table 3
Correlations (Pearson's correlations) between subjective sleep disturbances (ISI), depressive symptoms (DS), and family climate (FC), separately by adolescents, mothers and fathers.

		Adolescents			Mother			Father		
		ISI	DS	FC	ISI	DS	FC	ISI	DS	FC
		M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
		1.94 (.55)	1.46 (.22)	5.50 (1.03)	1.83 (.67)	1.50 (.24)	5.87 (.75)	1.75 (.53)	1.39 (.25)	5.79 (.73)
Adolescents	ISI	–	.30*	−.31*	.43**	.32*	−.39*	.12	.09	.10
	DS		–	−.35*	.39*	.56**	−.38*	.09	.19	.09
	FC			–	−.33*	−.49**	.59**	−.20	−.18	.19
Mother	ISI				–	.42**	−.44**	.32*	.29	−.12
	DS					–	−.39*	.19	.29	−.18
	FC						–	−.12	−.21	.35*
Father	ISI							–	.12	−.10
	DS								–	−.21
	FC									–

Notes: ISI = Insomnia Severity Index; DS = Depression Scale; FC = Family Climate; $^{*}P < .05$, $^{**}P < .01$.

present results fully confirmed this assumption. Thus, our results are in line with a wealth of previous research showing that young children's and the parents' sleep are associated (Li et al., 2010; Zhang et al., 2010). Furthermore, with the present data, we were able to extend the current literature by showing this pattern holds in mid adolescence and, importantly, on the basis of objective sleep assessment. However, previous studies have shown that children's sleep seems to be impaired by parental strain (Vignau et al., 1997), negative family atmosphere (Tynjälä et al., 1999), high family stress (Bernert et al., 2007), and adverse parenting styles (Brand et al., 2009a, 2009b). In the present study, a similar pattern of results was observed though, given the cross-sectional and correlational study design, the direction of influence remained uncertain.

Given the above considerations, our second prediction that adolescents', mothers' and fathers' objective sleep would be related to their subjective sleep and psychological well-being was also, although not fully, confirmed by the present findings. The present pattern of results is in line with previous research showing that children's subjective sleep and psychological well-being are related to parents' subjective sleep and psychological well-being (Bernert et al., 2007; Brand et al., 2009a, 2009b; Tynjälä et al., 1999; Vignau et al., 1997; Zhang et al., 2010). Thus, our results fit well with numerous studies indicating an interdependence of, first, these psychological dimensions with sleep, and second, across family members. Importantly, we were also able to extend the current literature to subjective sleep and well-being in mid adolescence.

With the third hypothesis, we anticipated that mothers would feel more responsible for family functioning than fathers, and our data gave support to this. The present pattern of results is in line with the Swiss Federal Statistical Office (SFSO, 2009) and previous studies (Brand et al., 2009a, 2009b), showing that mothers perceive themselves more responsible for family functioning than do fathers. The present results are also consistent with recent data from the SFSO report (2009), according to which mothers of children under 7 years and in a relationship were generally housewives and responsible for family functioning. As the present results suggest, mothers' sleep, as rated by them and as measured by sleep-EEG, appears to be related to adolescents' sleep and psychological well-being. Many studies have shown that sleep disturbances are related to psychological disturbances (Baglioni et al., 2010; Riemann et al., 2010), and importantly, this association holds true irrespective of age (Fricke-Oerkermann et al., 2007; Roberts et al.,

Table 4
Correlations (Pearson's correlations) between objectives sleep dimensions, subjective sleep disturbances (ISI), depressive symptoms (DS), and family climate (FC), separately by adolescents, mothers and fathers.

	Adolescents (n = 80)			Mother (n = 47)			Father (n = 39)		
Sleep-EEG	ISI	DS	FC	ISI	DS	FC	ISI	DS	FC
TST (h)	.13	.16	−.13	.00	−.17	.46*	−.26	−.64*	.09
SPT	.10	−.13	−.10	−.20	−.06	.17	−.16	−.69**	.05
Sleep efficiency (%)	−.30*	−.31*	.29*	−.33*	−.29	.35*	−.20	−.10	.14
WASO, Number of awakenings	.29*	.32*	−.30*	.27	.39*	−.34*	.12	.19	−.18
SOL (min)	.29*	.23	−.36*	.25	.28	−.32*	.11	.29	−.11
Light sleep (min)	.29	.25	−.29	.27	.30*	−.24	.14	.08	−.08
Light sleep (%)	.22	.29	−.24	.26	.22	−.14	.15	.07	−.12
SWS (min)	−.26	−.25	.13	−.20	−.29	.16	−.21	−.14	.11
SWS (%)	−.25	−.18	.12	−.26	−.19	.31*	−.13	−.16	.09
REM (min)	.08	.07	−.05	−.43*	−.14	.44*	−.11	−.21	.24
REM (%)	.04	.00	−.05	−.34*	−.11	.33*	−.01	.15	.24

Notes: TST = total sleep time; SOL = sleep onset latency; S = Stadium; REM = rapid eye movement; SWS = slow wave sleep; WASO = Wakening after sleep onset; $^{*}p < .05$, $^{**}p < .01$.

Table 5
Correlations (Pearson's correlations) between perceived responsibility for family functioning and employment level, subjective sleep disturbances (ISI), depressive symptoms (DS), and family climate (FC), separately by mothers and fathers.

		ISI	DS	FC
		r (p)	r (p)	r (p)
Mother ($n = 39$)	Responsibility	−.17 (.30)	−.16 (.33)	.10 (.54)
Father ($n = 25$)	Responsibility	−.06 (.78)	−.22 (.29)	.31 (.13)
Mother ($n = 36$)	Employment level	.20 (.24)	−.18 (.29)	.15 (.37)
Father ($n = 25$)	Employment level	.10 (.63)	−.15 (.48)	.15 (.49)

Notes: ISI = Insomnia Severity Index; DS = Depression Scale; FC = Family Climate; correlations with p-values in parenthesis.

2008). However, with respect to adolescence, family context as a possible influencing factor has not been taken sufficiently into account. In this regard, the present results indicate that family environment seems to be related to both favourable sleep and normal psychological functioning during adolescence, and also appears to confirm the critical role of mothers' behaviour. However, it remains unclear whether the emergence of sleep disturbances increases family problems or vice versa.

Several considerations illuminate the link between the parent–child relationship and children's psychological well-being and sleep. Some studies suggest that the mother's functioning plays a decisive role within family systems in general, and with regard to sleep in particular (Brand et al., 2009a, 2009b). The role of maternal well-being also can be seen in other contexts. For example, mothers of children diagnosed with cancer or who have suffered accident-related injury have been shown to display higher and more intense degrees of posttraumatic stress disorder when compared to fathers (Landolt et al., 2003). Moreover, compared to paternal stress, maternal stress has been found to be more strongly associated with behaviour problems of young children (Baker et al., 2000). Also Seiffge-Krenke and Kollmar (1998) have found that mothers' ratings of their children's behaviour were significantly correlated with adolescents' self-ratings, while fathers' ratings were not. Nevertheless, while the preeminent role of the mother has been demonstrated among infants, toddlers, pre-schoolers and children up to 14 years (Martin et al., 2007; Meltzer et al., 2007; Smedje et al., 1998), our data indicate that maternal influence may persist well into adolescence and even to the brink of early adulthood. This is also consistent with the view that children's emotional relationship with their parents remains important even in late adolescence (O'Koon, 1997) and challenges the concept that by adolescence family influences cease to matter (Harris, 1995).

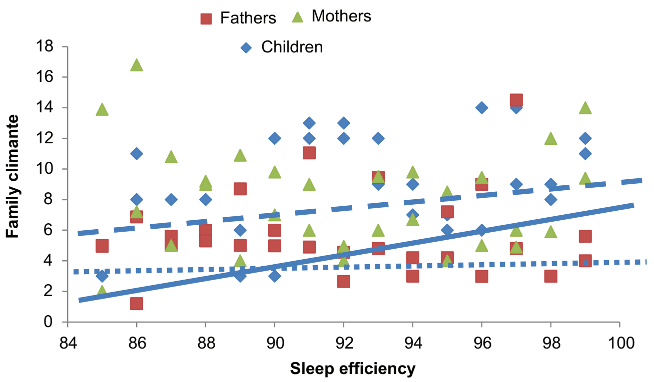

Fig. 3. Family climate was associated with increased objective sleep efficiency in children ($r = .29^{*}$; dashed line) and in mothers ($r = .35^{*}$; continuous line), but not in fathers ($r = 14$; dotted line). $^{*} = p < .05$.

There are also strong indications that the association between sleep and psychological functioning may be bidirectional. The results of Meltzer and Mindell (2007) and Brand et al. (2009a, 2009b) lend support to the concept of a reciprocal impact of mothers'/parents' and children's sleep: children's poor sleep quality predicted mothers' low sleep quality; mothers' poor sleep was in turn significantly associated with maternal symptoms of depression, sleepiness, fatigue and parental distress. In this respect in a longitudinal study, Bell and Belsky (2008) were able to show a close interrelationship between children's poor sleep and mothers' well-being over time: At the first time point, children's poor sleep was predicted if mothers were younger, experienced more adverse emotions and were less able to interact positively with their children, and if the mother–child relationship was frequently conflictual. Complementary to this, at the second time point, children's poor sleep predicted mothers' increased negative emotionality and decreased sensitivity. In brief, from this longitudinal study we can conclude that mothers' and children's sleep and mental health do reciprocally interact.

However, whereas the present study shows that family context seems to play an important role in adolescents' sleep and reacted behaviours, data do not allow a deeper analysis of the underlying mechanisms or clear conclusions about the direction of influence. Thus, it remains unclear to what extent adolescents' sleep is influenced by the parents' (and particularly mothers') sleep behaviour and psychological functioning, and to what extent parents' (and particularly mothers') sleep is influenced by their adolescents' sleep and behaviour reciprocally.

Last, even if not the focus of the present study, differences between adolescents' and adults' sleep patterns related to sleep continuity appear to be consistent with age- and maturation-related changes in sleep.

Despite the novelty of the present findings, several considerations argue against an over-generalization of the results and for their cautious interpretation. First, mothers were generally housewives and therefore more involved in the daily lives of their children. Future studies might examine whether our results reflect a mother-specific phenomena or instead a phenomena of responsibility. Second, unfavourable first night effects are possible in first sleep-EEG application (Agnew et al., 1966); an adaptation night would have been necessary for child participants. However, given that all participants slept in a familiar environment, these effects should be minimal. Third, the present study used a cross-section design which precludes conclusive causal interpretation. Moreover, rapid changes in physiology and behaviour are hallmarks of adolescence (Ge et al., 2001); a longitudinal study could shed more light on the progress of this complex mutual interaction. Fourth, participants were recruited by word-of-mouth recommendation in high schools and consequently the sample does not reflect a representative cross-section of adolescents with respect to educational level, socio-economic status, or ethnic origins. Fifth, our data might potentially be biased because only adolescents and parents who were willing and able to fill in the questionnaires and to undergo sleep-EEG registration for one night participated in the study. A positive selection bias cannot be excluded. Sixth, to avoid lack of statistical power, we did not examine differences between male and female adolescents. Future research, therefore, might include larger samples. Seventh, we applied classical inferential statistics assuming independence of observations. However, due to family structure and concomitant sleep assessment, one might also argue that data are not independent. Eighth, because of the familial vulnerability of some psychiatric disorders (Dashevsky and Kramer, 1998) and because neither participants nor their parents were thoroughly screened for psychiatric disorders, we cannot exclude the possibility that the sleep difficulties assessed are merely bi-products of such disorders. Therefore, future research should include independent screening of parents and children for psychiatric disorders. Last, the study design allowed no exploration of possible genetic factors (hereditability estimates of .40 have been proposed for sleep duration; (Dahl, 1996; Gottlieb et al., 2007; Heath et al., 1990) or neuroendocrine functioning. Nevertheless, it seems that psychological and environmental factors are more likely to shape adolescents' sleep than genetic factors. For instance, there is evidence for a non-genomic transmission of parental behaviour and stress responsiveness (Champagne and Meaney, 2001). Last, EEG spectral analyses were not performed; therefore, future research examine whether the present pattern of results can be replicated and extended by including data from EEG spectral analyses.

5. Conclusion

The pattern of results suggests first that, there may be a bi-directional association between family climate, family functioning and adolescents' sleep and well-being, and, second, that mothers' and adolescent children's sleep and well-being are particularly closely associated. The present findings therefore add to the existing literature in an important way in that we were able to show that parents' and adolescents' subjective, and especially objective, sleep and psychological well-being are interrelated. Future research might assess broader samples, including possibly families with different socio-economic, ethnic and cultural backgrounds. Further, both cross-sectional and longitudinal study designs, along with interventions on the sleep of the family members, might shed light on the extent to which improving sleep could positively impact on family climate and well-being.

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Contributors

NK, MG, RK, TM, UP, EHT and SB designed the study and wrote the protocol, and all of them managed the literature searches and analyses. NK and MG were highly engaged with data collection and data entry. SB undertook the statistical analyses, and NK and MG the statistical check. SB wrote the draft of the manuscript and coordinated the integration of the different comments and corrections of the authors. UP is MG's senior researchers. EHT is the responsible senior researcher of NK, TM and SB. SB is also the responsible senior researcher of NK. All authors contributed to and have approved the final manuscript.

Conflict of interest

All authors declare that they have no conflicts of interest.

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Original article

Daily Morning Running for 3 Weeks Improved Sleep and Psychological Functioning in Healthy Adolescents Compared With Controls

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A B S T R A C T

Purpose: To compare sleep electroencephalographic patterns and psychological functioning of healthy adolescents running regularly in the mornings with those of control subjects. Although several studies have shown that regular moderate-to-vigorous exercise is related to favorable sleep and psychological functioning in adolescents, research on the effectiveness of short interventions is more limited.
Methods: Fifty-one adolescents (mean age = 18.30 years; 27 female [53%]) took part in the study; they were randomly assigned either to a running or to a control group. The running group went running every morning for 30 minutes at moderate intensity during weekdays for 3 consecutive weeks. Sleep electroencephalographic patterns and psychological functioning were assessed in both groups before and after the 3-week period. All participants also kept a sleep log for 3 weeks.
Results: Objective sleep improved (slow-wave sleep increased; sleep onset latency decreased) in the running group compared with the control group. Subjective sleep quality, mood, and concentration during the day improved, whereas sleepiness during the day decreased.
Conclusions: Thirty minutes of running in the morning during weekdays for 3 consecutive weeks impacted positively on sleep and psychological functioning in healthy adolescents compared with control subjects. Running is inexpensive and easy to implement during school schedules, and as both objective and subjective improvements were observed within 3 weeks, regular physical exercise should be promoted.

IMPLICATIONS AND CONTRIBUTION

Moderate running in the morning for 3 consecutive weeks impacted positively on objective and subjective sleep and psychological functioning among healthy adolescents. Regular exercise, such as running should be promoted as both remedy and preventative measure for poor sleep and poor psychological functioning.

Adolescence is a critical period for both neural and psychological [1] development, in which sleep plays an important functional role [2,3]. Owing to a variety of different factors, such as physical maturation (e.g., dramatic increase in secretion of growth hormones), psychological factors (e.g., identity formation), social factors (relative dependence from parents and peers), and extracurricular factors (e.g., sports and leisure activities, academic achievements), total sleep time (TST) decreases [2–5], although adolescents seem to still require 9 or more hours of sleep per night [4,5]. Daytime sleepiness is common among adolescents, and acute [6] and chronic [7] sleep disturbances have been related to poor physical and psychological functioning. In a cross-sectional survey [8], >60% of respondents were categorized as poor-quality sleepers, and shorter sleep duration, poor sleep quality, and sleepiness were independently associated with poor school achievement in children and adolescents [9].

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Exercise appears to be a simple and inexpensive method for addressing sleep loss and daytime sleepiness. Although there is empirical evidence for young and elderly adults [10], relevant research on adolescents is scarce, and studies have predominantly involved cross-sectional designs [11,12]. In previous studies, we have been able to show a relation between exercising and improved subjective and objective sleep in adolescent elite athletes [13,14] and in moderately exercising adolescents [15], compared with control subjects. A limitation was that findings were derived from cross-sectional group-comparison designs, whereas intervention studies do allow stronger conclusions regarding the direct effects of exercising. In this respect, Dworak et al [16] were able to show that acute bouts of exercise increased objectively recorded sleep.

Additionally, there is evidence that regular exercise is associated with improved psychological functioning in adolescents [14,15,17,18]; exercising buffered the effects of family conflict on depressed mood [19], and sports participation has been shown to be a protective factor against depression and suicidal ideation, mediated by its impact on increased self-esteem and social support [20]. Additionally, there is also evidence that the implementation of regular exercise as a therapeutic intervention leads to positive psychological outcomes: regular exercising improved self-esteem in children and adolescents [21], and walking regularly for 30–45 minutes during weekdays for 12 consecutive weeks led to complete psychiatric remission in half of patients suffering from therapy-resistant major depressive disorders, as compared with control subjects [22].

Thus, there is reason to anticipate that exercise interventions can improve sleep and psychological functioning. Therefore, the following two hypotheses were formulated. First, we expected a positive impact of a moderate-to-vigorous exercise (here, moderate-to-vigorous exercise was defined as planned and continuous running without interruption at a speed such that conversation is not possible) training program on sleep [13,16] as compared with a control condition. Second, following previous research [13–18], we anticipated an improvement in psychological functioning (such as stress perception, curiosity, somatosensory amplification, mood, concentration, and sleepiness) in exercising adolescents as compared with control subjects.

Methods

Sample

Participants were recruited from a high school in the canton of Basel-Landschaft, a district of the German-speaking northwestern part of Switzerland. Figure 1 shows the study flowchart and dropout rates. Of the 60 adolescents originally approached, 51 (85%) completed the study (see Figure 1; age: mean [M] = 18.30 years; standard deviation [SD] = .89; range: 17.5–19.5 years): 27 were female (age: M = 18.11 years, SD = .80) and 24 were male (age: M = 18.13 years, SD = 1.00). Participants were randomly assigned to either the running or the control group (see later in the text). Neither gender distribution ($\chi^2(1) = .30$, $p = .87$) nor age (analysis of variance [ANOVA]: group: $F(1, 47) = .01$, $p = .97$; gender: $F(1, 47) = .02$, $p = .97$) differed significantly between the two groups. Body mass index differed significantly between male and female participants (male: M = 23.29, SD = 2.27; female: M = 20.74, SD = 1.54; gender: $F(1, 47) = 18.62$, $p = .000$) but not between the two groups (group: $F(1, 47) = .44$, $p = .51$). As in previous studies [14,15], mean weekly vigorous exercise was assessed through the following question: "For how many hours do you do vigorous exercise? Vigorous exercise means: You are playing sports at such a level as to have a markedly increased heart rate and to sweat." Answers indicated the number of hours over which intense exercise was undertaken for each of the 7 consecutive days. These values were then summarized to generate a total weekly exercise index (hrs/wk). At the beginning of the study, mean vigorous exercise did not statistically differ between the two groups (running group [RG]: M = 2.19 hours (SD = 1.56); control group [CG]: M = 2.24 hours (SD = 1.78); $t(49) = .53$, $p = .60$, $d = .15$).

All students were informed about the purpose of the study and about the voluntary basis of participation. Participants were assured of the confidentiality of their responses and gave written informed consent. Of the 51 participants, 10 were younger than 18 years. For these participants, parents' written informed consent was requested. For participation, they received a voucher of 30.00 Swiss francs for a sports shop. The study was approved by the local ethics committee of Basel (Switzerland; trial number: 72/10).

Procedure

Figure 1 depicts the study structure, assessments, randomization, and total sample sizes. First, a psychiatric interview [23] ensured that only participants without psychiatric disorders (e.g., affective disorders, eating disorders, substance abuse disorders, sleep disorders, or others) were enrolled in the study. Additionally, brief questions related to physical health state ensured that only participants without medical illnesses, allergies, and cardiovascular, pulmonary, or orthopedic diseases took part in the study. Thereafter, participants were asked to refrain from any intake of psychoactive or sleep-altering substances (alcohol, cannabis, nicotine, mood- or energy-enhancing drinks) for 2 weeks before commencement of and during the study itself.

Participants kept a sleep log (see later in the text) for 3 weeks (21 consecutive days), covering 3×5 weekdays and 3×2 weekend days. To compare possible effects of regular running, at the beginning and at the end of the study, participants completed a series of questionnaires related to psychological functioning and sleep (see later in the text). Additionally, at the beginning and at the end of the study, objective sleep assessment was executed (which will be described further).

The study was conducted during a school term from mid-August to the end of September 2010, that is, during the summer season with high light exposure from early morning.

Participants were randomly assigned to one of the two study conditions, namely, the RG or the CG. For 3 consecutive weeks, during the 5 school days per week, participants assigned to the RG or the CG met every morning at 7 AM at school. Afterward, the RG went running for between 30 and 37 minutes. All participants in the RG had 3×5 running sessions. Running was cross-country; after two laps on the school's running track, running continued in the forest close to school. Participants were allowed to maintain their own pace though while running without interruption in groups of at least four people. Running differed from jogging in that running speed was such that talking was more difficult. All participants had to pass a checkpoint and a turning point, and the track did not allow shortcuts. After participants completed the session, they got ready for school, and a breakfast was provided before school commenced.

In contrast to the RG participants, those in the CG remained on the school's running track, remained seated, followed

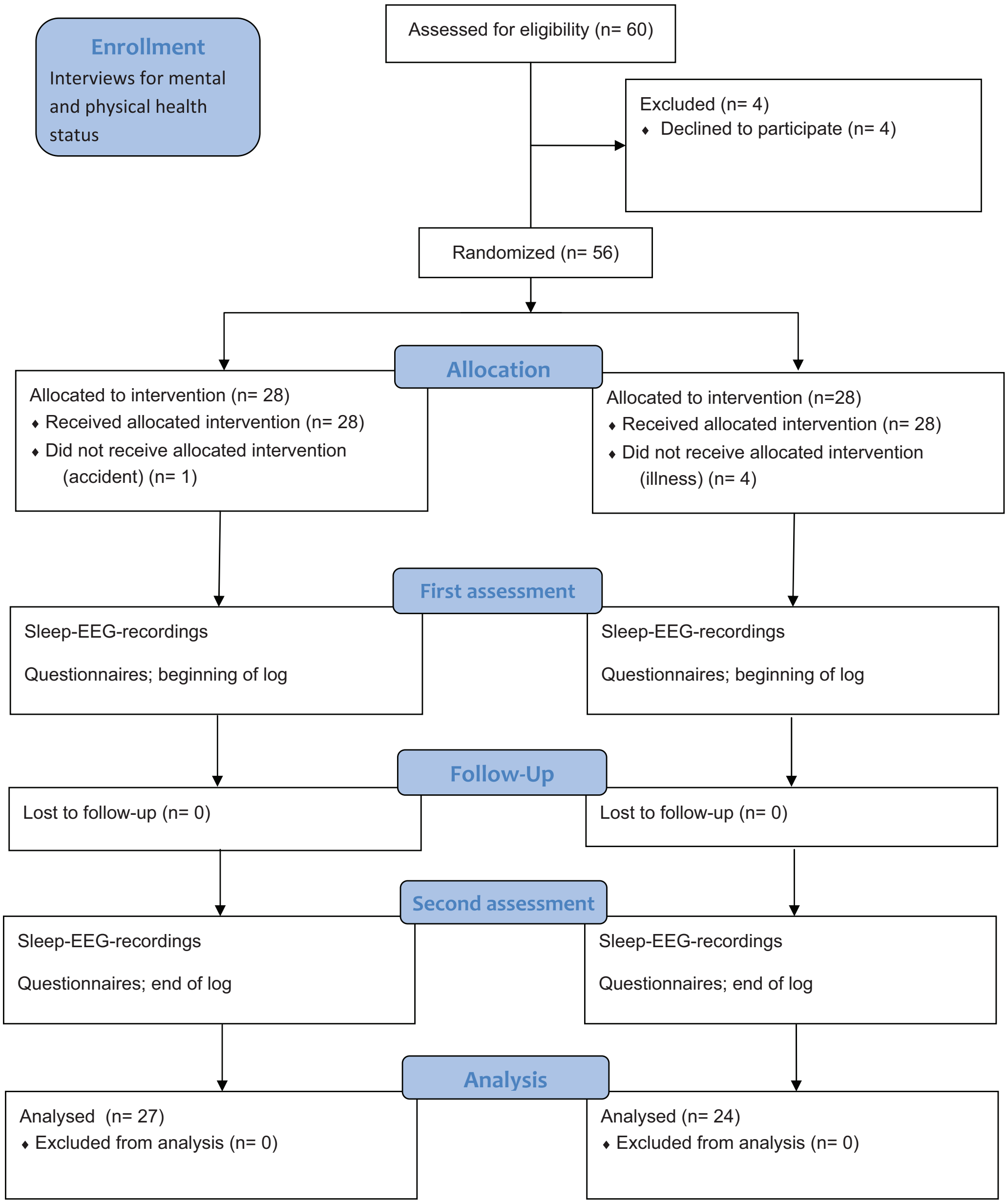

Figure 1. Flow diagram for recruitment and analysis of participants.

school activities, and completed homework. They could speak and interact with each other, but they were not allowed to use electronic devices such as mobile phones or electronic notebooks. Participants in the CG had 3 × 5 sessions of resting activity. They ceased their activities when the last of the runners returned. Next, after all participants in the RG had prepared for school, a breakfast was provided for both groups. By arranging the same study conditions (with the exception of running itself) for both the RG and the CG, potential confounders, such as morning schedule, exposure to daylight and artificial light, social interaction, and eating at school, were rigorously controlled for. Moreover, meeting at 7 AM at school did not interfere with participants' habitual sleep/wake pattern.

Assessing psychological functioning

Daily log. Participants filled out the sleep and mood log in the evening and in the morning. For evenings, participants answered questions on an 8-point visual analog scale about sleepiness during the day (1 = very sleepy; 8 = not at all sleepy), concentration during the day (1 = very bad concentration; 8 = very high concentration), and mood at bedtime (1 = very bad mood; 8 = very good mood). For mornings, the questionnaire asked about sleep quality (1 = very bad sleep quality; 8 = very good sleep quality) and mood on awaking, using the same analog scale (Cronbach α = .89). Nights were defined as weekday nights if the participant went to school the next day; weekend nights were

Friday and Saturday nights. To compute data, weekdays of a single week and weekend days of a single weekend were aggregated, resulting in three composite variables for weekdays (weeks 1, 2, and 3) and three composite variables for weekends (weekends 1, 2, and 3).

Similar to a previous study [15], we tested whether perceived stress, coping strategies, somatosensory perception, and curiosity and exploratory behavior (see later in the text) might change in a positive direction over time.

Perceived stress. The Perceived Stress Scale [24] consists of 10 items and was used to determine perceived overall stress occurring over the previous month. Answers were given on a 5-point rating scale ranging from 1 (never) to 5 (very often), with higher scores reflecting greater perceived stress (Cronbach $\alpha = .89$).

Coping with stress. The questionnaire consists of 18 items and assesses positive and negative coping strategies [25]. Positive coping strategies are those that reduce tension in both the short- and the long-term, including minimizing the situation, controlling the situation, and self-instruction. Negative coping strategies are those that reduce tension in the short-term but increase stress in the long-term, including social withdrawal, rumination, and resignation. Answers were given on a 5-point rating scale ranging from 1 (very unlikely) to 5 (very likely). The higher the score, the more pronounced is the coping strategy (Cronbach $\alpha =$ .82). Two composite mean scores were computed reflecting positive and negative coping strategies.

Somatosensory amplification. Somatosensory amplification refers to a tendency to experience somatic and visceral sensations as unusually intense, noxious, and disturbing. Assessment was through the Somatosensory Amplification Scale [26]. The questionnaire consists of 10 items relating to body hypervigilance and the predisposition to focus on certain weak and infrequent body sensations. Answers were given on a 5-point rating scale ranging from 1 (not at all true) to 5 (completely true). Higher scores reflect an increased tendency to somatosensory amplification (Cronbach $\alpha = .88$).

Curiosity and exploratory behavior. Kashdan et al's [27] Curiosity and Exploration Inventory was used to assess this dimension. Curiosity is conceptualized as a positive emotional–motivational system associated with the recognition, pursuit, and self-regulation of novelty and challenge. The inventory consists of seven items, and answers were given on a 7-point rating scale with the anchor points 1 (not at all true) to 7 (completely true). Higher scores indicate greater curiosity/exploration (Cronbach $\alpha = .79$).

Sleep evaluation

Objective sleep electroencephalographic recordings. Sleep was objectively assessed at the beginning and at the end of the study. At the beginning of the study, before starting the intervention, the sleep electroencephalographic (EEG) device was applied twice. With the first application, participants slept with the sleep EEG device to avoid possible unfavorable “first night effects.” No registration was performed. The following night, sleep registration was performed.

On the day of the recording night, participants had to attend regular schedules, but without evening exercise so as to avoid possible effects of acute bouts of exercise on sleep [16]. Participants were requested to go to bed at the usual time, which was between 9 and 10.30 PM and to get up between 6 and 6.30 AM. After the intervention was completed 3 weeks later, objective sleep assessment was repeated. Sleep EEG recordings were performed at home using a three-channel EEG device (Fp2-A1, C3-A2, C4-A1; electrooculogram; electromyogram; SOMNOwatch; Somnomedics, Randersacker, Germany). Sleep polygraphs were visually analyzed by two experienced raters according to the standard procedures [28] (inter-rater reliability: $\kappa = .91$). Raters were completely blinded to participants’ group assignments. The SOMNOwatch device provides assessment of TST, sleep period time, sleep onset latency (SOL), sleep efficiency, stages 1–4 (minutes and %), light sleep (stages 1 + 2), slow-wave sleep (stages 3 + 4), rapid eye movement (REM) sleep, REM sleep latency, and number and times of awaking after sleep onset.

Subjective assessment of sleep. Participants also completed at the beginning and at the end of the study the Insomnia Severity Index [29], a screening tool for insomnia. The seven items, answered on 5-point rating scales (1 = not at all, 5 = very much), refer to difficulty in falling asleep, difficulties maintaining sleep, increased daytime sleepiness, and worrying about sleep. The higher the overall score, the more the respondent is assumed to suffer from insomnia (Cronbach $\alpha = .86$).

Statistical analyses

To calculate changes on the daily log dimensions (e.g., mood, concentration) across the 3 weeks, a series of ANOVAs for repeated measures with the factors time (six conditions: weekdays weeks 1–3; weekend days weeks 1–3) and group (RG vs. CG) was performed. For before to after comparison of objective sleep variables, ANOVAs for repeated measures were performed with the factors time (pre vs. post) and group (RG vs. CG) as independent variables. In case of deviations from sphericity, statistical tests were performed using Greenhouse–Geisser-corrected degrees of freedom, and the original degrees of freedom are reported with the relevant Greenhouse–Geisser epsilon value (ε). Test results with an α level $<.05$ are reported as significant. Effect sizes for ANOVAs (partial eta squared [η^2]) were calculated following Cohen [30], with $.059 \geq \eta^2 \geq .01$ indicating negligible practical importance, $.139 \geq \eta^2 \geq .06$ indicating moderate practical importance, and $\eta^2 \geq .14$ indicating crucial practical importance effect sizes.

Results

Daily log

Tables 1 and 2 provide the descriptive and inferential statistical overview of the data from the daily log, separately by groups (RG vs. CG) and time (weeks 1–3, weekdays and weekend days).

Sleep quality significantly increased over time and was significantly higher in the RG compared with the CG; the group × time interaction was also significant, reflecting a significantly greater increase in sleep quality over time in the RG than in the CG (Figure 2).

Mood in the morning significantly improved over time and was significantly higher in the RG than the CG; the group × time interaction was also significant; mood in the morning increased significantly over time in the RG compared with the CG.

Table 1
Daily log: Overview of descriptive values, separately for weeks (week 1, week 2, week 3), for week days (weekdays, weekend days), and for groups (RG, CG)

Variables	Group	Study weeks					
		Week 1		Week 2		Week 3	
		Weekdays M (SD)	Weekend M (SD)	Weekdays M (SD)	Weekend M (SD)	Weekdays M (SD)	Weekend M (SD)
Sleep quality[a]	RG	4.44 (1.05)	5.50 (.95)	5.24 (.84)	6.13 (.78)	5.71 (.75)	6.35 (.72)
	CG	4.54 (.98)	5.13 (.90)	4.73 (.78)	4.92 (1.15)	4.80 (1.28)	5.15 (1.08)
Mood: Morning[a]	RG	4.28 (.76)	4.44 (1.05)	4.64 (.75)	5.11 (.68)	5.21 (.85)	5.53 (.97)
	CG	4.36 (.61)	4.54 (.98)	4.36 (.44)	4.53 (.90)	4.34 (.48)	4.91 (.85)
Concentration during the day[a]	RG	4.56 (1.40)	4.83 (1.06)	5.29 (1.18)	4.93 (.95)	5.74 (1.09)	5.60 (.88)
	CG	5.33 (1.58)	5.52 (1.00)	4.74 (.89)	5.45 (1.25)	4.71 (.85)	5.19 (.78)
Sleepiness during the day[a]	RG	3.84 (.67)	3.77 (.78)	3.93 (.75)	4.35 (.69)	4.77 (.70)	5.74 (.94)
	CG	3.98 (.69)	3.69 (.96)	3.90 (.89)	4.13 (.86)	4.01 (.67)	4.17 (1.49)
Mood: Evening[a]	RG	3.80 (.86)	4.32 (.87)	3.93 (.81)	4.71 (.71)	5.11 (1.50)	5.02 (.76)
	CG	4.12 (1.45)	5.05 (1.00)	4.04 (1.16)	4.86 (.72)	5.10 (1.84)	4.94 (.73)

M = mean; SD = standard deviation; RG = running group; CG = control group.
[a] Higher means reflect a more positive position on the dimension; for example, sleep quality increased in the weekdays from week 1 (RG = 4.44; CG = 4.54) to week 3 (RG = 6.35; CG = 5.15). Likewise, sleepiness during the day decreased from week 1 (RG = 3.84; CG = 3.98) to week 3 (RG = 5.74; CG = 4.17).

Concentration during the day did not differ between groups and did not change over time. However, the group × time interaction was significant; concentration increased significantly over time in the RG, but not in the CG.

Sleepiness during the day did not differ between groups but decreased significantly over time. The group × time interaction was significant; sleepiness decreased significantly over time in the RG compared with the CG.

Mood in the evening did not differ between groups. Over time, irrespective of group, mood in the evening improved. The group × time interaction was not significant.

Psychological functioning

Table 3 provides the descriptive and inferential statistical overview of objective sleep measurements, separately by groups (RG vs. CG) and time (before vs. after assessment).

Perceived stress, *positive and negative coping strategies*, and *curiosity and exploratory behavior* did not differ significantly between groups or over time. Moreover, no statistically significant group × time interactions were observed.

Somatosensory amplification scores decreased significantly over time. Moreover, the group × time interaction was statistically significant, with decreased scores over time in the RG compared with the CG.

Sleep

Subjective sleep. Insomnia scores decreased significantly over time. Moreover, the group × time interaction was statistically significant, with decreased scores over time in the RG compared with the CG.

Objective sleep recordings

Table 4 provides the descriptive and inferential statistical overview of objective sleep measurements, separately for groups (RG vs. CG) and time (before vs. after assessment).

No statistically significant mean differences between groups, over time (from before to after assessments), or combining group and time (group × time interactions) were observed for TST, awakenings after sleep onset (number, time), stage 2 (minutes), stage 3 (minutes), light sleep (minutes; %), or REM sleep (%).

SOL significantly decreased in the RG compared with the CG over time.

Sleep efficiency was significantly higher in the RG compared with the CG. No statistically significant mean differences were observed over time or for the group × time interaction.

Over time, stage 1 (minutes; %) significantly decreased, whereas stage 3 (%) and REM sleep (minutes) significantly increased, with no mean differences for group or for group × time interactions.

Table 2
Daily log: Overview of inferential statistics separately for group (RG vs. CG), and time (3 weeks; blocs of weekdays and weekend days)

Daily log variables	Greenhouse–Geisser epsilon value (ε)	Group		Time		Group × time interaction	
		F	η^2	F	η^2	F	η^2
Sleep quality	.611	14.02*	.223	17.28*	.261	5.98**	.11
Mood: Morning	.560	4.42***	.083	16.08*	.247	6.32**	.114
Concentration during the day	.687	.00	.000	3.02	.058	17.13*	.259
Sleepiness during the day	.692	2.68	.052	38.01*	.437	2.82***	.054
Mood: Evening	.492	1.05	.021	15.50*	.240	1.36	.027

Degrees of freedom: Always = (5, 245).
* $p < .05$.
** $p < .01$.
*** $p < .001$.

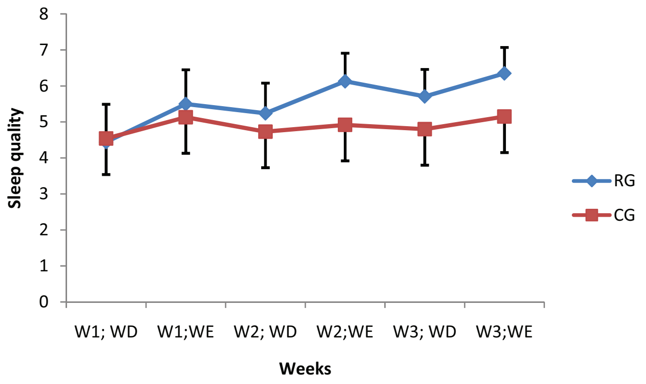

Figure 2. Subjective sleep quality improved over time in both the running group and the control group; however, improvement was more pronounced in the running group (for statistics see Tables 1 and 2). W1 = week 1; W2 = week 2; W3 = week 3; WD = weekdays; WE = weekend days; RG = running group; CG = control group. For further statistical information, see Tables 1 and 2. Points are means, and bars are standard deviations.

Stage 2 (%) was significantly higher in the control compared with the RG, with no significant time or group × time interactions.

Stage 4 (minutes, %) was significantly higher in the RG compared with the CG; the significant group × time interaction showed that stage 4 (minutes, %) increased in the RG compared with the CG from before to after assessment. Likewise, deep sleep (minutes; %) was significantly higher in the RG compared with the CG; moreover, the significant group × time interaction showed that deep sleep (minutes) increased in the RG compared with the CG from before to after assessment.

REM sleep latency (minutes) was significantly prolonged in the RG compared with the CG; moreover, the significant group × time interaction showed that REM sleep latency (minutes) was longer in the RG compared with the CG from before to after assessment.

Discussion

The key finding of the present study is that, compared with a control condition, an intervention involving running for 30 minutes in the morning daily during weekdays for 3 consecutive weeks improved sleep (objectively and subjectively) and psychological functioning. The results add to the existing literature in showing that even a short-term intervention of regular running in the morning does have a favorable impact on the sleep and psychological functioning of healthy adolescents.

Two hypotheses were formulated and each of these is now considered in turn.

With the first hypothesis, we expected a favorable impact of moderate-to-vigorous exercise on adolescents' sleep [13–16], and findings fully confirmed this; compared with control subjects, participants in the RG reported improved sleep quality, and objectively assessed sleep improved, in that deep sleep increased, SOL decreased, and REM sleep latency became longer over time. Thus, the present findings echo those of the numerous studies that have confirmed an association between exercise and sleep [13–16,31]. Importantly, the present results add to the literature in demonstrating the impact of moderate exercise, namely, running for 30 minutes in the morning for only 3 weeks.

With the second hypotheses, we anticipated a favorable influence of regular exercise on psychological functioning, but this was only partly confirmed. Whereas no changes were observed in perceived stress and coping or in curiosity and exploratory behavior, running was related to decreased pain perception. The lack of any association between exercising and stress is in marked contrast with the many studies demonstrating a positive influence of exercise on stress management [32–34]. The following are possible explanations for this difference: (a) The time interval of 3 weeks was too short to induce the relevant changes; (b) trait (as compared with state) characteristics, such as curiosity, perception of stress, and coping strategies, are relatively stable over time and therefore more difficult to modify; (c) perception of stress and coping did change but in ways too subtle to be captured by the questionnaires used; (d) participants were particularly healthy and this would result in ceiling effects.

By contrast, the experience and appraisal of bodily sensations and its cognitive–emotional elaboration (i.e., the somatosensory amplification or pain) is much more adaptable and sensitive to situation-specific conditions [35]. Our results suggest that pain threshold increased as a function of exercise, and this pattern of results is in accord with previous findings [15,35].

Despite the clarity of the findings, several issues warrant against overgeneralization. First, as in all studies with exercising, confounders, such as exposure to daylight and social contacts, may bias results. However, we note that social contacts, expo-

Table 3
Descriptive and statistical overview of psychological functioning, separately by group (RG vs. CG) and assessment time (before vs. after assessment)

Psychological functioning	RG Before assessment n = 27 M (SD)	RG After assessment n = 27 M (SD)	CG Before assessment n = 24 M (SD)	CG After assessment n = 24 M (SD)	Statistics Group F	Group η^2	Time F	Time η^2	Group × time interaction F	Group × time interaction η^2
Perceived stress scale	2.94 (.68)	2.95 (.68)	2.81 (.61)	2.63 (.63)	1.71	.034	2.25	.044	2.97	.057
Coping strategies										
Positive coping	3.29 (.64)	3.14 (.78)	3.32 (.68)	3.41 (1.22)	.45	.009	.12	.002	1.48	.029
Negative coping	2.93 (1.08)	2.65 (.68)	2.71 (.59)	2.63 (.67)	.40	.008	2.26	.044	.67	.014
Somatosensory amplification	14.74 (3.35)	12.14 (4.83)	15.25 (6.72)	15.58 (7.96)	1.55	.031	5.78*	.106	9.69**	.165
Curiosity and exploratory behavior	5.28 (.58)	5.26 (.49)	5.46 (.69)	5.28 (.73)	.37	.008	2.66	.051	1.75	.034
Insomnia severity	13.89 (3.83)	11.22 (3.30)	13.17 (3.03)	13.88 (3.45)	1.14	.023	8.94**	.154	26.57***	.352

Degrees of freedom: Always = (1, 49).
* $p < .05$.
** $p < .01$.
*** $p < .001$.

Table 4
Descriptive and statistical overview of sleep EEG variables, separately by group (running vs. control) and assessment time (before vs. after assessment)

	RG		CG		Statistics					
	Before assessment n = 27 M (SD)	After assessment n = 27 M (SD)	Before assessment n = 24 M (SD)	After assessment n = 24 M (SD)	Group		Time		Group × time interaction	
					F	η^2	F	η^2	F	η^2
TST (minutes)	409.32 (24.46)	434.89 (45.10)	400.17 (67.10)	406.00 (56.00)	2.71	.052	3.95	.075	1.56	.031
Sleep onset latency (minutes)	10.17 (5.33)	7.42 (4.73)	9.38 (9.16)	10.43 (4.41)	4.31*	.081	3.59	.082	6.12**	.120
Sleep efficiency	93.38 (4.41)	94.03 (2.22)	91.83 (4.72)	92.51 (3.65)	4.78*	.089	.66	.013	.00	.000
Awakenings after SO (number)	7.52 (7.64)	6.41 (3.25)	5.50 (3.79)	6.67 (2.75)	.70	.014	.01	.000	1.75	.034
Awakenings after SO (minutes)	22.76 (21.78)	22.18 (18.07)	29.86 (22.04)	20.67 (9.88)	.60	.012	1.64	.032	1.27	.025
Stage 1 (minutes)	13.06 (8.40)	7.57 (3.75)	13.13 (7.98)	10.04 (5.34)	.59	.012	24.23***	.331	1.90	.037
Stage 1 (%)	3.23 (2.32)	1.56 (1.14)	3.18 (1.88)	2.43 (1.26)	.91	.018	28.24***	.366	3.96	.075
Stage 2 (minutes)	186.28 (15.28)	192.96 (28.95)	190.75 (43.40)	199.21 (45.55)	.41	.008	2.26	.044	.03	.001
Stage 2 (%)	45.63 (4.48)	43.58 (6.68)	47.41 (6.92)	48.51 (6.86)	4.90*	.091	.28	.006	3.11	.060
Stage 3 (minutes)	28.07 (9.18)	29.65 (12.42)	26.08 (7.34)	30.29 (9.58)	.08	.002	3.65	.069	.76	.015
Stage 3 (%)	6.83 (1.99)	8.62 (3.89)	6.68 (2.09)	7.68 (3.05)	.61	.012	12.42***	.202	.99	.020
Stage 4 (minutes)	99.20 (21.40)	105.69 (15.05)	87.38 (24.13)	81.88 (11.38)	16.94***	.257	.03	.001	4.13*	.078
Stage 4 (%)	24.24 (5.33)	27.17 (7.38)	22.26 (7.02)	20.93 (6.45)	7.18**	.128	.61	.012	4.32*	.081
Light sleep (minutes)	199.33 (21.05)	200.17 (29.36)	203.04 (45.63)	209.25 (47.54)	.51	.010	.46	.009	.27	.005
Light sleep (%)	48.89 (6.33)	45.13 (7.32)	48.26 (10.97)	48.54 (9.85)	.51	.010	1.39	.028	1.89	.037
Deep sleep (minutes)	127.22 (24.23)	135.33 (18.04)	114.29 (21.22)	112.17 (15.72)	13.34***	.214	1.19	.024	4.49*	.099
Deep sleep (%)	31.05 (5.81)	35.78 (10.39)	29.48 (6.79)	28.06 (8.98)	5.72*	.105	1.79	.035	6.17**	.112
REM-S (minutes)	82.78 (18.11)	84.63 (27.65)	82.83 (24.77)	99.39 (30.30)	1.42	.028	6.36**	.115	4.12	.078
REM-S (%)	20.08 (3.37)	19.09 (5.76)	22.27 (9.09)	23.40 (10.94)	3.60	.068	.003	.000	.65	.013
REM latency (minutes)	83.88 (18.39)	98.53 (36.90)	80.20 (24.43)	75.75 (32.67)	4.50*	.091	1.15	.023	4.05*	.091

Degrees of freedom: Always = (1, 49).
TST = total sleep time; SO = sleep onset; REM-S = rapid eye movement sleep; M = mean; SD = standard deviation.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

sure to daylight, and eating at school were equal for both conditions; therefore, these possible confounders could be ruled out. Second, it is unclear to what extent the intervention was successful because it took place in the mornings as compared with interventions during the day or in the evening, and research on this is limited and results are inconclusive [36,37]. Specifically, there is no research with respect to adolescents. Third, results may potentially be biased because they are based on data from particularly healthy and motivated adolescents willing to complete questionnaires and to undergo sleep EEG registration. Thus, participants might not be representative for adolescents as a whole [6,7]. In this view, we also note that participants in the present sample were far from sleeping for the recommended 9 hours per night (see Table 4). Fourth, we did not assess individual fitness, nor did we assess running objectively. However, it was our firm intent to arrange a study design close to a practicable and easy-to-implement intervention. Finally, the relevant dimensions may be linked by means of as-yet unidentified further variables, such as the secretion of adenosine, cortisol, or melatonin or issues related to motivation and volition. Based on these limitations, future research should (a) compare exercise interventions at different times of day, (b) assess the impact of exercise intervention based on objectively assessed physiological parameters, or (c) assess neurobiological variables, such as cortisol, melatonin, or BDNF (brain derived neurotrophic factor).

Conclusion

Moderate running in the morning for 3 consecutive weeks impacted positively on objective and subjective sleep and psychological functioning among healthy adolescents. Moderate, but regular, exercise such as running should be promoted as both a remedy and a preventative measure for poor sleep and poor psychological functioning.

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ORIGINAL RESEARCH

Sleep duration and subjective psychological well-being in adolescence: a longitudinal study in Switzerland and Norway

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Background: Adolescents' sleep duration and subjective psychological well-being are related. However, few studies have examined the relationship between sleep duration and subjective psychological well-being longitudinally across adolescence – a time of profound biological and psychosocial change. The aim of this longitudinal study was to investigate whether shorter sleep duration in adolescents is predictive of lower subjective psychological well-being 6 months and 12 months later or whether lower subjective psychological well-being is predictive of shorter sleep duration.

Methods: Adolescents (age range, 10.02–15.99 years; mean age, 13.05±1.49 years; 51.8%, female) from German-speaking Switzerland (n=886) and Norway (n=715) reported their sleep duration and subjective psychological well-being on school days using self-rating questionnaires at baseline (T1), 6 months (T2), and 12 months from baseline (T3).

Results: Cross-sectional and longitudinal analyses revealed that sleep duration decreased with age. Longer sleep duration was concurrently associated with better subjective psychological well-being. Crossed-lagged autoregressive longitudinal panel analysis showed that sleep duration prospectively predicted subjective psychological well-being while there was no evidence for the reverse relationship.

Conclusion: Sleep duration is predictive of subjective psychological well-being. The findings offer further support for the importance of healthy sleep patterns during adolescence.

Keywords: adolescence, sleep duration, psychological well-being, international, longitudinal study

Introduction

Complaints about poor sleep and daytime sleepiness are common among adolescents,[1,2] and acute[3] and chronic[4] sleep disturbances have been related to poor psychological functioning, such as impaired cognitive performance,[5,6] depression,[7–12] and poor physical health.[13–16] Short sleep duration, insomnia, as well as interrupted sleep due to sleep apnea, nocturnal enuresis, and periodic limb movement in children and adolescents adversely affects learning, academic performance,[17–23] emotional processing,[24–26] and – relatedly – psychological functioning.[27–30] In a cross-sectional survey with a large population of college students (n=1,125; 17–24 years old), over 60% of respondents were categorized as poor-quality sleepers with shorter sleep duration.[19] Poor sleep quality and sleepiness were independently associated with poor school achievement in children and adolescents.[20] Remarkably, over 25% of adolescents report sleep disturbances.[7,31–34] Cross-sectional[19,35] and longitudinal studies, eg,[36,37] have shown

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that acute and chronic sleep disturbances persist over time, which may compromise adolescents' mental and physical health in the long run.

Although older adolescents of 15–16 years still require approximately 9 hours of sleep on average per night as do younger adolescents of around 10–11 years,[38–40] a wealth of studies shows that average sleep duration decreases significantly across adolescence.[22,41–44] Several factors may be responsible for this decrease, including: physical maturation; psychological factors; social factors, such as decreasing supervision by parents and increasing importance of peer relations; and issues related to education and training, involving pressure related to academic achievement, homework, vocational issues, and extracurricular activities.[27,28,38,39,45]

Taken together, the pattern of published evidence suggests that sufficient sleep during adolescence is related to adolescents' psychological well-being. Although there are numerous studies of the relationship between sleep and poor mental health, longitudinal studies focusing on the relationship between sleep duration and positive aspects of functioning, such as psychological well-being, are scarce.[46] An exception is a 3-year longitudinal study of 2,259 students aged 11–14 years that showed that depressive symptoms and low self-esteem were predicted by short sleep.[47] Positive psychological well-being involves both cognitive and affective aspects.[48] Cognitive aspects include evaluations of whether one's life is on the right track and whether one has a positive attitude toward one's future. Affective aspects include whether one experiences positive emotions and joy in life as well as an absence of negative affect and symptoms of mental distress.[48]

The present study extends upon previous research in two respects. First, we studied interrelations between sleep schedules and subjective psychological well-being (SPW) across three time points of measurement testing for both directions of prediction. The measurement points were each separated by 6 months (data were collected in May, November, and again in May). Second, we tested whether associations between sleep duration and SPW are different between age groups. We therefore divided the sample into three age categories: 10–11 year olds; 12–13 year olds; and 14–15 year olds. Sleep duration and SPW were assessed in two large samples of adolescents from Switzerland and Norway. Although both countries are examples of Western cultures, they, for instance, differ markedly with regard to day length in May and November, which may be associated with sleep patterns and SPW.[32]

Methods

Participants

In total, 2,703 adolescents provided data on at least one measurement time point. A total of 1,601 adolescents (age range at T1, 10.02–15.99 years; mean age, 13.05–1.49 years; 51.8% females) from two different European countries (Switzerland, n=886; Norway, n=715), and from a socioeconomically diverse sample provided complete data across all three measurement waves (T1, n=2,330; T2, n=2,094; T3, n=2,061. As data were assessed during school lessons with school classes, it is possible that, for instance, some participants provided no data at T1 but at a later assessment time). Comparing adolescents with complete data with the ones with incomplete data revealed that participants with complete data were younger (F[1; 2,520]=29.1; $P<0.001$), more often female (χ^2[1]=10.23; P=0.001), had higher levels of SPW at T1 (F[1; 2,363]=23.55; $P<0.001$), and at T2 (F[1; 2,139]=17.80; $P<0.001$), as well as longer sleep duration at T1 (F[1; 2,340]=116.04; $P<0.001$). The two nations did not differ with regard to the probability of having complete data (χ^2[1]=0.22; P=0.88). Furthermore, the two national groups differed with respect to age (F[1; 2520]=37.65; $P<0.001$); the Swiss sample mean age was 13.34±1.54 years; the Norwegian sample mean age was 12.97±1.50 years). Sex distribution was not significant (χ^2[1]=0.16; P=0.69). The grades sampled were from fourth to ninth; these school years are compulsory in both countries. Socioeconomic status was: 31%, upper class; 37%, middle class; and 32%, working class. The majority of adolescents lived with both parents (n=2,132; 80%), 18% (n=480) with their mothers only, and just 2% (n=53) with their fathers only.

Procedure

Participants were recruited by advertisements in the local schools in the canton of Bern, located in the German-speaking part of Switzerland, and in Bergen (Norway). The first wave of the investigation took place in early summer (May, T1), followed by further waves after 6 months in early winter (November, T2), and again 6 months later in early summer (May, T3). Each assessment took place in the classroom during a school lesson. All participants and their parents gave informed consent regarding study participation. The study followed the ethical principles required by the home institution of the study (the University of Bern, Switzerland) and laid down in the Declaration of Helsinki and was financially supported by the Swiss National Science

Foundation (Nationales Forschungsprogramm 33 [NFP-33]; project number, 4033-35779).

Materials

Self-assessment of SPW; Bern well-being questionnaire for adolescents

The present study used five items from the Bern well-being questionnaire for adolescents (BFW/J)-subscale. One item was: "Positive attitude towards life", such as "My future looks good", and "I enjoy life more than most of the other people". Four items from the BFW/J-subscale included: "Joy in life", such as "Did it occur in the past few weeks that you were pleased because you had achieved something?" or "Did it occur in the past few weeks that you were pleased because other people liked you?" Answers were given on four-point rating scales with 1= "not at all" and 4= "completely". To increase reliability, the nine items were combined to build a score of subjective psychological well-being. Cronbach's alpha of this score was 0.77 at T1, 0.81 at T2, and 0.82 at T3, which represents good internal consistency.

Sleep duration on weekdays

Sleep duration on weekdays was assessed with two items asking for time in bed before school days and time of getting up on school days. The participants had to fill in the respective clock times. Sleep duration was calculated by the difference between bed and getting up time.

Statistical analysis

To assess relationships between sleep duration and SPW in different age groups, we divided participants into three age groups representing very early adolescence: (ages 10–11 years; mean age, 11.20±0.50 years); late early adolescence (ages 12–13 years; mean age, 12.96±0.56 years); and early middle adolescence (ages 14–15 years; mean age, 14.94±0.54 years).

To compare differences in SPW and sleep duration between countries, age groups, and across the three waves, two analyses of variance (ANOVAs) for repeated measures were computed with the factors country (Switzerland versus Norway), age group ("10 to 11 year olds" versus "12 to 13 year olds" versus "14 to 15 year olds"), and assessment time (T1, baseline; T2, 6 months from T1; and T3, 12 months from T1). Additionally, Pearson's correlations between sleep duration and SPW were computed separately for the three age groups and the three assessment times. To test longitudinal relations between sleep duration and SPW controlling for the initial levels of these constructs, a crossed-lagged autoregressive longitudinal panel model was employed. This model specifies autoregressive paths (each construct is regressed on its level at the preceding measurement wave), crossed-lagged paths (each construct is regressed on the other construct's level at the preceding measurement wave), as well as correlations between the two constructs (or their residuals) on the concurrent measurement wave. This model was estimated separately for the three age groups applying multi-group comparison and the χ^2 difference test. For paths that were not significantly different between the three age groups as indicated by the χ^2 difference test, the paths were set equal across groups.

An alpha of $P<0.05$ was accepted as a nominal level of significance. All statistical computations were performed with IBM SPSS® (IBM Corporation, Armonk, NY, USA) and AMOS® 19 for Windows (Amos Development Corporation, Spring House, PA, USA). Missing values were not imputed for analyses conducted with SPSS® (ANOVA for repeated measures, correlations), while analyses conducted with the AMOS® applied estimation of missing values by the full information maximum likelihood method.

Results

Descriptive statistics for the course of sleep duration and SPW across adolescence

There were no significant differences between males and females in SPW ($F[df=1]=3.65$; $P=0.06$) or sleep duration ($F[df=1]=0.66$; $P=0.42$). Repeated measures ANOVA revealed that sleep duration decreased with age in cross-sectional analysis (ie, analyses comparing the age groups; [$F\{2;\ 1{,}584\}=532.23$; $P<0.001$]) and longitudinal analysis (analysis of the trend across the measurement points; [$F\{2;\ 1{,}583\}=276.07$; $P<0.0010$]). Sleep duration was shorter in Norway than in Switzerland ($F[1;\ 1{,}584]=39.94$; $P<0.001$). Age-group X measurement time, country X measurement time, country X age group interactions, and the three-way interaction country X age-group X measurement time were not significant ($P>0.10$). Table 1 provides descriptive statistics for sleep duration by countries (Switzerland and Norway), age groups ("10–11 year olds", "12–13 year olds", and "14–15 year olds"), and across the three measurement points (T1, T2, and T3). The decline in sleep duration across adolescence is reflected by a decline from 10.00 hours and 9.82 hours among the 10–11 year olds at T1 in Switzerland and Norway, respectively, while the 14–15 year olds slept 8.36 hours and 8.01 hours at T3 in Switzerland and Norway. Inspection of effect sizes of the decline in sleep

Table 1 Description of sleep duration and subjective psychological well-being, separated by: CH and N; age groups (I, 10–11 year olds; II, 12–13 year olds; III, 14–15 year olds); and the three measurement time points (T1, T2, and T3)

Age	Country	T1		T2		T3		Between T1 and T2		Between T2 and T3		Over T1 and T3	
		M (min)	SD	M (min)	SD	M (min)	SD	*t (df)*	*P/d*	*t (df)*	*P/d*	*t (df)*	*P/d*
Sleep duration													
I	CH	600	38	591	45	574	39	2.82 (211)	0.005/0.22	8.81 (248)	0.000/0.41	8.66 (201)	0.000/0.68
	N	589	45	583	44	571	37	3.05 (281)	0.003/0.13	6.37 (283)	0.000/0.31	8.20 (284)	0.000/0.45
II	CH	563	43	551	45	537	65	4.96 (360)	0.000/0.25	8.36 (440)	0.000/0.25	6.41 (370)	0.000/0.45
	N	550	48	541	44	522	51	4.58 (368)	0.000/0.19	8.70 (321)	0.000/0.39	12.01 (331)	0.000/0.56
III	CH	518	43	516	42	502	42	3.83 (364)	0.001/0.04	7.82 (375)	0.000/0.35	9.47 (359)	0.000/0.38
	N	502	51	497	50	481	52	2.51 (191)	0.013/0.10	5.01 (171)	0.000/0.33	5.23 (175)	0.000/0.42
		F(2; 2,178)=534.64; *P*<0.001		*F*(2; 2,072)=439.69; *P*<0.001		*F*(2; 2,024)=347.36; *P*<0.001							
Subjective psychological well-being													
I	CH	3.40	0.44	3.35	0.46	3.34	0.45	1.22 (212)	0.23/0.11	0.02 (256)	0.99/0.03	2.08 (215)	0.04/0.15
	N	3.44	0.43	3.35	0.47	3.27	0.50	3.22 (295)	0.00/0.20	3.78 (296)	0.00/0.17	6.21 (296)	0.00/0.36
II	CH	3.31	0.49	3.28	0.48	3.24	0.52	1.22 (363)	0.22/0.06	2.02 (457)	0.04/0.07	2.60 (378)	0.01/0.13
	N	3.29	0.48	3.20	0.51	3.09	0.52	4.64 (383)	0.00/0.18	5.60 (335)	0.00/0.20	8.19 (342)	0.00/0.39
III	CH	3.23	0.48	3.25	0.53	3.22	0.56	1.05 (371)	0.30/0.05	1.14 (386)	0.26/0.05	0.16 (366)	0.87/0.01
	N	3.19	0.48	3.12	0.54	3.06	0.54	1.49 (193)	0.14/0.13	0.57 (173)	0.57/0.11	2.50 (175)	0.01/0.25
		F(2; 2,198)=32.47; *P*<0.001		*F*(2; 2,103)=13.73; *P*<0.001		*F*(2; 2,066)=12.43; *P*<0.001							

Notes: Cohen's *d*=0.2–0.49, little effect; *d*=0.5–0.79, middle effect; *d*>0.8, large effect. Subjective psychological well-being was measured with the Bern well-being questionnaire for adolescents (BFW/J)-subscales: "Positive attitude towards life" and "Joy in life". Rating scales with higher mean values reflect greater psychological well-being.

Abbreviations: M, mean; SD, standard deviation; CH, Switzerland; N, Norway; T1, baseline in May; T2, November (6 months after T1); T3, (12 months after T1, again in May); I, mean age, 11.2 years; II, mean age, 13.0 years; III, mean age, 14.9 years; min, minutes.

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duration in both countries and all age groups indicated a considerably stronger decrease (ie, double the size or more) in the period from November–May than in the period from May–November (with the exception of the 12–13 year olds in Switzerland).

SPW also decreased with age in cross-sectional (F[2; 1,652]=18.87; $P<0.001$) and longitudinal analyses (F[2; 1,652]=39.44; $P<0.001$). SPW was lower in Norway than in Switzerland (F[1; 1,652]=10.93; $P<0.001$). Moreover, the age-group X measurement time interaction was significant (F[2; 1,652]=3.90; P=0.02; indicating a stronger decline among the 12–13 year olds than in the younger and older age groups), as was the country X measurement time interaction (F[2; 1,651]=8.47; $P<0.001$; indicating a stronger decline among Norwegian adolescents) while the country X age-group interaction and the three-way interaction were not significant ($P>0.10$).

Analysis of relationship between sleep duration and SPW

Table 2 gives the zero-order correlations between sleep duration and SPW in the three age groups. Concurrent correlations between sleep duration and SPW were significantly positive indicating higher levels of SPW among adolescents with longer sleep duration with the exception of concurrent correlations among the 10–11 year olds at T1 and among the 14–15 year olds at T3.

The longitudinal path analysis is displayed in Figure 1. The paths could be set equal across the three age groups (indicating similarity of the path coefficients in the three age groups) with the exception of the path from sleep duration at T2 on sleep duration at T3, which could only be set equal between the younger two age groups (fit indices for the model allowing this path to vary between the oldest age group and the two younger groups: χ^2[23]=28.01; P=0.22, root mean square error of approximation =0.007; fit indices for comparison with the model which additionally sets this path equal across all age groups: χ^2[1]=23.35; $P<0.001$). Generally, the stabilities of sleep duration and SPW from T1 to T2 to T3 were high to very high. Among the crossed lagged paths (the paths between the constructs of sleep duration and SPW across time points), only the path from sleep duration at T1 to SPW at T2 was significant indicating a positive relation between sleep duration at T1 and SPW at T2. This path was of equal strength in the three age groups; however, it represents a quite small effect size.

Discussion

Regarding the relationship between sleep duration and SPW, our findings echo evidence from numerous studies that have confirmed an association between adolescents' sleep duration and subjective psychological well-being.[19,35,49–52] Our findings indicate that sleep duration is a longitudinal predictor of SPW. The findings show that affect regulation is compromised by short sleep.[24] However, the size of the effect was weak when SPW at baseline was controlled. Moreover, the effect was not consistent across all measurement time points.

By contrast, our findings do not indicate that SPW is a longitudinal predictor of sleep duration. The pattern of results extends upon previous findings in showing that the relationship between sleep duration and SPW across one year is very similar in the three age groups of very early adolescents (10–11 year olds), late early adolescents (12–13 year olds), and early middle adolescents (14–15 year olds).

Table 2 Correlations between sleep duration and subjective psychological well-being, separated by the three age groups (I, 10–11 year olds; II, 12–13 year olds; III, 14–15 year olds) and three measurement time points (T1, T2, and T3)

SPW		Cronbach's alpha	Sleep duration		
			T1	T2	T3
I	T1	0.73	0.05	0.07	0.04
	T2	0.78	0.12**	0.11*	0.09*
	T3	0.82	0.11*	0.10*	0.10*
II	T1	0.78	0.14**	0.09*	0.10**
	T2	0.80	0.12**	0.14**	0.08*
	T3	0.82	0.12**	0.09**	0.12**
III	T1	0.79	0.20**	0.10*	0.10*
	T2	0.85	0.19**	0.13**	0.16**
	T3	0.84	0.12**	0.09*	0.06

Notes: *$P<0.05$. **$P<0.01$. Higher means reflect a more positive SPW.

Abbreviations: T1, baseline in May; T2, in November (6 months after T1); T3, May (12 months after T1); I, mean age, 11.2 years; II, mean age, 13.0 years; III, mean age, 14.9 years; SPW, subjective psychological well-being.

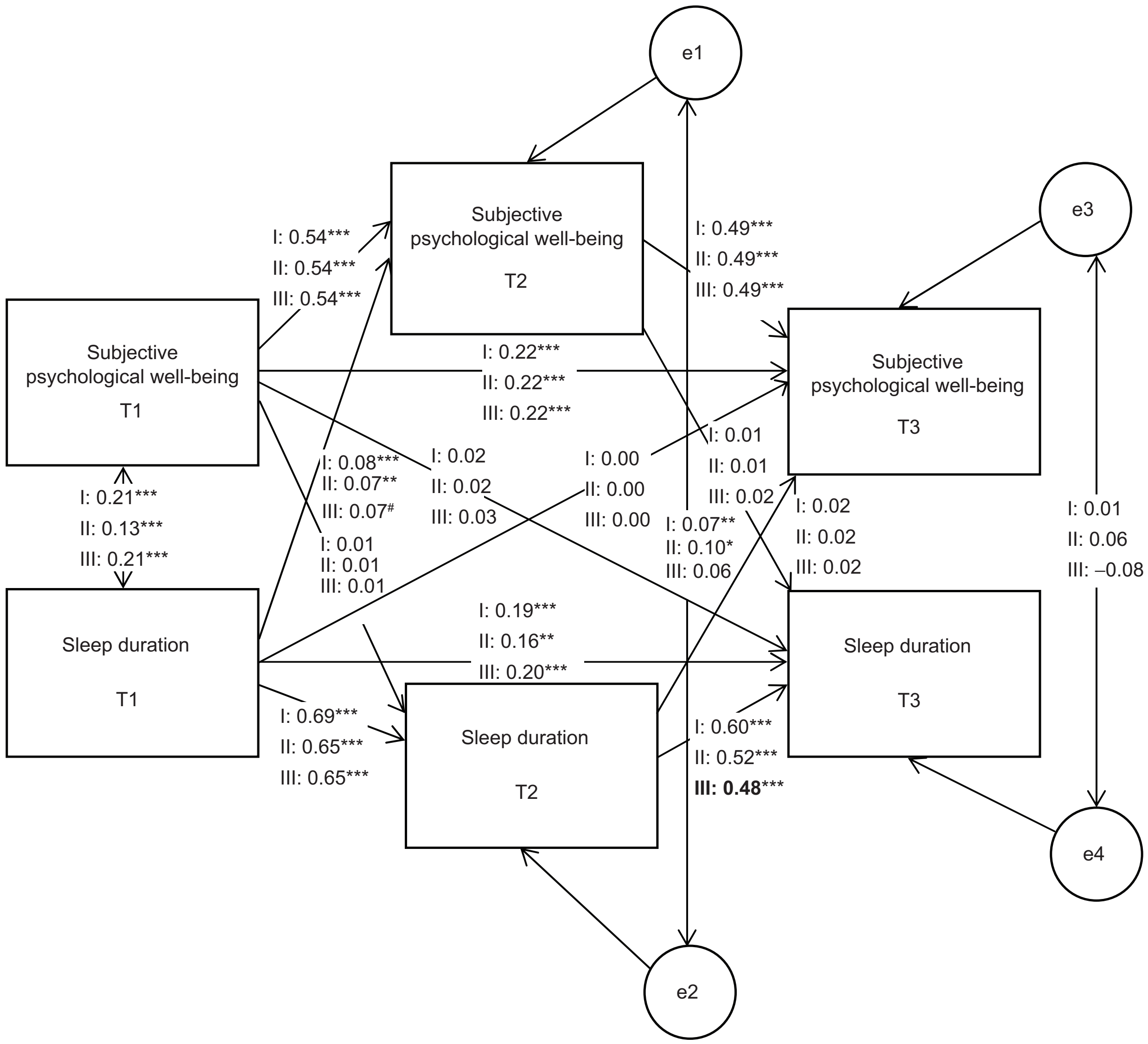

Figure 1 Longitudinal path model.

Notes: Standardized estimates are displayed. Bold letters indicate that this path is significantly different for the respective age group. Fit indices for the displayed model set all paths equal across age groups, except for the path between sleep duration at T2 and sleep duration at T3 for the oldest age group: χ^2=28.01; *df*=23; *P*=0.215; RMSEA =0.007. Model comparison of the displayed model with the model setting all paths equal across age groups: χ^2=23.35; *df*=1: *P*<0.001. #*P*=0.08; **P*<0.05; ***P*<0.01; ****P*<0.001.

Abbreviations: RMSEA, root mean square error of approximation; I, 10–11 year olds; II, 12–13 year olds; III, 14–15 year olds; e, error term.

Regarding changes in sleep duration and SPW across adolescence our findings are consistent with the existing literature by showing that adolescents' sleep duration decreases with age.[43,53] Interestingly, the reduction in sleep duration was smaller between May (a month with already relatively long day length in the northern hemisphere) and November (a month with relatively short day length in the northern hemisphere) than between November and the following May. This difference might reflect a stronger need for sleep in November than in May possibly due to shorter day length. Sleep duration is associated with seasonal changes in day length;[54–59] however, we did not find stronger seasonality of sleep duration in Norway than in Switzerland as one might have expected due to the more dramatic seasonal differences in day length in northern countries. While subjective psychological well-being decreased more from May–November than from November–May, this pattern was less pronounced and also inconsistent across subgroups.

Taken together, our findings add to the knowledge that the adolescents' sleep duration plays an important role for their subjective psychological well-being and may inform school counselors on the importance of adequate sleep duration for the adolescents' well-being. We note that, while the 10–13 year old adolescents on average still had the recommended sleep duration of 9 hours on weekday nights,[40,60] sleep duration was on average shorter for the 14–15 year olds although they still require the same amount of sleep as their younger peers.[40] We believe that both adolescents' and parents' education in sleep hygiene should be promoted, especially for older adolescents, because of their rapid changes in physiology and behavior,[61] including physical maturation, psychological factors, social factors (eg, parental monitoring decreases from younger adolescence to young adulthood, involvement in peer groups increase with a consequent increase in leisure activities), issues related to vocational development, and extracurricular issues. There is also evidence that favourable parental style as well as parental monitoring of adolescents' bedtimes and stricter household rules with regard to screen time were related to longer sleep and/or better sleep quality,[62,63] which may in turn play a role for adolescent's psychological well-being.[24,63–65]

Limitations

The strength of this study is the large sample size that allowed to study three different age groups separately, and its longitudinal design. There are also limitations that preclude overgeneralization of the findings. First, objective measurements (eg, actigraphy) would add to the study, allowing comparisons with subjective measurements. Second, we did not include subjective sleep quality to our analyses. Sleep duration is not necessarily associated with subjective sleep quality, and sleep quality and psychological functioning are associated.[66] In a related vein, we did not assess other possibly important sleep variables such as sleep debt or circadian preference that would have allowed a more comprehensive picture of adolescents' sleep habits and circadian rhythms. Third, SPW could have been defined and measured differently. More specifically, future research might include additional dimensions of SPW, such as optimism,[67] satisfaction with life,[68] and mental toughness.[69] Fourth, as no measure of depressive disorder was assessed, it was not possible to test whether the associations also hold if participants with clinically relevant depression were excluded. Finally, applying an intervention design to improve sleep would allow to investigate the causal relationship between sleep duration and psychological functioning.

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Disclosure

The authors report no conflicts of interest in this work.

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Basel, den 1. Juli 2015

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Selbständigkeitserklärung

Ich erkläre hiermit, dass ich die vorliegende Arbeit mit dem Titel „The role of sleep in the psychological functioning of adolescents“ ohne die Hilfe Dritter und ohne Benutzung anderer als der angegebenen Hilfsmittel selbstständig verfasst habe. Zu Hilfe genommene Quellen sind als solche gekennzeichnet. Die veröffentlichten eingereichten Manuskripte wurden in Zusammenarbeit mit den Koautoren erstellt und von keinem der Beteiligten an anderer Stelle publiziert, zur Publikation eingereicht, oder einer anderen Prüfungsbehörde als Qualifikationsarbeit vorgelegt. Es handelt sich dabei um folgende Manuskripte:

- Kalak, N., Gerber, M., Kirov, R., Mikoteit, T., Pühse, U., Holsboer-Trachsler, E., & Brand, S. (2012). The relation of objective sleep patterns, depressive symptoms, and sleep disturbances in adolescent children and their parents: A sleep-EEG study with 47 families. *Journal of Psychiatric Research, 46,* 1374-1382. (IF 2012: 4.66)

- Kalak, N., Gerber, M., Kirov, R., Mikoteit, T., Yordanova, J., Pühse, U., Holsboer-Trachsler, E., & Brand, S. (2012). Daily morning running for 3 weeks improved sleep and psychological functioning in healthy adolescents compared with controls. *Journal of Adolescent Health, 51*, 615-622. (IF 2012: 3.33)

- Kalak, N., Lemola, S., Brand, S., Holsboer-Trachsler, E., & Grob, A. (2014). Sleep duration and subjective psychological well-being in adolescence: a longitudinal study in Switzerland and Norway. *Neuropsychiatric Disease and Treatment, 10,* 1199-1207. (IF 2014: 1.81)

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