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Sleep trajectories from early adolescence to emerging adulthood: Evidence from a nine-year population-based study

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ABSTRACT

Introduction: Adolescence to emerging adulthood is a developmental period when individuals experience substantial biological changes and social transitions. In East Asian societies, this period is also marked by high pressure around college entrance exams. However, little is known about how young people's sleep changes over time, or how it is impacted by social institutions in the cultural context. This study fills this gap in the literature by examining sleep trajectories from adolescence to emerging adulthood using a population-based, longitudinal sample from Taiwan.
Methods: Multilevel models were applied to longitudinal data from the Taiwan Youth Project (N = 1,489) to estimate sleep trajectories from age 14 to 22 for total time in bed, bedtime, and wake-up time by gender and by educational pathway, controlling for family background.
Results: Analysis revealed that Taiwanese youth sleep less as adolescents than as emerging adults. Gender differences exist in adolescents' sleep trajectories but narrow after age 18. Differences in weekday and weekend time in bed vary by gender and change as individuals emerge into adulthood. Finally, college attendees and high school only attendees display differences in sleep that begin in high school and continue through college.
Conclusions: The findings provide evidence of developmental changes in sleep from adolescence to emerging adulthood and demonstrate that sleep trajectories are gendered and socially patterned. The study is also one of the first to examine the sleep trajectories of East Asian youth and, as such, sheds light on the role of educational and cultural context as an influential factor.

Sleep is crucial for health and everyday functioning. Scientists agree that getting enough sleep helps keep individuals healthy by lowering the risk of many physical and mental health problems (Cappuccio et al., 2010; Itani et al., 2017; Knutson et al., 2009). Even during adolescence and young adulthood when most people are relatively healthy, adequate sleep contributes significantly to subjective well-being, academic and job performance, and daily social functioning (Chen & Chen, 2019; Roberts et al., 2009; Steptoe et al., 2006). Given sleep's importance, it is imperative to understand how sleep is developmentally patterned during the period from adolescence to emerging adulthood and how individuals' sleep trajectories vary across societies.

1. Background

Extant evidence of sleep patterns during adolescence and emerging adulthood is sparse. Many studies focus on adolescence only,

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documenting a decline in sleep duration during this period (Leger et al., 2012; Lin et al., 2018; Olds et al., 2010; Patte et al., 2018; Williams et al., 2013). Only a few population-based, longitudinal studies have extended the investigation of sleep into emerging adulthood; the focus of these is on Western countries and the results are mixed. Machado et al. (2020) analyzed a sample of over 3,000 youth at 11, 18, and 22 years old and found a continuous pattern over time of increasingly later bedtimes and decreasing reported sleep duration, for both males and females. Similarly, Park et al. (2019) traced a sample of youth in Los Angeles over six years using wrist actigraphy to measure sleep; applying a multilevel growth model they found that sleep duration steadily declined from adolescence to emerging adulthood. Keyes et al. (2015) applied an age-period-cohort model to U.S. data and found that the likelihood of short sleep duration, i.e., less than 7 h of nighttime sleep, increases first throughout adolescence but declines after age 18. Hysing et al. (2020) linked two population-based studies from Norway found a similar pattern, as did Maslowsky and Ozer (2014) who used data from the U.S. National Longitudinal Study of Adolescent Health. However, Doane et al. (2015) differ: their survey of 82 U.S. students found sleep duration increases from the last year of high school through college.

Aside from the mixed findings, the prior studies have several limitations that limit understanding of how sleep is developmentally patterned. First, only a few prior studies consider sleep trajectories on both weekdays and weekends, a consequential limitation because adolescents and young adults spend their time quite differently on weekdays and weekends (Gracia et al., 2020; Laberge et al., 2001; Leger et al., 2012; Lin et al., 2018). Second, prior studies lack information on sleep trajectories in non-Western societies, which if included, would provide valuable insight on how education systems and cultures socially pattern adolescents' sleep (Carissimi et al., 2016; Roeser & Eccles, 1998). Finally, many of these studies do not provide a clear conceptual framework for how sleep trajectories may vary across societies and cultures. The present study fills these gaps in the literature by carefully investigating sleep trajectories on weekdays and weekends from adolescence to emerging adulthood, using nine years of population-based, longitudinal data from Taiwan.

Developmental perspective on sleep trajectories by educational pathways. The period from early adolescence to emerging adulthood is a crucial developmental period for sleep because it is characterized by key biological and social developments (Arnett, 2000; Steinberg, 2001). Physiological changes and changing social roles may both contribute to shifts in sleep during this period, but not necessarily in the same direction. Most significantly, the onset of puberty leads adolescents to stay awake later at night and delay bedtime (Crowley et al., 2007). But, since the biological need for sleep during this period does not decrease (Carskadon, 2002), one would expect that total sleep duration is relatively stable. However, most extant research finds changes in measured and reported sleep duration from adolescence to emerging adulthood (e.g., Keyes et al., 2015; Leger et al., 2012; Lin et al., 2018; Machado et al., 2020; Olds et al., 2010; Park et al., 2019; Patte et al., 2018; Williams et al., 2013). These findings imply that time demands and expectations from engagement in social institutions during adolescence and emerging adulthood may play a key role in shaping sleep trajectories.

Between adolescence and emerging adulthood, multiple institutions and settings create different opportunities and constraints for sleep—together these constitute the developmental context for sleep. One of the most studied developmental contexts for adolescents' sleep is family background. Voluminous research on sleep problems has identified parental education, marital status, and residential location as influential predictors of adolescents' sleep outcomes (Marco et al., 2012; Patte et al., 2018; Troxel et al., 2014); a finding that is confirmed by prior studies of sleep trajectories. For example, Keyes et al. (2015) found adolescents with higher parental education sleep longer and are less likely to have inadequate sleep, and other studies have found that adolescents and young adults in rural areas sleep longer (Keyes et al., 2015; Patte et al., 2017). These findings suggest the need to control for family background factors in statistical analysis. Aside from family, school system is a particularly crucial social institution that creates different opportunities and constraints for sleep (Roeser & Eccles, 1998), and which varies considerably across societies. Although prior studies have documented a strong link between school start time and adolescent sleep duration (Carissimi et al., 2016; Hansen et al., 2005; Owens et al., 2010), the simple focus on school start time may miss the bigger picture of how the education system influences sleep. There are two reasons to suspect the education system, defined as the governance structure and societal culture around education (Eccles & Roeser, 2011), is important. First, adolescents are active agents in their development (Roeser & Eccles, 1998), so the influence of education system on sleep is mediated by their subjective perceptions and actions in response to the system. Second, the education system may influence sleep in a more subtle but profound way, as prior studies have suggested that schools can affect behaviors through internalized culture and norms (Shaw, 1996; Zhao et al., 2010). In most modern societies, educational institutions not only set a rigid start time on school days but also foster a culture to motivate students and define the behavioral traits of good students (Zhao et al., 2010). To succeed in school, adolescents may organize their daily lives, including their sleep schedules, to align with such institutionalized culture and norms. Accordingly, adolescents who are successful in school and college bound may have diverging sleep trajectories from those who are not. In this way, sleep trajectories in adolescents may manifest the joint influence of the educational system and students' own agentic action.

Educational pathways and adolescent sleep trajectories in Taiwan. Taiwan offers a unique context to investigate sleep trajectories in adolescence and young adulthood and how they vary by educational pathway. After decades of rapid economic and social development, Taiwan's GDP per capita and life expectancy is now like that of Western countries (Infoplease, 2021; Taiwan.gov.tw, n.d.). However, like other East Asian countries, Taiwan's secondary schools and higher education institutions have intense competition for entrance and the culture prioritizes success in this domain over other aspects of adolescents' development (Chen & Avi Astor, 2009; Chou, 2015; Huang et al., 2021; Marginson, 2011). This system creates a considerably different developmental context for East Asian adolescents (Chen & Avi Astor, 2009; Chou, 2015; Zhao et al., 2010), with great implications for their sleep trajectories.

First, young Taiwanese who aspire to attend college, especially the prestigious public colleges, must first pass highly structured and competitive college entrance exams (Chou, 2015). As in other East Asian countries with a similar education system, to gain entry to college Taiwanese students must master and memorize material on multiple subjects from throughout high school, which requires studying a tremendous number of hours (Lee & Larson, 2000). The closer to the college entrance exam (i.e., the higher the grade), the

larger the pressure. This pressure may push adolescents toward a later bedtime and sacrificing hours of nighttime sleep (Wang et al., 2016a, 2016b). Furthermore, the system also fosters an "intensive studying" culture that is valued by adolescents and their parents and teachers (Stankov, 2010). Thus, the surrounding social relationships create a milieu that encourages adolescents to sacrifice sleep, on both weekdays and weekends (Wang, Jiang, et al., 2016). As such, we would expect that Taiwanese adolescents' bedtimes get gradually later from 10th grade to 12th grade, especially for those who ultimately enter college.

Second, in Taiwan and other East Asian societies, a successful educational pathway also carries the symbolic meaning of being a good student (Shaw, 1996). Being late for school is considered "deviant" by teachers and may negatively affect students' grades (Shaw, 1996), and some teachers and schools may even encourage students to arrive early for extra studying (Chen & Avi Astor, 2009). As such, we expect that young people who attend college may have earlier wake-up times in high school (adolescence) than their counterparts who do not attend college, with the largest differences on weekends when the ability to relax differs most.

In sum, we expect that sleep trajectories among Taiwanese adolescents who attend college will show a later bedtime, earlier wake-up time, and less total time in bed than adolescents who do not enter college—beginning in high school when they are preparing for college entrance exams. Once out of high school, social activities and internet use may encourage college students to stay awake later (Aiken et al., 2003; Hershner & Chervin, 2014), which may lead to different sleep schedules than their non-student peers.

Gender variation in sleep trajectories. Gender has been critical for understanding human development in early adolescence through emerging adulthood (Galambos, 2004). Some of the behavioral, attitudinal, and psychological differences that emerge between boys and girls are likely to also produce gender differences in sleep trajectories. First, research in education shows that girls spend more time studying than boys during high school and perform better academically (Ferrar et al., 2012; Houtte, 2004; Hu & Mu, 2020). Second, adolescent girls display fewer deviant behaviors, are more likely to follow institutionalized rules, and rate higher in self-regulation than boys (Hu & Mu, 2020; Kobayashi et al., 2008; Liu & Kaplan, 1999). These differences in behavior and psychology likely affect sleep timing. Specifically, we expect that girls will have a later bedtime, earlier wake-up time, and fewer hours of total sleep duration during high school (adolescence), irrespective of educational pathway.

1.1. Aims of the present study

This study will evaluate the hypotheses on differential sleep trajectories by examining educational pathways and gender using a unique, nine-year, population-based longitudinal sample from Taiwan. The results will enhance the scientific understanding of sleep in four ways. First, by tracing individuals' sleep from age 14 to 22 with data on nearly every year, the analysis will more precisely model the trajectories of sleep from adolescence to emerging adulthood than has been possible before. Second, by including data on weekday and weekend sleep separately, the analysis will yield new information on the trajectory of "social jetlag" (Wittmann et al., 2006) as individuals age. Third, by considering sleep trajectories by educational pathway and by gender, the analysis will bring a broader social view to the study of sleep than has been present before. Finally, by focusing on Taiwan, this study will provide some of the first information about sleep trajectories from adolescence to emerging adulthood in East Asia.

2. Methods

2.1. Data

The Taiwan Youth Project (TYP) is a population-based, longitudinal survey of Taiwanese youth that traces the development of two cohorts from Northern Taiwan started in 2000, a J1 cohort of 13-year-olds and a J3 cohort of 15-year-olds. The TYP was conducted by the Institute of Sociology at Taiwan's Academia Sinica and the survey was approved by its Institutional Review Board. Consent was obtained from each respondent and one of their parents (Taiwan Youth Project, n.d.). TYP data is restricted-use and is available for researchers worldwide through an application. The current study relies on data from the J1 cohort because that cohort has sleep information spanning the longest time. The TYP employed a combination of multistage; stratified; and school-based, cluster random sampling to draw respondents from metropolitan areas (i.e., Taipei City, New Taipei City) and rural areas (i.e., Yilan County). After wave one, respondents were surveyed yearly until they were 22 years old, with the exception of respondents' year 21 when no survey was conducted. More detailed information on the sampling design and data collection process can be found elsewhere (Yi, 2012).

The J1 cohort started with approximately 2,600 respondents in 2000. At wave nine in 2009, there were 1,875 respondents remaining in the study, a retention rate of 72%. Because not all waves included questions about sleep (i.e., the baseline wave and wave seven omitted these questions), this study analyzed data collected from waves 2–6 and waves 8–9. We further excluded respondents that had missing sleep information in at least one wave of the survey, which left a sample of 1,577 respondents. Next, we excluded respondents that had missing information on covariates, which was 6% of respondents. The final analytic sample includes 1,489 respondents with non-missing information on the sleep variables and the covariates.

2.2. Measures

Sleep measures. In each wave, respondents were asked to report their usual bedtime and wake-up times. Questions were: "*What time do you usually go to bed on weekdays?*", "*What time do you usually get up on weekdays?*", "*What time do you usually go to bed on weekends?*", and "*What time do you usually get up on weekends?*" Using this information, we constructed three sleep measures. First, respondents' bedtime and wake-up times were specified in 24-h military time. Second, respondents' time in bed (i.e., reported sleep duration) was calculated as the time elapsed between bedtime and wake-up time, measured in hours. For these two measures, we calculated

weekdays and weekends separately. The third measure captures the differences between bedtime, wake-up time, and time in bed on weekdays versus weekends, measured in hours.

Classification of educational pathway by gender. All respondents reported their school attendance status on each wave of the survey. All respondents were in high school before age 18, but only some respondents attended college. Thus, we classified respondents into two educational pathways: college attendee and high school only attendee. We further distinguished educational pathway by gender to create four groups of respondents for the statistical analysis: (1) male college attendee (38%), (2) female college attendee (40%), (3) male high school only attendee (12%), and (4) female high school only attendee (10%). In the statistical analysis, male college attendee was treated as the reference group.

Covariates. The statistical analysis also adjusted for key covariates. In the baseline wave of the TYP, respondents were asked about their residential location, parental education, and parental marital status. Residential location was coded as metropolitan area versus rural area; parental marital status was coded as two-parent family versus single-parent family; and parents' highest level of education was coded as less than high school, high school, some college, or bachelor's/advanced degree. Finally, the survey asked respondents to report the timing of pubertal development, as occurring on/before age 13 or on/after age 14. A binary variable was created from the answers.

2.3. Statistical analysis

To begin, we produced descriptive statistics for each sleep measure for each year of age to show trends in bedtime, wake-up time, and time in bed on weekdays and weekends, as well as weekday-weekend differences in each sleep measure. Next, we used the 2-level multilevel model to estimate sleep trajectories from adolescence to emerging adulthood, controlling for all covariates. The model specification was as follows:

$$Leve\ 1:\ Sleep_{ij} = \beta_{0i} + \beta_{1i}Age_{ij} + \beta_{2i}X_{2ij} + \varepsilon_{ij}$$

$$Level\ 2:\ \beta_{0i} = \gamma_{00} + \gamma_{11}EdPathways_i + \sum \gamma_{0q}z_{0qi} + \mu_{0i}$$

$$Level\ 2:\ \beta_{1i} = \gamma_{10} + \gamma_{11}EdPathways_i + \mu_{1i}$$

The level 1 equation modelled sleep measures as a function of age (i.e., a series of dummy indicators) and a time-varying covariate for parental marital status. The Level 2 equations modelled intercept and age coefficient as a function of gender specific educational pathways and person-specific, time-invariant covariates (i.e., residential location, parental education, and pubertal development).

The analysis did not assume a linear change in sleep trajectory and instead used a more flexible approach to model time trends with a series of dummy variables that capture the effect of each developmental stage. This approach can capture the rapid changes in sleep trajectories around key life events, such as entering college. Our inclusion of covariates allowed us to assess how sleep trajectories were influenced by respondents' individual and familial factors. All data analyses were conducted using Stata 16.0. This study solely relies on secondary data analysis and is exempt from ethics approval.

Table 1
Baseline (Age 14) descriptive characteristics of the respondents in Taiwan Youth Study.

	Percentage
Gender	
Male	49%
Female	51%
College attendance	
Yes	79%
No	21%
Residence	
Metropolitan area	73%
Rural area	27%
Parents' marital status	
Married	89%
Single	11%
Highest level of parent's education	
Less than high school	36%
High school	43%
Some college	7%
BA/Advanced	14%
Pubertal development	
During or before age 13	94%
During or after age 14	6%

3. Results

3.1. Descriptive results

Table 1 presents the descriptive characteristics for the analytical sample at baseline. Over 50 percent of respondents were female, and most respondents lived in a metropolitan area (79 percent). Seventy-nine percent of the sample attended college and 21 percent attended high school only. Around 90 percent of respondents lived in two-parent households. Less than half of respondents' parents had a high-school degree (43 percent), 7 percent had some college, and 14 percent had a bachelor's degree or higher. Almost all respondents began puberty at or before age 13 (94 percent).

Table 2 and Table 3 show descriptive statistics for time in bed, bedtime, and wake-up time at each year of age for weekdays and weekends separately. Results in Table 2 show that weekday time in bed steadily decreases from age 14 to age 18. At age 14, total time in bed averages 7.5 h and by age 18 drops to 6.7 h. Results also show that weekday time in bed is lowest at age 18 and then begins increasing. Interestingly, the decrease in time in bed from age 14 to 18 was driven by a later bedtime, whereas the increase in time in bed after age 18 was driven by a later wake-up time.

For weekends (Table 3), we did not observe the same pattern for time in bed. As respondents aged, weekend bedtime and wake-up time both got later, making respondents' weekend time in bed relatively stable over time. In contrast, weekday time in bed declined during adolescence (from 13 to 18 years of age) and increased during emerging adulthood (after 18 years of age).

Statistics from Tables 2 and 3 also show some notable differences by group. Female college attendees had the latest bedtime and earliest wake-up time before age 18 on weekdays. As such, they are the group with the shortest weekday time in bed. However bedtimes were similar across groups on weekends, but male college attendees had the earliest wake-up time before age 18, making them the group with the shortest weekend time in bed.

3.2. Regression results

Table 4 presents longitudinal results from the multilevel regressions that model sleep trajectories over time by gender and educational pathway. All regressions controlled for the full set of covariates, with weekdays, weekends, and weekday-weekend differences analyzed separately. We first discuss results of bedtime, followed by wake-up time, and time in bed.

Bedtime. Panel A show that female college attendees had later bedtimes than male college attendees on weekdays. This gender gap

Table 2
Weekday sleep duration, bedtime, and uptime from adolescence to emerging adulthood.

	Age 14	Age 15	Age 16	Age 17	Age 18	Age 20	Age 22
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Time in Bed (hours)							
Sample Mean	7.544 (1.033)	7.164 (1.188)	7.073 (0.947)	6.901 (0.951)	6.726 (1.157)	7.492 (1.355)	7.794 (1.342)
Male College Attendee	7.545 (1.030)	7.164 (1.188)	7.071 (0.947)	6.901 (0.952)	6.726 (1.157)	7.492 (1.355)	7.794 (1.342)
Female College Attendee	7.138 (0.997)	6.768 (1.287)	6.639 (1.092)	6.613 (1.065)	6.538 (1.164)	7.452 (1.469)	7.750 (1.461)
Male High School Only Attendee	7.859 (1.002)	7.692 (1.598)	7.644 (1.133)	7.501 (1.241)	7.816 (1.452)	8.330 (1.818)	7.824 (1.527)
Female High School Only Attendee	7.370 (1.531)	7.006 (1.066)	7.084 (1.234)	6.965 (1.368)	7.101 (1.518)	8.242 (1.774)	8.155 (1.848)
p value	<.001	<.001	<.001	<.001	<.001	<.001	<.05
Bedtime (24-h military time)							
Sample Mean	22.993 (1.034)	23.416 (1.301)	23.240 (1.015)	23.401 (1.002)	23.741 (1.072)	24.459 (1.329)	24.651 (1.386)
Male College Attendee	22.873 (1.003)	23.327 (1.198)	23.090 (0.964)	23.311 (0.910)	23.750 (1.045)	24.634 (1.165)	24.800 (1.318)
Female College Attendee	23.212 (0.979)	23.659 (1.285)	23.452 (1.004)	23.508 (0.974)	23.823 (0.968)	24.554 (1.272)	24.662 (1.261)
Male High School Only Attendee	22.551 (1.029)	22.823 (1.633)	22.903 (1.084)	23.115 () 1.107	23.344 (1.336)	23.580 (1.555)	24.096 (1.444)
Female High School Only Attendee	23.046 (1.147)	23.401 (1.090)	23.289 (0.990)	23.588 (1.261)	23.791 (1.174)	24.374 (1.494)	24.563 (1.896)
p value	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Wake-up Time (24-h military time)							
Sample Mean	6.389 (0.572)	6.459 (0.485)	6.181 (0.817)	6.256 (0.877)	6.545 (1.169)	8.103 (1.545)	8.463 (1.575)
Male College Attendee	6.416 (0.477)	6.492 (0.470)	6.155 (0.580)	6.231 (0.763)	6.476 (0.960)	8.126 (1.315)	8.593 (1.491)
Female College Attendee	6.350 (0.480)	6.427 (0.489)	6.081 (0.750)	6.121 (0.631)	6.362 (0.909)	8.006 (1.316)	8.412 (1.474)
Male High School Only Attendee	6.410 (0.463)	6.515 (0.485)	6.528 (1.240)	6.616 (1.112)	7.160 (1.719)	7.910 (2.194)	7.920 (1.651)
Female High School Only Attendee	6.417 (1.098)	6.407 (0.508)	6.352 (1.160)	6.591 (1.556)	6.893 (1.701)	8.616 (2.140)	8.717 (2.067)
p value	NS	<.05	<.001	<.001	<.001	<.001	<.001

Note. *p* value indicates the level of statistical significance from test that compares group means. NS denotes not statistically significant. Time in bed is measured in hours and bedtime and wake-up time are presented in 24-h military time.

Table 3
Weekend sleep duration, bedtime, and uptime from adolescence to emerging adulthood.

	Age 14	Age 15	Age 16	Age 17	Age 18	Age 20	Age 22
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Time in Bed (hours)							
Sample Mean	9.294 (1.642)	8.990 (1.771)	9.164 (1.843)	9.159 (1.709)	8.982 (1.858)	9.093 (1.609)	8.862 (1.569)
Male College Attendee	9.121 (1.580)	8.698 (1.571)	8.790 (1.674)	8.932 (1.627)	8.749 (1.825)	8.881 (1.584)	8.645 (1.326)
Female College Attendee	9.524 (1.461)	9.106 (1.769)	9.401 (1.903)	9.341 (1.612)	8.997 (1.753)	9.202 (1.543)	9.001 (1.576)
Male High School Only Attendee	8.926 (1.937)	9.121 (2.415)	9.102 (1.663)	9.041 (2.127)	9.069 (1.896)	9.117 (1.717)	8.692 (1.880)
Female High School Only Attendee	9.417 (2.034)	9.479 (1.488)	9.691 (2.126)	9.412 (1.877)	9.694 (2.161)	9.425 (1.752)	9.312 (1.921)
p value	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Bedtime (24-h military time)							
Sample Mean	23.973 (1.237)	24.183 (1.407)	23.903 (1.182)	24.138 (1.166)	24.270 (1.186)	25.168 (1.490)	25.301 (1.492)
Male College Attendee	23.877 (1.294)	24.182 (1.273)	23.887 (1.085)	24.113 (1.146)	24.225 (1.282)	25.328 (1.708)	25.480 (1.223)
Female College Attendee	24.022 (1.133)	24.180 (1.268)	23.900 (1.111)	24.132 (1.097)	24.247 (0.985)	25.241 (1.153)	25.255 (1.467)
Male High School Only Attendee	24.000 (1.371)	24.113 (2.225)	23.971 (1.368)	24.073 (1.315)	24.329 (1.538)	24.556 (1.575)	24.946 (1.798)
Female High School Only Attendee	24.108 (1.251)	24.278 (1.288)	23.901 (1.591)	24.331 (1.363)	24.468 (1.118)	24.936 (1.539)	25.142 (2.065)
p value	NS	NS	NS	NS	NS	<.001	<.001
Wake-up Time (24-h military time)							
Sample Mean	9.267 (1.668)	9.174 (1.723)	9.054 (1.897)	9.294 (1.822)	9.252 (1.993)	10.261 (1.826)	10.164 (1.759)
Male College Attendee	8.998 (1.589)	8.879 (1.590)	8.654 (1.738)	9.047 (1.666)	8.975 (1.958)	10.209 (1.720)	10.125 (1.626)
Female College Attendee	9.546 (1.501)	9.285 (1.685)	9.296 (1.989)	9.473 (1.724)	9.244 (1.816)	10.443 (1.733)	10.256 (1.754)
Male High School Only Attendee	8.926 (1.902)	9.233 (2.185)	9.065 (1.680)	9.088 (2.411)	9.398 (2.282)	9.673 (2.135)	9.638 (1.848)
Female High School Only Attendee	9.525 (2.065)	9.757 (1.594)	9.579 (2.025)	9.750 (2.009)	10.162 (2.209)	10.360 (2.072)	10.454 (2.085)
p value	<.001	<.001	<.001	<.001	<.001	<.001	<.001

Note. *p* value indicates the level of statistical significance from test that compares group means. NS denotes not statistically significant. Time in bed is measured in hours and bedtime and wake-up time are presented in 24-h military time.

in weekday bedtime was present in adolescence but narrowed after age 18. Female high school only also had later weekday bedtimes compared to male college attendees, with the gap narrowing after age 20. Males who attended high school only, however, had earlier bedtimes than male college attendees. The gap widened after age 20. On weekends (Panel B), differences in bedtime across groups were minimal and many interaction terms were not statistically significant.

Wake-up Time. Panel A shows that there was no difference in wake-up time at the baseline on weekdays. However, as adolescents grew older, males and females who attended high school only had later wake-up times than male college attendees (i.e., interaction terms were statistically significant). On weekends (Panel B), females (regardless of educational pathway) had later wake-up times than male college attendees. However, for female college attendees, the gap in weekend wake-up time narrowed after age 18.

Time in bed. Panel A shows that at baseline, female college attendees have a shorter weekday time in bed than male college attendees. Results also show that males' time in bed declines through adolescence (age 14–18) but not after age 18, which is different than the findings of some prior studies. Furthermore, Panel A also suggests a subtle change in time in bed between male and female college attendees. Because female college attendees spend less time in bed than male college attendees (i.e., the main effect), the significant and positive interaction terms between female college attendees and age suggest that, for college attendees, the gender gap in weekday time in bed that is present in adolescence narrows after age 18. In addition, female high school only attendees had a shorter weekday time in bed than male college attendees, whereas male high school only attendees had a longer weekday time in bed. Results indicate that regardless of gender, those who attend high school only have different weekday sleep trajectories than college attendees. High school only attendees showed a smaller decline in weekday time in bed during adolescence. However, after age 18, high school only attendees' weekday time in bed increased faster than college attendees' weekday time in bed. Panel B shows that, at baseline, female college attendees had a longer weekend time in bed than the reference group. In contrast to weekdays, this gap exists because female college attendees had later wake-up times than male college attendees. However, all the high school only attendees, regardless of gender, showed no difference in weekend time in bed compared to the reference group. In contrast to the trajectory of weekday time in bed (Panel A), weekend time in bed (Panel B) continues to increase for college attendees after 14 years of age. For high school only attendees, the trajectories of weekend time in bed appeared to fluctuate during this period.

Weekday-weekend differences. Lastly, Panel C shows the degree of "social jetlag" that respondents have, i.e., weekday-weekend differences in sleep measures. For both males and females, high school only attendees had less social jetlag than college attendees

Table 4
Longitudinal results in predicting sleep duration, bedtime, and wake-up time from adolescence to emerging adulthood.

	Panel A: Weekday			Panel B: Weekend			Panel C: Weekday-Weekend Differences		
	Time in Bed	Bedtime	Wake-up Time	Time in Bed	Bedtime	Wake-up Time	Time in Bed	Bedtime	Wake-up Time
	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)
Male College Attendee (Ref.)									
Female College Attendee	−0.397*** (0.072)	0.335*** (0.067)	−0.062 (0.062)	0.398*** (0.099)	0.116 (0.077)	0.514*** (0.104)	0.799*** (0.109)	−0.222** (0.072)	0.574*** (0.106)
Male High School Only Attendee	0.230* (0.110)	−0.241* (0.102)	−0.012 (0.095)	−0.260 (0.151)	0.129 (0.117)	−0.133 (0.159)	−0.492** (0.167)	0.368** (0.109)	−0.123 (0.162)
Female High School Only Attendee	−0.237* (0.113)	0.237* (0.104)	−0.001 (0.098)	0.247 (0.155)	0.227 (0.120)	0.473** (0.163)	0.483** (0.171)	−0.013 (0.112)	0.472*** (0.166)
Age (Ref: Age 14)									
Age 15	−0.380*** (0.066)	0.457*** (0.059)	0.078 (0.059)	−0.421*** (0.088)	0.304*** (0.066)	−0.116 (0.088)	−0.040 (0.101)	−0.155* (0.067)	−0.195* (0.095)
Age 16	−0.478*** (0.067)	0.217*** (0.060)	−0.260*** (0.060)	−0.336*** (0.090)	0.011 (0.067)	−0.346*** (0.090)	0.152 (0.104)	−0.215** (0.068)	−0.089 (0.097)
Age 17	−0.643*** (0.068)	0.442*** (0.061)	−0.181** (0.061)	−0.194* (0.091)	0.242*** (0.068)	0.048 (0.091)	0.454*** (0.104)	−0.208** (0.069)	0.228* (0.098)
Age 18	−0.829*** (0.070)	0.884*** (0.062)	0.059 (0.062)	−0.376*** (0.093)	0.361*** (0.069)	−0.013 (0.093)	0.454*** (0.107)	−0.529*** (0.071)	−0.074 (0.100)
Age 20	−0.050 (0.066)	1.760*** (0.058)	1.710*** (0.059)	−0.239** (0.088)	1.449*** (0.066)	1.210*** (0.088)	−0.190 (0.101)	−0.314*** (0.067)	−0.503*** (0.094)
Age 22	0.246*** (0.068)	1.926*** (0.060)	2.175*** (0.061)	−0.480*** (0.091)	1.599*** (0.068)	1.118*** (0.091)	−0.725*** (0.104)	−0.337*** (0.069)	−1.066*** (0.098)
Male College Attendee x Age									
Female College Attendee x Age 15	0.010 (0.092)	−0.012 (0.081)	−0.002 (0.082)	0.006 (0.122)	−0.152 (0.091)	−0.146 (0.123)	−0.009 (0.140)	−0.136 (0.093)	−0.142 (0.132)
Female College Attendee x Age 16	−0.018 (0.093)	0.022 (0.083)	−0.005 (0.083)	0.207 (0.125)	−0.132 (0.093)	0.096 (0.125)	0.202 (0.144)	−0.143 (0.095)	0.100 (0.134)
Female College Attendee x Age 17	0.122 (0.095)	−0.134 (0.084)	−0.037 (0.085)	0.024 (0.127)	−0.111 (0.095)	−0.084 (0.127)	−0.106 (0.145)	0.028 (0.096)	−0.055 (0.136)
Female College Attendee x Age 18	0.213* (0.097)	−0.262** (0.086)	−0.052 (0.087)	−0.149 (0.129)	−0.133 (0.096)	−0.284* (0.130)	−0.367* (0.148)	0.136 (0.098)	−0.230 (0.139)
Female College Attendee x Age 20	0.364*** (0.091)	−0.419*** (0.081)	−0.055 (0.082)	−0.082 (0.122)	−0.230* (0.091)	−0.312* (0.123)	−0.449** (0.140)	0.191* (0.093)	−0.255 (0.131)
Female College Attendee x Age 22	0.374*** (0.094)	−0.484*** (0.084)	−0.112 (0.084)	−0.029 (0.126)	−0.360*** (0.094)	−0.386** (0.126)	−0.407** (0.144)	0.131 (0.096)	−0.267* (0.135)
Male High School Only Attendee x Age 15	0.215 (0.140)	−0.186 (0.124)	0.028 (0.125)	0.621** (0.186)	−0.195 (0.139)	0.426* (0.187)	0.425* (0.214)	−0.005 (0.142)	0.419* (0.201)
Male High School Only Attendee x Age 16	0.288* (0.144)	0.119 (0.128)	0.390** (0.129)	0.496* (0.194)	−0.032 (0.145)	0.475* (0.194)	0.175 (0.223)	−0.127 (0.147)	0.083 (0.208)
Male High School Only Attendee x Age 17	0.277 (0.150)	0.128 (0.133)	0.386** (0.134)	0.273 (0.201)	−0.145 (0.150)	0.100 (0.201)	0.026 (0.230)	−0.258 (0.152)	−0.218 (0.216)

(*continued on next page*)

Table 4 (*continued*)

	Panel A: Weekday			Panel B: Weekend			Panel C: Weekday-Weekend Differences		
	Time in Bed	Bedtime	Wake-up Time	Time in Bed	Bedtime	Wake-up Time	Time in Bed	Bedtime	Wake-up Time
	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)
Male High School Only Attendee x Age 18	0.781*** (0.148)	−0.062 (0.131)	0.708*** (0.133)	0.528** (0.198)	0.025 (0.147)	0.555** (0.198)	−0.254 (0.226)	0.084 (0.150)	−0.164 (0.212)
Male High School Only Attendee x Age 20	0.521*** (0.139)	−0.731*** (0.123)	−0.211 (0.125)	0.430* (0.186)	−0.892*** (0.139)	−0.462* (0.186)	−0.090 (0.213)	−0.159 (0.141)	−0.250 (0.200)
Male High School Only Attendee x Age 22	−0.307* (0.148)	−0.349** (0.131)	−0.662*** (0.133)	0.236 (0.198)	−0.608*** (0.148)	−0.375 (0.199)	0.543* (0.226)	−0.255 (0.150)	0.295 (0.213)
Female High School Only Attendee x Age 15	0.015 (0.143)	−0.101 (0.127)	−0.087 (0.129)	0.487* (0.191)	−0.132 (0.143)	0.356 (0.192)	0.470* (0.219)	−0.029 (0.145)	0.442* (0.206)
Female High School Only Attendee x Age 16	0.183 (0.149)	0.061 (0.133)	0.220 (0.133)	0.590** (0.201)	−0.176 (0.149)	0.432* (0.201)	0.382 (0.232)	−0.235 (0.152)	0.174 (0.215)
Female High School Only Attendee x Age 17	0.277 (0.152)	0.122 (0.135)	0.400** (0.136)	0.246 (0.204)	0.030 (0.152)	0.290 (0.205)	−0.069 (0.234)	−0.098 (0.155)	−0.149 (0.219)
Female High School Only Attendee x Age 18	0.535*** (0.151)	−0.114 (0.134)	0.415** (0.136)	0.664** (0.202)	0.036 (0.151)	0.697** (0.203)	0.123 (0.232)	0.153 (0.153)	0.278 (0.217)
Female High School Only Attendee x Age 20	0.921*** (0.143)	−0.432** (0.127)	0.489*** (0.128)	0.250 (0.191)	−0.619*** (0.143)	−0.368 (0.192)	−0.663** (0.219)	−0.187 (0.145)	−0.850*** (0.206)
Female High School Only Attendee x Age 22	0.501** (0.151)	−0.381** (0.134)	0.116 (0.135)	0.342 (0.202)	−0.555*** (0.150)	−0.214 (0.202)	−0.157 (0.231)	−0.162 (0.153)	−0.316 (0.217)

Note. ***$p < .001$, **$p < .01$, *$p < .05$. Standard error is presented in parentheses. Time in bed is measured in hours and bedtime and wake-up time are presented in 24-h military time. All models control for the full set of covariates.

at every time point. Interestingly, trajectories of social jetlag did not differ substantially across the four groups. Social jetlag was largest at ages 17 to 18 and declined to the lowest level in young adulthood.

Graphical presentation of the results. To better illustrate the differential trajectories of sleep from early adolescence to emerging adulthood, Fig. 1 presents the predicted values of each sleep measure by gender and college attendance. The first row shows graphs for weekdays, the second row shows graphs for weekends, and the last row shows graphs for degree of social jetlag, i.e., weekday-weekend differences. Several interesting trends are worth mentioning. First, college attendees consistently had shorter time in bed than those who attended high school only. Second, for college attendees, the gender gap that exists in weekday time in bed and bedtime narrows over time: By young adulthood (age 22), there appears to be no difference in weekday time in bed or bedtime between male and female college attendees. However, a gender gap in weekend time in bed and wake-up time remains throughout the nine-year survey period. Finally, regardless of college attendance, female adolescents had larger social jetlag than male adolescents; by emerging adulthood, this gender gap narrows.

This study also conducted sensitivity analyses to check the robustness of the results. We compared regression results using multiple imputation instead of using listwise deletion (i.e., the main analysis); the results were very similar to the results in the main analysis.

4. Discussion

From adolescence to emerging adulthood, individuals experience substantial biological changes and social transitions, but little is understood about how sleep patterns change for individuals in this period. This study extends prior studies to demonstrate how sleep trajectories during the transition from adolescence to adulthood are developmentally patterned by gender and sensitive to a major life event, such as college attendance.

Importantly, the study finds that Taiwanese adolescents report sleeping less than Western adolescents typically report, with later bedtimes and earlier wake-up times (Laberge et al., 2001; Leger et al., 2012; Lin et al., 2018; Machado et al., 2020; Maslowsky & Ozer, 2014; Olds et al., 2010; Park et al., 2019; Patte et al., 2018; Williams et al., 2013). The results demonstrate that Taiwanese youth sleep far less than the recommended 8–10 h on weekdays during high school (as adolescents) but do sleep the recommended 7–9 h per night as young adults (Hirshkowitz et al., 2015). One potential explanation is that the Taiwanese educational system and culture emphasizes academic success more strongly than in Western societies (Stankov, 2010; Wang, Jiang, et al., 2016). Developmental studies of Western adolescents generally find that inadequate sleep is associated with negative learning and emotional consequences (Dewald et al., 2010; Gillen-O'Neel et al., 2013; Kortesoja et al., 2020). However, studies from East Asian societies are more mixed. Studying

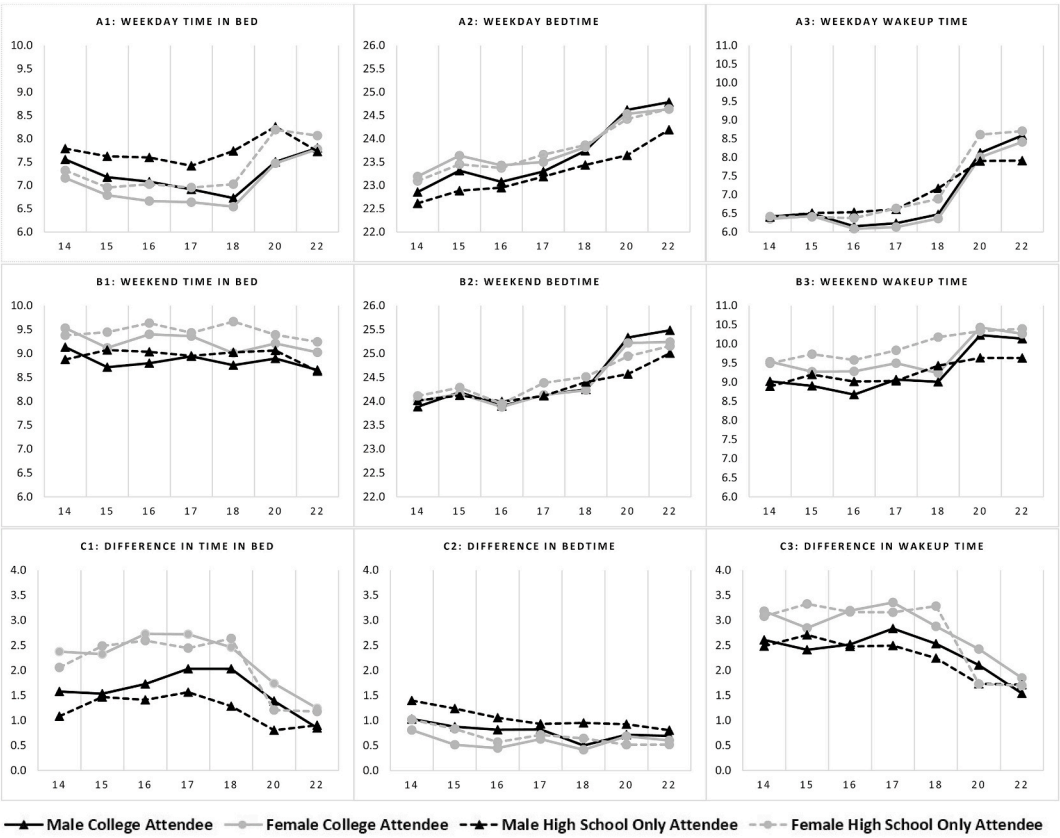

Fig. 1. Adjusted sleep trajectories: (A) Weekdays, (B) weekends, (C) weekday-weekday differences.

late at night does result in increased sleepiness during the daytime (Chen et al., 2015; Gau & Soong, 1995), but a recent study of Chinese adolescents also finds that later bedtimes are associated with higher college entrance exam scores (Wang, Ren, et al., 2016). Furthermore, Steger's study (2006) of Japanese high-school students suggests that sleepiness at school may be interpreted as a symbol of diligence that is valued in East Asian contexts. In this way, the East Asian educational system and broader culture may influence young people's sleep trajectories, rewarding staying awake later at night to study more hours.

In addition, we found that college attendees and those who attended high school only display differences in sleep that begin during high school and continue through college. This finding suggests that a life course change such as college attendance may be influential in health behaviors well before the change is realized, as individuals prepare. In Taiwan and other East Asian societies, competition for college admission is so intense that students begin to prepare as early as junior high school. In contrast, academic pressure in Western societies is less, making it a less salient factor for sleep. Recent studies are indicative of this: A recent review of what causes insufficient sleep in U.S. adolescents and young adults did not mention academic pressure as a potential cause (Owens & Adolescent Sleep Working Group, 2014). Similarly, Dewald et al. (2014) studied a group of adolescents around Amsterdam, Netherlands and found that academic stress had no association with sleep duration. Our findings that Taiwanese youth report less sleep than is typically reported for Western youth and that, importantly, these sleep trajectories differ for the college bound, points to the role of social institutions and culture in sleep trajectories over the life course.

Furthermore, we found that differences in weekday and weekend sleep duration change as adolescents emerge into adulthood, and vary by college attendance. These findings are consistent with prior studies (Park et al., 2019) that find weekday and weekend differences in sleep are largely due to ones' differing ability to alter sleep on days with rigid scheduling (weekdays) versus days with flexible scheduling (weekends). In Taiwan, the academic pressure for high-school students is strong and intensifies each year; students respond by spending more and more time afterschool studying. Thus, by 12th grade, many students study until midnight or later, particularly on weekdays. Emerging adulthood marks a key change: College attendees may have newfound flexibility to choose their schedule and increase sleep duration, absent the rigidity of a daily high-school schedule and parental control. Conversely, individuals who enter the labor market face a fixed schedule and rigid time demands from employment that may further diminish sleep duration.

Finally, we found that sleep patterns vary by gender in adolescence, but those differences decrease as respondents transition into adulthood. At college graduation (age 22), women reported sleeping more hours than men, a finding that is consistent with prior studies (Maslowsky & Ozer, 2014; Williams et al., 2013). In fact, other studies from Western societies suggest that adult women sleep more than men throughout the life course (Gale & Martyn, 1998; Hale, 2005; Krueger & Friedman, 2009). In this light, our findings for East Asia suggest that gender may influence sleep duration more consistently across cultural contexts than some other factors do.

Taken together, these findings not only demonstrate age-variant sleep trajectories, but also suggest that cultural context is an important factor for sleep that should be considered alongside physiology and changing social roles. Although physiological changes on adolescents and young adults are extremely similar across societies, cultural forces and social institutions are not. In Taiwan, the period from junior high school to senior high school is marked by enormous academic pressure, but this is less so in the US and other Western societies. This study provides insight into how this cultural difference between Western and non-Western societies may manifest in a specific health behavior, such as sleep.

Before concluding, some limitations of this study must be discussed. First, we note that the sleep measures use self-reported data. However, most large-scale, population-based studies of sleep rely on self-reported data and studies find that the self-reported data corresponds well to objective sleep measures (Tremaine et al., 2010). Furthermore, the sleep questions in the TYP are consistent with other large-scale surveys (e.g., National Longitudinal Study of Adolescent Health), giving this study's findings the advantage of being comparable to prior studies. As such, the self-reported sleep measures remain useful and valid in documenting the population trends and sub-population variations in sleep. Second, the data had no information on respondents' internet and mobile phone usage, which is a factor that affects adolescents' and young adults' sleep (Lemola et al., 2015). However, the first smartphone (e.g., iPhone) was not released in Taiwan until the end of 2008. As such, during the study waves (2001–2009), possession of smartphones was extremely low among Taiwanese youth and as such, mobile phone usage would likely have had little impact on the results.

Sleep is undoubtedly important for health. However, the understanding of how sleep is developmentally patterned from adolescence to early adulthood remains a relatively untapped topic that is in need of longitudinal study (Park et al., 2019). Improved understanding of the developmental patterns of sleep is important because it can inform the etiology of many health problems and provide the basis for effective health promotion strategies. This study contributes to that end by providing evidence of normative developmental changes over time from adolescence to emerging adulthood and, being among the first to use data from East Asia, provides sound evidence that sleep trajectories are gendered across cultural context and likely impacted by social institutions and norms.

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