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Seven-year survey of sleep timing in Russian children and adolescents: chronic 1-h forward transition of social clock is associated with increased social jetlag and winter pattern of mood seasonality

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ABSTRACT

Previous studies indicate that solar clock (daily changes in the Earth's surface illumination) is a main *zeitgeber* for human circadian system. It has been shown that human biological clock is weakly adjusted to such changes in social clock as daylight saving time (DST). There are two changes of social clock in Russian Federation: on 25 March 2011, DST has been replaced by permanent DST (DSTp), which was subsequently revoked on 26 October 2014 (non-DSTp). These manipulations with social clock may lead to prolonged disturbances of human circadian system. Our hypothesis is that during period of DSTp, the dissociation between social and biological clocks was greatest as compared with DST and non-DSTp periods. Here, we examine the effects of DSTp on the sleep timing, social jetlag (SJL), academic performance, and winter and summer seasonality of mood and behavior of 10–24-year-old inhabitants of European North of Russia. A cross-sectional retrospective analysis of questionnaire data (n = 7968) was performed using chi squared-test and analysis of covariance. Our findings indicate that SJL ($F_{2,7967} = 31.9$; $p < 0.0001$; $\eta^2 = 0.009$), and winter pattern of mood seasonality ($\chi^2_{2,7967} = 10.5$; $p < 0.01$) were increased in adolescents during the period of DSTp as compared with DST and non-DSTp periods. The largest increase in SJL was occurred in ages between 10 and 17-year-olds. The finding suggests that increase in SJL can be attributed to a later rise time on free days ($F_{2,7967} = 44.9$; $p < 0.0001$; $\eta^2 = 0.012$). Similar changes were observed in three subsamples obtained in Syktyvkar, Petrozavodsk, and Vorkuta. Effect sizes of studied relationships were small or very small. The greatest effect sizes (η^2 ~ 0.05) were observed in Arctic

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city of Vorkuta indicating that in polar region, solar clock is still stronger *zeitgeber* for human circadian system, than the social clock. In conclusion, we have shown for the first time that there is a greatest dissociation between social and biological clocks during the period of DSTp which potentially exerts a negative influence on adolescents' sleep habits, mood, and behavior. Our data indicate that "non-DSTp" social clock system most suitable for prevention dissociation between social and biological clocks.

Introduction

Social jetlag (SJL) is a misalignment between the social and the biological clock that is widespread among residents of industrialized countries (Roenneberg and Merrow 2007). Social jetlag has been shown apparently associated with poor academic performance (Haraszti et al. 2014; van der Vinne et al. 2015), depression (Levandovski et al. 2011), and obesity (Roenneberg et al. 2012). Previously, it was shown that human circadian system is purely adjusted to daylight saving time (DST) (Kantermann et al. 2007) and the increases in the sizes of time zones increase the risk of SJL (Borisenkov 2011). Therefore, such changes in social clock have the potential to adversely affect the cognitive function, well-being, and health of affected populations.

In the Russian Federation, two changes were made to the social time system over a short period. On 25 March 2011, the country replaced DST with permanent DST (DSTp). This DSTp was subsequently revoked on 26 October 2014 (non-DSTp). However, for more than 3 years, the population of the Russian Federation observed DSTp (Table 1; Figure 1). The aim of the present study was to evaluate the effects of chronic 1-h forward and backward transition of social clock on sleep timing, academic performance, and mood seasonality of Russian residents.

Materials and methods

Subjects and instruments

This study was approved by the ethical committee of the Institute of Physiology of Komi Science Centre, the Ural Branch of the Russian Academy of Sciences. A cross-sectional retrospective analysis was conducted on continuous data accumulated over a 7-year period (from 2009 to 2016). The study participants were enrolled in schools and universities located in 14 settlements in the European North of Russia. The data were obtained from 7968 participants aged 10 to 24 years. For each participant, personal data (i.e., date, place of residence, age, sex, height, weight, and academic performance) were collected. For details, see Figure 1 and Table 2. Chronotype, the degree of SJL, and sleep characteristics were estimated using the Munich ChronoType Questionnaire (Roenneberg et al. 2003). A mid-sleep phase shift between weekdays and weekend of ≥ 1 h and ≥ 2 h were used as the criteria for SJL ≥ 1 h and SJL ≥ 2 h group assignment, respectively. Winter and summer pattern of seasonality of mood and behavior were assessed using the Seasonal Pattern Assessment Questionnaire

Table 1. Description of time periods studied.

#	Period	The social time system	Abbreviation
I	Before 25 March 2011	Daylight saving time	DST
II	26 March 2011–26 October 2014	Permanent DST	DSTp
III	After 27 October 2014	Permanent non-DST	non-DSTp

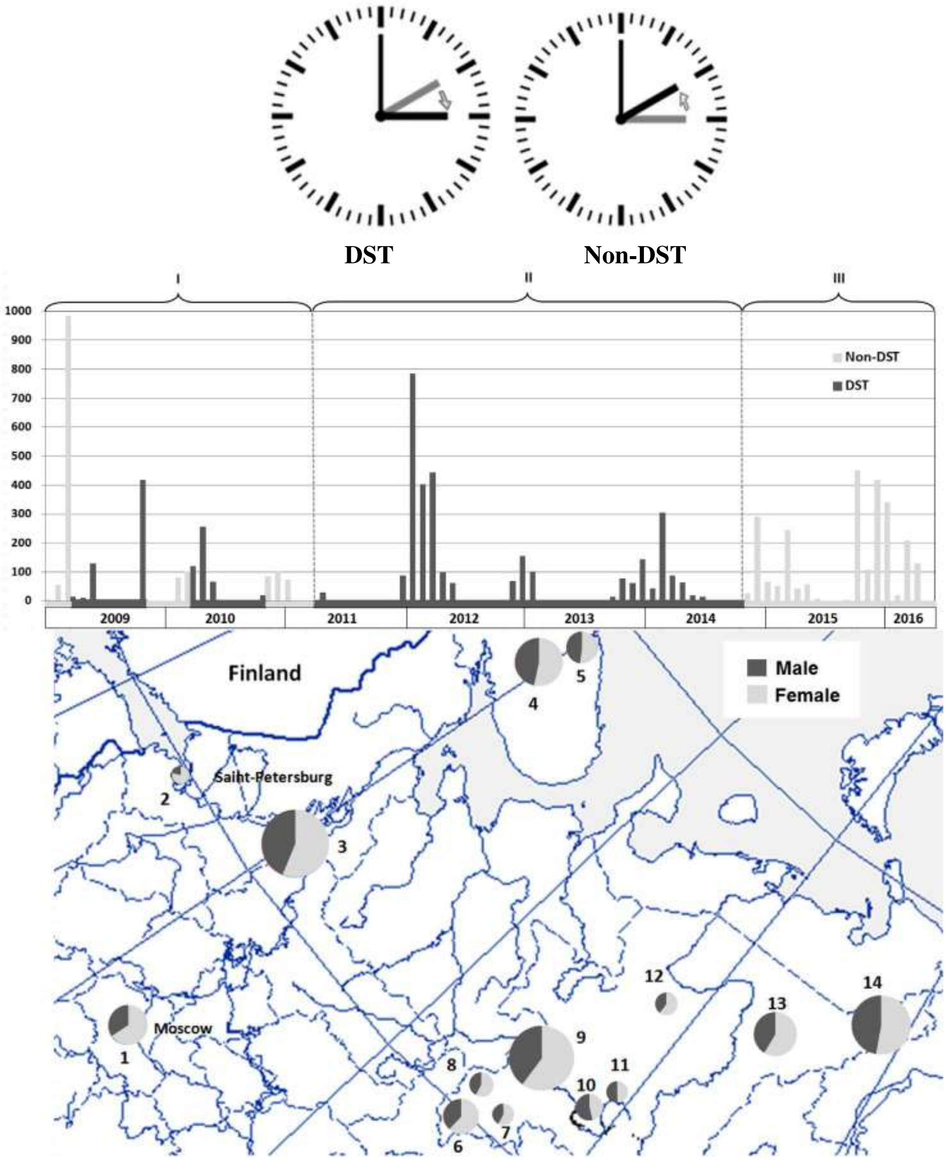

Figure 1. The time and place of the study. Upper panel: Scheme illustrating daylight saving time (DST) and non-DST social time system. Middle panel: The study was carried out at three periods. I: from 01 January 2009 to 26 March 2011 – during the period DST (i.e. DST acting yearly from April to October); II: from 27 March 2011 to 26 October 2014 – during the period of permanent DST (DST_p) (i.e. DST acting permanently throughout the year); III: from 27 October 2014 until the present – when DST was canceled (non-DSTp) (i.e. non-DST acting permanently throughout the year). Columns indicate the number of persons surveyed. Lower panel: The study was carried out in 14 settlements (for details see Table 2) located in the northern European Russia. The sizes of circles are proportional to the number of persons surveyed. Data on sex ratio are also presented in the scheme.

according to criteria described by Rosen and colleagues (1990). For details, see Table 3 and our previous publication (Borisenkov et al. 2015).

Table 2. Short characteristics of place of residence and subject of study.

Settlement		Coordinate		Months and periods of survey				
#	Population	Lat.	Long.	I	II	III	Age, *M* (SD)	*N*
1	11980000	55.8	37.6	–	1–5,10–12	2,3,10–12	19.4 (2.2)	311
2	5190000	59.8	30.3	–	10,12	2–4,10–12	17.4 (4.3)	76
3	270000	61.8	34.3	–	1–6,10–12	1,10–12	14.9 (2.5)	2537
4	60000	67.6	33.4	3,10	–	3	15.4 (2.7)	562
5	300000	69.0	33.1	–	–	3,4,12	15.2 (2.9)	135
6	800	59.5	49.5	3,5,10	–	–	14.5 (2.0)	245
7	1000	60.3	51.5	4	–	–	14.1 (2.2)	76
8	6000	60.2	49.4	–	1–4,12	–	14.7 (1.9)	97
9	250000	61.7	50.9	1–5,10–12	1–6,9–12	1–6,9–12	18.0 (3.2)	2127
10	5000	61.7	53.7	3–5	–	–	13.2 (2.1)	97
11	1200	61.9	55.1	1,2	–	–	14.5 (2.1)	79
12	4000	65.0	53.9	4–6	4,5	–	15.7 (1.8)	126
13	40000	66.0	60.1	1,3,12	–	12	14.0 (1.9)	431
14	87000	67.4	64.1	4	1,4,11,12	1,3,10,12	14.4 (1.7)	1069
Total							15.9 (3.1)	7968

Notes: 1: Moscow; 2: Saint-Petersburg; 3: Petrozavodsk; 4: Apatity; 5: Murmansk; 6: Mutnitsa; 7: Kazhym; 8: Ob'yachevo; 9: Syktyvkar; 10: Ust-Kulom; 11: Timsher; 12: Izhma; 13: Inta; 14: Vorkuta. Lat.: latitude; Long.: longitude; *M* (SD): mean (standard deviation); F/M: sex ratio; *N*: number of persons surveyed.

Table 3. Criterions for winter and summer patterns of seasonality assessment (Rosen et al. 1990).

	Item		
Pattern	#11	#17	#12
SADw	≥10	≥2	
sub-SADw	≥10	0, 1	1, 2, 12 (plus any other combination of months excluding 6, 7, 8)
sub-SADw	8, 9	≥0	
SADs	≥10	≥2	
sub-SADs	≥10	0, 1	6, 7, 8 (plus any other combination of months excluding 1, 2, 12)
sub-SADs	8, 9	≥0	
no-SAD	Respondents who failed to meet the criteria defined above for SAD or sub-SAD		

Notes: We assessed the type (winter, summer) and severity (SAD, sub-SAD, or no-SAD) of seasonal affective disorder in study participants using the responses on the items #11, 12 and 17 of SPAQ. Item#11 – Global Seasonality Score (GSS). Changed from 0 to 24 scores.
Item#12 – "At what time of year do you feel the worst?" Changed from 1 (Jan.) to 12 (Dec.).
Item#17 – Seasonal changes to be problematic. Changed from: 0 (none), 1 (mild), 2 (moderate), 3 (marked), 4 (severe), 5 (disabling).

Statistical analysis

All the data were divided into three periods as described in Table 1. A chi squared-test was used for analysis of influence of periods on non-parametric variables. Two series of one way analyses of covariance (ANCOVA) were performed for normally distributed variables. Firstly, we performed the analysis using "period" as fixed factor, "anthropometric characteristics", "school start time" (SST), "achievement", and "Global Seasonality Scores" (GSS) as dependent variables, and "month of survey", "year of survey", "settlement population", "latitude", "longitude", "time of sunrise", "day length", and "age" as covariates. The variables "BMI" and "settlement population" are non-normally distributed, therefore, we used normalized "*ln*BMI" and "*ln*(settlement population)" in analysis. There is a certain imbalance in age, anthropometric characteristics and SST in the three groups studied (Table 4) Therefore, the above characteristics were included in the second set of ANCOVAs as covariates. Secondly, one way ANCOVAs were performed using "period" as fixed factor, "chronotype, SJL, and sleep

Table 4. Anthropometric characteristics of persons studied.

Parameter	Period I ($n = 2499$)	Period II ($n = 3033$)	Period III ($n = 2436$)	v	F	P	η^2
Sex (F/M), %	57.0/43.0	57.7/42.3	57.4/42.6				
Age, yrs	$15.4 \pm 2.8^{a,d}$	$15.6 \pm 3.0^{A,d}$	16.6 ± 3.2^{D}	7967	56.4	0.001	0.014
Weight, kg	54.9 ± 12.5^{d}	55.1 ± 12.7^{d}	58.9 ± 13.0^{D}	7967	23.2	0.001	0.006
Height, cm	$165.0 \pm 10.6^{a,c}$	$165.7 \pm 10.9^{A,c}$	167.7 ± 9.5^{C}	7967	8.6	0.001	0.002
BMI, kg/m^2	20.0 ± 3.2^{c}	19.9 ± 3.2^{c}	20.8 ± 3.4^{C}	7967	18.6	0.001	0.005
SST, h:mm	$8{:}35 \pm 0{:}46^{A}$	$8{:}32 \pm 0{:}37^{a}$	$8{:}33 \pm 1{:}30$	7967	3.2	0.041	0.004

Notes: BMI: body mass index; SST: school start time; Data presented as mean ± SD; one way analysis of covariance were performed using "period" as fixed factor, "anthropometric characteristics" as dependent variables, and parameters presented in the Table 2 as covariates; the variables "BMI" and "settlement population" are non-normally distributed, therefore we used normalized "*ln*BMI" and "*ln*(settlement population)" in analysis; F – Fisher tests; P – significance of F-test; η^2 – effect size; differences between values marked with the letters are significant (A > a – P < 0.05; B > b – P < 0.01; C > c – P < 0.001; D > d – P < 0.0001) (*post hoc* comparisons, Tukey test).

characteristics" as dependent variables, and "moth of survey", "year of survey", "settlement population", "latitude", "longitude", "time of sunrise", "day length", "age", "weight", "height", "BMI", and "SST" as covariates. The variables "BMI", "settlement population", "sleep onset latency on week and free days" ($SOL_{W(F)}$), "sleep inertia" ($SII_{W(F)}$), "SJL", and "chronotype" (MSFsc) are non-normally distributed, therefore we used normalized "*ln*BMI", "*ln*(settlement population)", "*Sqr*$SOL_{W(F)}$", "*Sqr*$SII_{W(F)}$", "*ln*SJL", and "*ln*MSFsc" in analysis.

Results

Social jetlag ≥ 1 and 2 h was observed in 86.4 and 59.3% of individuals surveyed, respectively (Figure 2A). During the period of time corresponding to DSTp, the proportions of people with SJL ≥ 1 h and 2 h increased by 6.7% ($\chi^2_{2,7967} = 92.3$; $p < 0.00001$) and 16.3% ($\chi^2_{2,7967} = 1241.8$; $p < 0.0000001$; Figure 2A; Table 5b), respectively. An increase in GSS ($F_{2,7967} = 48.9$; $p < 0.0001$; $\eta^2 = 0.015$; Table 5a) and winter pattern of mood seasonality ($\chi^2_{2,7967} = 10.5$; $p < 0.01$; Table 5b) were also observed during the period of time corresponding to DSTp. There were no significant changes in summer pattern of mood seasonality during three period studied (data not shown). The largest increase in SJL occurred in 10 to 17-year-olds (Figure 2B). This finding can be primarily attributed to a later rise time on free days ($F_{2,7967} = 44.9$; $p < 0.0001$; $\eta^2 = 0.012$; Figure 3F; Tables 5a and 6). Two analyses of covariance were performed to evaluate the hypothesis that the changes in SJL can be primarily attributed to a later rise time on free days (Table 5a): 1: according to the procedure described above; 2: in addition, "get-up time on free days" was used as covariate. Significant influence of "period" on SJL was found only in first analysis ($F_{2,7967} = 31.9$; $p < 0.0001$; $\eta^2 = 0.009$) but not in second one ($F_{2,7967} = .133$; $p = 0.875$; $\eta^2 = 0.000$) indicating that our hypothesis is true.

Similar data were observed in three subsamples obtained in Syktyvkar, Petrozavodsk, and Vorkuta with some features (Table 5a, b; Figure 2C–E). In Petrozavodsk was observed significant impact of "period" on "academic performance" with maximal values during the non-DSTp period ($F_{2,2535} = 20.0$; $p = 0.0001$; $\eta^2 = 0.009$). There were no significant effect of "period" on SADw in Petrozavodsk and Vorkuta. "Period" had greatest effect size ($\eta^2 \sim 0.05$) on SJL, GUT_F, and GSS in Vorkuta's subsample (Table 5a). There was a lower percentage of SADw in children and adolescents living in Vorkuta, as compared with their peers living in other

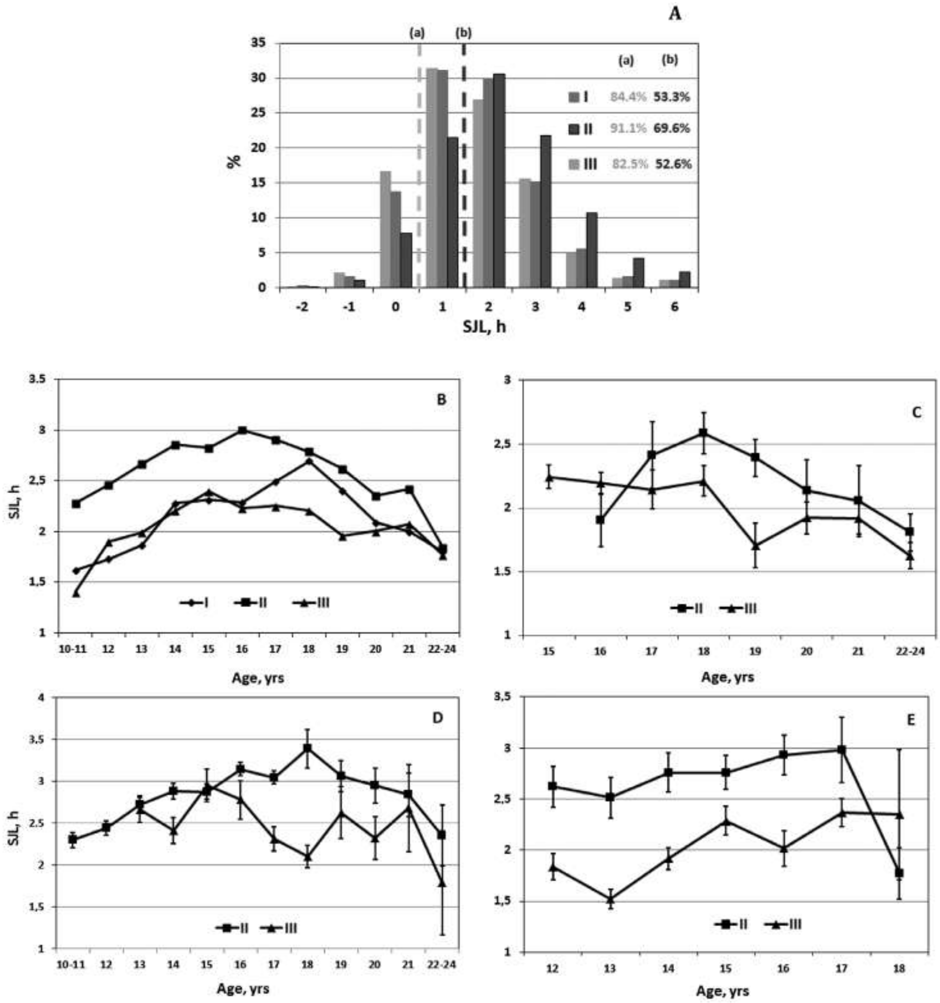

Figure 2. A: Percentage of SJL ≥ 1 h (a) and SJL ≥ 2 h (b) in children and adolescents in all population at I–III preiod studied; B–E: Age-associated changes in SJL in all population (B), Syktyvkar (C), Petrozavodsk (D), and Vorkuta (E) subsamples; Error bars represent SE.

settlements of Northern European Russia (7.13% vs. 5.14%; $\chi^2_{1,7967} = 8.96$; $p < 0.005$). At the same time, mean values of GSS were the same in compared groups (9.09 vs. 9.02; $t_{1,7967} = 0.46$; $p > 0.05$). This means that children and adolescents from Vorkuta less likely to perceive seasonal changes in their mood and behavior as a serious problem. However, this question is outside the scope of the study.

Discussion

The main finding of the study is that during the period when DSTp was observed in Russian Federation, the number of people suffering from SJL (i.e. those with chronic sleep deprivation during workweek nights) was significantly increased. To compensate sleep deprivation, people began to sleep more on weekend nights, mainly due to delay time of awakening.

Table 5a. SJL, academic performance, and Global Seasinality Scores in children and adolescents.

Parameter	Group	Period I	Period II	Period III	v	F	P	η^2
SJL, h$^{\#}$	All	2.16 ± 1.29^{d}	2.70 ± 1.44^{D}	2.13 ± 1.33^{d}	7967	1: 31.9	0.0001	0.009
						2: *.133*	*0.875*	*0.000*
	Syktyvkar	2.18 ± 1.23^{B}	2.17 ± 1.17	2.03 ± 1.23^{b}	2125	6.5	0.001	0.007
	Petrozavodsk	–	2.83 ± 1.47^{C}	2.52 ± 1.45^{c}	2535	11.9	0.001	0.005
	Vorkuta	2.46 ± 1.63^{B}	2.70 ± 1.48^{D}	$1.95 \pm 1.32^{b,d}$	1067	23.4	0.0001	0.045
GUT_F, h	All	10.24 ± 1.85^{d}	11.11 ± 1.96^{D}	10.27 ± 1.91^{d}	7967	44.9	0.0001	0.012
	Syktyvkar	10.22 ± 1.68^{A}	10.40 ± 1.69^{C}	$10.03 \pm 1.75^{a,c}$	2125	6.6	0.001	0.008
	Petrozavodsk	–	11.26 ± 1.96^{C}	10.84 ± 1.92^{c}	2535	16.5	0.0001	0.007
	Vorkuta	10.37 ± 2.16^{a}	$10.92 \pm 2.15^{A,D}$	9.90 ± 1.99^{d}	1067	25.4	0.0001	0.049
GSS, scores	All	9.70 ± 4.87^{C}	9.54 ± 4.86^{C}	8.26 ± 4.92^{c}	7967	48.9	0.0001	0.015
	Syktyvkar	8.68 ± 4.43	9.51 ± 4.92^{B}	8.17 ± 4.84^{b}	2125	7.5	0.001	0.011
	Petrozavodsk	–	9.37 ± 4.92^{B}	8.69 ± 4.88^{b}	2535	10.9	0.001	0.005
	Vorkuta	8.91 ± 4.50^{c}	$10.73 \pm 4.46^{C,D}$	8.12 ± 5.04^{d}	1067	27.2	0.0001	0.054
Achievement$^{\&}$, scores	All	4.04 ± 0.61^{a}	4.03 ± 0.55^{b}	$4.09 \pm 0.57^{A,B}$	7967	*.614*	*0.541*	*0.000*
	Syktyvkar	4.05 ± 0.59	4.17 ± 0.51	4.13 ± 0.57	2125	*2.9*	*0.056*	*0.004*
	Petrozavodsk	–	4.00 ± 0.53^{b}	4.07 ± 0.54^{B}	2535	20.0	0.0001	0.009
	Vorkuta	3.84 ± 0.53^{b}	3.98 ± 0.58	4.03 ± 0.55^{B}	1067	*2.4*	*0.091*	*0.005*

$^{\&}$the Russian grading system is coded into five grades: 1–5. A low grade indicates low achievement; SJL: social jetlag; GSS: global seasonality scores; one way analysis of covariance was performed as described in Materials and Methods.

$^{\#}$two analyses were performed to assess the hypothesis that can be primarily attributed to a later rise time on free days 1: according to the procedure described above; 2: in addition, "get-up time on free days" was used as covariate; v – degrees of freedom; F – Fisher tests; P – significance of F-test; η^2 – effect size; differences between values marked with the letters are significant (A > a – P < 0.05; B > b – P < 0.01; C > c – P < 0.001; D > d – P < 0.0001) (*post hoc* comparisons, Tukey test); values marked with italics are insignificant, $p > 0.05$.

Table 5b. Percentage of SJL and SADw in children and adolescents.

Parameter	Group	Period I	Period II	Period III	v	χ^2	P
SJL ≥ 1 h, %	All	84.43^{d}	91.10^{D}	82.47^{d}	7967	92.3	0.00001
	Syktyvkar	85.55^{A}	85.20	80.86^{a}	2125	8.0	0.025
	Petrozavodsk	–	92.60^{B}	88.53^{b}	2535	8.8	0.005
	Vorkuta	83.33^{a}	$90.21^{A,C}$	78.79^{c}	1067	19.8	0.001
SJL ≥ 2 h, %	All	53.34^{d}	69.70^{D}	52.63^{d}	7967	1241.8	0.0000001
	Syktyvkar	55.35^{A}	57.89^{A}	49.59^{a}	2125	9.3	0.01
	Petrozavodsk	–	73.04^{C}	63.78^{c}	2535	16.7	0.001
	Vorkuta	60.42^{A}	67.28^{D}	$47.06^{a,d}$	1067	37.3	0.0001
S-SADw, %	All	10.98^{c}	14.82^{C}	11.60^{c}	7967	19.1	0.001
	Syktyvkar	8.11^{a}	9.38	13.20^{A}	2125	7.4	0.025
	Petrozavodsk	–	14.63	11.69	2535	*2.8*	*0.1*
	Vorkuta	8.51^{a}	$18.21^{A,D}$	7.96^{d}	1067	23.6	0.001
SADw, %	All	8.33	9.33^{B}	7.13^{b}	7967	10.5	0.01
	Syktyvkar	7.03	11.25^{A}	6.13^{a}	2125	5.9	0.05
	Petrozavodsk	–	8.90	8.77	2535	*0.5*	*0.5*
	Vorkuta	6.38	6.17	5.14	1067	*3.8*	*0.25*

Notes: S-SADw: sub-syndrome of winter seasonal affective disorder; SADw: winter SAD; χ^2 – hi-squared statistics; the rest abbreviations as in Table 5a.

Previously, it was shown that human circadian system entrained by solar but not social clocks (Roenneberg et al. 2007). The practice of yearly forward and backward transitions of social clock reduces the ability of the human biological clock to seasonal adjustment (Kantermann et al. 2007). Our data indicate that DSTp causes chronic dissociation between social and biological clock that persists for more than three years. The greatest dissociation

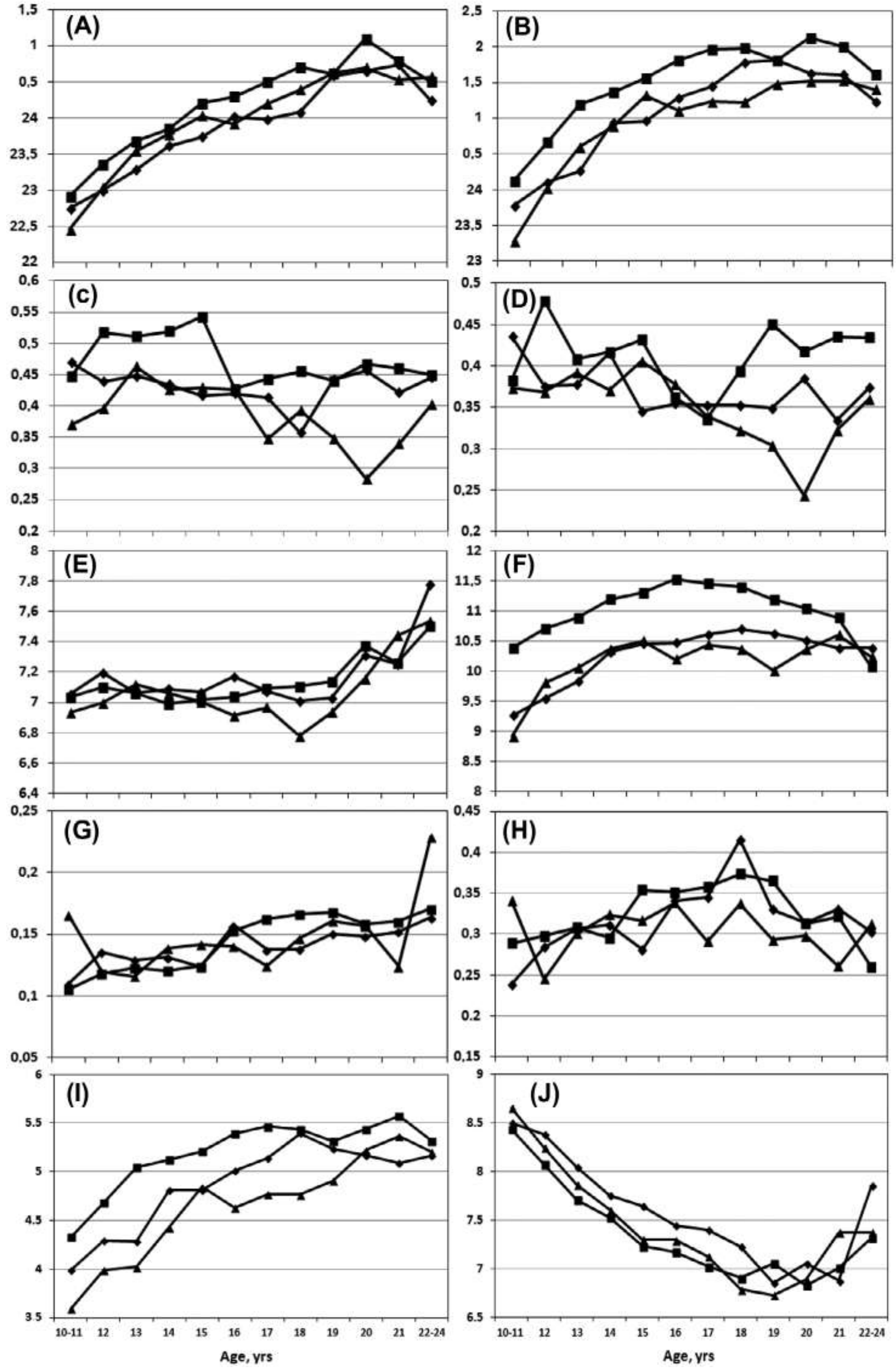

Figure 3. Age-associated changes in sleep onset on week- (A) and free (B) days; sleep onset latency on week- (C) and free (D) days; get-up time on week- (E) and free (F) days; sleep inertia on week- (G), and free (H) days; chronotype (MSFsc) (I), and sleep duration (J) at three periods studied. All parameters are expressed in hours. I period II period III period.

Table 6. Impact of three periods on chronotype and sleep characteristics.

Parameter	Period I	Period II	Period III	*F*	*P*	η^2
Weekdays						
SlOw, h	$23.73 \pm 1.23^{d,b}$	$24.10 \pm 1.31^{D,E}$	$23.89 \pm 2.30^{e,B}$	11.26	0.001	0.005
SOLw, h	$0.43 \pm 0.39^{A,b}$	$0.48 \pm 0.45^{B,C}$	$0.40 \pm 0.44^{a,c}$	14.89	0.000	0.004
GUTw, h	$7.13 \pm 0.78^{A,B}$	7.09 ± 0.68^{a}	7.05 ± 0.80^{b}	9.68	0.000	0.003
SIIw, h	0.14 ± 0.14	0.14 ± 0.16	0.14 ± 0.16	3.40	0.034	0.001
Free days						
SlO_F, h	24.94 ± 1.73^{d}	25.47 ± 1.86^{D}	24.85 ± 2.90^{d}	25.08	0.000	0.007
SOL_F, h	0.37 ± 0.40^{a}	$0.40 \pm 0.44^{A,C}$	0.36 ± 0.42^{c}	14.26	0.000	0.004
GUT_F, h	10.24 ± 1.85^{d}	11.11 ± 1.96^{D}	10.27 ± 1.91^{d}	44.85	0.000	0.012
SII_F, h	0.31 ± 0.29^{a}	0.33 ± 0.35^{A}	0.32 ± 0.41	5.90	0.003	0.002
Weekdays/free days						
MSFsc, h	4.78 ± 1.48^{c}	5.17 ± 1.57^{C}	4.77 ± 1.54^{c}	30.33	0.000	0.008
SlD, h	7.69 ± 1.18^{C}	7.40 ± 1.21^{c}	7.34 ± 1.31^{c}	*1.01*	*0.366*	*0.000*

Notes: $SlO_{W(F)}$: sleep onset on weekdays (free days); $SOL_{W(F)}$: sleep onset latency on weekdays (free days); $GUT_{W(F)}$: get-up time on weekdays (free days); $SII_{W(F)}$: sleep inertia on weekdays (free days); MSF_{SC}: chronotype; SlD average weekly sleep duration; One way analysis of covariance were performed using "period" as fixed factor, "chronotype and sleep characteristics" as dependent variables, and parameters presented in the Tables 2 and 4 as covariates; the variables "BMI", "settlement population", "$SOL_{W(F)}$", "$SII_{W(F)}$" "SJL", and "MSFsc" are non-normally distributed, therefore we used normalized "*ln*BMI" and "*ln*(settlement population)", "*Sqr*$SOL_{W(F)}$", "*Sqr*$SII_{W(F)}$", "*ln*SJL", and "*ln*MSFsc" in analysis; *F* – Fisher tests; *P* – significance of *F*-test; η^2 – effect size; differences between values marked with the letters are significant (A > a – $P < 0.05$; B > b, E > e – $P < 0.01$; C > c – $P < 0.001$; D > d – $P < 0.0001$) (*post hoc* comparisons, Tukey test); values marked with italics are insignificant, $p > 0.05$.

between social and biological clocks was observed in 10–17-year-olds. One possible explanation for this – higher sensitivity of the circadian system of adolescents to light signals (Crowley et al. 2015).

Surprisingly, social clock manipulations had the greatest effect on SJL, GUT_F, and GSS in children and adolescents living in the Arctic city of Vorkuta. This means that in polar region the solar clock is still stronger *zeitgeber* for human circadian system, than the social clock. This issue requires more thorough study in special research.

According to Roenneberg et al. (2012), SJL ≥ 1 h occurs in 70% of the population. The higher SJL index values that we observed can potentially be attributed to the fact that we focused primarily on young people, who are at greater risk of SJL than adults (Roenneberg et al. 2004). In addition, our study involved only residents living at high latitudes. These residents more commonly exhibit late chronotype (Borisenkov 2010) and, accordingly, SJL.

Previous studies have shown that changes in the circadian system are associated with SJL; SJL ≥ 1 h is associated with a marked decrease in the amplitude of the circadian rhythm of wrist temperature (Polugrudov et al. 2016), SJL ≥ 2 h is associated with a larger cortisol awakening response (Rutters et al. 2014) and an increased risk of depression (Levandovski et al. 2011).

Limitations

The study was carried out retrospectively, therefore it was impossible to organize data collection in accordance with the goal and objectives of the research. All significant effects were either small or very small in size (eta squared less than 0.05). We used a cross-sectional study design, which does not allow to find out the cause-effect relationships between the studied parameters.

Conclusion

We have shown for the first time an increase in SJL, delay in rise time on free days and increased percentage of winter pattern of seasonality of mood and behavior in children and adolescents during the period of time that DSTp was observed in the Russian Federation. Chronic 1-h forward transition of social clock potentially exerts a negative influence on adolescents' sleep habits, mood, and behavior.

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Borisenkov MF. 2010. Human chronotypes in the North. Hum Physiol. 36:117–122.
Borisenkov MF. 2011. The pattern of entrainment of the human sleep-wake rhythm by the natural photoperiod in the North. Chronobiol Int. 28:921–929.
Borisenkov MF, Petrova NB, Timonin VD, Fradkova LI, Kolomeichuk SN, Kosova AL, Kasyanova ON. 2015. Sleep characteristics, chronotype, and winter depression in 10–20-year-olds in northern European Russia. J Sleep Res. 24:288–295.
Crowley SJ, Cain SW, Burns AC, Acebo C, Carskadon MA. 2015. Increased sensitivity of the circadian system to light in early/mid-puberty. J Clin Endocrinol Metab. 100:4067–4073.
Haraszti RÁ, Ella K, Gyöngyösi N, Roenneberg T, Káldi K. 2014. Social jetlag negatively correlates with academic performance in undergraduates. Chronobiol Int. 31:603–612.
Kantermann T, Juda M, Merrow M, Roenneberg T. 2007. The human circadian clock's seasonal adjustment is disrupted by daylight saving time. Curr Biol. 17:1996–2000.
Levandovski R, Dantas G, Fernandes LC, Caumo W, Torres I, Roenneberg T, Hidalgo MP, Allebrandt KV. 2011. Depression scores associate with chronotype and social jetlag in a rural population. Chronobiol Int. 28:771–778.
Polugrudov AS, Panev AS, Smirnov VV, Paderin NM, Borisenkov MF, Popov SV. 2016. Wrist temperature and cortisol awakening response in humans with social jetlag in the North. Chronobiol Int. 33:802–809.
Roenneberg T, Merrow M. 2007. Entrainment of the human circadian clock. Cold Spring Harb Symp Quant Biol. 72:293–299.
Roenneberg T, Wirz-Justice A, Merrow M. 2003. Life between clocks: daily temporal patterns of human chronotypes. J Biol Rhythms. 18:80–90.
Roenneberg T, Kuehnle T, Pramstaller PP, Ricken J, Havel M, Guth A, Merrow M. 2004. A marker for the end of adolescence. Curr Biol. 14:R1038–R1039.
Roenneberg T, Kumar CJ, Merrow M. 2007. The human circadian clock entrains to sun time. Curr Biol. 17:R44–R45.
Roenneberg T, Allebrandt KV, Merrow M, Vetter C. 2012. Social jetlag and obesity. Curr Biol. 22:939–943.
Rosen LN, Targum SD, Terman M, Bryant MJ, Hoffman H, Kasper SF, Hamovit JR, Docherty PJ, Welch B, Rosenthal NE. 1990. Prevalence of seasonal affective disorder at four latitudes. Psychiatry Res. 31:131–144.
Rutters F, Lemmens SG, Adam TC, Bremmer MA, Elders PJ, Nijpels G, Dekker JM. 2014. Is social jetlag associated with an adverse endocrine, behavioral, and cardiovascular risk profile? J Biol Rhythms. 29:377–383.
van der Vinne V, Zerbini G, Siersema A, Pieper A, Merrow M, Hut RA, Roenneberg T, Kantermann T. 2015. Timing of examinations affects school performance differently in early and late chronotypes. J Biol Rhythms. 30:53–60.