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The association between chronotype and wages at mid-age

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ABSTRACT

Sleep has been shown to affect economic outcomes, including wages. The mechanisms by which sleep affects wages remain unclear. We examine the relationship between chronotype – morning larks, evening owls – and wages at mid-age. We propose a novel model relating chronotype to wages in consideration of human, social, and health capital constructs. Empirically, we explore the effects of chronotype mediated through life course choices, such as work experience, trust, and health behaviour. The data come from the 46-year-old follow-up study of the Northern Finland Birth Cohort (1966) and from registers of the Finnish Tax Administration. We find evening chronotype to have a significant indirect negative effect on wages, which occurs through accumulating less work experience and through poor health outcomes. The effect is largest for male workers, with a total indirect effect on average wages of − 4%. We also provide evidence that chronotype has a long-term association with wages between 29 and 50 years of age. We conclude that evening-type workers are less suited to typical working hours and accumulate less human, social and health capital which in turn negatively affects their wages. Our findings are of great socio-economic importance because evening chronotypes make up a significant part of the population.

1. Introduction

Economists have made progress in understanding the relationship between sleep and wages. Early work by Biddle and Hamermesh (1990) shows evidence of higher wages being associated with less sleep, while recent works by Kajitani (2021) and Gibson and Shrader (2018) provide evidence that more sleep leads to higher wages. The literature so far, though, has not yet explored the mechanisms by which sleep affects wages, nor has anyone been able to study a true long-term effect of sleep on wages – over a time span of years, as opposed to days. In this paper, we address both issues by using an individual's chronotype as a long-term indicator of sleep.

Chronotype is the internal circadian rhythm or body clock of an individual that influences the cycle of sleep and preferred timing of activity in a 24-hour period. When one claims to be more of a morning person (a lark) or more of an evening person (an owl), one gives an indication of one's chronotype. Prior works have explored the association between sleep and productivity (good reviews can be found in Hafner et al., 2017 and Kajitani, 2021), but the effect of chronotype on labour market outcomes has received little attention. This is an important gap in the literature, since chronotype is associated with preferences for many types of behaviour. Chronotype is associated with important variables that affect wages such as school performance, productivity, health, and prosocial behaviour (Zerbini and Merrow, 2017; Solomon and Zeitzer, 2019). To the best of our knowledge, there is only one previous study (Bonke, 2012) that explores the relationship between chronotype and wages. Bonke utilizes a time-use survey from Denmark and finds a positive effect on wages for morning-types relative to evening-types.

To go beyond the simple association of sleep with wages and identify the mechanisms by which sleep may affect wages, we propose a theoretical framework that combines the human capital model of Becker (1962), the social capital model of Glaeser et al. (2002), and the Grossman health capital model (Grossman, 1972). Our model allows chronotype to affect an individual's accumulation of human, social, and health capital, which in turn affect productivity and wages. The data come from a large population-based cohort survey, the Northern Finland Birth Cohort (1966) (henceforth NFBC1966) (University of Oulu, 1966), which we have linked with detailed annual wage data from the Finnish Tax Administration. In addition to observations on chronotype and sleep

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habits, the NFBC1966 follow-up data collection in 2012 also has extensive observations on socioeconomic characteristics, lifestyle choices, and health behaviours. We use annual wage data from the Finnish Tax Administration, giving us a bias-free observation on wages. Our data are thus ideally suited to study the links between chronotype and human capital, social capital, and health capital, and the resulting association with wages.

Our empirical strategy is to use simple mediation and multiple mediation analysis, allowing us to test for both direct and indirect effects of chronotype on wages. The direct effect gives an estimate of the difference in average wages for two people who are similar in every way except for chronotype. The motivation for estimating the indirect effect comes from the idea that chronotype may be related to an individual's choices in the life course. The indirect effect involves choices made earlier in life, such as education, work experience, and occupations, but also choices made later in life, such as lifestyle, social interaction, and bedtime decisions. The choices made through the life course affect the accumulation of human, social, and health capital. We hypothesize that the indirect effect of chronotype on wages is channelled through our proposed capital constructs.

Our approach to estimating the relationship between chronotype and wages differs from the methods used in Kajitani (2021) and Gibson and Shrader (2018). They address the potential endogeneity problem between sleep and wages by using variation in sunshine duration (Kajitani, 2021) and sunset time (Gibson and Shrader) as instruments for sleep.[1] We argue that chronotype is plausibly exogenous to wages, at least much more so than hours of sleep. Chronotype is known to have a significant genetic component (Barclay et al., 2013). The prevalence of social jetlag[2] (Wittmann et al., 2006) is evidence that while the amount and schedule of sleep may adjust to environmental cues when necessary, there is a tendency to revert to the preferred schedule when given the opportunity (Zerbini et al., 2020); social jetlag is indicative of one's chronotype being more stable than one's reported hours of sleep. Our long-term estimates also rely on the persistence of chronotype. There is strong evidence that, on average, chronotype is at its latest around age 19 and then shifts earlier (Fischer et al., 2017; Merikanto et al., 2015). This implies that evening chronotypes in our sample (observed at age 46) were very likely evening chronotypes at an earlier age. Our estimates of the effects of evening chronotype on wages can therefore be viewed as a lower bound of the true effect.

We present novel evidence that the effects of chronotype on wages are mediated by human capital (years of work experience), social capital (trust), and health capital (self-assessed health). Simple mediation models show an indirect effect of evening chronotype on wages ranging from − 2% per year of work experience to reductions larger than − 7% for poor health outcomes. Even in our full multiple mediation model, later chronotypes are associated with lower average wages, with total indirect effects of − 1% for evening chronotype women and − 4% for evening chronotype men. Poor self-assessed health, which has been shown to be a strong predictor of hospitalizations and mortality and is thus a useful indicator of health status in epidemiological studies (Idler and Benyamini, 1997), shows a significant indirect negative effect for both evening-type men and evening-type women. The indirect negative effect of evening chronotype through accumulated work experience is significant for men only.

The literature on the relationship between sleep and wages is growing. Some works find evidence for causality running from sleep to wages (Kajitani, 2021; Gibson and Shrader, 2018), others find evidence for employment status (Blanchflower and Bryson, 2021) and wages (Ásgeirsdóttir and Ólafsson, 2015; Hamermesh and Pfann, 2022) influencing sleep. We build on this literature by identifying potential mechanisms through which sleep affects wages. Our use of an individual's chronotype as an indicator of sleep is also a long-term measurement. The chronotype questionnaire (see Section 3.2) assesses respondents' inclinations and preferences regarding the timing of sleep and activity. These observations plausibly capture one's long-term behaviour much better than asking for detailed time use over the previous 24 h (the method of the commonly used American Time Use Survey of the Bureau of Labor Statistics, e.g., Hamermesh et al., 2005). Also, our estimate of the long-term effect of chronotype on wages is at the individual level as opposed to the location average level used in Gibson and Shrader (2018).

The remainder of the paper is organized as follows. In Section 2 we present our conceptual framework and our mediation methods. Section 3 discusses the data and measures of our analysis. Section 4 presents results and Section 5 additional analyses. Section 6 offers discussion and implications of our findings. Section 7 concludes.

2. Conceptual framework and methods

2.1. Chronotype and wage-determining factors

There are several mechanisms by which chronotype may impact wages. We concentrate on human capital, health capital, and social capital in exploring this impact. Human capital theory of wages states that earnings in the labour market depend upon the employee's knowledge and skills. Early life-choices markedly affect human capital. Typically, economists measure human capital as accumulated years of schooling and work experience (Becker, 1962; Mincer, 1974). There is some evidence linking chronotype and educational attainment, with some studies finding later chronotypes associated with greater education attainment (e.g., Lane et al., 2016; Antypa et al., 2016; our sample, see Table 3). Leaving school early to enter the labour force may lead to more years of work experience, but these years of experience likely come with a lower wage. Chronotype may also influence an individual's choice of occupation. The disparity of wages across chronotypes might be explained by individuals self-selecting into occupations which fit their chronotype, with non-pecuniary benefits offsetting a lower wage.[3]

We also suggest that chronotype affects wages through health behaviour. Health capital models (Grossman, 1972) present that variations in health and health behaviour affect wages markedly. First, sleep deprivation is an important element for loss of productivity, especially at mid-age. A recent paper (Räihä et al., 2021) shows that work ability is markedly lower for evening chronotype people. In addition, evening chronotype people may not be fully (mentally) functioning at their jobs if their working times are not optimally suited to their chronotype. The optimal time for executing a cognitive task and being most efficient and alert varies from morning to evening person. The later the chronotype, the later are the optimal hours to work. It is almost certain that some people, by choice or other constraint, are not working when their alertness is at its highest level, implying that these individuals' productivity might be lower than for those (similar in other aspects) who are working at their most alert times.

Second, chronotype has been shown to be related to many unhealthy lifestyle choices. There is evidence that evening chronotype people are less physically active, smoke and use alcohol more often than morning type people (e.g., Fabbian et al., 2016; Nauha et al., 2020). It should be also noted that evening chronotype people tend to have more cognitive impairment and mental health complications (Antypa et al., 2016).

[1] Variation in sunshine duration and sunset times are associated with variation in bedtimes but not with later work/school starting times, leading to later sunset times being associated with less sleep.

[2] Social jetlag is the tendency to adjust one's sleep schedule on non-working (non-school) days in an attempt to recover from sleep lost to the misalignment of chronotype with work (school) schedules (Wittmann et al., 2006).

[3] The mechanism would be similar to that in Cobb-Clark and Tan (2011), who show occupational segregation due to non-cognitive skills contributes to wage disparity.

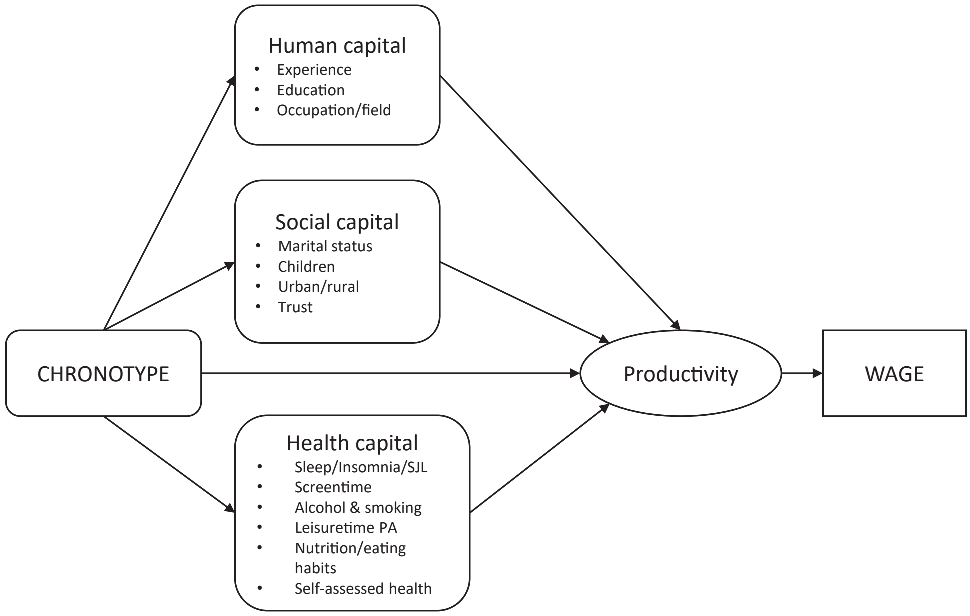

Fig. 1. The proposed relationship between chronotype and wages.

Table 1
Variable names and definitions.

Variable	Definition
Human Capital	
Educ.tertiary	= 1 if completed tertiary education (ISCED 5–8)
Work Exp.	number of years in full-time or part-time work, 1982–2011
Poor worktime control	= 1 if control over hours is somewhat, not much, or very little
Hours40 +	= 1 if hours of paid work per week is greater than 40
Employed 2012	= 1 if in full- or part-time work, either permanently or fixed-term contract
Social Capital	
Married-cohab.	= 1 if married or cohabitating; 0 otherwise
Children at home	= 1 if there are children under 18 living at home
Urban	= 1 if living in metropolitan area
Trust	general willingness to trust others, Likert scale 0 (not at all) to 10 (fully willing)
Health Capital	
High SJL[a]	= 1 if social jetlag > = 1.5 h
Insomnia[b]	= 1 if insomnia (a score of 4 or higher on the AIS-5)
Sleep < 7 h	= 1 if average amount of sleep per night < 7 h
Alcohol g/week	from survey responses about types and quantities of alcoholic drink consumption
Smoker-active	= 1 if regularly smoking on one or more days per week
Low phys. act.	= 1 if leisure time is not spent doing physical activities
BMI-obese	= 1 if BMI > = 30
Screen time	weekday hours of TV or computer at home, upper values winsorized to 7 h
Vegetables infrequently	= 1 if eating fresh or cooked vegetables less frequently than nearly daily
Poor general health	= 1 if current health rated at moderate, poor, or very poor (vs good or very good)
Poor work ability	= 1 if ability to work < = 7 on scale 0 (unable to work) to 10 (highest possible)

Notes: Variable names and brief definitions. [a]) Social jetlag is the difference between the midpoint of time in bed (as measured by a 24-hour clock) on free days and the midpoint of time in bed on workdays (as in Räihä et al., 2021). [b]) AIS-5 is the Athens Insomnia Scale (Soldatos et al., 2003). The cutoff is the same as used in Räihä et al. (2021).

Third, chronotype also markedly affects sleep and bed-time choices. The later someone's chronotype is, the less sleep this individual is likely to get during the normal 8 am to 4 pm working-week. For an evening person, it is hard to get the recommended 7–9 h of sleep during the workweek due to the mismatch between the individual's internal clock and society's social clock (Wittmann et al., 2006). This creates social jetlag for the affected individual implying lower sleeping hours during the workweek. In addition, chronotype reflects preferences for the timing of many types of behaviour. This might lead to non-optimal bed-time choices during weekends.

Social capital also has an important role as a key determinant of an individual's labour market performance. Social capital is a factor that is related to the interdependence of individuals and their interpersonal ties. Its role has been recognized in the economics literature (Glaeser et al., 2002; Karlan, 2005) and public health literature (Kawachi et al., 1997) There is some evidence suggesting that social interaction leads to knowledge and productivity spillovers (Zacchia, 2020). Higher social capital may lead to higher worker productivity (Bandiera et al., 2008). There is also evidence that chronotype affects prosocial behaviour (Solomon and Zeitzer, 2019). A commonly used measure of social capital is trust, and there is evidence that trust behaviour is reduced when making decisions in suboptimal times of the day, e.g., an evening person working in morning hours (Dickinson and McElroy, 2017).

We sketch our conceptual framework in Fig. 1. The framework allows for a direct effect of chronotype on wages. When we use a single-equation OLS framework to test the direct effect of chronotype on wages (a replication of Bonke, 2012; please see Table A1 in the Appendix), we do not find a significant effect for chronotype on wages. This lack of a direct effect of chronotype on wages, combined with evidence of chronotype affecting common factors known to affect wages (see Section 2.1), motivates our use of this framework. While we acknowledge that there may be reverse causality from our presumed mediators to chronotype, or even from wages to the mediators (e.g., Leigh, 2021), the nature of our data precludes tests of causality (all variables except income are observed at a single point in time; no suitable instrumental variable for chronotype).

2.2. Mediation analysis

To test the relationship between chronotype and wages proposed in Fig. 1, we use mediation analysis following the guidelines in Zhao et al. (2010).[4] The simple mediation model is as follows:

[4] Zhao et al. (2010) provide a discussion on the use of the classic mediation model of Baron and Kenny (1986).

Table 2
Descriptive Statistics.

Variable	N (total N = 5020)	MEN Morning (N = 1027)	MEN Intermediate (N = 988)	MEN Evening (N = 216)	WOMEN Morning (N = 1237)	WOMEN Intermediate (N = 1228)	WOMEN Evening (N = 324)
Human Capital							
Avg. wage (1000 s)	5020	43.2	44.9	42.8	33.5	33.6	36.0
Educ.tertiary	2716	0.42	0.50	0.48	0.58	0.62	0.66
Work Exp. in years	5020	22.4(6.30)	22.1(5.93)	21.1(7.39)	19.6(6.05)	18.9(6.31)	19.9(6.23)
Poor worktime ctrl	2684	0.53	0.55	0.58	0.66	0.67	0.70
Hours40 +	1028	0.37	0.32	0.33	0.15	0.14	0.19
Employed 2012	4314	0.85	0.87	0.77	0.89	0.85	0.84
Social Capital							
Married-cohab.	3922	0.81	0.79	0.73	0.80	0.76	0.73
Children at home	2647	0.51	0.52	0.47	0.54	0.55	0.50
Urban	3333	0.62	0.67	0.74	0.64	0.68	0.73
Trust, scale 0–10	4786	6.6(2.35)	6.5(2.33)	5.8(2.72)	6.9(2.13)	7.0(2.02)	6.7(2.34)
Health Capital							
High SJL	1895	0.27	0.41	0.50	0.32	0.48	0.60
Insomnia	1652	0.29	0.35	0.48	0.30	0.36	0.44
Sleep < 7 h	852	0.20	0.22	0.32	0.12	0.13	0.15
Alcohol g/week	5020	89.6	101.3	122.5	37.1	41.4	53.1
Smoker-active	932	0.21	0.22	0.24	0.15	0.16	0.22
Low phys. act.	981	0.16	0.19	0.37	0.16	0.21	0.31
BMI-obese	1014	0.22	0.18	0.26	0.19	0.19	0.27
Screen time in hours	4632	2.8(1.56)	3.1(1.67)	3.5(1.87)	2.5(1.42)	2.5(1.30)	2.8(1.57)
Vegs. infreq.	1348	0.34	0.36	0.47	0.18	0.18	0.28
Poor general health	1477	0.27	0.33	0.49	0.24	0.28	0.42
Poor work ability	672	0.14	0.15	0.27	0.10	0.12	0.21

Notes: Variable means with standard deviations in parentheses. Avg. wage (1000 s) is the average annual wage over 2011–2016 in Euros. For categorical variables, Column 2 shows the total number observations with value = 1. For continuous variables, Column 2 shows the total number of observations for the sample. Values in Columns 3–8 are within the specific gender-chronotype group. Omitted groups may lead to totals less than 100%.

Table 3
Simple Mediation.

Mediator	Men Intermediate Ind.eff.	Men Intermediate p-value	Men Evening Ind.eff.	Men Evening p-value	Women Intermediate Ind.eff.	Women Intermediate p-value	Women Evening Ind.eff.	Women Evening p-value
Human capital								
Educ.tertiary	0.038 * **	< .001	0.032 *	0.055	0.013 * *	0.041	0.029 * **	0.006
Work Exp.(years)	-0.005	0.286	-0.022 * *	0.027	-0.009 * *	0.016	0.004	0.491
Social capital								
Married-cohab.	-0.007	0.333	-0.033 * *	0.016	-0.002	0.141	-0.005 *	0.076
Children	0.006	0.333	-0.011	0.288	0	0.846	-0.063 *	0.053
Urban	0.018 * *	0.023	0.029 * **	0.003	0.006 * *	0.044	0.024 * **	0.003
Trust(0–10)	-0.005	0.254	-0.033 * **	0.002	0.003	0.356	-0.006	0.245
Health capital								
High SJL	-0.010 * *	0.021	-0.014 * *	0.022	0.004	0.15	0.007	0.151
Insomnia	-0.009 * **	0.001	-0.027 * **	< .001	-0.002	0.274	-0.004	0.244
Sleep < 7 h	-0.002	0.436	-0.017 * *	0.01	-0.001	0.446	-0.002	0.148
Alcohol (g/week)	-0.006 *	0.072	-0.015 * *	0.043	0	0.761	-0.001	0.738
Smoker-active	-0.001	0.888	-0.011	0.324	-0.001	0.703	-0.015 * **	0.007
Low phys. act.	-0.004	0.217	-0.032 * **	< .001	-0.006 * **	0.005	-0.018 * **	< .001
BMI-obese	0.001	0.309	-0.002	0.452	0.001	0.77	-0.007 * *	0.023
Screen time	-0.028 * **	< .001	-0.071 * **	< .001	0	0.933	-0.025 * **	0.003
Vegs. infrequently	-0.006	0.332	-0.039 * **	< .001	-0.002	0.66	-0.021 * **	< .001
Poor gen.health	-0.016 * **	0.005	-0.054 * **	< .001	-0.010 * **	0.005	-0.031 * **	< .001
Poor wrk.ability	-0.011	0.101	-0.053 * **	< .001	-0.006	0.131	-0.038 * **	< .001

Notes: Ind.eff. is the indirect effect of intermediate or evening chronotype on ln(mean wage 2011–2016) through the mediator, relative to morning chronotype. We compute the indirect effect of chronotype through each mediator separately using Eqs. (1) and (2) of Section 2.2, separately for men and women. Morning chronotype is the omitted group from the equations. Work Exp., Trust, and Alcohol are continuous with units in parentheses. Other mediators are categorical. * , * *, and * ** represent statistical significance at the 10%, 5%, and 1% levels, respectively. p-values are calculated from bootstrapped standard errors using 5000 replications.

$$\ln(wage_i) = \alpha_1 + \beta_1 Chrono_i + \beta_2 Z_i + e_i \quad (1)$$

$$Z_i = \alpha_2 + \gamma_1 Chrono_i + u_i \quad (2)$$

where $\ln(wage_i)$ is the log of the wage earned by individual *i*, $Chrono_i$ is the individual's chronotype, and Z_i is the proposed mediator.

We run OLS on Eqs. (1) and (2) using R version 4.1.0. The direct effect of chronotype on wages is estimated by β_1. The indirect effect of chronotype on wages through the mediator is calculated by multiplying the coefficients $\gamma_1 * \beta_2$ and the total effect of chronotype on wages is $\beta_1 + \gamma_1 * \beta_2$. The standard errors of the indirect and total effects are bootstrapped using 5000 replications. We calculate the indirect effect, the total effect, and their respective standard errors for all mediators, regardless of the statistical significance of the individual β_1, γ_1, or β_2. Our method for calculating the direct, indirect, and total effects and their respective standard errors is analogous to that used in Han et al.

Table 4
Multiple Mediation.

Panel A. Restricted Model	Intermediate chronotype			Evening chronotype	
	β	p-value		β	p-value
Indirect Effects			Men		
Human cap. (work exp.)	-0.010	0.265		-0.042 * *	0.022
Social cap. (trust)	-0.003	0.287		-0.016 * *	0.015
Health cap. (poor gen. health)	-0.009 * **	0.006		-0.029 * **	< .001
Total indirect effect	-0.022	0.372		-0.087 * **	< .001
Direct effect	0.005	0.862		0.012	0.780
Total effect	-0.017	0.886		-0.075	0.155
Indirect Effects			Women		
Human cap. (work exp.)	-0.010 * **	0.010		0.004	0.490
Social cap. (trust)	0.001	0.370		-0.002	0.281
Health cap. (poor gen. health)	-0.005 * *	0.011		-0.015 * **	< .001
Total indirect effect	-0.014	0.733		-0.013 * *	0.031
Direct effect	0.005	0.775		0.046 *	0.094
Total effect	-0.009	0.917		0.033 *	0.067
Panel B. Full Model					
	Intermediate chronotype			Evening chronotype	
	β	p-value		β	p-value
Indirect Effects			Men		
Human cap. (work exp.)	-0.004	0.289		-0.018 * *	0.029
Social cap. (trust)	-0.001	0.421		-0.005	0.165
Health cap. (poor gen. health)	-0.004 * *	0.022		-0.014 * **	0.004
Total indirect effect	-0.009	0.397		-0.037 * **	0.008
Direct effect	0.002	0.909		0.018	0.593
Total effect	-0.007	0.547		-0.019	0.954
Indirect Effects			Women		
Human cap. (work exp.)	-0.006 * *	0.015		0.003	0.485
Social cap. (trust)	0.001	0.402		-0.002	0.302
Health cap. (poor gen. health)	-0.003 * *	0.016		-0.010 * **	< .001
Total indirect effect	-0.008	0.729		-0.009 * *	0.036
Direct effect	0.016	0.291		0.068 * **	0.005
Total effect	0.008	0.361		0.059 * **	0.005

Notes: The indirect effects are the effect of intermediate or evening chronotype on ln(mean wage 2011–2016) through the mediators, relative to morning chronotype. We compute the indirect effects using Eqs. (3) and (4) of Section 2.2, separately for men and women. Morning chronotype is the omitted group from the equations. The total indirect effect is the sum of the three indirect effects. The total effect is the sum of the total indirect effect and direct effect. In Panel A, the restricted model includes controls for occupations and education. In Panel B, the full model includes controls for occupation, education, poor worktime control, married/cohabitating, children, working more than 40 h per week, urban, and being employed in 2012. * , * *, and * ** represent statistical significance at the 10%, 5%, and 1% levels, respectively. p-values are calculated from bootstrapped standard errors using 5000 replications.

(2011) and that recommended by Zhao et al. (2010).

We first test the various human, social, and health capital mediators individually. The effects of each mediator (e.g., years of work experience) are estimated separately from the other potential mediators, see Table 3 for results.

In the multiple mediation analyses, we use multiple mediators Z_i in the estimation. Formally, the model is

$$\ln(wage_i) = \alpha_1 + \beta_1 Chrono_i + \beta_2 Z_{1,i} + \beta_3 Z_{2,i} + \beta_4 Z_{3,i} + \beta_5 X_i + e_i \quad (3)$$

$$Z_{k,i} = \alpha_k + \gamma_k Chrono_i + u_{k,i} \quad (4)$$

with $k \in [1, 3]$. The direct effect of chronotype is estimated by β_1, as above. We again use OLS and find the indirect effect of chronotype on wages through Z_k by multiplying the coefficients $\gamma_k * \beta_{k+1}$. In this multiple mediation model, we are now able to estimate the total indirect effect of chronotype by summing the indirect effects of each mediator. We are also able to estimate a total effect of chronotype on wages by summing the direct effect and all the indirect effects of chronotype on wages (see Table 4 for results). The standard errors of the indirect and total effects are bootstrapped using 5000 replications.

Despite the relative simplicity of the method, it is the proper way to explore the potential indirect effects of chronotype on wages through our proposed mediators – i.e., to explore the potential mechanisms by which sleep affects wages. We acknowledge that the validity of our results relies on the exogeneity of chronotype to both wages and the other variables in our model. An observation on chronotype from a younger age would allow other methods and provide an opportunity to test for causality, but such data do not exist for our sample. We do not have a suitable instrumental variable satisfying the exclusion restriction. We argue that the genetic component of chronotype (Barclay et al., 2013) and the tendency of chronotype to shift in only one direction after adolescence (evening types may shift to intermediate- or morning types, but it is rarer for morning types to shift to intermediate- or evening types) (Fischer et al., 2017; Merikanto et al., 2015) are strong enough to take chronotype as being plausibly exogenous, thus allowing the use of mediation analysis.

3. Data and descriptive statistics

Table 1 presents brief but concise definitions of the variables used in this analysis. The rest of this section describes our data sources and provides more detail on our measures for chronotype and wages.

3.1. NFBC1966

We employ data from the Northern Finland Birth Cohort 1966 (NFBC1966) to explore the relationship between chronotype and labour market wages. The NFBC1966 is an ongoing longitudinal study, originally consisting of 12,058 live-born children (6169 boys and 5889 girls), 96% of all births in the two northernmost provinces of Finland in 1966. Our observation on chronotype is based on the 46-year follow-up survey conducted in 2012.

3.2. Chronotype and wages

Chronotype is assessed using the short Finnish version of the original Horne-Östberg morningness-eveningness questionnaire (MEQ) (Horne and Östberg, 1976; Urrila and Partonen, 2014; Merikanto et al., 2015). The questionnaire contains six questions, 1) easiness of waking up in the morning, 2) tiredness during the first half hour, 3) anticipated performance in an exercise programme in the morning, 4) desired timing of two-hour physically demanding work, 5) desired timing of five consecutive hours of work (e.g., 7:00–12:00) with pay based on performance, 6) self-rated extent of being a "morning" or "evening" person. Responses are Likert scales (points 1–4 for items #1–4, points 1–5 for item #5 and points 0, 2, 4 or 6 for item #6. The respondents are classified into morning (M), intermediate (I), or evening people (E) based on their total score, using cut-off points previously determined in a Finnish general population study (Merikanto et al., 2015): Evening 5–12; Intermediate 13–18; Morning 19–27.

Table 5
Interaction of chronotype and human, social, and health capital variables.

	Men				Women			
	Intermediate		Evening		Intermediate		Evening	
Moderator	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
Human capital								
Educ.tertiary	0.028	0.627	0.128	0.14	0.007	0.876	0.139 * *	0.022
Work Exp.(years)	0.012 *	0.079	0.013 *	0.095	0.002	0.647	-0.002	0.761
Social capital								
Married-cohab.	0.061	0.479	0.077	0.534	0.129 * *	0.026	0.047	0.556
Children	0.054	0.361	0.025	0.79	0.012	0.789	0.037	0.559
Urban	-0.019	0.734	-0.128	0.162	0.016	0.738	-0.013	0.846
Trust(0–10)	0.011	0.53	0.002	0.903	0.015	0.245	-0.023	0.123
Health capital								
High SJL	-0.067	0.265	0.036	0.709	0.061	0.120	0.211 * **	0.002
Insomnia	0.005	0.935	-0.111	0.26	-0.030	0.484	-0.101	0.141
Sleep < 7 h	0.016	0.84	-0.034	0.745	0.089 *	0.086	0.072	0.471
Alcohol (g/week)	0.0	0.228	0	0.846	0.0	0.871	-0.001 * **	0.005
Smoker-active	-0.023	0.773	0.01	0.932	-0.035	0.634	-0.005	0.948
Low phys. act.	-0.125	0.173	-0.106	0.308	0.092 *	0.082	0.107	0.151
BMI-obese	0.082	0.211	0.114	0.285	-0.006	0.903	0.04	0.576
Screen time	0.001	0.975	-0.018	0.603	-0.002	0.929	0.02	0.492
Vegs. infrequently	-0.031	0.619	0.014	0.885	-0.067	0.322	-0.079	0.289

Note: Coeff. is the coefficient of the interaction term (chronotype x moderator) from Eq. (5) in Section 5.1. We run separate regressions for each moderator. Morning chronotype is the omitted group from the equations. The dependent variable is ln(mean wage 2011–2016). Work Exp., Trust, and Alcohol are continuous with units in parentheses. * , * *, and * ** represent statistical significance at the 10%, 5%, and 1% levels, respectively. p-values are calculated from robust standard errors.

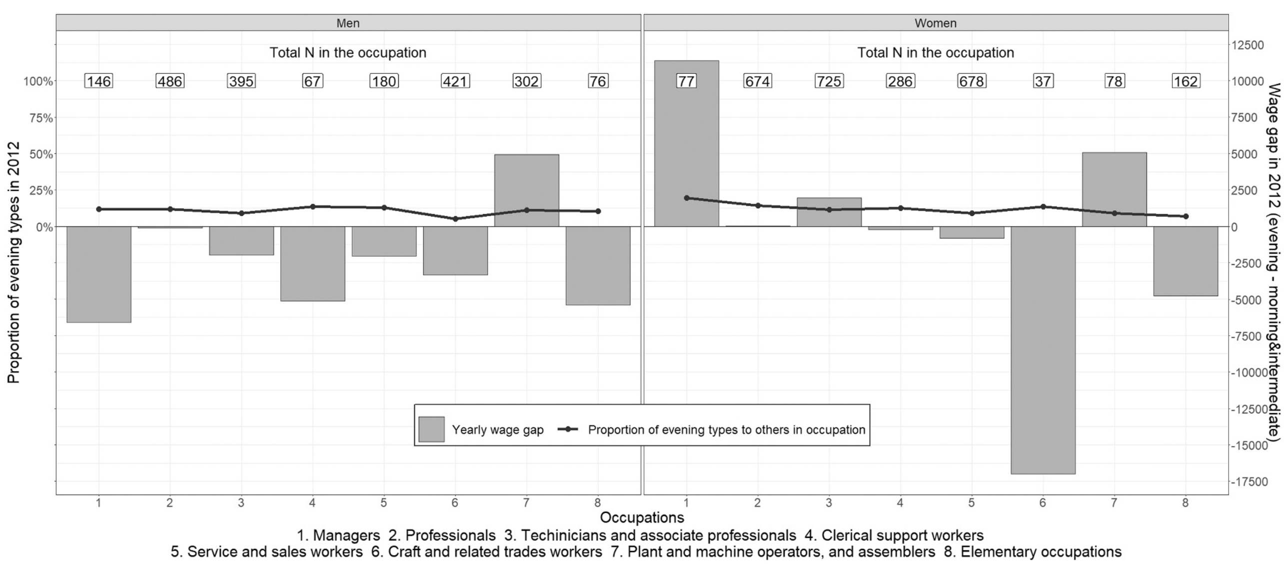

Fig. 2. Occupational wage gaps (2012) for evening chronotypes.

Table 6
Wage difference over time, cohort members vs. national median.

Men	Morning	Intermediate	Evening
N	390	405	89
% of gender-chronotype group in cohort	38.0%	41.0%	41.2%
Mean wage difference 1995	-811 €	-957 €	-1015 €
Mean wage difference 2012	3123 €	1515 €	857 €
Women	Morning	Intermediate	Evening
N	423	477	148
% of gender-chronotype group in cohort	34.2%	38.8%	45.7%
Mean wage difference 1995	-2486 €	-2288 €	-784 €
Mean wage difference 2012	-1545 €	-2049 €	-888 €

Notes: The subsample used for this analysis consists of those individuals who were in the same occupation in both 1995 and 2012. We subtract the national median wage from each individual's wage, matched by gender and occupation. We then find the mean of these differences for years 1995 and 2012 by gender and chronotype.

Wages are obtained from registers of the Finnish Tax Administration.[5] We exclude the self-employed, farmers, and retired persons from our sample due to difficulty with comparing their annual wages to that of wageworkers. To avoid outliers, we exclude individuals with an average annual wage less than 6000€ or greater than 200,000€ over the period 1995–2016.

3.3. *Sample descriptive statistics*

Of the target population of the 46-year follow-up study (alive with an address in Finland; n = 10,321), 7147 (69%) participated in the survey

[5] All work in this study uses annual wage data that has been translated into 2019 constant euro terms. See https://www.stat.fi/til/khi/2019/khi_2019_2020–01–16_tau_001.html (Statistics Finland, 2020). The choice of base year does not affect the results.

Table A1
OLS regression of ln(mean wage 2011–2016) on chronotype and controls.

	(1) Men	(2) Women	(3) Men	(4) Women	(5) Men	(6) Women
Intermed. chronotype	0.023	-0.009	0.051	0.017	-0.006	0.009
	(0.030)	(0.021)	(0.039)	(0.036)	(0.020)	(0.015)
Evening chronotype	-0.017	0.049	0.070	0.068	-0.005	0.053 * *
	(0.048)	(0.033)2	(0.067)	(0.058)	(0.035)	(0.024)
Poor worktime control			-0.227 * **	-0.166 * **		
			(0.031)	(0.027)		
Sleep < 7 h	-0.172 * **	-0.085 * **	-0.129 * **	-0.097 * **	-0.087 * **	-0.063 * **
	(0.037)	(0.025)	(0.025)	(0.022)	(0.022)	(0.020)
Intermed.chrono*poor wrktm ctrl			-0.042	-0.000		
			(0.047)	(0.041)		
Evening.chrono*poor wrktm ctrl			-0.095	0.041		
			(0.084)	(0.065)		
Educ.tertiary					0.299 * **	0.284 * **
					(0.022)	(0.015)
Married-cohab.					0.160 * **	0.026
					(0.029)	(0.017)
Children					0.093 * **	0.033 * *
					(0.021)	(0.014)
Hours40 +					0.242 * **	0.220 * **
					(0.020)	(0.023)
Urban					0.167 * **	0.112 * **
					(0.021)	(0.015)
Building and construction					-0.198 * **	-0.171 * **
					(0.037)	(0.065)
Manufacturing					-0.103 * **	-0.001
					(0.033)	(0.039)
Trade, restaurant, and hotel					-0.244 * **	-0.185 * **
					(0.051)	(0.038)
Public administration and services					-0.145 * **	-0.099 * **
					(0.031)	(0.029)
Other sector					-0.150 * *	-0.256 * **
					(0.076)	(0.058)
Employed 2012					0.484 * **	0.427 * **
					(0.104)	(0.078)
Constant	10.559 * **	10.328 * **	10.777 * **	10.487 * **	9.806 * **	9.746 * **
	(0.020)	(0.014)	(0.026)	(0.024)	(0.112)	(0.086)
N	2225	2783	1916	2455	1900	2429
Adjusted R^2	0.011	0.003	0.080	0.043	0.329	0.274
F-statistic	9.02 * **	3.67 * *	28.74 * **	19.29 * **	67.48 * **	66.51 * **

Note: The dependent variable is ln(mean wage 2011–2016). Intermediate and evening chronotype are indicators, morning chronotype is the omitted group. The models used for this table are near replications of those used in Bonke (2012). Robust standard errors are in parentheses below the coefficients. * , * *, and * ** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

using either a web-based or postal questionnaire. To be included in our final sample, a cohort member needs to have (the number in parentheses is the sample size after applying the filter): permission to use the data (n = 7071); observations for chronotype (n = 6574); status as an employee (not self-employed, farmer, or retiree) (n = 5708); average annual wage between 6000€ and 200,000€ to exclude outliers (n = 5679); and no pension granted during the sample period (n = 5020). This final sample of 5020 has 2231 men and 2789 women.

Table 2 provides descriptive statistics by chronotype and by gender. Evening chronotypes make up 9.7% of the men and 11.6% of the women. Our sample has nearly equal proportions of morning- and intermediate chronotypes for both genders.

For most variables, we see a general trend of evening chronotypes displaying a higher rate of the "worse" outcome. The exception is for the human capital variables, where there is no clear trend. For men, evening chronotypes have a slightly higher average annual wage than morning types but a lower wage than intermediate chronotypes. For women, evening chronotypes have a higher average wage than both morning and intermediate chronotypes. We remind the reader that these are unconditional means for each gender-chronotype group, and we note that there is statistical significance in the mean differences across these groups for women but not for men (one-way ANOVA p-values are for men p = 0.273 and for women p = 0.012).[6] Evening chronotype men achieve a rate of tertiary education higher than morning chronotypes and only slightly below that of intermediate chronotypes. Evening chronotype women have the highest level of education in our sample. Men's average work experience, though, is lower for evening types than both morning and intermediate types, while amongst women, evening chronotypes have the highest average work experience.

With regards to social capital, evening types are less likely to be married, less likely to have children at home, have lower levels of trust,[7] and are more likely to live in an urban area. These trends hold for both men and women.

[6] These absolute mean wage differences might be due to occupational selection, but we find no strong evidence for this. We address the issue of occupational selection in Section 5.2.

[7] We use the response to the standard trust question (see Table 2) as a proxy for social capital. Glaeser et al. (2002) and Karlan (2005) provide evidence that the trust question seems to better capture one's trustworthiness as opposed to one's willingness to trust others. We argue that whether the trust question better measures trust or trustworthiness is of little consequence for our purpose – individuals who are more trusting (or who are more trustworthy) are likely to work better with others and be more productive in the firm, leading them to earn higher wages.

Table A2
Multiple Mediations using Work Ability in place of Poor General Health.

Panel A. Restricted Model	Intermediate chronotype			Evening chronotype	
	β	p-value		β	p-value
Indirect Effects			Men		
Human cap. (work exp.)	-0.009	0.270		-0.040 * *	0.021
Social cap. (trust)	-0.003	0.299		-0.016 * *	0.016
Poor work ability	-0.007	0.123		-0.034 * **	0.003
Total indirect effect	-0.019	0.527		-0.090 * **	0.002
Direct effect	0.002	0.936		0.008	0.837
Total effect	-0.017	0.861		-0.082	0.148
Indirect Effects			Women		
Human cap. (work exp.)	-0.010 * *	0.010		0.004	0.487
Social cap. (trust)	0.001	0.369		-0.002	0.288
Poor work ability	-0.004	0.137		-0.023 * **	< .001
Total indirect effect	-0.013	0.867		-0.021 * *	0.014
Direct effect	0.006	0.749		0.054 * *	0.043
Total effect	-0.007	0.954		0.033 *	0.058
Panel B. Full Model					
	Intermediate chronotype			Evening chronotype	
	β	p-value		β	p-value
Indirect Effects			Men		
Human cap. (work exp.)	-0.004	0.290		-0.017 * *	0.028
Social cap. (trust)	-0.001	0.401		-0.005	0.168
Poor work ability	-0.002	0.190		-0.010 * *	0.025
Total indirect effect	-0.007	0.779		-0.032 * *	0.030
Direct effect	0.004	0.848		0.012	0.712
Total effect	-0.003	0.465		-0.020	0.940
Indirect Effects			Women		
Human cap. (work exp.)	-0.006 * *	0.015		0.003	0.497
Social cap. (trust)	0.001	0.403		-0.002	0.316
Poor work ability	-0.002	0.146		-0.015 * **	< .001
Total indirect effect	-0.007	0.875		-0.014 * *	0.015
Direct effect	0.016	0.278		0.072 * **	0.003
Total effect	0.009	0.379		0.059 * **	0.003

Notes: The indirect effects are the effect of intermediate or evening chronotype on ln(mean wage 2011–2016) through the mediators, relative to morning chronotype. We compute the indirect effects using Eqs. (3) and (4) of Section 2.2, separately for men and women. Morning chronotype is the omitted group from the equations. The total indirect effect is the sum of the three indirect effects. The total effect is the sum of the total indirect effect and direct effect. In Panel A, the restricted model includes controls for occupations and education. In Panel B, the full model includes controls for occupation, education, poor worktime control, married/cohabitating, children, working more than 40 h per week, urban, and being employed in 2012. * , * *, and * ** represent statistical significance at the 10%, 5%, and 1% levels, respectively. p-values are calculated from bootstrapped standard errors using 5000 replications.

The health capital variables show the clearest differences across chronotypes. Our health variables are defined so that higher values indicate a worse outcome. Evening chronotypes of both genders consistently show higher rates of bad health outcomes. There is not one variable for which evening types display better average health outcomes. We find this striking, as our health variables range from those reflecting easily reversible choices (screen time, eating vegetables) to those not easily reversible (BMI, smoking) or possibly not under conscious control (insomnia).

4. Results

4.1. Simple mediation

We start with showing the simple mediation model (Eqs. (1) and (2))

Table A3
Multiple mediations after excluding part-time workers.

Panel A. Restricted Model	Intermediate chronotype			Evening chronotype	
	β	p-value		β	p-value
Indirect Effects			Men		
Human cap. (work exp.)	-0.005 *	0.076		-0.003	0.488
Social cap. (trust)	-0.001	0.379		-0.009 * *	0.044
Health cap. (poor gen. health)	-0.006 * *	0.023		-0.018 * **	0.003
Total indirect effect	-0.012	0.102		-0.030 * **	0.002
Direct effect	-0.010	0.620		0.009	0.771
Total effect	-0.022	0.677		-0.021	0.238
Indirect Effects			Women		
Human cap. (work exp.)	-0.003 *	0.092		0.003	0.213
Social cap. (trust)	0.001	0.292		-0.002	0.272
Health cap. (poor gen. health)	-0.004 * **	0.007		-0.010 * **	< .001
Total indirect effect	-0.006	0.525		-0.009 * *	0.031
Direct effect	0.023	0.103		0.075 * **	0.003
Total effect	0.017 *	0.099		0.066 * **	< .001
Panel B. Full Model					
	Intermediate chronotype			Evening chronotype	
	β	p-value		β	p-value
Indirect Effects			Men		
Human cap. (work exp.)	-0.004 *	0.082		-0.003	0.485
Social cap. (trust)	-0.001	0.551		-0.003	0.351
Health cap. (poor gen. health)	-0.004 * *	0.035		-0.013 * **	0.007
Total indirect effect	-0.009	0.364		-0.019 *	0.084
Direct effect	0.004	0.838		0.023	0.439
Total effect	-0.005	0.628		0.004	0.982
Indirect Effects			Women		
Human cap. (work exp.)	-0.003	0.106		0.003	0.210
Social cap. (trust)	0.001	0.334		-0.002	0.289
Health cap. (poor gen. health)	-0.003 * *	0.015		-0.008 * **	0.003
Total indirect effect	-0.005	0.734		-0.007 *	0.100
Direct effect	0.025 *	0.063		0.067 * **	0.004
Total effect	0.020 * *	0.031		0.060 * **	< .001

Notes: The sample used to produce this table excluded part-time workers. The indirect effects are the effect of intermediate or evening chronotype on ln(mean wage 2011–2016) through the mediators, relative to morning chronotype. We compute the indirect effects using Eqs. (3) and (4) of Section 2.2, separately for men and women. Morning chronotype is the omitted group from the equations. The total indirect effect is the sum of the three indirect effects. The total effect is the sum of the total indirect effect and direct effect. In Panel A, the restricted model includes controls for occupations and education. In Panel B, the full model includes controls for occupation, education, poor worktime control, married/cohabitating, children, working more than 40 h per week, urban, and being employed in 2012. * , * *, and * ** represent statistical significance at the 10%, 5%, and 1% levels, respectively. p-values are calculated from bootstrapped standard errors using 5000 replications. The sample has N = 4072 observations (1849 men; 2223 women).

results in Table 3.[8] We compute the mediated effects of chronotype for each mediator individually and separately by gender. Both intermediate and evening chronotype show indirect effects on wages via mediators in all three areas of human, social, and health capital, for both men and women. These indirect effects shown in Table 3 are the average effect (in

[8] In separate analysis replicating models used in Bonke (2012), we find no evidence for a direct effect of chronotype on wages. The OLS estimates replicating Bonke (2012) are presented in the appendix, Table A1.

Table A4
Multiple mediations after excluding part-time workers and overtime workers.

Panel A. Restricted Model	Intermediate chronotype			Evening chronotype	
	β	p-value		β	p-value
Indirect Effects			Men		
Human cap. (work exp.)	-0.007 *	0.064		-0.005	0.370
Social cap. (trust)	-0.001	0.428		-0.008	0.123
Health cap. (poor gen. health)	-0.005 *	0.075		-0.019 * **	0.006
Total indirect effect	-0.013	0.547		-0.032 * *	0.014
Direct effect	-0.024	0.290		0.042	0.265
Total effect	-0.037	0.518		0.010	0.533
Indirect Effects			Women		
Human cap. (work exp.)	-0.002	0.196		0.002	0.274
Social cap. (trust)	0.001	0.218		-0.002	0.303
Health cap. (poor gen. health)	-0.003 * *	0.018		-0.008 * **	0.006
Total indirect effect	-0.004	0.541		-0.008	0.983
Direct effect	0.039 * **	0.004		0.055 * *	0.019
Total effect	0.035 * **	0.005		0.047 * **	0.003
Panel B. Full Model					
	Intermediate chronotype			Evening chronotype	
	β	p-value		β	p-value
Indirect Effects			Men		
Human cap. (work exp.)	-0.007 *	0.069		-0.005	0.379
Social cap. (trust)	-0.001	0.519		-0.005	0.287
Health cap. (poor gen. health)	0.000	0.712		-0.004	0.311
Total indirect effect	-0.008	0.786		-0.014 *	0.077
Direct effect	-0.017	0.417		0.045	0.210
Total effect	-0.025	0.828		0.031	0.984
Indirect Effects			Women		
Human cap. (work exp.)	-0.002	0.199		0.002	0.277
Social cap. (trust)	0.001	0.285		-0.001	0.349
Health cap. (poor gen. health)	-0.003 * *	0.021		-0.007 * **	0.008
Total indirect effect	-0.004	0.513		-0.006	0.794
Direct effect	0.040 * **	0.004		0.055 * *	0.017
Total effect	0.036 * **	0.002		0.049 * **	0.001

Notes: The sample used to produce this table excluded part-time workers and those who worked more than 40 h per week. The indirect effects are effect of intermediate or evening chronotype on ln(mean wage 2011–2016) through the mediators, relative to morning chronotype. We compute the indirect effects using Eqs. (3) and (4) of Section 2.2, separately for men and women. Morning chronotype is the omitted group from the equations. The total indirect effect is the sum of the three indirect effects. The total effect is the sum of the total indirect effect and direct effect. In Panel A, the restricted model includes controls for occupations and education. In Panel B, the full model includes controls for occupation, education, poor worktime control, married/cohabitating, children, working more than 40 h per week, urban, and being employed in 2012. * , * *, and * ** represent statistical significance at the 10%, 5%, and 1% levels, respectively. p-values are calculated from bootstrapped standard errors using 5000 replications. The sample has N = 3021 observations (1183 men; 1838 women).

percentage) on wages for intermediate and evening chronotype through the mediator, relative to morning chronotype.

Under human capital, we find that intermediate and evening chronotypes have a positive indirect effect on wages through education. This effect holds for both men and women. Morning chronotypes of both genders have the lowest level of educational attainment. As higher education is correlated with higher wages, this positive indirect effect of chronotype is not surprising.

The mediated effect of chronotype through work experience is negative, as we find a negative indirect effect on wages for evening-type men. Evening-chronotype men accumulate less work experience, which is associated with lower wages. For women, there is a negative indirect effect for intermediate chronotype but not for evening chronotype.

For the social capital mediators, we find significant negative indirect effects for married/cohabitating and trust for men. The mediated effect of chronotype through urban is positive for both evening and intermediate types of both genders. These results are likely capturing the higher probability of evening- and intermediate chronotypes living in urban areas combined with the overall wage premium urban workers receive relative to workers in rural areas.

Under health capital, for men, the mediated effects evening chronotype through health variables are all negative and significant, except for BMI and smoking. In all cases, evening chronotype men are more likely than morning chronotypes to exhibit the bad health outcomes, and these bad health outcomes are associated with lower wages. Evening chronotype women are also more likely than morning chronotypes to exhibit the bad health outcomes, but the effects of these health outcomes on wages are generally more subdued for women than for men. Only BMI and smoking show larger effects for women than for men amongst evening chronotypes.

4.2. Multiple mediation

To expand on the simple mediation tests, we perform multiple mediation analysis (Eqs. (3) and (4)). To keep the model as simple as possible, we use one proxy for each form of capital: work experience for human capital; trust for social capital; poor general health for health capital. We choose work experience as our proxy for human capital because it is likely a better channel to capture the effect of chronotype throughout adult life. The choice for educational attainment is usually made early in adulthood, with limited changes after starting a career. Work experience in adulthood can vary due to choice (e.g., purposely not seeking employment for a time, family leave), and we seek to capture any effect chronotype might have on these choices. We keep education in the model as a control, due to its clear relevance in determining wages.

Of our four measures of social capital, trust seems to be the best proxy for social capital, and it is least likely to suffer endogeneity problem with respect to wages. While marital status (Einolf and Philbrick, 2014), having children (Offer and Schneider, 2007), and living in an urban environment (Sørensen, 2016) may be related to social capital, there is stronger evidence for trust being a proxy of social capital (Liu et al., 2018). We choose poor general health as the one proxy for health capital, as it is positively correlated with all the poor health outcomes except for High SJL (see Tables A5 and A6 for correlations). Poor general health, in contrast to any one of the individual measures of health behaviour, is also likely to better capture the cumulative effects of poor lifestyle choices throughout adulthood that contribute to one's overall level of health capital at age 46.

The results of these multiple mediation analyses are in the two panels of Table 4. Panel A is a restricted model, using the proxies for each form of capital along with controls for occupation and education. Panel B shows the results of the full model, which uses the same variables as the restricted model while adding controls for poor worktime control, married/cohabitating, children, working more than 40 h per week, urban, and being employed in 2012 (see Table 2 for definitions).

The results of the restricted model in Table 4 Panel A show that evening chronotype has a large and significant negative indirect effect on wages for men, with the effect coming through all three types of capital. The largest indirect effect is through human capital (work experience), contributing to almost half of the total indirect effect. For women, the significant indirect effect of evening chronotype on wages comes through health capital only. There is no direct effect of evening chronotype on wages for men. The total effect (combination of indirect and direct effects) for women is positive and significant at the 10% level,

Table A5
Correlations – Men.

Panel A:										
	Educ. tert.	Work Exp.	P.wrk.ctrol	Hours40 +	Emp.2012	Mar.cohab	Children	Urban		
Work Exp.	**-0.162**									
P.wrk.ctrol	**-0.292**	**0.063**								
Hours40 +	0.00	**0.089**	**-0.123**							
Emp.2012	**0.118**	**0.402**	**0.065**	-0.035						
Mar.cohab	**0.12**	**0.08**	**-0.099**	0.009	**0.15**					
Children	**0.173**	**0.054**	**-0.06**	-0.022	**0.143**	**0.421**				
Urban	**0.23**	**-0.091**	**-0.116**	-0.015	**0.069**	0.016	0.04			
Trust	**0.144**	0.035	**-0.074**	0.02	**0.11**	**0.151**	**0.117**	0.034		
Panel B:										
	Educ. tert.	Work Exp.	P.wrk.ctrol	Hours40 +	Emp.2012	Mar.cohab	Children	Urban	Trust	
High SJL	**-0.176**	**0.07**	**0.151**	-0.003	**0.049**	-0.021	**-0.058**	-0.019	-0.022	
Insomnia	**-0.09**	-0.021	**0.11**	0.007	**-0.07**	**-0.11**	**-0.071**	-0.016	**-0.152**	
Sleep < 7 h	**-0.117**	0.028	**0.05**	0.037	0.004	**-0.06**	-0.012	**-0.055**	**-0.09**	
Alc.g/wk	**-0.061**	0.019	-0.029	0.018	**-0.117**	**-0.069**	**-0.128**	**0.057**	**-0.09**	
Smoker	**-0.248**	-0.028	**0.058**	0.014	**-0.145**	**-0.139**	**-0.149**	**-0.084**	**-0.058**	
L.phys.act.	**-0.083**	-0.023	0.017	0.023	**-0.039**	**-0.06**	-0.037	**0.048**	**-0.045**	
BMI-obese	**-0.053**	-0.03	**-0.051**	0.01	**-0.065**	0.01	-0.03	**-0.069**	-0.039	
Screentime	**-0.124**	**-0.124**	**0.055**	**-0.113**	**-0.257**	**-0.189**	**-0.141**	**0.054**	**-0.126**	
Vegs.infreq	**-0.245**	-0.035	**0.119**	-0.001	**-0.124**	**-0.152**	**-0.126**	**-0.132**	**-0.115**	
P.gen.hlth	**-0.16**	-0.041	**0.099**	-0.026	**-0.15**	**-0.144**	**-0.089**	**-0.085**	**-0.176**	
P.work.ability	**-0.107**	**-0.057**	**0.06**	-0.025	**-0.166**	**-0.064**	**-0.066**	**-0.05**	**-0.141**	
Panel C:										
	High SJL	Insomnia	Sleep < 7 h	Alc.g/wk	Smoker	L.phys.act.	BMI-obese	Screentime	Vegs.infreq	P.gen.hlth
Insomnia	0.036									
Sleep < 7 h	**0.095**	**0.216**								
Alc.g/wk	**0.114**	**0.12**	**0.056**							
Smoker	**0.085**	**0.065**	**0.107**	**0.232**						
L.phys.act.	**0.079**	**0.117**	**0.114**	**0.141**	**0.187**					
BMI-obese	0.019	0.033	0.018	**0.094**	0.012	**0.137**				
Screentime	0.034	**0.129**	**0.116**	**0.17**	**0.19**	**0.205**	**0.098**			
Vegs.infreq	**0.094**	**0.081**	**0.083**	**0.074**	**0.194**	**0.145**	**0.058**	**0.138**		
P.gen.hlth	0.014	**0.22**	**0.076**	**0.142**	**0.196**	**0.278**	**0.211**	**0.184**	**0.154**	
P.work.ability	0.024	**0.21**	**0.086**	**0.133**	**0.096**	**0.148**	**0.12**	**0.143**	**0.098**	**0.40**

Notes: The table shows Pearson correlation coefficients for the subsample of men only. Coefficients in bold are significant at the 5% level. To make the table more visibly appealing, the table is broken into Panels A, B, and C, and the variable names have been abbreviated when necessary.

with the positive direct effect countering the negative indirect effect.

The full multiple mediation model in Table 4 Panel B still shows significant negative indirect effects of evening chronotype on wages for both men and women, but the magnitude of the effects is smaller than in the restricted model due to the additional controls. For evening-type men, the mediated effects through both human and health capital remain significant. For women, the mediated effect comes solely through health capital. The significant positive direct effect of evening chronotype on wages for women is similar to the effect shown in Column 6 of Appendix Table A1. Table A1 also shows that the effect of evening chronotype on wages for women is statistically significant only when we include controls for education and occupation in the model. The overall takeaway is that there is a mediate effect of chronotype on wages, with a stronger effect for evening chronotypes over intermediate types, and the effect is channelled through both health capital (for both men and women) and human capital (for men only).

5. Additional analyses

5.1. Moderation analysis

The results in Sections 4.1 and 4.2 provide evidence of a mediated effect of chronotype on wages, with limited evidence of a direct effect. With a limited direct effect, it is possible that the mediated effects we find could be better modelled through moderation – the interaction of chronotype with our human, social, and health capital variables. We test for interaction effects for each variable individually, with the model having only chronotype, the moderator, and the interaction term as explanatory variables:

$$\ln(wage_i) = \alpha_1 + \beta_1 Chrono_i + \beta_2 Z_i + \beta_3 (Chrono_i \quad x \quad Z_i) + e_i \tag{5}$$

The results are displayed in Table 5. We find limited evidence of significant interaction effects of chronotype with other variables. For men, there are no interaction terms significant at the 5% level. For women, there are a few significant interactions: evening types with education (positive effect); intermediate types with married/cohabiting (positive effect); evening types with high SJL (positive effect) and evening types with alcohol consumption (negative effect). The paucity of significant interaction effects supports our model framework, in that the effect of chronotype on wages is mediated by our human, social, and health capital measures, not moderated by them.

5.2. Occupational selection

We also check if individuals self-select into occupations based on their chronotype. This could affect our results in two ways. First, individuals may self-select into occupations that allow them to work hours that best fit their chronotype, even if these occupations have lower average wages. Second, if evening types are concentrated in only a few occupational sectors, a shock to employment or wages in these sectors could lead to our findings of chronotype affecting wages.

Fig. 2 helps address both these questions. The black line in Fig. 2 shows the proportion of evening chronotype workers in each sector. We see that no one sector has an outsized proportion of evening chronotypes, for either men or women.

The proportion of evening chronotypes lies within a narrow range across all sectors. Fig. 2 also shows the difference in average wages between evening chronotypes and non-evening types in each sector.

Table A6
Correlations – women.

Panel A:

	Educ. tert.	Work Exp.	P.wrk.ctrol	Hours40 +	Emp.2012	Mar.cohab	Children	Urban
Work Exp.	**-0.052**							
P.wrk.ctrol	**-0.147**	-0.006						
Hours40 +	**0.062**	**0.057**	**-0.118**					
Emp.2012	**0.09**	**0.343**	0.036	-0.031				
Mar.cohab	0.021	**-0.055**	-0.013	-0.01	0.021			
Children	**0.153**	**-0.133**	-0.018	0.016	0.028	**0.167**		
Urban	**0.162**	**0.068**	**-0.073**	**0.057**	**0.046**	**-0.134**	-0.023	
Trust	**0.129**	0.014	**-0.069**	0.039	**0.065**	**0.052**	**0.103**	**0.046**

Panel B:

	Educ. tert.	Work Exp.	P.wrk.ctrol	Hours40 +	Emp.2012	Mar.cohab	Children	Urban	Trust
High SJL	**-0.084**	**0.055**	**0.059**	0.016	**0.069**	**-0.044**	-0.032	**0.049**	-0.021
Insomnia	-0.03	0.007	**0.051**	0	-0.003	-0.008	**-0.057**	0.001	**-0.105**
Sleep < 7 h	**-0.096**	**0.038**	0.031	-0.004	0.018	**-0.038**	**-0.094**	0.006	**-0.089**
Alc.g/wk	-0.019	**0.06**	-0.016	0.019	-0.029	-0.019	**-0.055**	**0.072**	-0.026
Smoker	**-0.207**	**0.045**	0.021	-0.019	**-0.077**	**-0.093**	**-0.108**	-0.016	**-0.121**
L.phys.act.	**-0.077**	0.007	-0.007	-0.02	**-0.039**	**-0.064**	-0.008	0.001	**-0.038**
BMI-obese	**-0.065**	0.012	-0.008	-0.012	**-0.05**	**-0.037**	-0.033	**-0.048**	**-0.077**
Screentime	**-0.155**	**0.061**	-0.008	-0.001	**-0.229**	**-0.121**	**-0.147**	0.003	**-0.137**
Vegs.infreq	**-0.144**	-0.02	0.011	**-0.057**	**-0.085**	**-0.052**	-0.026	**-0.063**	**-0.107**
P.gen.hlth	**-0.127**	-0.017	0.037	-0.023	**-0.101**	**-0.057**	**-0.08**	**-0.038**	**-0.17**
P.work.ability	**-0.083**	-0.013	0.029	**-0.052**	**-0.133**	**-0.038**	**-0.05**	-0.035	**-0.131**

Panel C:

	High SJL	Insomnia	Sleep < 7 h	Alc.g/wk	Smoker	L.phys.act.	BMI-obese	Screentime	Vegs.infreq	P.gen.hlth
Insomnia	**0.043**									
Sleep < 7 h	**0.085**	**0.179**								
Alc.g/wk	**0.111**	**0.08**	0.018							
Smoker	**0.123**	0.031	**0.093**	**0.17**						
L.phys.act.	**0.047**	**0.065**	**0.086**	**0.041**	**0.156**					
BMI-obese	**0.05**	0.028	**0.085**	0.016	0.026	**0.202**				
Screentime	0.02	**0.075**	**0.084**	**0.125**	**0.178**	**0.188**	**0.156**			
Vegs.infreq	0.028	**0.073**	**0.04**	0.014	**0.149**	**0.175**	**0.07**	**0.152**		
P.gen.hlth	0.025	**0.213**	**0.097**	**0.079**	**0.151**	**0.253**	**0.232**	**0.161**	**0.136**	
P.work.ability	0.007	**0.155**	**0.047**	0.034	**0.063**	**0.107**	**0.092**	**0.124**	**0.116**	**0.364**

Notes: The table shows Pearson correlation coefficients for the subsample of women only. Coefficients in bold are significant at the 5% level. To make the table more visibly appealing, the table is broken into Panels A, B, and C, and the variable names have been abbreviated when necessary.

While evening chronotypes have lower average wages in most sectors, the difference in mean wages between evening types and morning types is not statistically significant at the 5% level for any sector.[9] The higher average wages of evening chronotype *Managers* (sector 1 in Fig. 2) amongst women is likely due to a few exceptional cases, as there are only 14 women with evening chronotype in this sector. Evening chronotype women in the sector *Technicians and associate professionals* (sector 3) have higher average wages than non-evening types, but the opposite is true for men. For the occupation *Plant and machine operators, and assemblers*, evening chronotypes of both genders have higher average wages than morning and intermediate chronotypes. Despite the higher average wage evening types earn in this sector, the sector is not drawing a higher percentage of evening chronotype individuals. Thus it does not seem to be the case that evening chronotypes self-select into lower-wage occupations, nor does it seem that evening chronotypes are concentrated in sectors that may have suffered shocks to employment or wages. The significant positive direct effect of evening chronotype on wages for women is possibly related to education and occupational choice (as presented in Table 4 and Table A1), but we are unable to clearly identify the relationship in our data. We highlight this incongruity to help future research.

5.3. Wage changes over time

Our main results in Tables 3 and 4 use the log of average annual wages over the period 2011–2016. This provides a much longer-term analysis than any used in the literature to date. We now take an even longer-term view. For each individual who was in the same occupation in both 1995 and in 2012, we find the difference between the individual's annual wage and the national median wage, matching by gender and occupation (using the same occupational categories as in Fig. 2). We calculate this for years 1995 and 2012 and summarize by gender and chronotype. Table 6 shows the results.

The lower wage for NFBC66 cohort members relative to the national median in 1995 can be partly explained by two things not related to chronotype. A large portion of the Finnish population lives in the Helsinki region, where wages are higher than the Oulu and Lapland regions. Also, in 1995 at the age of 29, the cohort members are younger than the average worker while in 2012 at the age of 46, the cohort members are older than the average worker; the locations and the age discrepancy explain at least part of the difference in wages. The main takeaway from the table, however, is the relative performance of evening chronotypes compared to earlier chronotypes. Evening chronotype men, despite seeing an increase in annual wages relative to the respective national median wage, show the smallest increase of the three chronotypes. Evening chronotype women fare worse, relative to the national median. Morning and intermediate chronotype women made up ground relative the national median wage while evening chronotype women actually lost ground relative to the national median wage from 1995 to 2012. This is a somewhat crude test, but it shows the long-term challenges evening chronotypes have faced in the labour market relative to earlier chronotypes.

[9] Evening chronotype women in the craft and related trades sector earn less than morning- and intermediate chronotypes at the 10% statistical significance level (p-value = 0.07).

6. Discussion

This large general population-based study explores the extent to which chronotype is associated with wages. The motivation for the paper is, firstly, the hypothesis that chronotype may operate through choices in the life course that in turn are related to wage gaps across chronotypes at mid-age, and secondly that the literature is lacking a multi-year test of chronotype on wages. We show that evening chronotypes accumulate less human, social, and health capital, which in turn are negatively associated with wages. The association is especially apparent in men. In our full model specification, the mediated effects of evening chronotype on average wages are − 1.8% through work experience and − 1.4% through poor general health. The total mediated effected of chronotype on average wages is − 3.7%. Our main finding is that evening chronotype is an important factor related to wages in the long-term, with more evidence for a mediated effect in men than in women.

The novelty of our findings is our identification of the potential mechanisms through which chronotype is related to wages. We show that chronotype is associated with an individual's behaviour, which in turn has a powerful impact on wages in mid-age. The two main channels through which the effect of evening chronotype are poor health behaviour choices and reduced work experience. Unsurprisingly, we find that evening chronotype is associated with the poor sleep outcomes of insomnia and sleeping less than 7 h per night. But we also find the choice of low physical activity in leisure time, higher alcohol consumption, and poor eating habits are more common for evening chronotypes than for morning chronotype individuals.

The main implication of our study is that evening chronotype is poorly suited for current labour markets. The typical 8 am to 4 pm workday is not optimal for evening chronotype individuals, as they would not be working during their most productive hours of the day. This mismatch between chronotype and typical work schedules is associated with lower work ability and an increase in disability pensions (Räihä et al., 2021). The optimal policy response would be more flexibility in working hours but mandating flexible working hours is clearly not feasible in all occupations.

The strength of this study is that it is based on a large, population-level sample with individuals employed in a wide range of Finland's economy and occupations. The NFBC1966 cohort has maintained a high participation rate in follow-up studies, including a participation rate of almost 70% for the 2012 follow-up that we use in this paper. In addition, the sample data is linked with highly accurate and reliable Finnish national register data on income. This allows us to highlight the importance of chronotype in many lifetime choices individuals have made and how they are associated with wages at mid-age.

This study also comes with some limitations. First, much of our data is collected via questionnaires. The use of self-reported information may lead individuals to overstate or understate their true lifestyle behaviour, especially related to health choices. To alleviate this bias, the questionnaires include qualitatively different questions inquiring both frequencies of behaviours and more general opinions. A second limitation is that the study observes the chronotype only at a single point in time, when participants are 46 years old. While evening chronotypes at age 46 are highly likely to have been evening chronotypes at younger ages, we cannot be as certain that morning and intermediate chronotypes observed at age 46 were of the same chronotype at younger ages. This is because chronotype is generally earlier when we are children, reaches its peak lateness around 19 years of age, and begins gradually to become earlier again as adolescence ends and we grow older (Fischer et al., 2017). As we focus on associations of evening chronotypes and work productivity, the conclusions made for evening people in our study are well-founded. However, the single observation on chronotype precludes the use of difference-in-differences or regression discontinuity models, leaving us unable to make claims about causal effects of chronotype on wages. We also acknowledge that it is possible for there to be reverse causality between our presumed mediators and chronotype; for example, depression or other health issues could to some extent lead to responses on the MEQ questionnaire that are similar to those of evening chronotype. A third limitation is that our results are based on within-country data for Finland, making the results' external validity somewhat limited. A fourth limitation is that chronotype might be correlated with some unobservable individual attributes, such as personality traits, risk preference and time preference, which may affect productivity and, hence, also wages.

In future work, we would like to better understand how chronotype affects actual work performance. It is evident that suboptimal sleep leads to failure by workers as presented in Mullainathan (2014). Additionally, suboptimal sleep likely leads to bad choices in other aspects of household economics, especially when optimal decision making requires significant cognitive effort. A deeper analysis of the effects of chronotype on health behaviour choices, such as eating habits, may help to understand the obesity epidemic, as suggested in Asgeirsdottir and Zoega (2011). Further research in this area should be encouraged.

7. Conclusions

We use population-based data from the Northern Finland Birth Cohort (1966) and show that evening chronotype has a mediated effect on wages for mid-age people. The negative effect of chronotype on wages is mediated by human, social, and health capital constructs, with most of the effect being mediated by health capital measures. Evening chronotype is associated with adverse health outcomes, which in turn are associated with lower wages. Our results are important, as a significant portion of the population is of evening chronotype, with many of these individuals not working during their most productive period of the day.

CRediT authorship contribution statement

Andrew Conlin: Conceptualization, Methodology, Writing - Original Draft, Writing - Review & Editing. Iiro Nerg: Methodology, Software, Visualization, Writing - Review & Editing. Leena Ala-Mursula: Conceptualization, Methodology, Writing - Review & Editing. Tapio Räihä:Conceptualization, Methodology, Writing - Review & Editing. Marko Korhonen:Conceptualization, Methodology, Writing - Original Draft, Writing - Review & Editing.

Data availability

NFBC data is available from the University of Oulu, Infrastructure for Population Studies. Permission to use the data can be applied for research purposes via electronic material request portal. In the use of data, we follow the EU general data protection regulation (679/2016) and Finnish Data Protection Act. The use of personal data is based on cohort participant's written informed consent at his/her latest follow-up study, which may cause limitations to its use. Please, contact NFBC project center (NFBCprojectcenter@oulu.fi) and visit the cohort website (www.oulu.fi/nfbc) for more information.

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Declarations of interest

None.

Appendix

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