EVENING CHRONOTYPE IS ASSOCIATED WITH POOR WORK ABILITY AND DISABILITY PENSIONS AT MIDLIFE – A NORTHERN FINLAND BIRTH COHORT 1966 STUDY

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ABSTRACT

Objectives This is the first general population study to evaluate whether evening chronotypes (E) have poorer work ability (WA) and higher probability for early disability pensions (DP) than morning types (M) in middle age.

Methods Among non-retired individuals (n=5831; 2672 men, 3159 women) of the Northern Finland Birth Cohort 1966, chronotype was determined at the age of 46 years with shortened Morningness-Eveningness Questionnaire (MEQs) in 2012. The outcomes were poor WA in 2012, indicated by scores 0-7/10 of Work Ability Score, and registered emergence of DPs in 2013-2016. Multivariate logistic and Cox regression analyses were separately adjusted for factors related to sleep, health and behaviours, sociodemographic and economic factors, or working times.

Results E-types represented 10% (n=264) of men and 12% (n=382) of women. Compared to M-types, the unadjusted odds ratios with 95% confidence intervals (OR, 95% CI) of poor WA for E-type men and women were 2.24 (1.62 - 3.08) and 2.33 (1.74 - 3.10), respectively. The odds remained statistically significant and approximately two-fold in all separate adjustment models tested. During 2013-2016, 8 (3.0%) E-type men and 10 (2.6%) E-type women were granted DP, which, compared to M-types, represented a higher hazard ratio (HR) that was statistically significant for men (HR 3.12, CI 1.27 - 7.63) and remained significant except when multiple sleep variables or working times were adjusted for.

Conclusions Eveningness appears a previously unrecognised risk factor for poor work ability and early disability. We suggest that individual chronotype be considered in attempts to lengthen work careers.

Key words circadian clock; disability retirement; employment; health; longitudinal cohort study

WHAT THIS PAPER ADDS

What is already known about this subject? Evening chronotypes (E-types) have been shown to have poorer health and their ability to function during standard working hours can be impaired compared to morning chronotypes (M-types). Poor health and functioning represent major risk factors for poor work ability (WA) and pre-term disability pensions (DP). Still, there are no previous studies on the role of chronotype on WA using population-level data, and no previous studies on chronotype in relation to DPs.

What are the new findings? Using population-level data, we measured chronotype and perceived WA of 5831 non-retired individuals at age 46 (year 2012) and followed the emergence of new registered DPs during the next 4 years (2013-16). 72% of E-types worked in day jobs in 2012. Even when adjusted for a wide variety of potential confounders, we found that E-type was associated with double-sized odds of poor WA compared to M-types. E-type men also had a three-fold hazard ratio for receiving DPs during the follow-up in the unadjusted model, although this association was diluted to non-significant when multiple sleep variables or working times were adjusted for.

How might this impact on policy or clinical practice in the foreseeable future? In occupational health practice, we suggest chronotype be taken into account in supporting WA, both at the individual level of health promotion and at the organizational level of planning work schedules. Especially with E-types, the importance of a healthy lifestyle, sleep and suitable working times should be emphasised.

INTRODUCTION

Understanding risk factors for pre-term disability pensions (DP) and poor work ability (WA) is an urgent research priority as there is a serious need to prolong work careers in aging Western societies.[1] Of all origins of work disability,[2] the key criteria for granting disability benefits in the social insurance systems include a health problem as the cause of the disability and the mismatch of an individual's functioning with the demands of work.[3] Evening chronotypes (E) may indeed be at risk for poorer WA and early DP because of known risks for poorer health and because their ability to function during standard morning working hours can be impaired.[4-10]

Chronotype can be described as an individual's diurnal preference for timing of sleep and activities or as a phenotype reflecting the underlying circadian rhythm. The inner clock influences the cycles of sleep, activity, eating, body temperature and hormone excretion in an approximately 24-hour period.[5] Morning types (M) tend to do better early in the morning, evening types (E) later in the evening, while intermediate types (I) have no strong preference. Chronotype is largely genetic but environmental factors (in German: Zeitgebers) such as daylight and the schedules of work, family, or society help in synchronizing the body's internal rhythm with the Earth's 24-hour rotational rhythm.[5,11-12] Despite zeitgebers, the rhythm of M-types prevails earlier and the rhythm of E-types later as compared to overall population.[5,12]

Due to a mismatch between the internal clock and society's social clock, it is harder for late chronotypes to fall asleep early enough to get the recommended 7-9 hours of sleep on standard working days, leading to sleep debt on workdays and catch-up sleep and later rhythm on free days.[12-13] The difference in sleep timing between workdays and free days is called social jetlag (SJL) and it correlates with health problems.[5,12] Compared to early chronotypes, later chronotypes are more likely to have mental and somatic symptoms and illnesses, as well as

unhealthy lifestyles, such as smoking, drinking and sedentariness.[4,5,14] Short and insufficient sleep is common among E-types.[15] In turn, chronic sleep deprivation has been shown to deteriorate health and cognition, potentially hampering productivity at work.[16]

The poorer performance of late chronotypes in the morning hours has been observed in experimental environments concerning cognition, behaviour and physical performance.[6,8-9] In real world settings, later chronotype has been associated with poorer school performance, especially if science-related subjects are examined early in the day.[7,17] Regarding chronotype and work, previous research has concentrated on shift work tolerance without direct focus on WA. With biomarkers, sleep, and performance tests as outcomes, late chronotypes do better on night shifts and worse on morning shifts compared to early types, whereas early chronotypes experience more problems during night shifts.[10,18] We found only one study reporting that chronotype per se was not associated with Work Ability Index (WAI).[19] This cross-sectional industrial company -based study determined chronotype using the Munich ChronoType Questionnaire (MCTQ), differing from the widely used Morningness-Eveningness Questionnaire (MEQ) -based approach.[20-22] To date, there are no studies on chronotype and WA during the standard working hours constituting a “continuous morning shift”, or utilising population-level data, and, importantly, no previous studies on chronotype in relation to disability retirement.

In this study, based on data from the Northern Finland Birth Cohort 1966 Study (NFBC1966) linked with national registers, we hypothesised that E, with proneness for poorer health and decreased functional capacity in the morning, would be associated with poor WA and DP. We further hypothesised that these potential associations could be affected by sleep and work schedule. Our first study question was whether there exists an association between chronotype and poor WA at midlife. Second, we studied whether chronotype would predict the emergence of registered DPs

granted in the next four years. Lastly, we examined if these potential associations were influenced by characteristics of sleep, health and health behaviours, marital status, socioeconomic or employment-related factors including working times.

METHODS

Participants

NFBC1966 is an ongoing general population-based 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. The present study is based on the 46-year survey in 2012 where the chronotype was determined for the first time. By using national unique personal identification numbers, the survey data were linked with register data from the Social Insurance Institution (SII), Finnish Centre for Pensions (FCP), Finnish Tax Administration and Statistics Finland.

Of the target population of the 46-year follow-up study (alive and address in Finland; n=10,321), 6,868 (67%) participated in the survey using either a web-based or postal questionnaire. We included individuals who 1) answered the chronotype questions and 2) belonged to the labour force, i.e., did not report being retired or had not received any form of registered DP in 2012. We excluded individuals who reported sleeping less than 4 or more than 14 hours daily, as suggested previously.[23] This resulted in the final study population of 2672 men and 3159 women (n=5831) at baseline in 2012. During the 4-year follow-up (2013-2016), 84 individuals received a new DP, either fixed-term or permanent, partial or full. During this period, 17 individuals died and 3 of them had been granted a DP.

Chronotype

Developed for epidemiological purposes and translated into several languages, with abbreviated versions, the Morningness-Eveningness Questionnaire (MEQ) correlates with circadian rhythms measured by body temperature.[20-21] We used the shortened (6-item) Finnish version (MEQs) of the original MEQ, inquiring 1) easiness of waking up in the morning, 2) tiredness during the first half hour, 3) anticipated performance in an exercise program in the morning, 4) desired timing of 2-hour physically demanding work, 5) desired timing of all 24 hours of 5 consecutive hours of work which get paid according to the results, 6) self-rated extent of belonging to 'morning' or 'evening' people. Responses were obtained on Likert scales (points 1-4 for items 1-4, points 1-5 for the item 5 and points 0,2,4 or 6 for item 6). Finally, the respondents were classified into M-, I- or E-chronotypes according to their total score (range 6-26) using the cutoff points previously determined in a Finnish general population study (E: up to 12, I: 13-18, M: 19 or more).[15]

Work ability (WA)

In 2012, the respondents rated their current perceived WA on a scale of 0-10, with 0 indicating not being able to work at all and 10 demonstrating lifetime best WA. This Work Ability Score (WAS) is the first item of the Work Ability Index (WAI),[24] and has been shown to strongly reflect the WAI regarding several outcomes, including DPs.[25-26] Thus, WAS is a valid and reliable indicator of WA in epidemiological research. As previously,[27] we dichotomised the scores into good (8-10) vs. poor (0-7) WA.

Disability pensions (DP)

During the 4-year follow-up (2013—2016) of the SII and FCP registers, we identified all new DPs among those who were not retired in 2012. In the Finnish social insurance system, a DP can be granted after an individual's sickness absenteeism has lasted approximately one year, or if the individual's ability to function in relation to the requirements of work has significantly decreased

due to a health reason for over one year, resulting in a fixed term or permanent disability grant. The permanent DP is valid until the statutory retirement age. As any DP is an indication of significantly reduced ability to work, the first registered receipt of any DP (full/partial, permanent/fixed-term) was treated as an outcome. Recurrent decisions were not counted.

Potential covariates

Sleeping habits at 46 years were measured using the following three questions. 1) “At what time do you usually go to bed to get sleep?”, 2) “At what time do you usually get out of bed?” and 3) “How many hours (overnight) do you sleep on average?”. The questions 1 and 2 were asked separately for working days and free days in order to estimate the difference between the midpoint of time in bed (MB) on free days (MBF) and on working days (MBW): ΔMB = |MBF-MBW|. We used ΔMB as a proxy of SJL and dichotomised it at median value.[19] Regarding the average duration of sleep, less than 7 hours was defined as lower than sufficient.[13] We used the Athens Insomnia Scale (AIS-5) to inquire about sleep induction, nocturnal awakenings, morning awakenings, total sleep duration and sleep quality on 4-point Likert scales (0-3),[28] and considered 4 points or more as the cut-off for insomnia.[29]

For health and related behaviours, the participants’ overall ratings of health on a 5-point scale were dichotomised, with ratings below good defined as self-rated poor health, a powerful indicator of both poor health and disability.[30] Body mass index (BMI, weight/squared height, kg/m^2) was classified into normal (under 25), overweight (25-30) and obese (over 30). Smoking habits were dichotomised as current smokers vs not. Consumption of alcohol was calculated from frequencies and amounts per occasion of various types of beverages and categorised into abstinence (0g/week), moderate use (up to 288 g/week for men and 192 g /week for women) and

excessive use (exceeding the aforementioned limits).[31] Leisure time physical activity was estimated from weekly times spent in different activities and categorised as low vs not.[32]

Of family- and work-related factors,[10-11,18,33] we considered the following. Marital status at 46 years was dichotomised as married or cohabiting vs. not. Employment status was classified to three categories: 1) “employed” for those who were in paid employment or self-employed but did not simultaneously belong to other categories; 2) “unemployed”; 3) “other” for homemakers, students or individuals on parental or sabbatical leave. The self-assessed employment histories were dichotomised as continuous (always or mainly worked in permanent contracts) vs discontinuous. The survey-based socioeconomic status was categorised as 1) upper white-collar employee, 2) lower white-collar employee, 3) manual labourer, 4) entrepreneur or farmer or 5) other. Obtained primarily from registers of Statistics Finland and secondarily from the survey, the lifetime highest level of education was classified as basic (9 years), secondary (matriculation examination or vocational education) or tertiary (short-cycle tertiary or university level) education. Individual taxable income in 2012, derived from Finnish Tax Administration, was divided into sex-based tertiles. Regarding working times at 46 years, we categorised the self-reported hours worked as under 40, 41-50 and over 50 hours per week and the work schedule into three categories: day work only (between 6 am to 6 pm), shift work including also evening shifts and shift work including night shifts (including at least 3 hours between 11 pm to 6 am).

Statistical analysis

All analyses were conducted separately for men and women. We first calculated the distributions of categorical variables and means with standard deviations (SD) of continuous variables. The potential covariates, based on the literature, were required to be associated with either chronotype or the outcomes to be included in further models. Cross-tabulation and χ^2-test were

used to test the differences regarding all categorised variables and ANOVA was used for the underlying continuous variables. Next, we used Cox proportional hazards regression, fit with coxph-function from the R package survival,[34] to calculate the hazard ratio (HR) with 95% confidence interval (CI) for receiving a new DP during 2013-16 after reporting poor WA at baseline in 2012. Standard cross-sectional logistic regression was then used to estimate the odds ratios (OR) with 95% CIs of poor WA by chronotype, adjusting separately for each group of variables as related to 1) sleep 2) health and health behaviours, 3) marital status, 4) employment-related socioeconomic factors, 5) working times, and finally for 6) all covariates simultaneously. Lastly, with analogous adjustments, we used Cox regression to examine the association between chronotype in 2012 and DPs during 2013-2016. The 14 individuals who died during the follow-up without a preceding DP were considered censored in all Cox regressions. Since only the year of death was known, an actuarial assumption was applied, and the date of death was set to the 1st of July of the given year. We used R version 4.0.2 for all analyses.[35]

RESULTS

As shown in table 1, E-types represented minorities among both sexes. The proportions of M-, I- and E-types, respectively, were 46%, 44% and 10% among men and 44%, 44% and 12% among women. Compared to earlier chronotypes, E-types had worse ratings in every variable related to sleep and health, in at least one, if not both sexes. E-types reported more often short sleep, insomnia and high SJL. Expressed in minutes, the mean(SD) SJLs in M-, I- and E-types, respectively, were 71(47), 90(52) and 101(69) among men ($p<0.001$) and 79(45), 94(48) and 110(61) among women ($p<0.001$). Most of the sociodemographic, economic and work-related factors varied by chronotype except employment history and taxable income in 2012. Compared to M-types, E-types more often lacked a spouse or employment. Among women, E-types had higher education

and occupational socioeconomic status. Although shift work including night shifts was more common with E-types than with other chronotypes, the vast majority of any chronotype (even about 70% of E-types) worked in day jobs in 2012.

Table 1. Descriptives. Prevalence (N, %) of covariates by chronotypes in men and women.

	Total	**Men, N= 2672**				**Women, N= 3159**			
		Morning	Intermediate	Evening		Morning	Intermediate	Evening	
	N=5831	N=1222	N=1186	N=264	p value[a]	N=1392	N=1385	N=382	p value[a]
Social jetlag	5599				< 0.001				< 0.001
Low (below or at median)		781 (66.4)	563 (49.5)	104 (41.4)		771 (57.3)	578 (43.8)	124 (33.5)	
High (over median)		395 (33.6)	574 (50.5)	147 (58.6)		574 (42.7)	742 (56.2)	246 (66.5)	
Avg. sleeping hours	5831				< 0.001				0.239
7h or more		965 (79.0)	929 (78.3)	180 (68.2)		1216 (87.4)	1198 (86.5)	321 (84.0)	
Below 7h		257 (21.0)	257 (21.7)	84 (31.8)		176 (12.6)	187 (13.5)	61 (16.0)	
Insomnia	5659				< 0.001				< 0.001
No		836 (70.8)	738 (64.7)	132 (51.2)		956 (70.2)	859 (63.6)	207 (56.1)	
Yes		344 (29.2)	402 (35.3)	126 (48.8)		405 (29.8)	492 (36.4)	162 (43.9)	
General health	5802				< 0.001				< 0.001
Good		876 (72.3)	769 (64.9)	134 (51.3)		1045 (75.5)	972 (70.5)	216 (56.8)	
Poor		336 (27.7)	416 (35.1)	127 (48.7)		340 (24.5)	407 (29.5)	164 (43.2)	
Body mass index (kg/m²)	5765				0.244				0.007
Under 25		361 (29.9)	376 (31.9)	81 (30.8)		721 (52.4)	643 (47.3)	180 (47.2)	
25-30		616 (51.0)	595 (50.5)	121 (46.0)		429 (31.2)	478 (35.2)	116 (30.4)	
Over 30		231 (19.1)	208 (17.6)	61 (23.2)		225 (16.4)	238 (17.5)	85 (22.3)	
Low physical activity	5801				< 0.001				< 0.001
No		1009 (83.2)	931 (79.4)	164 (62.1)		1160 (83.6)	1085 (78.5)	262 (68.8)	
Yes		204 (16.8)	241 (20.6)	100 (37.9)		228 (16.4)	298 (21.5)	119 (31.2)	
Alcohol (grams/week) by sex	5320				0.030				0.062
Abstainer (0/0)		1 (0.1)	1 (0.1)	1 (0.4)		7 (0.6)	6 (0.5)	1 (0.3)	
Moderate (up to 288/192)		1053 (93.9)	1025 (94.0)	221 (88.8)		1215 (97.0)	1213 (96.8)	333 (94.3)	
Excessive (over 288/192)		68 (6.1)	64 (5.9)	27 (10.8)		31 (2.5)	34 (2.7)	19 (5.4)	
Current smoker	5764				0.114				0.026
No		958 (79.2)	914 (78.1)	193 (73.4)		1155 (84.0)	1139 (83.4)	298 (78.2)	
Yes		251 (20.8)	256 (21.9)	70 (26.6)		220 (16.0)	227 (16.6)	83 (21.8)	
Marital status	5816				0.019				0.004
Married or cohabiting		992 (81.6)	937 (79.1)	196 (74.2)		1111 (80.1)	1058 (76.4)	278 (72.8)	
Not married or cohabiting		223 (18.4)	247 (20.9)	68 (25.8)		276 (19.9)	326 (23.6)	104 (27.2)	
Employment status	5645				0.007				0.033
Employed		1069 (90.4)	1060 (91.8)	220 (88.4)		1238 (91.4)	1191 (89.3)	320 (86.5)	
Unemployed		80 (6.8)	84 (7.3)	25 (10.0)		67 (4.9)	69 (5.2)	26 (7.0)	
Other		33 (2.8)	11 (1.0)	4 (1.6)		50 (3.7)	74 (5.5)	24 (6.5)	
Employment history	5635				0.135				0.120
Continuous		950 (80.3)	912 (78.8)	186 (74.7)		1000 (73.9)	962 (72.8)	255 (68.5)	
Discontinuous		233 (19.7)	245 (21.2)	63 (25.3)		353 (26.1)	359 (27.2)	117 (31.5)	
Highest degree of education	5831				0.007				0.040
Basic		53 (4.3)	50 (4.2)	13 (4.9)		24 (1.7)	21 (1.5)	8 (2.1)	
Secondary		686 (56.1)	586 (49.4)	126 (47.7)		594 (42.7)	536 (38.7)	133 (34.8)	
Tertiary		483 (39.5)	550 (46.4)	125 (47.3)		774 (55.6)	828 (59.8)	241 (63.1)	
Sosioeconomic status	5634				0.408				0.004
Upper white collar		233 (19.7)	271 (23.6)	59 (23.7)		211 (15.6)	237 (17.8)	82 (22.0)	
Lower white collar		168 (14.2)	170 (14.8)	31 (12.4)		298 (22.1)	290 (21.8)	83 (22.3)	
Manual worker		546 (46.2)	482 (41.9)	106 (42.6)		681 (50.4)	624 (46.9)	147 (39.4)	
Entrepreneur or farmer		198 (16.8)	194 (16.9)	46 (18.5)		115 (8.5)	118 (8.9)	37 (9.9)	
Other		36 (3.0)	32 (2.8)	7 (2.8)		46 (3.4)	62 (4.7)	24 (6.4)	
Taxed income (€/2012) by sex	5831				0.157				0.072
Tertile 1 (ad 29566/24623)		414 (33.9)	379 (32.0)	97 (36.7)		487 (35.0)	435 (31.4)	130 (34.0)	
Tertile 2 (ad 44093/33756)		418 (34.2)	399 (33.6)	72 (27.3)		470 (33.8)	470 (33.9)	112 (29.3)	
Tertile 3 (over 44093/33756)		390 (31.9)	408 (34.4)	95 (36.0)		435 (31.2)	480 (34.7)	140 (36.6)	
Working hours per week	5085				0.145				0.001
Under 40h		608 (57.5)	640 (61.2)	129 (59.2)		1012 (82.3)	1008 (83.9)	262 (78.7)	
41h - 50h		334 (31.6)	279 (26.7)	60 (27.5)		189 (15.4)	154 (12.8)	49 (14.7)	
51h or more		116 (11.0)	126 (12.1)	29 (13.3)		29 (2.4)	39 (3.2)	22 (6.6)	
Work schedule	5050				< 0.001				< 0.001
Day work (between6am-6pm)		899 (85.9)	829 (79.9)	151 (69.9)		987 (80.5)	927 (77.8)	242 (73.1)	

Also evenings	93 (8.9)	107 (10.3)	24 (11.1)	184 (15.0)	187 (15.7)	54 (16.3)
Also night shifts (>3hours between 11pm-6am)	55 (5.3)	102 (9.8)	41 (19.0)	55 (4.5)	78 (6.5)	35 (10.6)

[a] Chi-squared test was used to test the differences.

Figure 1 presents the distribution of chronotype (MEQs) scores in association with the corresponding mean (SD) WAS (range 0-10), showing a decreasing trend of WAS along increasing lateness of chronotype. For the categorised M-, I- and E-types, respectively, the mean(SD) WAS was 8.6(1.4), 8.4(1.4), 8.0(1.7) in men ($p<0.001$) and 8.7(1.3), 8.5(1.4), 8.1(1.8) in women ($p<0.001$).

As shown in table 2, approximately every fourth man and woman (28% and 24%, respectively) with E-type had poor WA at the age of 46 years, significantly more often than with other chronotypes. During the 4-year follow-up, 3.0% of E-type men (n=8) and 2.6% of E-type women (n=10) were granted a new DP. The corresponding proportions among I-types and M-types were 1.0% among men and 1.5% among women. Except SJL, all covariates were associated with either poor WA or emerging DPs for at least one of the sexes.

Table 2. Proportion of individuals with poor work ability (0-7/10) in 2012 and emergent disability pensions during 2013-16 (N, %) by chronotypes and potential baseline covariates in men and women.

		Poor WA (0-7/10) in 2012, N (%)					**Disability pension in 2013-2016, N (%)**			
	Total	**MEN**		**WOMEN**			**MEN**		**WOMEN**	
	N	442 (17.1)	p[a]	433 (14.2)	p[a]	Total	32 (1.2)	p[a]	52 (1.7)	p[a]
Chronotype	5640		< 0.001		< 0.001	5831		0.016		0.282
Morning		173 (14.7)		162 (11.9)			12 (1.0)		21 (1.5)	
Intermediate		200 (17.3)		182 (13.7)			12 (1.0)		21 (1.5)	
Evening		69 (27.8)		89 (24.0)			8 (3.0)		10 (2.6)	
Social jetlag	5419		0.826		0.977	5599		0.276		0.621
Low (below or at median)		237 (17.0)		200 (14.0)			14 (1.0)		26 (1.8)	
High (over median)		188 (17.4)		212 (14.0)			16 (1.4)		24 (1.5)	
Avg. sleeping hours	5640		< 0.001		0.003	5831		0.433		0.039
7h or more		302 (15.1)		356 (13.4)			23 (1.1)		40 (1.5)	
Below 7h		140 (24.1)		77 (19.0)			9 (1.5)		12 (2.8)	
Insomnia	5478		< 0.001		< 0.001	5659		0.002		0.054
No		181 (11.0)		196 (10.0)			12 (0.7)		27 (1.3)	
Yes		241 (28.6)		227 (22.1)			18 (2.1)		24 (2.3)	
General health	5613		< 0.001		< 0.001	5802		< 0.001		< 0.001
Good		107 (6.2)		116 (5.4)			11 (0.6)		22 (1.0)	
Poor		330 (39.5)		313 (35.5)			20 (2.3)		30 (3.3)	
Body mass index (kg/m²)	5582		< 0.001		< 0.001	5765		0.191		0.032
Under 25		107 (13.5)		171 (11.4)			9 (1.1)		26 (1.7)	
25-30		198 (15.4)		140 (14.1)			13 (1.0)		10 (1.0)	
Over 30		132 (27.7)		111 (21.1)			10 (2.0)		15 (2.7)	
Low physical activity	5611		< 0.001		< 0.001	5801		0.052		0.244
No		280 (13.8)		294 (12.1)			21 (1.0)		38 (1.5)	
Yes		160 (30.5)		137 (21.9)			11 (2.0)		14 (2.2)	
Alcohol (grams/week) by sex	5145		< 0.001		0.003	5320		0.013		0.452

Abstainer (0/0)		1 (33.3)		0 (0.0)		0 (0.0)		0 (0.0)	
Moderate (under 288/192)		349 (15.7)		355 (13.3)		25 (1.1)		44 (1.6)	
Excessive (over 288/192)		57 (37.7)		20 (25.3)		6 (3.8)		0 (0.0)	
Current smoker	5577		< 0.001		< 0.001	5764	< 0.001		0.418
No		298 (14.9)		332 (13.2)		16 (0.8)		41 (1.6)	
Yes		136 (24.7)		97 (19.1)		16 (2.8)		11 (2.1)	
Marital status	5626		0.003		0.031	5816	0.014		0.014
Married or cohabiting		329 (16.0)		318 (13.4)		20 (0.9)		33 (1.3)	
Not		112 (21.6)		114 (16.7)		12 (2.2)		19 (2.7)	
Employment status	5618		< 0.001		< 0.001	5645	< 0.001		< 0.001
Employed		351 (15.0)		333 (12.2)		19 (0.8)		36 (1.3)	
Unemployed		67 (35.8)		54 (33.5)		11 (5.8)		6 (3.7)	
Other		23 (48.9)		40 (27.0)		1 (2.1)		7 (4.7)	
Employment history	5612		< 0.001		< 0.001	5635	0.044		0.005
Continuous		294 (14.4)		267 (12.1)		20 (1.0)		27 (1.2)	
Discontinuous		147 (27.3)		164 (19.9)		11 (2.0)		22 (2.7)	
Highest degree of education	5640		< 0.001		< 0.001	5831	< 0.001		0.059
Primary		34 (30.4)		20 (39.2)		6 (5.2)		1 (1.9)	
Secondary		272 (20.3)		210 (17.2)		21 (1.5)		29 (2.3)	
Tertiary		136 (12.1)		203 (11.3)		5 (0.4)		22 (1.2)	
Sosioeconomic status	5606		< 0.001		< 0.001	5634	0.074		0.080
Upper white collar		44 (7.9)		35 (6.6)		2 (0.4)		5 (0.9)	
Lower white collar		54 (14.7)		77 (11.5)		3 (0.8)		6 (0.9)	
Manual worker		226 (20.1)		229 (15.8)		20 (1.8)		30 (2.1)	
Entrepreneur or farmer		89 (20.4)		45 (16.7)		4 (0.9)		8 (3.0)	
Other		27 (36.5)		40 (30.5)		2 (2.7)		2 (1.5)	
Taxed income (€/2012) by sex	5640		< 0.001		< 0.001	5831	< 0.001		< 0.001
Tertile 1 (< 29566/24623)		228 (27.0)		222 (21.7)		24 (2.7)		33 (3.1)	
Tertile 2 (< 44093/33756)		126 (14.6)		131 (12.8)		6 (0.7)		12 (1.1)	
Tertile 3 (> 44093/33756)		88 (10.1)		80 (7.9)		2 (0.2)		7 (0.7)	
Working hours per week	5064		0.002		0.012	5085	0.414		0.779
Under 40h		206 (15.0)		281 (12.4)		12 (0.9)		31 (1.4)	
41h - 50h		80 (11.9)		35 (9.0)		4 (0.6)		7 (1.8)	
51h or more		57 (21.1)		18 (20.0)		4 (1.5)		1 (1.1)	
Work schedule	5029		0.119		0.456	5050	0.642		0.016
Day work (between6am-6pm)		268 (14.3)		253 (11.8)		16 (0.9)		23 (1.1)	
Also evenings		32 (14.3)		59 (13.9)		3 (1.3)		12 (2.8)	
Also night shifts (>3hours between 11pm-6am)		39 (19.8)		20 (11.9)		1 (0.5)		3 (1.8)	

[a] Chi-squared test was used to test the differences.

Illustrating the relation of the two outcomes and the predictive value of poor WA on consequent DP, the unadjusted risk (HR, 95% CI) of a new DP in 2013-2016 in association with poor WA in 2012 was very high both for men (9.00, 4.31 – 18.79) and for women (7.10, 4.09 – 12.30).

In both sexes, the odds of poor WA were double or more among E-types as compared to M-types, even after adjustments for sleep, sociodemographic and economic factors or working times (table 3). Adjustments for health and behavioural factors slightly attenuated these results. Even in the final model, simultaneously adjusting for all potential covariates, the odds of poor WA in E-type women were twice as high as compared to M-type women. The ORs for I-types were not, as a rule, different from M-types.

Table 3. Odds ratios (OR) and 95% confidence intervals (CI) for poor work ability (0-7/10) in 2012 by chronotypes: unadjusted, adjusted separately for each group of variables, lastly simultaneously for all. Logistic regression.

		Men			Women		
	Chronotype	Cases/Total	OR	(95% CI)	Cases/Total	OR	(95% CI)
Model 1: unadjusted		442/2579			433/3061		
	Morning		1			1	
	Intermediate		1.22	(0.98 - 1.52)		1.17	(0.93 - 1.46)
	Evening		2.24	(1.62 - 3.08)		2.33	(1.74 - 3.10)
Model 2: adjusted for sleep[a]		407/2393			403/2878		
	Morning		1			1	
	Intermediate		1.14	(0.90 – 1.45)		1.16	(0.91 – 1.47)
	Evening		1.98	(1.39 – 2.80)		2.19	(1.60 – 2.98)
Model 3: adjusted for health and behaviours[b]		389/2304			358/2695		
	Morning		1			1	
	Intermediate		1.03	(0.79 – 1.34)		1.15	(0.88 – 1.50)
	Evening		1.59	(1.08 – 2.32)		1.81	(1.26 – 2.52)
Model 4: adjusted for employment related socioeconomic factors[c]		438/2557			419/3004		
	Morning		1			1	
	Intermediate		1.30	(1.03 – 1.64)		1.21	(0.95 – 1.53)
	Evening		2.36	(1.68 – 3.30)		2.49	(1.84 – 3.37)
Model 5: adjusted for marital status		441/2571			432/3055		
	Morning		1			1	
	Intermediate		1.21	(0.97 – 1.52)		1.16	(0.92 – 1.46)
	Evening		2.18	(1.57 – 3.00)		2.29	(1.71 – 3.06)
Model 6: adjusted for working times[d]		339/2287			331/2733		
	Morning		1			1	
	Intermediate		1.20	(0.93 – 1.55)		1.14	(0.88 – 1.47)
	Evening		2.09	(1.44 – 3.00)		2.06	(1.47 – 2.86)
Model 7: fully adjusted[e]		277/1900			258/2257		
	Morning		1			1	
	Intermediate		0.98	(0.71 - 1.35)		1.28	(0.93 - 1.76)
	Evening		1.51	(0.94 - 2.41)		2.05	(1.34 - 3.12)

a: adjusted for social jetlag (SJL), insomnia and average nightly sleep duration
b: adjusted for body mass index (BMI), smoking, alcohol, physical activity and general health
c: adjusted for employment status, employment history, socioeconomic status, education and income 2012
d: adjusted for working hours and work schedule
e: adjusted for SJL, insomnia, avg. sleep duration, BMI, smoking, alcohol, physical activity, general health, employment status, employment history, socioeconomic status, education, income 2012, marital status, working hours and work schedule

Table 4 shows that for the E-type men, the unadjusted risk of DP during the 4-year follow-up was more than three-fold (HR 3.12, 95% CI 1.27 - 7.63) when compared to M-types. Following the

same adjustment strategy as with WA in table 3, the result among men remained significant with only slightly smaller figures when health and behaviours or sociodemographic and economic factors were adjusted for. However, the association was diluted to non-significant when multiple sleep variables or working times were taken into account, and also in the fully adjusted model. In additional analyses, adjusting for the three sleep measures separately did not dilute the aforementioned result to non-significant (HRs ranging from 2.76 to 3.04, lower limits of CIs 1.07 to 1.24), whereas the two measures of working times diluted the result also when separately adjusted for (HRs 2.63 to 2.88, lower limits of CIs 0.88 to 0.95). In E-type women, no significant associations with DPs were found. Notably though, the non-significantly heightened HRs, varying between 1.4 – 1.8, were reduced to the level of M-types (HR 1.1), when working times were adjusted for.

Table 4. Hazard ratios (HR) and 95% confidence intervals (CI) for disability pension (DP) by chronotypes: unadjusted, adjusted separately for each group of variables, lastly simultaneously for all. Cox regression.

		Men			Women		
	Chronotype	Cases / Total	HR	(95% CI)	Cases / Total	HR	(95% CI)
Model 1: unadjusted		32/2672			52/3159		
	Morning		1			1	
	Intermediate		1.03	(0.46 - 2.29)		1.01	(0.55 - 1.84)
	Evening		3.12	(1.27 - 7.63)		1.75	(0.83 - 3.72)
Model 2: adjusted for sleep[a]		29/2480			49/2964		
	Morning		1			1	
	Intermediate		0.94	(0.4 - 2.2)		0.88	(0.47 - 1.66)
	Evening		2.37	(0.89 - 6.31)		1.74	(0.8 - 3.75)
Model 3: adjusted for health and behaviours[b]		30/2389			43/2773		
	Morning		1			1	
	Intermediate		0.98	(0.42 - 2.27)		0.87	(0.44 - 1.70)
	Evening		2.65	(1.04 - 6.76)		1.44	(0.64 - 3.24)
Model 4: adjusted for employment related socioeconomic factors[c]		31/2570			47/3014		
	Morning		1			1	
	Intermediate		1.12	(0.50 - 2.49)		1.11	(0.59 - 2.10)
	Evening		2.85	(1.10 - 7.35)		1.55	(0.68 - 3.56)
Model 5: adjusted for marital status		32/2663			52/3153		
	Morning		1			1	

	Intermediate		1.00	(0.45 - 2.23)	0.97	(0.53 - 1.78)
	Evening		2.89	(1.18 - 7.08)	1.65	(0.78 - 3.51)
Model 6: adjusted for working times[d]		20/2297			38/2743	
	Morning		1		1	
	Intermediate		0.67	(0.24 - 1.88)	1.07	(0.54 - 2.13)
	Evening		2.81	(0.93 - 8.48)	1.11	(0.41 - 3.06)
Model 7: fully adjusted[e]		17/1906			28/2263	
	Morning		1		1	
	Intermediate		0.54	(0.16 – 1.82)	0.85	(0.37 - 1.93)
	Evening		2.01	(0.52 – 7.68)	0.81	(0.25 - 2.64)

a: adjusted for social jetlag (SJL), insomnia and average nightly sleep duration
b: adjusted for body mass index (BMI), smoking, alcohol, physical activity and general health
c: adjusted for employment status, employment history, socioeconomic status, education and income 2012
d: adjusted for working hours and work schedule
e: adjusted for SJL, insomnia, avg. sleep duration, BMI, smoking, alcohol, physical activity, general health, employment status, employment history, socioeconomic status, education, income 2012, marital status, working hours and work schedule

DISCUSSION

To the best of our knowledge, this is the first population-level study on the association of chronotype with WA and early DP. Based on data from a general population birth cohort in their late forties, we found that E was associated with two-fold odds of poor WA in both sexes and a three-fold risk of DPs in men.

Ability to work is part of overall functional capacity. According to previous literature, the functional capacity of E-types is lower during daytime.[6-10] Our finding of poor WA of E-types is in line with this evidence, since the vast majority of E-types had daytime work. The association between E-type and poor WA is robust, as it withstands adjustments from several different perspectives, including working times, and falls subtly below statistical significance only in our fully adjusted model in men but not in women. In the fully adjusted model, overadjustment is possible. Of covariate categories, health and behaviours attenuated the result the most, but E-types still showed significant disposition towards poor WA.

In terms of the heightened risk of premature DP among E-type men, the effect of the chronotype remained after adjusting for health and socioeconomic factors but was diluted to non-significant when multiple sleep variables or working times were taken into account, providing some support to our hypotheses. Again, the effect of the chronotype decreased the most in the fully adjusted model. In the gendered labour market, more men than women work in strenuous occupations,[27] and highly educated employees are at a reduced risk of DP.[3] The women in our sample being healthier and more highly educated than men may at least partly explain why we found an association of E with disability only in men, not in women, although E was associated with poorer WA in both sexes. In addition, the HR of consequent DP after reporting poor WA was higher among men (9.0) than among women (7.1).

Our findings on the distribution of chronotypes and their associations with covariates were in line with previous literature, including the poorer health and sleep of E-types and some socioeconomic differences. E-types have been shown to have more difficulty in sleeping than others and dissatisfaction with the amount of their sleep. [5,12,15] Like in previous Finnish research,[15] E-types in our sample had higher than average level of education.

Methodologically, an important strength in our design is that it is based on a large general population study covering the total work force with all sectors of economy, socioeconomic classes and occupations. We determined chonotype by MEQs with the cut-off points introduced by Merikanto et al. thus benefiting from previous validation in terms of cultural values and societal settings, general population sample and age frame.[15,20-21] MEQ is also a useful measure in populations where insomnia is common.[15,36] Even though chronotype changes during the life course, it is in a stable plateau stage in both sexes between 40-50 years.[37] Hence, we do not think that chronotype change was a confounder in our four-year follow-up. We used a well-

documented measure for perceived WA, shown to predict future disabilities in previous literature as also in this study. The national register data on both DPs and covariates are reliable and accurate. We used an extensive range of established potential confounders in literature, including a proxy for social jetlag (ΔMB), to account for discrepancies in sleep rhythm.

Our results should be interpreted considering the following limitations. The number of new and indeed early disability pension cases was expectedly small during the four-year follow-up (2013 to 2016, ages 47-50) following the measurement of chronotype (in 2012 at age 46). It is possible that existing health problems in 2012 may have affected both the reporting of chronotype and the risk of subsequent pension. However, the adjustment for self-reported health in 2012 was targeted to capture this potential confounding. As the chronotype was measured for the first time at the age of 46, our findings could be age specific. We cannot study whether chronotype during the earlier phases of careers had already affected work ability and disability. This is possible in light of the well-known healthy worker effect,[38] indicating that the individuals with poorest health - potentially E-types - leave the work force early. Moreover, there has been greater attrition in the study participants among men and among those with lower socioeconomic status, who generally have poorer health. In Finland, office workers typically start working rather early at 8 am and manual workers start even earlier, which may influence the impact of late chronotype on work ability. Finally, unmeasured uncontrolled factors are always possible in an observational study like ours.

Additional longitudinal studies in diverse settings and in different age groups are needed to confirm our results, to study causal mechanisms, and to develop interventions. Utilizing different chronotype measures, more detailed and objective sleep measures, potentially co-occurring personality factors and additional work-related variables including worktime control, as well as

cause-specific disability measures could add value. In occupational health practice, we suggest chronotype be taken into account in supporting WA, both in individual-level health promotion and organisational-level planning of work schedules. Especially with E-types, the importance of a healthy lifestyle, sleep and suitable working times should be remembered. Actions matching the internal and social rhythm, targeted to either the individual, the environment, or both, could help to support careers of E-types.[17,39-40]

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Data availability statement 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, the University follows 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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