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COMPARISON OF THE MUNICH CHRONOTYPE QUESTIONNAIRE WITH THE HORNE-ÖSTBERG'S MORNINGNESS-EVENINGNESS SCORE

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We report on results from an Internet survey of sleeping habits in a Dutch population using the Munich Chronotype Questionnaire (MCTQ), supplemented with the Horne-Östberg Morningness-Eveningness Questionnaire (MEQ). The MCTQ was completed by 5,055 responders, of which 2,481 also completed the MEQ. MEQ score correlated well with the MCTQ assessment of time of mid-sleep on free days (MSF; $r = -0.73$) and on workdays (MSW; $r = -0.61$). MEQ was more strongly correlated with MSF (50% of sleep time) than with sleep onset (0%), rise time (100%), or with any other percentile (10 to 40, 60% to 90%) of sleep on free days. The study shows that chronotype (based on MSF as measured by the MCTQ) strongly correlates with morningness-eveningness (as measured by the MEQ). However, the MCTQ collects additional detailed information on sleep-wake behavior under natural conditions.

Keywords Human chronotypes, Sleep, Survey, Horne-Östberg's Morningness-Eveningness Questionnaire, Munich Chronotype Questionnaire

INTRODUCTION

The sleep-wake cycle is the most prominent daily pattern in human behavior. Activity is generally confined to the natural day and early evening, while sleep occupies the remaining hours of the night. There is considerable inter-individual variation in the preferred timing of the

sleep-wake rhythm, with extreme morning and evening types often called 'larks' and 'owls' respectively. The timing of sleep is largely under the control of the central circadian pacemaker, located in the suprachiasmatic nuclei (SCN) of the hypothalamus (Daan et al., 1984). The other major regulatory component of the steady sleep-wake maintenance is the homeostatic component (Daan et al., 1984; Dijk and Czeisler, 1995). Both a stable relationship between endogenous (or internal) and external time as well as a good and well-timed sleep are believed to be essential for human health (Roenneberg et al., 2005; Dijk and Lockley, 2002; Rajaratnam and Arendt, 2001). Systematic investigations of individual circadian phase preferences have been stimulated by the publication of the Morningness-Eveningness Questionnaire (MEQ) by Horne and Östberg (1976). The MEQ score was correlated with core parameters of human circadian organisation, such as sleep timing (Carrier et al., 1997; Andrade et al., 1992; Laberge et al., 2000) and endogenous period (Duffy et al., 2001). The use of the MEQ in inter-individual experiments has enabled consistent segregation of putative 'larks' from 'owls' (Andrade et al., 1992; Duffy et al., 1999; Baehr et al., 2000; Bailey and Heitkemper, 2001). The administration of MEQ in large-scale epidemiological surveys has allowed investigators to probe circadian preference profiles of a variety of subclasses in a population, such as different age groups (Carrier et al., 1997; Laberge et al., 2000; Giannotti et al., 2002; Ishihara et al., 1992), gender (Adan and Natale, 2002), and social and professional groups (Park et al., 1998a, 1998b). The MEQ contains 19 questions aimed at determining when during the daily temporal span the respondent's maximum propensity to be active lies. Most questions are preferential, in the sense that the respondent is asked to indicate when, for example, he/she would prefer to wake up or start sleep, rather than when he/she actually does. Questions are multiple choice, with each answer being assigned a value. Their sum gives a score ranging from 16 to 86, with lower values corresponding to evening types.

A new questionnaire has recently been designed to collect information about the *actual* timing of daily sleep (and activity): the Munich ChronoType Questionnaire (MCTQ) (Roenneberg et al., 2003). It essentially is a tool to collect primary sleep times, such as bed- and rise-times, plus the clock time of becoming fully awake as well as sleep latency and inertia, in addition to other time points (*e.g.*, siesta). The MCTQ also asks the respondents to rate themselves as one of the seven chronotypes (Extreme Early, Moderate Early, Slightly Early, Normal, Slightly Late, Moderate Late, Extreme Late). This particular question thus contains a *relative* judgment, *i.e.*, a judgment on the subject's own behavior in comparison to others. Subjects are also asked to judge their chronotype at different life stages, such as in childhood, adolescence,

etc., which allows an intra-individual assessments of how chronotype changes with age.

The MCTQ asks that all information be specified as precisely as possible relative to the respondents' *present* circumstances, *i.e.*, regardless of what the respondents may consider preferential for themselves. This enables the investigators to draw up a survey of the sleeping habits in a given community, to follow the dynamics of sleep parameters over the seasons or different ages (Roenneberg et al., 2004), to draw conclusions about possible risks of insufficient sleep (and the resulting fatigue), and to suggest ways to improve public services, *etc*. The MCTQ is currently being used in Groningen, Munich, and Basel. A particularly valuable feature of the MCTQ is the separate treatment of work and free days. This division is left at the respondents' discretion, in the sense that they may consider Saturday a workday as long as they work on weekends. The timing of daily activities is obviously different between work and free days, and this difference is greater in later chronotypes (Roenneberg et al., 2003).

It is obvious that individuals will commonly tend to follow their individual preferences as long as they do not conflict with external demands. It is of interest to know the extent to which the MCTQ parameters, reflecting actual behavior, co-vary with the MEQ score, reflecting preferred behavior. Since both the MCTQ and the MEQ aim to quantify 'chronotype' (Roenneberg et al., 2003) and since the latter has been the standard instrument, it is useful to establish how well indices produced by these two questionnaires correlate. This analysis is based on 2,481 respondents who completed both questionnaires during one online session. While conducting separate analyses of parameters contained in the MCTQ, we did not attempt to 'disassemble' the MEQ, and thus restricted our investigation to the calculated overall score (for a principal component analysis of MEQ parameters, see Taillard et al., 2004). We also assessed the extent to which the MCTQ self-ratings are indicative of the tendency of the respondents to be 'evening' or 'morning' types, *i.e.*, how well their perceived notions of being 'larks' and 'owls' agree with the sleep timings they report.

MATERIALS AND METHODS

We created a website (*http://chrono.biol.rug.nl*) on which both MCTQ and MEQ were available for electronic submission. The English text of the MCTQ was translated into Dutch. The translation was validated by back-translating the Dutch version into English by an uninvolved person. After the authors had verified the back-translation, the Dutch version was posted on the site, along with the original English text. The text of the MEQ was also available in both languages (the Dutch version

by Prof. Dr. G. A. Kerkhof, Amsterdam). Since the protocol only required completion of a short questionnaire without intimate questions, our study is not considered to be a medical trial according to the Central Committee on Research Involving Human Subjects (CCMO) in the Netherlands. In such cases approval by the medical ethics committee is not required. Nonetheless we conducted the study and treated the results in compliance with the good practice standards expected by *Chronobiology International* (Touitou et al., 2004).

All students (approximately 20,000) at the University of Groningen were sent an e-mail (containing a link to the MCTQ web page) on May 10, 2003 inviting them to participate in the study. This campaign was also widely advertised via many different channels. Upon submission of their MCTQ questionnaire, respondents automatically received a report (to the supplied e-mail address) containing information on how the subject compares to the rest of the database. The browser window subsequently displayed a page with a further link to the MEQ page for those also interested in completing it. Thus, all respondents to the MEQ also responded to the MCTQ, but not *vice versa*. Responses were checked for consistency before storing data into the database. These checks prevented, for example, wake-up times being earlier than the sleep-onset times, and they ensured that 'time-of-day' fields were within 0 and 24, *etc*. The criteria were selected only to filter out illogical responses while avoiding any constraint on the respondent's possible daily pattern. In the case any of these checks failed, the respondent was given a message stating the error with the request to correct it and to resubmit the form. Less than 0.1% of completed questionnaires were rejected.

From mid-May, 2003 until the end of May, 2004, a total of 5,055 subjects responded, 49% of which ($n = 2,481$) completed both questionnaires (Figure 1A and 1B). All MEQ score-derived correlations in the following sections are based on this sub-sample. Most respondents were university students[1] (for age distribution see Figure 1A), and the rest were Dutch residents, almost without exception.

Statistical analyses included the Pearson's product-moment correlation coefficient (r). The Fisher z transformation was applied to compare r values.

RESULTS

The range of MEQ scores observed among the 2,481 respondents varied from 17 to 78 (out of a potential range of 16 to 86). The general

[1]Although we have no specific information about social background of the responders, we must assume that our collective is neither representative for the social composition nor the age distribution of the Dutch population. After all, practically all responders were Internet and email users.
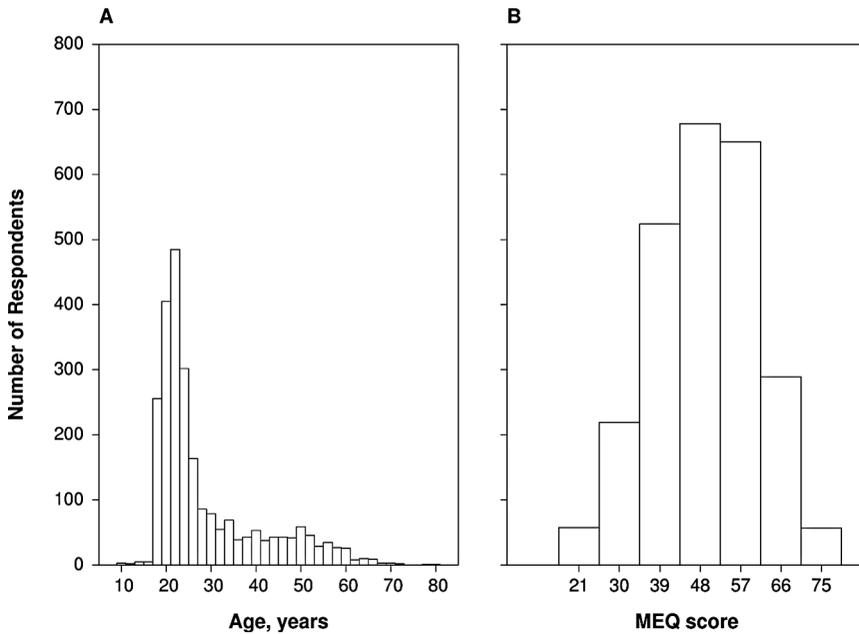
FIGURE 1 Distribution of ages (A, n = 2,481) and MEQ scores (B, n = 2,481).

distribution of the MEQ scores over 7 bins (17 to 25, 26 to 34, *etc.*) is shown in Figure 1B. Based on the multiple questions, the MEQ total score results in a continuous measure leading to an almost Gaussian distribution.

In view of the well-known age dependence of sleep timing (Park et al., 1998a, 1998b; Dijk et al., 2000), further analyses were carried out separately on four age groups (I: <25 years; II: 25 to 30 years; III: 30 to 40 years; IV: > 40 years). Table 1 provides the statistics on the MEQ scores and several variables derived from the MCTQ for both work days and free days. The results show a progressive advance of sleep times with increasing age, which is consistent with the results of another MCTQ-based study involving a larger population sample ($n \approx 25,000$) with a broader age distribution (Roenneberg et al., 2004). We calculated the correlations with the individual MEQ score for the following MCTQ variables: sleep duration, sleep onset time (SO, *i.e.*, bedtime plus sleep latency), rise time (RT), and midpoint of sleep (MS). This was done separately for work days and free days (indicated by 'W' and 'F,' respectively), since sleep timing is conspicuously different between work and free days (Figure 2). The results are summarized in Table 2. The strongest correlation ($|r| > 0.7$) was found between MEQ and the midpoint of sleep on free days (MSF; see also Roenneberg et al., 2003). Sleep onset correlated with the MEQ score usually slightly better than sleep-end times, especially on work days; we discuss this in more detail below. Sleep duration was not significantly correlated with MEQ in our sample,

TABLE 1 Average Values of the MCTQ Parameters Included in the Analysis (MEQ Subsample), Per Age Group

Age group (yrs)	Subjects, n	MEQ score	MCTQ Parameters								
			Work days				Free days			
			Sleep onset	Mid-sleep	Rise time	Sleep duration, h	Sleep onset	Mid-sleep	Rise time	Sleep duration, h
I (<25)	1,342	47.0 (10.5)	00:00 h (1.10)	04:02 h (0.95)	08:04 h (1.10)	8.07 (1.06)	01:01 h (1.20)	05:23 h (1.23)	09:45 h (1.43)	8.73 (1.34)
II (25–29)	372	47.8 (11.9)	23:48 h (1.08)	03:43 h (0.95)	07:38 h (1.07)	7.85 (0.99)	00:48 h (1.35)	05:00 h (1.23)	09:13 h (1.45)	8.43 (1.30)
III (30–39)	285	50.2 (12.2)	23:34 h (1.03)	03:20 h (0.83)	07:06 h (0.90)	7.53 (0.99)	00:20 h (1.15)	04:25 h (1.15)	08:29 h (1.45)	8.15 (1.25)
IV (>39)	482	54.5 (11.9)	23:42 h (1.22)	03:23 h (0.92)	07:04 h (1.00)	7.36 (1.23)	00:19 h (1.12)	04:04 h (1.08)	07:48 h (1.42)	7.50 (1.32)
All groups	2,481	48.9 (11.5)	23:52 h (1.12)	03:47 h (0.98)	07:43 h (1.15)	7.84 (1.11)	00:46 h (1.33)	04:57 h (1.32)	09:09 h (1.63)	8.39 (1.40)

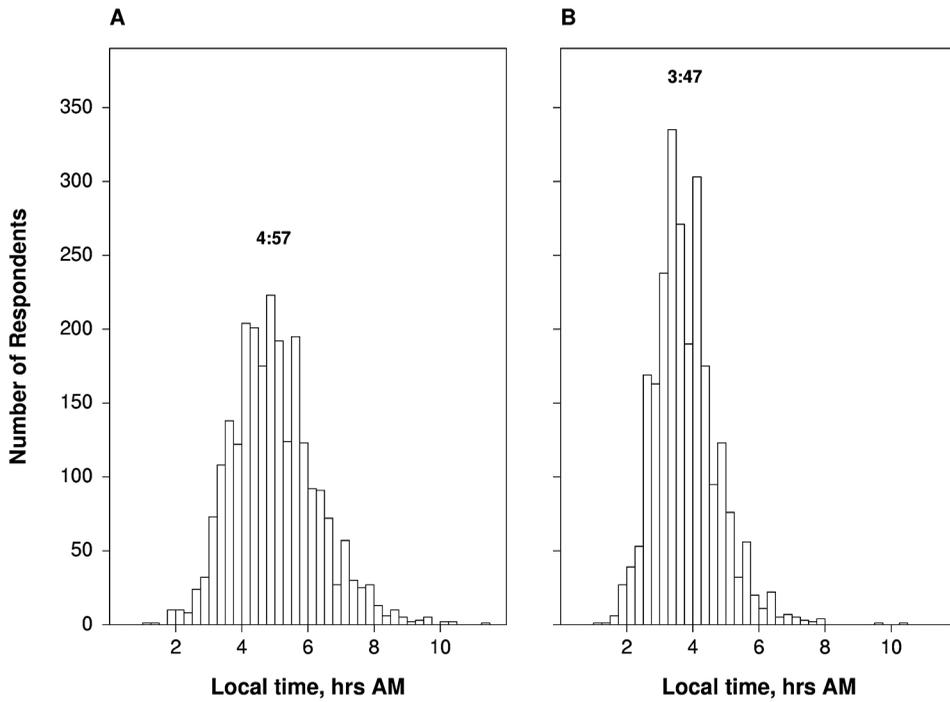In Parentheses are Standard Deviations (h).

FIGURE 2 Distribution of mid-sleep times, on workdays (A, msw) and free days (B, msf) for the subjects ($n = 2,481$). Clock times near the peaks are means of the respective midsleep time.

agreeing with previous reports (Roenneberg et al., 2003, 2004). Other variables, such as sleep latency, time spent outdoors, time of peak alertness, least awake time, and time spent reading before falling asleep, did not reach significant correlation ($|r| < 0.1$ throughout) with MEQ score and are therefore not reported here.

TABLE 2 Correlation Coefficients (Pearson's r) of Some of the MCTQ Parameters with the MEQ Score (MEQ Score Increases from 'Eveningness' to 'Morningness')

Age group (yrs)	Work days				Free days			
	Sleep onset	Mid-sleep	Rise time	Sleep duration	Sleep onset	Mid-sleep	Rise time	Sleep duration
I (<25)	−0.61	−0.60	−0.43	0.18	−0.60	−0.72	−0.66	−0.09
II (25−29)	−0.61	−0.61	−0.46	0.18	−0.66	−0.74	−0.66	−0.05
III (30−39)	−0.56	−0.59	−0.45	0.18	−0.64	−0.71	−0.63	−0.15
IV (>39)	−0.53	−0.58	−0.44	0.17	−0.67	−0.71	−0.56	−0.04
Total	−0.59	−0.61	−0.48	0.11	−0.64	−0.73	−0.66	−0.16

All correlations significant at the 0.01 level, two-tailed. For the total sample, the correlations were tested by applying Fisher transformation and comparing those pairwise ($z_{\text{sleep onset}}$ vs. z_{midsleep}, z_{midsleep} vs. z_{risetime}, and $z_{\text{sleep onset}}$ vs. z_{risetime}). All compared correlations were significantly different ($p < 0.01$) except for free-day $z_{\text{sleep onset}}$ vs. z_{risetime}.

Association of Sleep Timing with MEQ Score

Sleep duration showed a gradual reduction with age both on work and free days (Table 1), but its correlation with the MEQ score remained low in all age groups, from -0.15 in age group 30 to 39 years to 0.18 in those older than 39 years (Table 2). The correlation of sleep duration to MEQ score changes sign between work and free days. Workday sleep onset became progressively earlier from age group I ($<$25 years) to age group IV ($>$39 years): the advance was on average 26 min (Table 1). The oldest group (IV) has an 8-min delay relative to age group III. As this delay is not counterbalanced by a corresponding change in the sleep-end time, the resulting mid-sleep time in age group IV is also slightly later than in age group III. The correlation of workday mid-sleep time with the MEQ score (Table 2) remains at the same level (-0.6) in all age groups and is comparable to the correlation for workday sleep onset and MEQ.

Sleep onset and rise times on free days follow the age-dependent trend toward earlier clock time seen on workdays, except that the age-dependent advance of sleep timing on free days is about twice as large (79 vs. 39 min based on MS; Table 1). The sleep onset is advanced by 18 min from age group I to IV on workdays versus 42 mins on free days. This difference is even more pronounced for sleep-end times (60 min and 117 min, respectively).

Mid-sleep, rather than sleep onset or end time, gave the best correlation with the MEQ score. This can also be seen in the narrower scatter for MEQ vs. MSF compared to sleep onset or rise time on free days (Figure 3). MEQ scores correlated better with MSF (-0.73) compared to MSW (-0.61). This MSF-MEQ correlation appeared higher than the correlation between the MEQ score and SOF ($p < 0.001$ for all correlation comparisons mentioned). This makes free-day sleep timing dissimilar from that on work days, in which sleep onset and mid-sleep are associated similarly well with the MEQ score (-0.61 and -0.59, respectively).

MSF Correlates Better with the MEQ Scores Than Any Other Sleep-Related Phase Marker

The different degree of correlation between the various sleep-related reference points, (sleep onset, mid-sleep, and rise time) led us to perform a more detailed examination by dividing the sleep episode into 10 percentiles φ_x (for $x = 10, 20, \ldots, 90$). Figure 4 shows that on both sides of the MSF, the Pearson's r gradually decreases towards the beginning and end of the sleep period, strongly indicating that mid-sleep (a) is the best time point for correlations between the MCTQ and the MEQ and (b) may be the best marker for sleep-based assessments of chronotype.
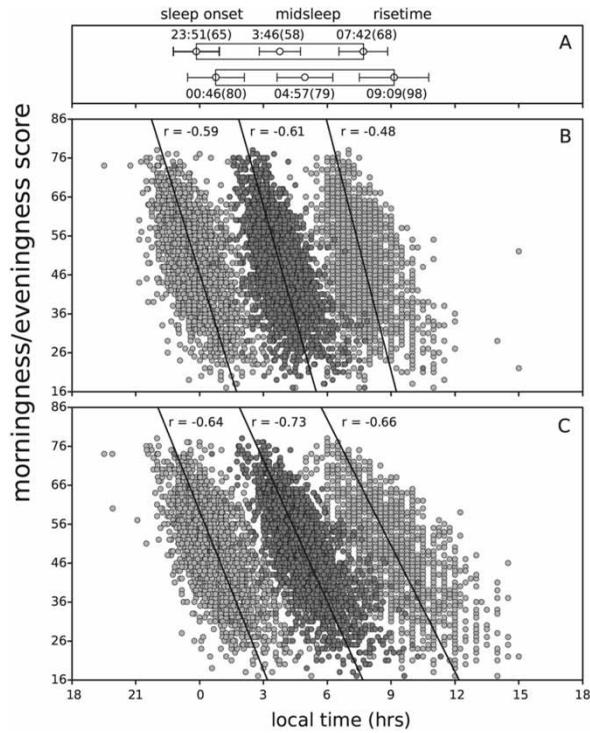
FIGURE 3 Mean values of primary sleep timings (A, standard deviations in parentheses, minutes; upper bar, workdays; lower bar, free days). Association of MEQ score with workday (B) and free-day (C) sleep timings. Two-tailed, all significant at $p = 0.01$. Lines are reduced major axes.
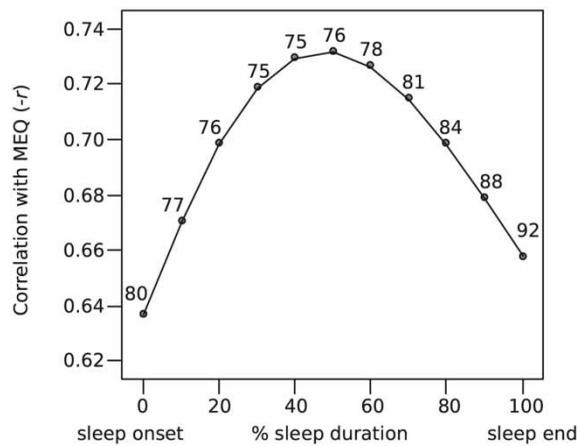

FIGURE 4 Pearson's correlation coefficients (r) of MEQ score and free-day sleep timepoints (φ_x, see text). The largest value, observed at φ_{50} (*i.e.*, msf), was 0.73. Labels to points are standard deviations (minutes) for the corresponding φ_x.

The highest correlation between MSF and MEQ-scores is not merely a consequence of reduced estimation error. Although the standard deviations observed for MSF are smaller than for sleep onset and rise time, the φ_{30} and φ_{40} show even smaller standard deviations (Figure 4), but worse correlations with MEQ scores.

DISCUSSION

Not surprisingly, sleep is on average earlier on workdays than on free days, and there is less inter-individual variation in its timing. Several authors (Roenneberg et al., 2003; Taillard et al., 1999; Dijk et al., 2000) have observed that later chronotypes suffer more from sleep loss caused by their work schedules. The larger discrepancy between the individual preference for specific sleep times and the obligations of social schedules (*e.g.*, school or work start times) lead to larger differences in sleep durations between work and free days. Although sleep onset is later in owls than in larks, sleep end times on work days is largely dictated by the alarm clock. For these reasons, MEQ may be correlated positively with sleep duration on work days, and negatively with sleep duration on free days (Table 2). This means that earlier chronotypes get more sleep on workdays than later chronotypes; whereas, the opposite is true for free days (Roenneberg et al., 2003, 2005).

The clear result that MSF, rather than any other phase reference points of sleep, shows the best correlation with MEQ-score may reflect the considerable variation in individual sleep duration. On workdays, sleep timing (especially sleep-end time) is largely dictated by social timing, and for later chronotypes sleep duration is kept near its minimum (depending on age: 7.36 to 8.07 h). On free days, sleep duration varies over a broader range (averages for different age groups: 7.50 to 8.73 h). While sleep duration on work days is directly influenced by the alarm clock, it may still be influenced on free days by the work schedules as an after-effect because working people, particularly later chronotypes, have to compensate for the sleep debt accumulated during the work week. Since sleep duration shows little systematic variation with MEQ score nor with MCTQ-derived chronotype (Roenneberg et al., 2003, 2005), each chronotype category contains a similar portion of short and long sleepers. Thus, short sleepers appear to go to bed later and rise earlier around their individual mid-sleep on free days, while long sleepers go to bed earlier and rise later around their MSF.

A physiological circadian phase marker, the dim-light melatonin onset (DLMO), also shows higher correlation with mid-sleep time than with either sleep onset or rise time (Martin and Eastman, 2002; Terman et al., 2001). A correlation between dim-light melatonin offset, circadian preference, and sleep timing has been reported as well (Laberge et al.,

2000); this study, however, did not specifically report mid-sleep correlations. Finally, MSF shows high correlations with the minimum of the daily cortisol rhythm of an individual measured in a constant routine (Roenneberg et al., 2004).

Our analysis demonstrates that an estimate of the actual timing of sleep on free days obtained with the MCTQ is strongly related to the MEQ score, and that the timing of mid-sleep on free days, in particular, is a good predictor of chronotype (as judged by sleep preferences). Detailed information on the timing of human behavior under natural circumstances and the refined description of the individual chronotype are prerequisites for future research on the mechanisms of circadian rhythm generation and entrainment. For example, possibilities to gain reliable insights into the genetic basis of a given trait are greatly improved by refined phenotyping.

ACKNOWLEDGEMENTS

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