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MEASURING THE CHRONOTYPE IN POLISH POPULATION

POMIAR CHRONOTYPU POPULACJI POLSKIEJ

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Summary

Chronotype is an attribute connected with an individual, preferred pattern of circadian activity on the continuum of morningness-eveningness. It mirrors the inter-individual differences in the course of circadian rhythms [1, 2]. The studies indicate its connections with sleep-wake cycle, i.e.: time of sleep onset, wake up time and duration of sleep [3, 4].

Two methods of describing human chronotypes are considered in this paper: a subjective – questionnaire method and an objective method – actigraphy that measures the gross motor activity.

The aim of the study was to assess the relation between results of Polish adaptation of Horne and Östberg Morningness-Eveningness Questionnaire [5] and circadian activity measured with actigraphs in order to compare and evaluate the usefulness of both methods in chronotype related studies. Also, the purpose was to assess the relation between chronotype and socio-demographic factors such as sex, age and education in Polish population.

The research group included 150 healthy volunteers of genders, 75 women and 75 men. The age of the respondents fell between 19 and 60 years old (34.25±12.13 EX±SD).

The obtained results confirmed the usefulness of actigraphy in chronotype related studies. Also they confirmed modulation of chronotype with age and revealed differences in circadian activity between men and women.

Streszczenie

Chronotyp to indywidualny, preferowany przez jednostkę wzór aktywności okołodobowej na wymiarach ranności-wieczorności, który odzwierciedla różnice indywidualne przebiegu rytmów okołodobowych [1, 2]. Badania wskazują, że jest on ściśle związany z przebiegiem rytmu sen-czuwanie, m.in. czasem zaśnięcia i budzenia się oraz czasem trwania snu [3, 4].

W pracy zastosowano dwie metody pomiaru chronotypu: kwestionariuszową oraz pomiar aktograficzny aktywności ruchowej.

Celem pracy była ocena związku pomiędzy wynikami polskiej adaptacji kwestionariusza Morningness-Eveningness Questionnaire (MEQ) Horna i Ostberga [5] a dobową aktywnością ruchową mierzoną aktograficznie oraz porównanie i ocena przydatności obu metod w badaniach nad chronotypem. Ponadto, dokonano oceny związku pomiędzy chronotypem i czynnikami społeczno-demograficznymi, takimi jak: płeć, wiek i wykształcenie, w populacji polskiej.

Badaniami objęto grupę 150 zdrowych ochotników obu płci, 75 kobiet i 75 mężczyzn w wieku 19-60 lat (34.25±12.13; EX±SD).

Uzyskane wyniki potwierdziły przydatność aktografii w badaniach nad chronotypem. Wyniki potwierdziły związek chronotypu z wiekiem oraz ujawniły różnice w aktywności dobowej między mężczyznami i kobietami.

Key words: actigraphy, actigraph, sleep, motor activity, chronotype, chronobiology
Słowa kluczowe: aktografia, aktograf, sen, aktywność ruchowa, chronotyp, chronobiologia

INTRODUCTION

Chronotype is an attribute connected with an individual, preferred pattern of circadian activity on the continuum of morningness-eveningness. It mirrors the inter-individual differences in the course of circadian rhythms [1, 2]. It is commonly reduced to sleeping habits. The studies indicated differences in sleep-wake timing between chronotypes, such that individuals with morning type fall asleep and wake up earlier than with evening type [6, 7].

Two methods of describing human chronotypes were considered in this paper. A subjective – questionnaire method and an objective method – actigraphy that measures the gross motor activity.

A commonly known and widely spread questionnaire method of determining the chronotypes is the Morningness-Eveningness Questionnaire by Horne and Östberg [5]. For assessing the chronotypes in this study, the authors used the Circadian Activity Rhythm Questionnaire (Kwestionariusz Rytmu Aktywności Dobowej - KRAD) designed by professor Ciarkowska from the University of Warsaw which is a Polish validated adaptation of the Morningness-Eveningness Questionnaire [8]. It consists of 21 questions including 18 of the 19 original items (original item 18 was dropped), the scalesteps of two of the original items were modified, and three items were added. The questionnaire allows an assignment of individual's chronotype to one of the following five categories: extremely morning, moderate morning, moderate, moderate evening and extremely evening. However, in researches the most frequently applied categorisation of chronotypes is: morning, moderate (neutral) and evening. Such a division has been applied in this paper as we compiled extreme and moderate morning types in morning category and extreme and moderate evening types in evening category. The questionnaire method is a subjective one. The examined person inputs data to the questionnaire on the basis of personal observations of their lives, behaviour, experiences, senses etc.

For the objective measurement of the chronotype, the authors used the actigraph – a device that is used to measure the gross motor activity [9]. Actigraphs have been used for a several dozen years already, for studying both humans and animals [10]. Still, its early versions were purely mechanical. It was not until the stride in electronic at the turn of the 80's and 90's, when the creation of fully electronic, miniature actigraphs was possible. In his research he used miniature, multiday, digital actigraphs. The first actigraph of such a kind in Poland was constructed by the co-author of this project, Tadeusz Pracki, in 1987 [11]. Most often, the sensor of the actigraph (an accelerometer) is a piezoelectric element that produces voltage proportional to its deflection which, in turn, depends on the acceleration that influences the sensor. If the acceleration goes beyond a specified threshold value (most frequently 0.1 G), then the signal from the sensor, after its amplification and transformation, generates a single electric impulse of a specified lasting time, of the order of tenth or one-hundredth of a second. If subsequent impulses occur at this time they are omitted. This mechanism eliminates a multiple counting of the same deflections of the sensor. Eventually, the impulses are summed up in certain amounts of time, most frequently every 2 min., and saved to the digital memory of the device. After completing a test, the data from the actigraph is sent to a computer, where it is analyzed. The whole work of an actigraph is supervised by a built-in microprocessor controller. Actigraph is an irreplaceable tool for conducting research and observations of chronobiological rhythms, especially in shift working, disorganised circadian rhythm, jet lag syndrome, shift of the phases of sleep, and, finally, in the research over sleep and sleep disorders [12]. Specific recommendations concerning the use of actigraphs are provided by the American Academy of Sleep Medicine in their reports of 2002 and 2007 [13, 14]. Of great advantage of the actigraph are its small size (the size of a watch), small costs of both the device and the research, non-invasiveness and the easiness of the measurement. Moreover, the measurement is taken in natural conditions which significantly eliminates an influence of stress on the result of the research which cannot be omitted in studies with i.e. polisomnographs. The disadvantage, however, is a not perfectly accurate measurement of the human sleep parameters. Pracki et al. [10] examined the significance of the gross motor activity measurement for the research over sleep. The results appeared to be strongly encouraging. It was revealed that an actigraph may be used to distinct between the sleep and the wakefulness of an individual. The only problem exists in determining the first stage of sleep. Nevertheless, the same problem appears in the classic visual or computer-aid analysis such as i.e. Fast Fourier Transform (FFT) [15]. Moreover, the first stage of sleep in healthy subjects takes less than a couple of minutes of the gross sleeping time during one night so it may be omitted in analysis.

The previous research over chronotype has revealed a strong influence of demographic factors such as age and gender on its formation. They have indicated that from the age of 13 to 25 there is a growing prevalence of the evening chronotypes which, then, decreases systematically until it is transformed into the morning chronotypes prevalence among people over 50 years of age [16, 17, 18]. The analysis of the questionnaire data carried out by Roenneberg et al. [4] showed that the peak of eveningness is obtained around the age of 20. Moreover, the authors point out that people over 60 display a stronger morning chronotype than they used to in childhood. These observations were also confirmed by the research conducted by Merikanto et al. [19], where in both male and female groups, the number of people with the evening chronotype decreases with age in contrast to the increasing number of respondents with the morning chronotype.

The meta-analysis of the research over chronotype, conducted by Cavallera and Guidici, revealed more frequent cases of eveningness among men [2]. Furthermore, the research by Chelminski et al. [20] indicate that the morning chronotype is much more frequent among women, which has been confirmed by the research of Natale and Danesi [21], where a greater percentage of women with the morning chronotype and men with the evening chronotype was stated. Similar results concerning the eveningness among men were obtained in the studies by Adan and Natale [22] and in the Polish research [1]. Recently, the predominance of the morning chronotype in girls and women and the evening chronotype among boys and men was acknowledged by the analyses done by Natale and Di Milia [23], Randler et al. [24], Borisenkov et al. [25].

MATERIAL AND METHODS

The aim of the study was to assess the relation between results of the Polish adaptation of Horne and Östberg, 1976 Morningness-Eveningness Questionnaire [5] and circadian activity measured with actigraphs in order to compare and evaluate the usefulness of actigraphy in chronotype related studies. Also, the study aims at assessing the relation between chronotype and socio-demographic factors such as sex and age in Polish population.

The research group included 150 healthy volunteers of genders, 75 women and 75 men. The age of the respondents fell between 19 and 60 years old (34.25±12.13 EX±SD), where 33.29±10.98 was the value for women and 35.21±13.19, for men.

Before the beginning of the research the participants filled in the KRAD questionnaire to assess their chronotype. Each of the respondents received an actigraph and wore it on the wrist for three days. The actigraph was programmed in such a way that it automatically initiated measurements at 3 p.m. The motor activity was measured and recorded in the memory of the device for every 2-minute clusters of data.

For the purpose of the research digital, water resistant hand actigraphs Actiwatch Plus (AW4) were applied together with a cordless scanner and the Actiwatch Sleep (v. 7.15) software by Cambridge Neurotechnology Ltd. The actigraphs have a built in button (marker), by pressing of which, the respondent indicated that the device was temporarily taken off. All actigraphs had been calibrated before the research.

After the research was completed, the data from the actigraphs was wirelessly transmitted to a computer and analyzed. For the analysis of the data the Actiwatch Sleep (v.7.15.) software was used as well as a self-created software designed especially for this research (Borland Pascal v.7.0), MS Excel 2007 and Statistica (v.8.0) for the statistic calculations.

Firstly, the correctness and integrity of the data was checked with visual and computer methods.

Secondly, a visual analysis of the motor activity data was carried out by a scientist certified by the Polish Sleep Studies Association who is highly experienced in studying and analyzing human sleep. For every respondent and every day of the measurement the sleep onset and wake up times were established and a coefficient of the sleep/wake periods was calculated. Eventually, the average value for the sleep onset and wake up times was calculated and so were the average duration of the sleep periods during the 3 days. The calculations were used in further data analysis. Every fifteen, subsequent, 2-minute clusters of data producing a 30-minute sample of motor activity recording of the whole three days were added up and averaged. Finally, for every participant, 48 clusters of motor activity recordings for subsequent 30 minutes were obtained. The data was acknowledged to be the sample of the average circadian motor activity for every participant and was further analyzed. For obtained data such values were calculated as: the time of sleep onset and wake up time, an average motor activity, duration of sleep period, sleep/wake ratio and the cosine-peak being the point of the highest activity during 24 hours.

RESULTS

The possibility of an automatic establishing of the sleep and wake periods duration with the use of the actigraphic data was first checked. With this aim, for the outcome obtained from the 3-day-averaged, 2-minute clusters of data of all the participants (Fig. 1), a correlation coefficient between the visually and computer estimated beginnings of the sleep and wake periods was calculated.

First, the constant threshold value of the motor activity has been changed from the value of 1 and the step of 1. Providing the value of the respondent is equal or lower than the threshold value the particular fragment of the recording was acknowledged as the lack of activity, hence, the sleep period. Otherwise it was assumed to be the wake (activity) period. For the value of activity amounting to 27, the highest correlation coefficient of 0.526 ($P \leq 0.001$) was obtained which suggests that the visually established and computer calculated samples are highly correlated.

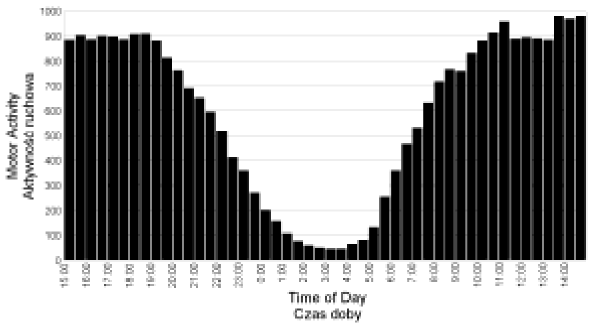

Fig. 1. *A three-day-averaged motor activity for all the participants of the research (n=150) for the 30-minute clusters of data*

Ryc. 1. *Zapisy 3-dobowej aktywności ruchowej uśrednione 30-min. bloków danych, dla wszystkich badanych osób (n=150)*

The next stage was to change the activity threshold value in a relative manner by setting the threshold value as a percent of the total, average activity of every respondent beginning with the value of 0.001% with the step being 0.001. For the value of 6.756%, the highest positive correlation coefficient of 0.529 ($P \leq 0.001$) was obtained.

The outcome achieved for both threshold values gives evidence for actigraphs being useful in the automatic establishing of human sleep/wake periods.

Next, an average circadian activity was counted among women and men. In women the activity was higher 635.3±136.1 (EX, SD) than in men 573.1±169.5 ($P \leq 0.005$). Moreover, statistically significant differences were observed ($P \leq 0.02$) for the cosine-peak that equals 15:42±1:25 for women and 14:37±1:27 for men.

To proceed with the analysis of circadian activity and age (as a continuous variable), we found the correlation between age and wake up time (r=-0.210. $P \leq 0.01$). The older the subjects were, the earlier their wake up time was.

The participants were also divided into two age groups, according to developmental stages [26, 27] up to 35 years old (early adulthood n=80) and above 35 years old (middle adulthood n=70), see Table I. The following results for the wake up time have been obtained: 7:17±1:32 in the younger group and 6:34±1:26 in the older group ($P \leq 0.001$); for the duration of sleep, 7:23±1:23 and 6:52±1:10 ($P \leq 0.005$), respectively; for this data the coefficients of sleep/wake periods were 0.454±0.123 and 0.407±0.099 ($P \leq 0.025$), respectively. The time of sleep onset in both group differed minimally, 23:53±1:14 and 23:42 ±0:58 respectively (N.S.).

Eventually, the KRAD questionnaires were analyzed. The results were divided into three chronotypes: morning, moderate and evening.

For both the time of falling asleep and wake up time significant differences have been observed (Table II) for the evening and the moderate groups (respectively, *P*≤0.001 and *P*≤0.001) and for the morning and the evening ones (respectively, *P*≤0.001 and *P*≤0.0025). The results demonstrate that the time of sleep onset and wake up time is the earliest in morning type (23:26 and 6:32, respectively), then in moderate type (23:31 and 6:41), finally with evening one (24:16 and 7:25).

Table I. *The results of the actigraphy parameters for the age groups*
Tabela I. *Wyniki parametrów aktograficznych dla grup wiekowych*

Age Wiek	Time of sleep onset (Hour) Czas początku snu (godz.)	Wake up Time (Hour) Czas przebudzenia (godz.)	Sleep Duration (Hour) Czas trwania snu (godz.)	Rest/activity Period Współczynnik czuwanie/ aktywność	Average motor activity (No) Uśredniona aktywność ruchowa (#)	Cosine-peak (Hour) (godz.)	n
19-35	23:53±1:14	7:17±1:32	7:23±1:23	0.454±0.123	612.4±159.9	14:47±1:29	80
36-60	23:42±0:58	6:34±1:26	6:52±1:10	0.407±0.099	594.8±152.8	14:55±1:25	70
P	N.s.	*P*≤0.001	*P*≤0.005	*P*≤0.025	N.s.	N.s.	-

For the Cosine-peak, statistically significant differences have been achieved (*P*≤0.05) for the evening (15:02±1:37) and the moderate (14:36±1:23) types. For the average motor activity the results were statistically significant for the evening and the moderate groups (*P*≤0.001) and for the moderate and the morning ones (*P*≤0.0025). The moderate chronotype showed higher level of motor activity than morning and evening types.

We also carried out the analysis of KRAD results in relation to sex, age, and education.

We found no differences in distribution of chronotypes between women and men.

While analysing the relation between age and KRAD results, we found the correlation between chronotype and age treated as a continuous variable (r=0.342, *P* ≤0.001) as well as with the age groups (r=0.280. *P* ≤0.001). The obtained results indicate the growing prevalence of morning type with the age of subjects.

Finally, we compared the results of KRAD (raw data) with actigraphic measurements using test for correlation coefficient. The results for KRAD and time of sleep onset was –0.308 (*P*≤0.001); for KRAD and wake up time was –0.318 (*P*≤0.001). It shows that the higher score in KRAD (more morning type) the earlier time of sleep onset and wake up time are.

Table II. *The results of the time of sleep onset, wake up time, Cosine-peak, and the motor activity obtained for various chronotypes (the size of the chronotypes: the morning group – n=34; the moderate group – n=54 and the evening group – n=62)*
Tabela II. *Wyniki czasu początku snu, czasu przebudzenia, Cosine-peak i aktywności ruchowej dla poszczególnych chronotypów (liczebność grup chronotypów: poranna – n=34; pośrednia – n=54; wieczorna – n=62)*

Parameters Parametry	Chronotypes Chronotyp	Evening Poranny	Moderate Pośredni	
Time of Sleep onset (Hour) Czas początku snu (godz.)	Morning Poranny	23:26±1:03	*P*≤0.001	N.s.
	Moderate Pośredni	23:31±1:07	*P*≤0.001	-
	Evening Wieczorny	24:16±0:06	-	
Wake up time (Hour) Czas przebudzenia (godz.)	Morning Poranny	6:32±1:20	*P*≤0.0025	N.s.
	Moderate Pośredni	6:41±1:23	*P*≤0.001	-
	Evening Wieczorny	7:25±1:37	-	
Cosine-peak (Hour) (godz.)	Morning Poranny	14:51±1:11	N.s.	N.s.
	Moderate Pośredni	14:36±1:23	*P*≤0.05	-
	Evening Wieczorny	15:02±1:37	-	
Motor Activity (No) Aktywność ruchowa (#)	Morning Poranny	594.3±157.9	N.s.	*P*≤0.0025
	Moderate Pośredni	653.3±156.8	*P*≤0.001	-
	Evening Wieczorny	566.9±145.8	-	

DISCUSSION AND CONCLUSIONS

The questionnaire method is commonly applied when it comes to the estimation of a chronotype. However, it is the respondent who inputs the data to the questionnaire on the basis of their personal life observations, behaviour, senses and self-evaluation.

For the sake of the objectification of the data, a measuring device, the actigraph, was employed, which measured the gross motor activity.

The results obtained with KRAD were confirmed with actigraphic measurements. As expected, subjects with the morning chronotype were falling asleep and waking up the earliest, followed by subjects with the moderate type, while the evening chronotype subjects were the tardiest. Also individuals with the evening chronotype reached their cosine peak significantly later than those with the moderate chronotype. These results confirmed previous findings on differences between chronotypes in sleep timings and activity peaks [6, 7].

Moreover, the moderate chronotype showed higher level of motor activity than morning and evening types.

The analysis also revealed that in parameters of time of sleep onset and wake up time, the questionnaire results and actigraphic data are correlated, hence congruent.

The results concerning relation of chronotype with sex were inconsistent. The analysis of distribution of KRAD results did not show any difference between males and females. However, analysis of actigraphic data demonstrated that females have higher level of motor activity and reached cosine peak later than men. The differences may be due to social synchronizers connected with cultural sex roles. These results are contrary to most of previous studies. It may be explained by specificity of the studied group which were carried out in i.e. students cohorts or in different cultural background i.e. Spain, Italy [21, 22].

Moreover, the obtained results confirmed the relation of chronotype with age. It was revealed using both methods: questionnaire and actigraphy. KRAD results showed that with age subjects are getting more morning type, while actigraphic measurements demonstrated earlier wake up time and shorter duration of sleep and lower sleep/wake ratio in older subjects. The outcome is consistent with the scientific knowledge concerning the earlier time of awakening and the shortening of the rest period with age of the respondents [10, 18, 19, 28, 29].

The achieved outcome proves that an objective assessment of a human chronotype is possible with the use of an actigraphs, which also enriches the questionnaire measurement. It has to be stated that the research is being carried on. It seems that an enlargement of the research group may effect in an increase of the reliability of the results.

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