DIAGNOSIS OF PRIMARY INSOMNIA BY ACTIGRAPHY – IMPROVED RESULTS BY DATA SELECTION

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Study objectives – In spite of the useful information provided by actigraphy in sleep medicine it is still not an independent tool either in the clinical diagnosis or in the follow-up. In the frame of a retrospective study, a simple new method of data reduction was applied with the aim of improving the clinical impact of actigraphy for the diagnosis of primary insomnia.
Methods – Actigraphic records with a duration of 1 week produced on 47 subjects who met the inclusion-exclusion criteria. The daily activities during the investigational period were registered by means a self-completed questionnaire. Three parameters (sleep latency, sleep fragmentation and sleep efficiency) and only their three 'worse – as regards insomnia' daily values were analyzed statistically. The study participants comprised 13 healthy controls, 17 healthy 'bad sleepers' and 17 subjects with primary insomnia.
Results – The post-hoc tests did not reveal statistically significant difference in the three parameters between the healthy and 'bad sleeper' groups, but these two groups differed statistically from the primary insomnia group.
Conclusion – The actigraphic analysis of sleep latency, sleep fragmentation and sleep efficacy allows a significant differentiation between subjects with primary insomnia and healthy controls, but not between healthy controls and healthy 'bad sleepers'. Statistical algorithms indicated 'models' for clinically good and bad sleepers. Further studies on large populations are necessary before this method can be introduced in the routine medical care of individuals with primary insomnia.

Keywords: *actigraphy, primary insomnia, sleep latency, sleep fragmentation, sleep efficiency*

A PRIMER INSOMNIA DIAGNOSZTIZÁLÁSA AKTIGRÁFIÁVAL – JOBB EREDMÉNYEK AZ ADATOK KIVÁLOGATÁSÁVAL

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Célkitűzés – Az alvásmedicinában az aktigráfia által biztosított hasznos információk ellenére a módszer még mindig nem jelent független eszközt sem a klinikai diagnózisban, sem a követésben. Retrospektív vizsgálat keretében az adatredukció egyszerű, új módszerét alkalmaztuk, hogy javítsuk az aktigráfia klinikai teljesítményét a primer insomnia diagnosztikájában.
Módszerek – A beválasztási kritériumoknak megfelelő 47 vizsgálati alany egyhetes aktigráfiás eredményeit használtuk. A vizsgálati időszakban önkitöltős kérdőívvel rögzítettük a napi aktivitást. Három paramétert (az alvás latenciája, fragmentációja és hatékonysága) és csak három, „az insomnia szempontjából rosszabb" napi értéket elemeztünk statisztikailag. A vizsgálatban 13 egészséges kontroll, 17 egészséges „rossz alvó" és 17, primer insomniában szenvedő beteg vett részt.
Eredmények – A post hoc tesztek nem mutattak statisztikailag szignifikáns különbséget az egészséges és a „rossz alvó" csoport három paraméterében, de ez a két csoport statisztikailag különbözött a primer insomniában szenvedők csoportjától.
Következtetés – Az alvás latenciájának, fragmentációjának és hatékonyságának az aktigráfiás elemzése lehetővé teszi a primer insomniában szenvedők és az egészséges kontrollok, valamint az egészséges „rossz alvók" szignifikáns elkülönítését. Statisztikai algoritmusok „modellt" jeleztek a klinikailag jól és rosszul alvókra. Nagy populációkon végzett további vizsgálatokra van szükség, mielőtt a módszer bevezethető a primer insomniában szenvedők rutin orvosi ellátásába.

Kulcsszavak: *aktigráfia, primer insomnia, alvási latencia, alvás fragmentációja, alvás hatékonysága*

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Actigraphy (ACT) has an important role in sleep medicine, based on the strong correlation observed between the level of alertness and the intensity and duration of movements. This correlation can be utilized for the diagnosis and follow-up of insomnia, whereas the application of another technique, polysomnography (PSG), is limited because of its inconvenient technical conditions. At least theoretically, ACT must be able to provide 'objective' data on sleep disorders which otherwise belong otherwise the most 'subjective' syndromes. Implementation of a long-term ACT investigation is very simple. The tool itself becomes unperceived and the maintained home-situation preserves the common sleeping conditions just completely (only the emotional-psychic but not the physical factors of the 'first night' phenomenon can work). The key question of the ACT recording is whether accelerometric evaluation alone for determination of the quality of night sleep is sufficient for demonstrating or excluding the presence of sleep disorders.

Primary insomnia (PRI) is a very common disorder, primarily among in the middle-aged and elderly. In the 2003 Sleep in America Poll study[1], 1506 adults in the age range 55–84 years of age were interviewed and 48% were found to have at least one symptom of insomnia on more than one night per week. Changes in sleep patterns with age precipitated sleep complaints in older adults. A National Center for Complementary and Alternative Medicine survey assessing insomnia found that, over a 12-month period, 17.4% of the adult population reported problems with insomnia[2].

Great efforts have been made to find the most appropriate and simple method for the diagnosis of PRI. Unfortunately, neither PSG nor ACT can be accepted as the optimal tool at present. PSG is very expensive and is unable to provide the calm conditions required for undisturbed night sleep for technical reasons. In spite of its better general conditions, the results of the ACT studies are still not clear-cut. During the generally accepted registration period of one week, the daily data are very variable. The actual level of physical strain and the life rhythms of patients differ and this can weaken the correlation between movements and sleep patterns. The typical movement patterns of basic biological activities (such as reading, computer-work, eating, participation in sport) and the verification of superficial and deeper sleep phases, etc. in ACT records have not been described to date. From aspect of PRI ACT at present is rather merely the tool that helps the patient recognize his/her diurnal movement rhythm in a somewhat spectacular graphical way. With some exaggeration we might say that ACT is currently a tool that lends support to the suggestions of the physician regarding the care of PRI.

In an earlier paper[3] we discussed the direct advantages and disadvantages of the autonomic application of ACT in sleep medicine. The conclusion was drawn that both the diurnal rhythms and the common daily movement loading of sufferers from sleep disorders exhibit extesive dispersion. For such reasons and also because other occasional factors can exert distortive effects on the daily biorhythms the results of the relevant studies are as yet, unable to demonstrate the usefulness of the information provided by ACT at the appropriate statistical level[4]. The present paper reports on a post-hoc analysis of PRI patients which involved a targeted reduction of the ACT parameters.

Methods

SUBJECTS

In the period (01.08.2009 – 01.08.2011) 82 individuals voluntered as potential participants in our study. They were distributed as follows: 16 healthy controls, 47 PRI patients and 19 healthy 'bad sleepers'. The probands for the first and third groups were relatives, friends or acquaintances of the staff. Finally, from our laboratory database contained 147 persons. Finally 47 of these 82 persons met the inclusion and exclusion criteria: 13 healthy controls, 17 healthy 'bad sleepers' and 17 PRI patients were enrolled in the study. All 47 underwent the same medical control, involving general, neurological and psychiatric examinations and including some test batteries (the Beck Depression Inventory[5], Pittsburgh Sleep Quality Index[6] and Epworth Sleepiness Scale[7]). Primary insomnia was diagnosed in accordance with the valid Hungarian protocol[8]. Polysomnography was not performed in the majority of patiens because their symptoms were obvious. The inclusion and exclusion criteria together with the definition of healthy 'bad sleepers' and diagnostic criteria of PRI, are listed on **Table 1**. The basic demographic data on the investigated groups are to be seen in **Table 2**.

ASSESSMENT

We used the same equipment (Actiwatch, Cambridge Neurotechnology) for all recordings, with the standard laboratory practice for ACT recording. Each participants received detailed written instructions on how to wear the tool. They were asked to push the marker to signalize the moment of decision

Table 1. *Inclusion and exclusion criteria*

Inclusion criteria Groups ® Conditions ↓	Healthy (13)	Healthy 'bad sleepers' (17)	PRI patients* (17)
Voluntary	+	+	+
Onset of complaints	–	–	>1 month
Intake of sedato-hypnotics	Occasionally, once a week at most	Occasionally, once a week at most	Occasionally, once a week at most
Intake of any psychotropics	–	–	not limited
PSQI**	<5	5–10	>10
Beck Depression Inventory***	not performed	<10	<10

Exclusion criteria (same for all groups)
Presence of any actual biological conditions that may influence night sleep
Night/shift-work or regular activity at night
More than one marginal value (one or five) for any items of the self-completed questionnaire (see **Table 3.**) accompanying for the ACT recording
Daytime hypersomnia (total score >16 on the Epworth Sleepiness Scale)

***** Diagnostic criteria for PRI:
– no indication of existing general medical conditions with a proved influence on sleep
– no existing neurological disease influencing the night sleep
– no existing psychiatric disease influencing the night sleep
– all the above conditions were investigated by the same professional (first author)
** Pittsburgh Sleep Quality Index (5)
*** shortened version, Hungarian adaptation (6)

Table 2. *Basic demographic data on the investigated groups*

Groups ® Demographics ↓	Healthy	Healthy – 'bad sleepers'	PRI patients
Age (year)	24–86 (average 41.75)	21–38 (average 28.18)	19–77 (average 47.7)
Gender female / male	10 / 7	10 / 9	8 / 9
Nature of the enrolled population	Health-are staff, relatives of patients, volunteers	Health-care staff, relatives of patients, volunteers	Out-patients

Table 3. *Self-completed questionnaires for routine actigraphic recording*

Actigraph investigation
Self-completed questionnaire
Name: Date of first investigational day: DD/MMM/YYYY Duration: days

1. Physical strain during the investigational period – compared to that in the previous month:
   strongly increased (5) – slightly increased (4) – unchanged (3) – slightly decreased (2) – strongly decreased (1)
2. Psychological-emotional strain during the investigational period – compared to that in the previous month:
   strongly increased (5) – slightly increased (4) – unchanged (3) – slightly decreased (2) – strongly decreased (1)
3. Quantity of night sleep during the investigational period – compar to that in the previous month:
   strongly increased (5) – slightly increased (4) – unchanged (3) – slightly decreased (2) – strongly decreased (1)
4. Quality of night sleep during the investigational period – comparing to that in the previous month:
   much worse (5) – worse (4) – unchanged (3) – better (2) – much better (1)
5. My physical conditions during the investigational period:
   much worse (5) – worse (4) – unchanged (3) – better (2) – much better (1)
6. My psychological–emotional conditions during the investigational period:
   much worse (5) – worse (4) – unchanged (3) – better (2) – much better (1)

Date of completion out: ..... Signature: .....

of starting to sleep ('Switch off the light before falling asleep') and the moment when they voluntarily got up ('getting-up moment'). During the 1-week recording period, kept a diary detailing the main elements of their daily activities together with any additional events that potentially influenced

their sleep-wake rhythm. After the ACT procedure, the whole period was evaluated and the night sleeps were graded on a five-point scale **(Table 3.)**.

DATA SELECTION

We set out to achieve a rational data reduction of the routine ACT recording (with a duration of one week) with the aim of finding key parameters suitable for proving the presence of PRI. We made three working hypotheses.

1st hypothesis

On the basis of literature reports on the information value of different ACT parameters (see later), we chose the three ACT parameters that were assumed to be the most informative and most stable for further analysis: sleep latency (SL), sleep fragmentation (SF) and sleep efficiency (SE).

2nd hypothesis

We omitted the data from the 'extreme days', i.e. the edge values of the chosen parameters in every proband. However, this involved certain problems:

User ID	CSONKI						
Start date of recording	2010.02.09						
Start time of recording	22:01						
Subject age	19						
Subject gender	M						
Epoch	0,5						
Date	2010.02.09	2011.02.10	2012.02.11	2013.02.12	2014.02.13	2015.02.14	2016.02.15
Bed time	0:27	23:05	23:26	23:54	3:34	23:21	22:39
Get up time	9:49	9:30	11:10	9:40	12:14	5:59	10:24
Time in bed (h:min)	9:22	10:25	11:44	9:46	8:40	6:38	11:45
Sleep start time	1:51	3:15	4:24	0:01	4:01	0:21	23:10
Sleep end time	9:36	9:23	11:09	8:26	11:42	5:28	10:00
Assumed sleep duration (h:min)	7:45	6:08	6:45	8:25	7:41	5:07	10:50
Actual sleep time (h:min)	6:10	5:45	2:39	7:46	7:02	1:19	9:58
Actual sleep time (%)	79,7	93,9	39,3	92,3	91,6	25,7	92,1
Actual wake time	1:34	0:22	4:06	0:39	0:38	3:48	0:51
Actual wake time (%)	20,3	6,1	60,7	7,7	8,4	74,3	7,9
Sleep efficiency	65,9	**55,3**	**22,6**	79,5	81,3	**19,8**	84,9
Sleep latency	**1:24**	**4:10**	**4:58**	0:07	0:27	1:00	0:31
Sleep bouts	39	22	45	26	25	35	30
Wake bouts	38	21	45	26	25	35	30
Mean sleep bout time	0:09:30	0:15:42	0:03:32	0:17:55	0:16:54	0:02:15	0:19:57
Mean wake bout time	0:02:29	0:01:04	0:05:28	0:01:30	0:01:32	0:06:31	0:01:43
Immobility time (mins)	388	344,5	162	479	437	92	607
Immobile time (%)	83,4	93,6	40	94,9	94,8	30	93,4
Moving time (mins)	77	23,5	243	26	24	215	43
Moving time (%)	16,6	6,4	60	5,1	5,2	70	6,6
No. of immobility phases	58	32	59	32	33	62	43
Mean length of immobility (mins)	6,7	10,8	2,7	15	13,2	1,5	14,1
One-minute immobility	19	6	45	2	3	36	3
One-minute immobility (%)	32,8	18,8	76,3	6,3	9,1	58,1	7
Total activity score	15459	3118	52329	5134	5537	37539	8241
Mean activity score	16,62	4,24	64,6	5,08	6,01	61,14	6,34
Mean score in active periods	100,38	66,34	107,67	98,73	115,35	87,3	95,83
Fragmentation index	**49,4**	25,2	**136,3**	11,4	14,3	**128,1**	13,6
Avg wake movement	49,7	172,7	141,9	172,9	111,4	155,2	160,4

Figure 1. *Sleep summary report on a patient. The data depict the 'worst' values of the chosen parameters (horizontally) and simultaneously indicate the investigated days selected for the statistical analysis (vertically)*

– SE is a complicated parameter. It considers subjective factors such as SL and the latency from the completion of sleep to the voluntary getting-up. Its value is based on the signals of both the proband and the reporting physician.

– There is a real risk that the proband forgets to signal the moments necessary to determine SL. The lack of a complete set of SL values can lead to the overall interpretation of the 1-week records being false.

3rd hypothesis

Our experience encouraged us to introduce a 'rational data reduction method': in view of the existence of two main types of PRI, we analyzed the three investigational groups in two separate ways:

1. Evaluation of 'sleep onset PRI': we omitted the data from the two days with the lowest and the highest values of SL and evaluated only the data from the remaining (five to three) days.

2. Evaluation of 'sleep quality PRI': we omitted the days with the lowest and the highest values of SF and immobility duration and evaluated only the data from the remaining (three to five) days. These parameters yielded the essence of the accelerometric as regards the movement-performance of sleep. Their values were automatically calculated in a completely objective manner.

In this way, three databases were available for comparative analyses from every proband: (a) a database containing all data for all nights, (b) a database containing all data for the days remaining after the omission of those with edge values of SL, and (c) a database containing all data for the days remaining after the omission of those with edge values of SF and immobility durations.

The basic concept remained unchanged: while exact data are not available on daytime performances, the elimination of 'extreme values' will improve the statistical evaluation of the differences between the patients and the healthy controls. However, the analysis did not support this preconception either.

4th (winner) hypothesis

1. We retained the three chosen parameters (SL, SE and SF) and evaluated the data for each group again separately for each parameter.

2. We analyzed the data on the three nights per person that were most relevant from the aspect of PRI (longest SLs, lowest SEs and highest SFs).

We demonstrate this simple selection process with a record from one PRI patient in **Figure 1**.

Table 4. *Descriptive statistical results of the evaluated three parameters in the three clinical groups (For the definition of Healthy 'bad sleepers' and PRI, see text)*

ACT parameters	Sleep efficiency				Sleep latency				Fragmentation index			
Groups ↓	min	max	mean	sd	min	max	mean	sd	min	max	mean	sd
Healthy	69.37	87.50	*77.46*	5.22	760.00	5440.00	*2006.15*	1659.06	22.20	62.10	*42.65*	12.08
Healthy 'bad sleepers'	72.77	87.17	*81.33*	4.69	420.00	2540.00	*1308.24*	596.32	20.70	55.70	*34.33*	10.71
PRI	27.23	92.00	*67.94*	20.47	340.00	12640.00	*3520.00*	3462.78	5.77	132.37	*54.22*	32.02

Table 5. *Results of multiple comparisons with ANOVA (Tukey HSD post-hoc test)*

Dependent variable	(I) group	(J) group difference (I-J)	Mean	Standard error	p value	95% confidence interval Lower bound	Upper bound
mean_efficiency	healthy	healthy bad sleepers	–3.87	4.77	0.698	–15.45	7.70
		PPI	9.51*	4.77	0.026	–2.05	21.09
	healthy 'bad sleepers'	healthy	3.87	4.77	0.698	–7.70	15.45
		PPI	13.39*	4.44	0.012	2.61	24.17
	PRI	healthy	–9.51*	4.77	0.026	–21.09	2.05
		healthy bad sleepers	–13.39*	4.44	0.012	–24.17	–2.61
mean_latency	healthy	healthy bad sleepers	697.91	8.43	0.688	–1347.77	2743.61
		PPI	–1515.02*	8.43	0.013	–3560.71	530.66
	healthy 'bad sleepers'	healthy	–697.91	8.43	0.688	–2743.61	1347.77
		PPI	–2212.94*	7.85	0.019	–4117.37	–308.50
	PRI	healthy	1515.02*	8.43	0.013	–530.66	3560.71
		healthy bad sleepers	2212.94*	7.85	0.019	308.50	4117.37
mean_fragmentation	healthy	healthy bad sleepers	8.31	7.85	0.544	–10.73	27.36
		PPI	–11.57*	7.85	0.013	–30.62	7.47
	healthy 'bad sleepers'	healthy	–8.31	7.85	0.544	–27.36	10.73
		PPI	–19.89*	7.31	0.025	–37.62	–2.15
	PRI	healthy	11.57*	7.85	0.013	–7.47	30.62
		healthy bad sleepers	19.89*	7.31	0.025	2.15	37.62

* The mean difference is significant at the 0.05 level.

STATISTICAL ANALYSIS

To determine the group differences, variance analysis was performed, the results of which are used to characterize the three distinguishable 'types' with the aid of discriminant analysis. The statistical analysis was carried out with the SPSS.16 for Windows program. During the statistical treatment, it was necessary to exclude the data on six persons (two healthy controls and 4 PRI cases because of the lack of some SL values (non-compliance). **Table 4.** contains the descriptive statistical results on the three evaluated parameters for the three groups.

Results

GROUP DIFFERENCES (ANOVA)

The variance analysis indicated that the three investigational groups differed significantly in all the three parameters [SE (F(46)=4,764), SL (F(46)= 4,121] and SF [F(46)=3,729)]. We observed the highest differences in the values of SL. The post-hoc tests did not reveal a statistically significant difference between the healthy controls and the healthy 'bad sleeper' group, but these two groups did differ statistically significantly from the PRI group **(Table 5.)**.

Table 6. *Group statistics in discriminant analysis for the three groups*

Groups		Mean	Standard deviation	Valid N (listwise) Unweighted	Weighted
Healthy	mean efficiency	77.45	5.22	13	13.00
	mean latency	2006.15	1659.06	13	13.00
	mean fragmentation	42.64	12.07	13	13.00
Healthy 'bad sleepers'	mean efficiency	81.33	4.69	17	17.00
	mean latency	1308.23	596.32	17	17.00
	mean fragmentation	34.33	10.70	17	17.00
PRI	mean efficiency	67.93	20.47	17	17.00
	mean latency	3521.17	3462.77	17	17.00
	mean fragmentation	54.22	32.02	17	17.00

DISCRIMINANT ANALYSIS

In terms of the quality of sleep, we classified the participants into three clinical groups and analyzed three ACT parameters (SL, SE and SF), in an attempt to identify constellations that characterize the single types for each group. The previous group statistics demonstrated that an average SE and SF and a decreased SL were most characteristic for the healthy controls, an average SE, an increased SL and a decreased SF for the healthy 'bad sleepers', and a decreased SE and an increased SL and SF for the PRI group **(Table 6.)**. A comparison of our sample reveals that the heterogeneity of the explaining variables within the types does not decrease significantly, as indicated by the Wilks' lambda data concerning individual variables. Although these figures approach 1.0 but the connecting *F* values are sufficiently in enough in their significance to confirm our hypothesis, and the average values of the correlations for each type are also acceptable from a statistical aspect. Our approaches for the statistical confirmation of the hypothesis mentioned earlier were briefly as follows:

1st approach: SL + SE + SF: this did not provide statistically significant group differences (Wilks's lambda: 0,774; 'Chi square': 11,002; sig: 0,088).

2nd approach: SL + SE: this model did reveal significant differences between the groups (Wilks's lambda: 0,793; 'Chi square': 10,064; sig: 0,039).

3rd approach: SE + SF: this model did not give significant differences (Wilks's lambda: 0,811; 'Chi square': 9,099; sig: 0,059).

4th approach: SL + SF a this model again expressed significant group differences (Wilks's lambda: 0,787; 'Chi square': 10,424; sig: 0,034).

Thus, the discriminant analysis demonstrated significant results in two of the four theoretical combinations of the parameters (SE, SL and SF) after their reduction with regard to the three worst night values. These were the combinations SE + SL and SL + SF, which gave discriminant functions with high differences between the groups defined by the dependent variables. Statistical results (Eigenvalue % of variance) concerning the discriminant functions are presented in **Table 7.**

Table 7. *Summary of Canonical Discriminant: Eigenvalues and Wilks' lambdas in two theoretical combinations among the three ACT parameters (SE, SL and SF)*

	Sleep efficiency + latency	Sleep latency + fragmentation
Value	0.26	0.26
% of variance	99.9%	99.5%
Wilks'lambda	0.79	0.78
Chi-square	10.06	10.42
Significance	0.039	0.034

The number of cases grouped correctly by the discriminating functions strengthens our hypothesis and circumscribes two 'models'. **Table 8.A, B** details the distributions. With these 'models' the groups that we created exclusively on a clinical basis became statistically relevant categories.

Conclusions

The conventional sleep report data from conventional ACT of 1 week records were reduced to three parameters (SL, SE and SF), considered only for the three 'worst' days of PRI. The following results were obtained with the four combinations of the parameters. The combinations SL + SE + SF and SE + SF did not indicate statistically significant differences between the clinical groups, whereas could be differentiated on application of SL +SE and SL + SF combinations. Analysis of our results from a

Table 8.A *Classification results for the groups in the Sleep efficiency + latency theoretical model*

		Predicted group			Total	Groups	Correctly classified %
		Healthy	Healthy ' bad sleepers'	PRI			
Groups	Healthy	4	6	3	13	Healthy	30.77
	Healthy 'bad sleepers'	4	13	0	17	Healthy 'bad sleepers'	76.47
	PRI	4	5	8	17	PRI	47.06
	Total	12	24	11	47	Healthy + Healthy 'bad sleepers'	90

Table 8.B *Classification results for the groups in the Sleep latency + fragmentation theoretical model*

		Predicted group			Total	Groups	Correctly classified %
		Healthy	Healthy 'bad sleepers'	PRI			
Groups	Healthy	5	5	3	13	Healthy	38.46
	Healthy 'bad sleepers'	6	11	0	17	Healthy 'bad sleepers'	64.71
	PRI	3	5	9	17	PRI	52.94
	Total	14	21	12	47	Healthy + Healthy 'bad sleepers'	90

clinical context might reveal more speculative explanations. We presume that both successful combinations may serve as the basis of *functional* models.

Functional model 1: sleep latency + efficiency. This function includes the two variables, containing SL with low negative (-0.848) and SE with high positive (0.912) values. With the coexistence of low SL and high SE regarded as an *expression of good sleep,* the results can be visualizedin two-dimensional space **(Figure 2.)**.

Functional model 2: sleep latency + fragmentation. This function includes the two variables, containing SL with high positive (0.793) and SF with high positive (0.834) values. With the coexistence of high SL high SF regarded as an *expression of bad sleep,* the results can be visualized our results in two-dimensional space **(Figure 3.)**.

Both 'functioning' models contain the parameter SL. This highlights the extreme importance of the fact that the start of the night sleep within a short time statistically signalizes a better sleep and vica versa.

Unsuccessful combinations can also contain important information. We consider that, in spite of the strong influencing effects of SE and SF on sleep, neither of them is an independent key parameter in PRI.

In view of its simplicity, the value of ACT in the

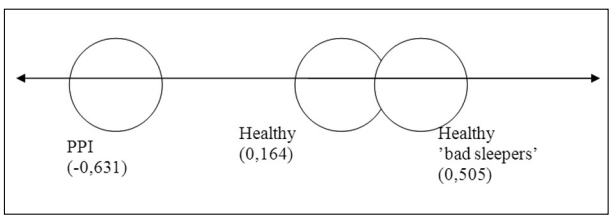

Figure 2. *Two-dimensional demonstration of model 1: expression of good sleep based on the combination of data on sleep latency + efficiency. For details, see the text*

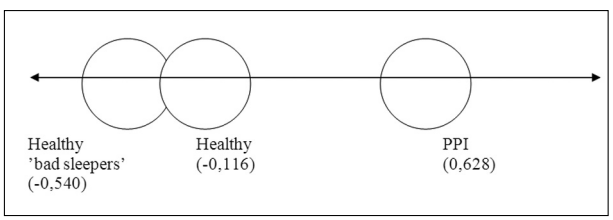

Figure 3. *Two-dimensional demonstration of model 2: expression of bad sleep based on the combination of data on sleep latency + fragmentation. For details, see the text*

diagnostic armamentarium has been investigated quite widely, primarily in comparison with PSG. Some papers found good accordance[9], but others considered its information content weak in relation

to the subjective evaluation of sleep quality or to the data recorded in sleep diaries[10]). It is quite obvious that the most exhaustive information would be obtained by the use of both methods simultaneously (PSG to create the hypnogram, and ACT for the analysis of the individual circadian rhythm in general), but the cost/benefit ratio of this protocol is questionable. In comparison with PSG, the intraindividual variability can be investigated far more easily via an ACT recording, and this parameter was found to be a key variable between good-sleeper elderly people and chronic insomnia patients of the same age[11]. Another important result of ACT studies was that the values of SL, SE and SF were statistically different in patients with posttraumatic stress disorder (most of whom also suffer from PRI) and in normal control[12]. The relatively contradictory nature of the results may be explained by the facts that: differentiation between calm awake and hypovigil awake periods and light sleep phases is difficult[13]), and that ACT does not reveal the presence of slow wave sleep stages which are crucial in the diagnosis of PRI. Both arguments are naturally true for the ACT parameters measured routinely. Investigators therefore strive to determine ACT parameters relatively independently of these problems. In a recent paper in which ACT and PSG were compared from technical methodological aspects, acceptable equivalence presented in sleep duration, SE, SL and the duration of longer (>5 min) wake after sleep onset (WASO)[9, 14]. Others found the evaluation of SL, total sleep time (TST) and SE to be the most informative[10, 15] or the analysis of only TST and SE[12, 16]. In other retrospective studies, the authors were able to differentiate between normal subjects and insomnia patients with the help of all the important ACT parameters except the 'time in bed' value, but the most sensitive parameters were SL, TST, SE and WASO[13, 17]. A detailed consideration of the relevant literature led us to decide to try to make a clear distinction between clinical populations with the following modifications: 1. Instead of all the ACT data, we evaluated only the parameters that have an exact clinical meaning as concernins the given clinical syndrome (SL, SE and SF in our present PRI study); 2. we tried to diminish the spontaneous fluctuation of the recording on consecutive nights by using the data from only three days; and 3. we considered the 'strongest/worst' three data of each parameter referring to the given clinical diagnosis.

It should be mentioned that our patients often complained of shortening of their night sleep. Although TST is well measurable by ACT, and the values display good concordance with those of PSG[18], we omitted this parameter: in spite of its relative intraindividual stability, its interindividual variability is extremely high and genetically determined (long and short sleepers). We therefore recommend the clinical consideration of TST exclusively in personal self-controlled investigations. The results in papers which compared the values of questionnaires regarding the levels of loneliness, stress, depression and anxiety (all emotional bases in the occurrence of PRI) with ACT parameters in healthy people are consonant with our findings. A strong positive correlation was detected for SF and loneliness, but not for TST[19]. Similarly TST did not correlate with the quality of night sleep in healthy schoolchildren[20]. However, SF correlated well with the arousal index measured by PSG in children[21]. SF may be an important marker in the elderly. There is indirect experience that, in the comparison of the good and bad-sleeper elderly, better sleep correlated primarily not with SL, but rather with the duration of wake time during sleep (which leads to an obligatory fragmentation of sleep[22]. SF in the elderly was a probable risk factor of falls[23] and also correlated with obesity[24]. The importance of SL is unquestionable: its increase is one of the basic complaints of PRI patients. Nevertheless, the fact that registration of the onset of SL requires the cooperation of the patients can mean a difficulty in its validation[25].

Among the weak points of our study, it must be mentioned that the number of subjects in each group was quite low, and the healthy 'bad sleepers' who satisfied the inclusion criteria were far younger and more homogeneous. The PRI patients answered only the shortened version of the Beck Depression Inventory and underwent 'routine' psychiatric examinations; the presence of co-morbid mild depression in which the ACT parameters can independently change[26] could not be excluded. The patients in the PRI group were rather heterogeneous. The majority of them were on antidepressive treatment (13/17) and different kinds of anxiety disorders (9/17) or mixed anxiety and depressive disorders had been diagnosed. However, at the time of the ACT recording, insomnia was their main symptom.

Although the mentioned limitations may raise questions concerning the classification of our patient group, they do not decrease the importance of our results from practical clinical aspects. ACT and its evaluation by the rational data selection procedure we applied may make the diagnosis of PRI more objective, may add important details to the syndrome and may therefore become a cheap and useful technique promoting tailored successful treatment (pharmaco- or psychotherapy or both). For its use in everyday routine, further studies are

clearly necessary on larger populations. The creation of normal databases including descriptions of age-related trends, is needed. We have to increase our knowledge on the characteristic motor patterns of the different stages of slow wave sleep. ACT offers an easy method with which to investigate the physiological and pathophysiological correlations of motor performance between daytime and sleep phases (which have already been studied in the investigation of circadian rhythms of probands with an extro- or introversive personality[27]). To increase the sensitivity of ACT for sleep medicine, more sophisticated and 'sleep-specific' software must be developed[28].

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