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Published in:
Perceptual and Motor Skills

DOI:
[10.2466/03.15.PMS.111.6.936-946](https://doi.org/10.2466/03.15.PMS.111.6.936-946)

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Document Version
Publisher's PDF, also known as Version of record

Publication date:
2010

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Bossenbroek, L., Kosse, N., ten Hacken, N., Gordijn, M., van der Hoeven, J., & de Greef, M. (2010). Validation of the Dynaport Minimod during sleep: A pilot study. *Perceptual and Motor Skills*, 111(3), 936-946. <https://doi.org/10.2466/03.15.PMS.111.6.936-946>

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VALIDATION OF THE DYNAPORT MINIMOD DURING SLEEP: A PILOT STUDY^{1,2}

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Summary.—To measure activity during sleep, polysomnography and actigraphy are often used. The DynaPort MiniMod measures movement intensity and body position day and night. The goal was to examine the validity of the DynaPort MiniMod in assessing physical activity and body posture during sleep. In Study A, 10 healthy participants slept with the DynaPort MiniMod and the Actiwatch for one night. In Study B, 8 participants suspected of having Obstructive Sleep Apnoea Syndrome slept for one night with the DynaPort MiniMod and underwent complete polysomnography as part of the typical care protocol. In Study A, there was a significant moderate correlation ($r = .70$) between the movement scores of the Actiwatch and the DynaPort MiniMod. In Study B, a high intraclass correlation ($r = .84$) between body posture scores of the DynaPort MiniMod and the polysomnography position sensor was observed. The DynaPort MiniMod is a valid measurement device for physical activity during sleep.

Disruptions in sleep occur in any condition in which sleep doesn't follow the normal sleep-wake cycles or a particular sleep cycle does not last as long as it should. Sources of sleep disruption could vary from bad sleep hygiene and stressful life events to the use of drugs, tobacco, or alcohol, or be related to mood disturbances such as depression and possibly sedentariness. While lying awake, physical activity during the night may increase. Disruptions in sleep could also affect amount of daily physical activity during the day and affect perceived quality of life (Kutty, 2004). Obstructive Sleep Apnoea, a sleep disorder characterized by severe pauses in breathing during sleep, is the most common type of sleep disorder.

To examine sleep problems it is relevant to register disruptions in

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²The authors thank all participants and the polysomnography team of the Department of Neurology, University Medical Center Groningen, University of Groningen, and Dr. W.P. Krijnen for his statistic view and comments.

the sleep/wake cycle and movements during the night. This can be measured using a number of devices. Polysomnography is the current gold standard in measuring sleep. It registers the sleep pattern with an ambulant sleep system with 12 different channels (Michaelson, Allan, Chaney, & Mair, 2006). This device is not always practical for recordings of 24 hours or longer (Lockley, Skene, & Arendt, 1999). In addition, it is expensive, and recording requires professional placement and use (Ancoli-Israel, Cole, Alessi, Chambers, Moorcroft, & Pollak, 2003). In contrast, actigraphy is one of the most frequently used, reliable methods for assessing sleep and wakefulness (Jean-Louis, von Gizycki, Zizi, Spielman, Hauri, & Taub, 1997a, 1997b) in sleep research. One such device, the Actiwatch, is worn on the wrist and is used to estimate sleep and wakefulness based on motor activity of the upper extremity (Morgenthaler, Alessi, Friedman, Owens, Kapur, Boehlecke, *et al.*, 2007). One advantage of actigraphy is its relatively low cost. The Actiwatch can conveniently record sleep at night continuously for up to several weeks (Ancoli-Israel, *et al.*, 2003). Comparison of actigraphy with polysomnography, the "gold standard," has yielded agreement rates in the range of 78 to 95% (Kushida, Chang, Gadkary, Guilleminault, Carrillo, & Dement, 2001). Actigraphy is valid for assessing sleep durations and sleep/wake activity, but less reliable for more specific measures such as sleep offset or sleep efficiency (Ancoli-Israel, *et al.*, 2003). The disadvantage of actigraphy is that it measures only the presence of movement (Ancoli-Israel, *et al.*, 2003); there is no information about body posture and little information about the intensity of movements.

To evaluate subtle changes in body position and possibly related sleep disruptions, a device is needed which measures accurately the body position and movement intensity over a longer period of time, including the sleep period. In this respect, the DynaPort MiniMod (McRoberts BV, The Hague, The Netherlands) seems a more useful device. The DynaPort MiniMod is a triaxial accelerometer especially designed to measure intensity of movements and to register position of the human body with respect to gravity, which ensures a more realistic picture of physical activities (Pitta, Troosters, Spruit, Decramer, & Gosselink, 2005). With little adjustment, the device is able to assess exact position and movement during sleep. Apparently, the DynaPort MiniMod has only been used once before to assess physical activity at night; however, it was not compared with other sleep measurements (Bulthuis, Vollenbroek-Hutten, Hermens, Vendrig, & van Lummel, 2004).

The aim of this study was to examine the validity of the DynaPort MiniMod in assessing body posture and physical activity during sleep. The goal of Study A was to calculate the correlation between the movement times measured by the DynaPort MiniMod and the Actiwatch in

healthy adults and, in Study B, the correlation between the posture registration of the DynaPort MiniMod and polysomnography.

METHOD

Measures

Actigraphy.—Movement analyses were assessed noninvasively using an Actiwatch (Actiwatch AW 7, Cambridge Neurotechnology, Cambridge, UK). The Actiwatch has the size and shape of a watch and is worn on the nondominant wrist to register acceleration-induced wrist movements. The Actiwatch quantifies accelerations due to motor activity of the arm and integrates these over 30-sec. periods. “Practice guidelines for Actigraphy” established by the Standards of Practice Committee of the American Academy of Sleep Medicine state that actigraphy is reliable and valid in normal, healthy populations (Kushida, *et al.*, 2001; Littner, Kushida, Anderson, Bailey, Berry, Davila, *et al.*, 2003).

Polysomnography.—Polysomnographic examination was conducted by the ambulatory use of an Embla A10 digital recorder (Medcare, Reykjavik, Iceland). To stage sleep according to standardized criteria, surface electroencephalography (EEG), submental and leg (tibial anterior muscle) electromyography (EMG), as well as left and right electrooculography (EOG) were used. A pulseoximeter (Oximeter Flex Sensor—8000J-3, Medcare, Reykjavik, Iceland) recorded oxyhemoglobin saturation (SaO₂), and electrocardiography (ECG) monitored the cardiac function. Oronasal airflow was recorded with a pressure cannula, and respiratory effort by thoracic and abdominal strain gauges. An anterior tibial EMG was recorded to screen for periodic limb movements, and analog output of a body position sensor in three directions was monitored (Chesson, Ferber, Fry, Grigg-Damberger, Hartse, Hurwitz, *et al.*, 1997; Hoekema, Stegenga, van der Aa, Meinesz, van der Hoeven, & Wijkstra, 2006; Nesse, Hoekema, Stegenga, van der Hoeven, de Bont, & Roodenburg, 2006).

Accelerometry.—Accelerations were measured by the DynaPort MiniMod, a small and lightweight measurement device (5.6 cm × 6.1 cm × 1.5 cm, 54 g; McRoberts BV, The Hague, The Netherlands). It consists of three orthogonally mounted accelerometers and has a local memory card for data storage. Data were collected at 100 Hz and stored on a Secure Digital Memory Card. The DynaPort MiniMod was firmly fixed in a belt, which was worn above the nightclothes around the trunk at the back (Brandes, Zijlstra, Heikens, van Lummel, & Rosenbaum, 2006). Under controlled conditions, performed in a shaker device, the results obtained by the DynaPort MiniMod are highly reproducible (intraclass correlation coefficients of .97 and .88 for intra- and interobserver studies, respectively; van Hees, Slootmaker, de Groot, van Mechelen, & van Lummel, 2009).

Participants and Procedure

Study A.—The DynaPort MiniMod was compared with the Actiwatch in 10 healthy participants, 3 males and 7 females with a mean age of 26 years (standard deviation = 14, range 13–54). Participants wore both devices during one night's sleep at home. The devices differ in detection and presentation of movements, but do measure movement time in seconds during sleep. The DynaPort MiniMod was positioned at the back and assesses movement time in seconds based on the changes in gravitation measured at 100 Hz. The Actiwatch measures a movement score every 30 sec. based on the motor activity around the wrist. The movement time of the DynaPort MiniMod and the movement score of the Actiwatch were synchronized per minute for each participant. To compare these two datasets, the summary score for every sequential 10 min., based on the previous 10 min. at each minute of the recording, was calculated for both devices. The outcome of the Actiwatch is the number of movement scores per minute, and of the DynaPort is the movement time in seconds per minute. The Actiwatch and DynaPort MiniMod were started and stopped simultaneously. Participants recorded in a diary the time of starting and stopping the devices and the time spent in and out of bed. The participants were free to choose their own bedtimes and awakening times. The next morning the data stored on the memory card of the DynaPort MiniMod and actigraphy were transferred to a laptop computer.

Study B.—The DynaPort MiniMod was compared with the position sensor of the polysomnography in eight patients suspected to have Obstructive Sleep Apnoea Syndrome, five men and three women (M age = 50 yr., SD = 12, range 29–69). The participants were pulmonary outpatients recruited from the University Medical Center Groningen. Participants wore both devices at home during a period of 20 to 22 hours including sleep during one night. Both devices detect body posture per second, and measure postures during lying down for the back, front, left, and right, respectively. The outcome for both methods is position per second. The dataset of the DynaPort MiniMod and the position sensor of the polysomnography were synchronized per second for each participant. Polysomnography and the DynaPort MiniMod measures were started simultaneously at the Department of Clinical Neurophysiology of the University Medical Center Groningen. Participants marked the time from getting to bed until waking up; only the nighttime data were used for analysis. Participants were free to choose their own bedtimes and awakening times and were instructed to stop wearing the DynaPort MiniMod if the device was perceived as unpleasant to wear. The next morning participants came to the hospital where the devices were removed and the obtained data stored on the memory card were transferred to a computer.

Statistical Analysis

The Actiwatch and DynaPort MiniMod data were synchronized for each participant. The summary scores of the movement times and scores for every 10 previous min. were calculated per minute for both methods. The DynaPort MiniMod and the polysomnography both gave the body position per second. Missing position outcomes were filled in as unknown. All analyses were conducted using the Statistical Package for Social Sciences (SPSS Version 16.0) for Windows. For Study A, correlations were calculated to measure interdevice agreement. For Study B, intraclass correlation coefficients (ICC) were calculated to measure reproducibility of replicated measures from the same participant. Cronbach’s alpha was calculated to assess internal consistency. According to Fleiss (1986), intraclass correlations smaller than 0.4 indicate reproducibility is poor, between .4 and .75 good, and larger than .75 excellent. Significance was set at $p < .05$.

RESULTS

Study A: DynaPort MiniMod and Actiwatch

Visual inspection of the DynaPort MiniMod and the Actiwatch registrations of the 10 healthy participants showed a highly comparable pattern over time within individuals. An example of the sum results of a participant wearing the DynaPort MiniMod and Actiwatch during the night is shown in Fig. 1. In total, 4,434 movement scores were analyzed; the mean number for each participant was 443 movement scores ($SD = .82$).

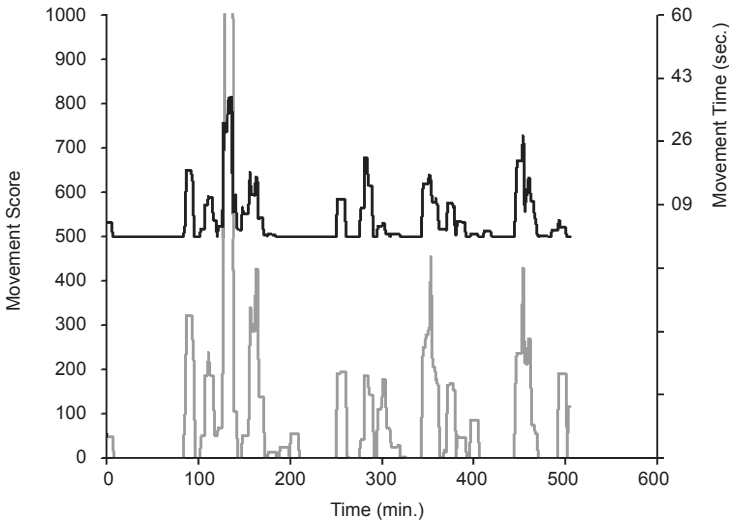


FIG. 1. Study A: example of the Actigraph movement score (—) and the DynaPort MiniMod movement time (---). The horizontal line indicates the time in minutes.

The reliability and internal consistency between the DynaPort Mini-Mod and the Actiwatch are given in Table 1. The correlations for the 10 participants ranged from .51 to .91 ($M = .75, SD = .11$). The overall correlation coefficient for the 10 measurements (4,434 scores) was .70. Cronbach's alpha ranged from .67 to .95; for the mean summary score, Cronbach's alpha was .82.

TABLE 1
PARTICIPANTS' CHARACTERISTICS, CORRELATIONS, AND CRONBACH'S ALPHA (STUDY A): COMPARISON OF ACTIVITY MEASURED BY ACTIWATCH (MOVEMENT SCORES PER MIN.) AND DYNAPORT MINIMOD (MOVEMENT TIME IN SEC. PER MIN.) DURING ONE NIGHT IN 10 HEALTHY PARTICIPANTS

Participant	Sex	Age	BMI	No. of Measurements (min.)	DynaPort	Actiwatch	<i>r</i>	95%CI	α	
1	<i>M</i> ± <i>SD</i>	F	21	24	553	17 ± 20	119 ± 273	.72*	.12, .62	.84
	Range					0-84	0-1,889			
2	<i>M</i> ± <i>SD</i>	F	21	23	434	5 ± 7	55 ± 78	.79*	.19, .21	.88
	Range					0-31	0-433			
3	<i>M</i> ± <i>SD</i>	F	26	24	473	9 ± 13	97 ± 276	.72*	.49, .23	.84
	Range					0-69	0-2,179			
4	<i>M</i> ± <i>SD</i>	M	54	29	393	8 ± 11	71 ± 189	.66*	-.02, .16	.80
	Range					0-51	0-1,226			
5	<i>M</i> ± <i>SD</i>	M	22	20	419	11 ± 19	105 ± 191	.91*	-.03, .17	.95
	Range					0-45	0-1,293			
6	<i>M</i> ± <i>SD</i>	F	21	22	524	10 ± 11	139 ± 194	.76*	.08, .27	.86
	Range					0-45	0-1,744			
7	<i>M</i> ± <i>SD</i>	F	49	26	390	5 ± 8	48 ± 74	.77*	.002, .17	.86
	Range					0-48	0-518			
8	<i>M</i> ± <i>SD</i>	F	20	23	506	3 ± 7	88 ± 170	.87*	.06, .25	.93
	Range					0-38	0-1,114			
9	<i>M</i> ± <i>SD</i>	M	13	16	477	2 ± 4	58 ± 165	.51*	-.06, .12	.67
	Range					0-26	0-2,429			
10	<i>M</i> ± <i>SD</i>	F	17	20	265	2 ± 6	109 ± 220	.79*	-.07, .16	.88
	Range					0-43	0-2,309			
Total					4,434					
<i>M</i>							.70*			.82

* $p < .01$.

Study B: DynaPort MiniMod and Polysomnography Position Sensor

The analysis of the DynaPort MiniMod and the polysomnography position sensor registrations of the eight participants suspected to have Obstructive Sleep Apnoea were based on body posture per second, specified in four possible postures during lying down, namely, back, front, left, and right (Table 2 and Fig. 2).

The reliability and internal consistency between the DynaPort Mini-Mod and the polysomnography position sensors are shown in Table 3.

TABLE 2
 PERCENTAGE OF POSITIONS TAKEN (BACK, FRONT, LEFT, RIGHT, AND UNKNOWN) DURING ONE NIGHT WITH DYNAPORT MINIMOD (DP) AND POLYSOMNOGRAPHY POSITION SENSOR (PPS)

Device	Total Sec.	Back %	Front %	Left %	Right %	Unknown %
1. DP	40,807	93.7	0.0	0.0	0.0	6.3
PPS		94.3	0.2	0.1	0.0	5.4
2. DP	30,442	40.3	0.0	11.6	47.6	0.5
PPS		42.1	1.2	11.3	44.6	0.8
3. DP	32,254	46.8	0.0	5.3	39.5	8.4
PPS		29.2	3.0	14.4	39.6	13.8
4. DP	30,432	22.3	0.4	54.2	20.2	2.9
PPS		36.4	1.1	40.2	18.9	3.4
5. DP	35,926	47.9	0.0	4.6	46.2	1.3
PPS		45.4	0.2	4.6	45.5	4.3
6. DP	40,618	51.9	2.0	13.9	30.2	2.0
PPS		39.0	2.1	13.9	30.1	14.9
7. DP	34,383	72.2	0.0	26.9	0.0	0.9
PPS		54.9	3.8	16.0	16.3	9.0
8. DP	25,912	72.0	0.0	20.8	3.8	3.4
PPS		70.6	3.8	11.3	13.2	1.1

ICCs ranged between .66 and .95 ($M = .84$, $SD = .11$). ICC for eight nights (total seconds in which movement scores are recorded: 270,774 sec.) was .84. Cronbach's alpha ranged between .66 and .95 ($M = .84$).

Feasibility of the DynaPort MiniMod

The feasibility of the DynaPort MiniMod in measuring position dur-

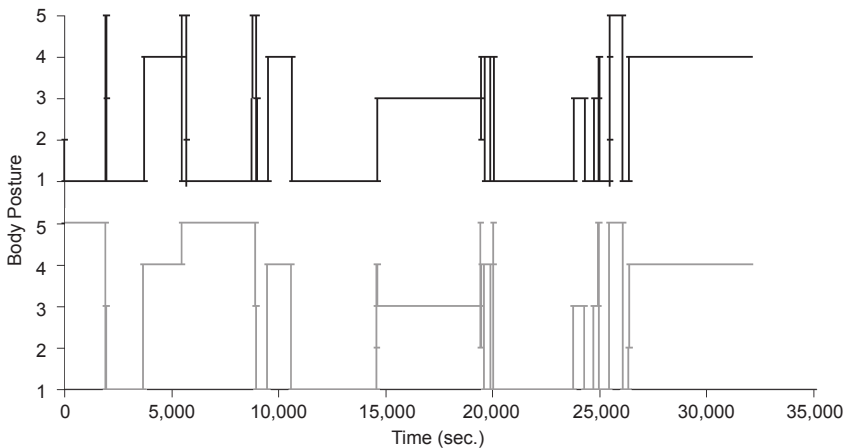


FIG. 2. Study B: body posture registered by the DynaPort MiniMod (—) and the polysomnography position sensor (---). The horizontal line indicates the time in seconds. The body posture is scaled 1 to 5, 1 to 4 are lying down positions, 1: back, 2: front, 3: left, and 4: right. Scale 5 represents all other positions described as unknown.

TABLE 3

PARTICIPANTS' CHARACTERISTICS, INTRAClass CORRELATION, AND CRONBACH ALPHA FOR STUDY B: COMPARISON OF BODY POSTURE DETECTED BY POLYSOMNOGRAPHY AND DYNAPORT MINIMOD DURING 1 NIGHT IN 8 PATIENTS SUSPECTED TO HAVE OBSTRUCTIVE SLEEP APNOEA SYNDROME

Participant	Sex	Age	BMI	No. of Measurements (sec.)	ICC	α
1	M	69	36	40,807	.95*	.95
2	M	42	37	30,442	.94*	.94
3	M	58	27	32,254	.75*	.75
4	F	50	41	30,432	.86*	.86
5	M	52	35	35,926	.90*	.90
6	F	29	26	40,618	.72*	.72
7	F	50	30	34,383	.66*	.66
8	M	42	31	25,912	.89*	.89
Total				270,774		
M					.84*	.84

* $p < .01$.

ing sleep was examined. None of the participants stopped wearing the DynaPort MiniMod, so the device was not unpleasant for the participants to wear during a night. The sleep reports were easy to interpret. If a participant was not lying down, the position was reported as "missing." Polysomnography gives a position different than lying down the code "unknown." Missing values in the DynaPort MiniMod data were interpreted as unknown. Data analyses showed in polysomnographic data a mean of 6.6% unknown compared to 3.2% of the data measured with the DynaPort MiniMod.

DISCUSSION

In this study, the validity, reliability, and feasibility of the DynaPort MiniMod were examined in assessing physical activity during sleep. In 10 healthy participants, the DynaPort MiniMod had a significant correlation ($r = .70$) with actigraphy during one night's sleep at home. In eight participants suspected to have Obstructive Sleep Apnoea Syndrome, data from the DynaPort MiniMod had a significant correlation ($ICC = .84$) with data from the polysomnography position sensor during one night's sleep at home. In both studies, internal consistency was satisfactory (Study A, $\alpha = .82$; Study B, $\alpha = .84$). The DynaPort MiniMod is a valid and feasible device for assessing intensity of physical activity and changes of body position during sleep.

A methodological issue relevant for the interpretation of the data is the different positions of the DynaPort MiniMod and Actiwatch on the body. The DynaPort MiniMod is placed on the back of the trunk, while the Actiwatch is worn at the wrist. One might anticipate movements of the

wrist to differ significantly from movements of the trunk; however, Kushida, *et al.* (2001) showed actigraphy and polysomnography registered the same type and number of movements. This is consistent with Littner, *et al.* (2003), who reported no difference between movement detections collected from actigraphy placed at different locations (e.g., dominant wrist, nondominant wrist, ankle, or trunk). The use of the Actiwatch in this study was suitable for validating the DynaPort MiniMod.

By comparing the DynaPort MiniMod with the Actiwatch and the polysomnography position sensor, a number of registration problems occurred. Both the Actiwatch and polysomnography have an internal clock running parallel to the connected computer. The DynaPort MiniMod does not have an internal clock which runs parallel to the connected computer. The DynaPort MiniMod primarily reconstructs the recorded time. The absence of a parallel running internal clock in the DynaPort MiniMod could affect the synchronization of the results because an exact point for measurement start is lacking. To avoid this synchronization problem of the DynaPort MiniMod and Actiwatch, both devices were started at the same clock time for every measurement. Another synchronization problem occurred with the measured timeframe. The Actiwatch records at a frequency of 2 Hz, and the DynaPort MiniMod at 100 Hz. It was not possible to synchronize on the exact second between these two devices. In contrast, the DynaPort MiniMod and polysomnography position sensor could be synchronized to the second.

The feasibility of using the DynaPort MiniMod was good. Participants deemed the DynaPort MiniMod suitable to wear. Participants were heterogeneous on age and sex, neither of which seemed to affect data. All participants were informed about the use of the DynaPort MiniMod and the Actiwatch in the same way. The DynaPort MiniMod was also useful in measuring activity during sleep of overweight participants, since there were no differences in outcomes between participants who were overweight and average weight.

In conclusion, the validity of the DynaPort MiniMod for assessing physical activity and changes in body position during sleep was examined. The DynaPort MiniMod was significantly moderately correlated with actigraphy during one night's sleep at home in a small number of healthy participants. The DynaPort MiniMod was strongly correlated with body position detected by polysomnography in a small number of participants suspected to have Obstructive Sleep Apnoea Syndrome. This suggests the DynaPort MiniMod can be useful in recording physical activity during night as well as during day. A potential shortcoming for sleep studies is the lack of an internal clock. This should be improved before carrying out further sleep validation studies with other patient groups.

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Accepted November 29, 2010.