Measuring physical activity levels in hospitalized patients: a comparison between behavioural mapping and data from an accelerometer

Karin Valkenet[1] , Petra Bor[1],
Lotte van Delft[1] and Cindy Veenhof[1,2]

Abstract

Objective: To investigate the level of agreement of the behavioural mapping method with an accelerometer to measure physical activity of hospitalized patients.

Design: A prospective single-centre observational study.

Setting: A university medical centre in the Netherlands.

Subjects: Patients admitted to the hospital.

Main measures: Physical activity of participants was measured for one day from 9 AM to 4 PM with the behavioural mapping method and an accelerometer simultaneously. The level of agreement between the percentages spent lying, sitting and moving from both measures was evaluated using the Bland–Altman method and by calculating Intraclass Correlation Coefficients.

Results: In total, 30 patients were included. Mean ($\pm$SD) age was 63.0 (16.8) years and the majority of patients were men ($n = 18$). The mean percentage of time (SD) spent lying was 47.2 (23.3) and 49.7 (29.8); sitting 42.6 (20.5) and 40.0 (26.2); and active 10.2 (6.1) and 10.3 (8.3) according to the accelerometer and observations, respectively. The Intraclass Correlation Coefficient and mean difference (SD) between the two measures were 0.852 and −2.56 (19.33) for lying; 0.836 and 2.60 (17.72) for sitting; and 0.782 and −0.065 (6.23) for moving. The mean difference between the two measures is small ($\leqslant$2.6%) for all three physical activity levels. On patient level, the variation between both measures is large with differences above and below the mean of $\geqslant$20% being common.

Conclusion: The overall level of agreement between the behavioural mapping method and an accelerometer to identify the physical activity levels 'lying', 'sitting' and 'moving' of hospitalized patients is reasonable.

[1]Department of Rehabilitation, Physical Therapy Science
& Sports, University Medical Center Utrecht, Utrecht
University, Utrecht, The Netherlands
[2]Expertise Center Innovation of Care, Research Group
Innovation of Mobility Care, University of Applied Sciences
Utrecht, Utrecht, The Netherlands

Corresponding author:
Karin Valkenet, Department of Rehabilitation, Physical
Therapy Science & Sports, University Medical Center Utrecht,
Utrecht University, Heidelberglaan 100, 3584 CX Utrecht,
The Netherlands.
Email: k.valkenet@umcutrecht.nl

Introduction

Higher amounts of physical activity during hospital stay are associated with lower complication rates, shorter length of stay and earlier return to functional independence.[1–3] Despite this evidence, the current culture in hospitals is to send patients to their beds in their pyjama's even when they are self-supporting and able to be active independently.[4] As a result, hospital stays are associated with high levels of sedentary behaviour. A hospital day is spent in bed for up to 83% of the time and only 6% of the time is spent active.[5–8] This leads to unnecessary and preventable loss of muscle mass and physical functioning which may lead to functional dependency.[9,10]

The quantification of physical activity of hospitalized patients is important to establish objective and reliable data of physical behaviour of inpatients. This is essential to create more awareness in both healthcare professionals and patients of the amount of physical (in)activity during hospital stay. It furthermore enables objective evaluation of the impact of interventions aiming to stimulate inpatients' physical activity levels and discourage the immobilizing culture in hospital wards.

Two available measures to assess physical activity in healthcare settings are accelerometers and the behavioural mapping method. Accelerometers are instruments that deliver continuous physical activity data and are used in all kinds of populations.[11–13] Behavioural mapping is a structured method where participants are intermittently observed at set intervals.[14] In addition to physical activity, environmental factors like the location, persons attending and the daily activity of the patient can be recorded during the observations.[15] Both measures have their own advantages and disadvantages for assessing physical activity; however, no studies have investigated the relationship between the physical activity outcomes of both measures in inpatients across the hospital.

Therefore, the aim of this study is to investigate the level of agreement between the behavioural mapping method and an accelerometer to measure physical activity levels in hospitalized patients.

Methods

This was a prospective single-centre observational study. Patients admitted to a university medical centre in the Netherlands were eligible for inclusion. The day prior to the day of assessment, patients were approached for participation and asked for their consent. Patients with strict bed rest orders, patients receiving end-of-life care or patients planned for discharge during the day of assessment were excluded. The physical activity of participants was assessed during one day between 9 AM and 4 PM. The study protocol was approved by the medical ethical committee of the University Medical Centre Utrecht, the Netherlands. Patients had to give written informed consent to be included.

Assessment of physical activity

The behavioural mapping method was used to observe patients between 9 AM and 4 PM. Patients were observed in a fixed order for 1 minute every 10 minutes following the protocols of van de Port et al.[15] and Bernhardt et al.[16] This protocol has shown good to excellent inter-rater reliability.[15,16] During the observations, the physical activity of the patient, persons attending, location and daily activity were scored according to predefined items (Supplemental Appendix 1). Participants were not observed when a patient was outside the ward or out of the observers' sight (i.e. during bathing). When more than one body positions were observed for an equal amount of time during the minute of observation, the one with the highest intensity was recorded. The observations were performed by physiotherapy graduation students who were allowed three separate 10 minute breaks during the assessment day. Per observer a maximum of eight patients could be observed per day. The results were directly recorded in Microsoft Excel on a tablet computer.

The Dynaport MoveMonitor (McRoberts, The Hague, The Netherlands) was used as comparison. This three-axial accelerometer records the physical activities lying, sitting, standing, shuffling and walking. It also records when the accelerometer is not worn. The Dynaport MoveMonitor has shown

Table 1. Classification of the physical activity levels.

Physical activity level	Items observations	Items accelerometer
Lying	Lying in bed with back-rest <30° and sitting in bed with back-rest >30°	Lying
Sitting	Sitting on bedside and sitting (toilet) chair	Sitting
Moving	Moving (bed-chair), standing, walking and ergometer cycling	Standing, shuffling and walking

good construct validity to measure lying, sitting and walking.[11,13,17] During the observations, the accelerometer was worn by the participants on the lumbar waist using an elastic band. The physical activity outcomes of the accelerometer are displayed per minute or at posture change in a structured data file.

Data processing

Per participant the number of times an item was observed within the category physical activity was counted. This sum was divided by the total number of observations for that participant resulting in a percentage of time spent per observed item. For example, a participant who was observed sitting for 21 of the 39 completed observations was considered as sitting for 54% of the time.

For the accelerometer, the total time per physical activity was counted up per participant. This sum was divided by the total measurement time for that participant resulting in a percentage of time spent performing a specific physical activity.

For the analyses, only the data were used for the time period where participants were observed and wore the accelerometer simultaneously. For example, when a participant removed the accelerometer before the end of the observations, only the data of both measures were analysed for the time period that the accelerometer was worn.

The outcomes of both measures were classified into three levels of physical activity: lying, sitting and moving (Table 1). The observation 'sitting in bed with back-rest > 30°' was included within the level 'lying' to make a more clear distinction between passive and more active behaviour. Subsequently, for both the observations and accelerometer, the percentages of time spent per level were calculated per participant.

Later, the intraclass correlation coefficients (ICCs) were calculated to examine the relationship between data obtained with the behavioural mapping method and with the Dynaport MoveMonitor. An ICC of <0.3 indicates weak agreement, between 0.3–0.7 indicates moderate agreement and >0.7 indicates strong agreement.[18] Scatterplots and Bland–Altman plots were created to further assess the level of agreement between the two measures.[19] For the Bland–Altman plots, the upper and lower limits of agreement were set at the mean difference ±1.96 SD.[19,20] IBM SPSS statistics (version 25) was used for the data analyses.

Results

Data collection took place between February 2016 and November 2017. In total, 30 hospitalized patients were included with a mean (±SD) age of 63.0 (16.8) years (Table 2). Of these, 18 (60%) were men and 26 (87%) had independent levels of mobility. In four patients, the observations started 1 hour later than planned, and in four patients, the measurements stopped 2 hours earlier due to unplanned discharge ($n=2$) and discomfort of the accelerometer ($n=2$). One patient removed the accelerometer after 1.5 hours wear time due to discomfort. The resulting mean time that patients were observed while wearing the accelerometer was 310 (±67 SD) minutes. The mean percentage of time (SD) spent lying was 47.2 (±23.3 SD) and 49.7 (±29.8 SD), sitting 42.6 (±20.5 SD) and 40.0 (±26.2 SD) and moving 10.2 (±6.1 SD) and 10.3 (±8.3 SD) according to the accelerometer and observations, respectively (Table 3).
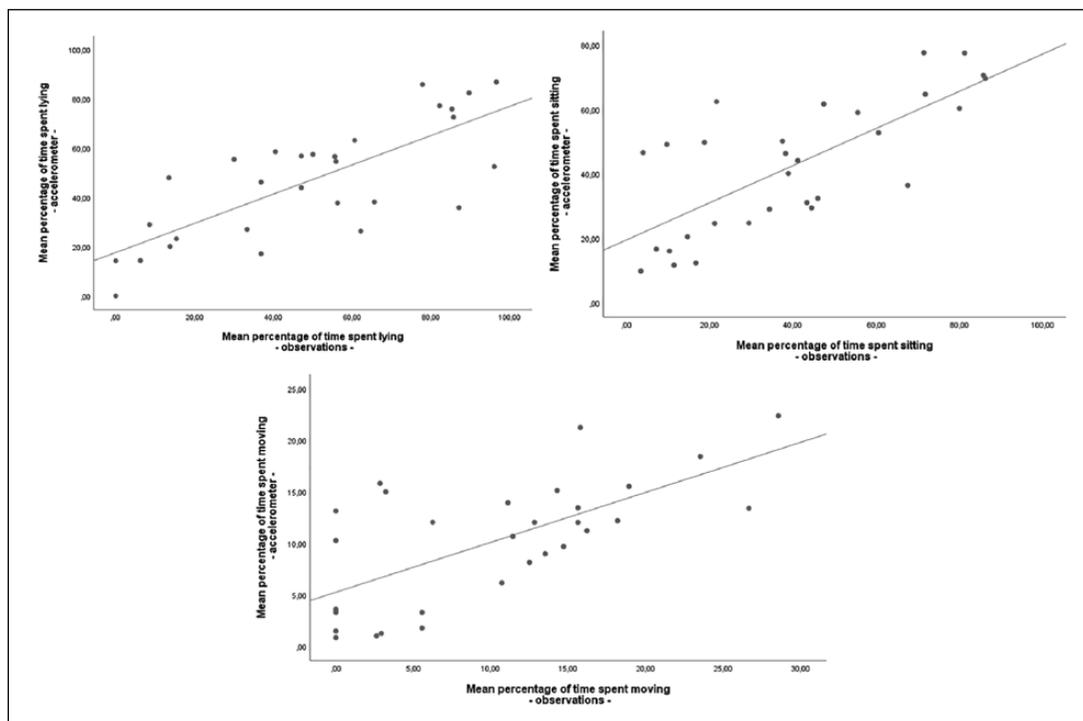
Figure 1. Scatterplots for the observations and the accelerometer. The X and Y axis represent mean percentages of time spent lying, sitting and moving.

Table 2. Patient characteristics.

	N = 30
Men, N (%)	18 (60)
Age (years), mean (SD)	63.0 (16.8)
Height (cm), mean (SD)	173.4 (10.4)
Weight (kg), mean (SD)	75.4 (18.0)
BMI, mean (SD)	24.9 (4.8)
Mobility level, N (%)	
- Independent	26 (87)
- Partially dependent	3 (10)
- Totally dependent	1 (3)
Length of stay, at inclusion (days), mean (SD)	8.7 (6.7)
Length of stay, total (days), mean (SD)	12.9 (7.4)
Medical specialism, N (%)	
- Cardiothoracic surgery	8 (27)
- Cardiology	6 (20)
- Oncology	6 (20)

Table 2. (Continued)

	N = 30
- Geriatrics	5 (17)
- Gastroenterology	3 (10)
- Lung disease	1 (3)
- Internal medicine	1 (3)

BMI, body mass index.

The mean difference between the two measures is small ($\leq 2.6\%$) for all three physical activity levels (Table 3). In addition, the ICCs of ≥ 0.782 indicate strong correlations between the two measures (Table 3). The scatterplots for the observations and the accelerometer are displayed in Figure 1. Bland–Altman plots (Figure 2) show that the variabilities across the mean are fairly consistent as the averages get higher. However, within all three physical

Table 3. Physical activity outcomes and level of agreement statistics.

	Physical activity outcomes		Level of agreement statistics			
	Accelerometer, % of time* (SD)	Observations, % of time* (SD)	Mean difference (SD)	Absolute difference, min to max	Limits of agreement	ICC
Lying	47.1 (23.3)	49.7 (29.8)	−2.56 (19.33)	−51.2 to 34.5	−40.45 to 35.32	0.852
Sitting	42.6 (20.5)	40.0 (26.2)	2.60 (17.72)	−31.1 to 42.6	−32.13 to 37.33	0.836
Moving	10.2 (6.1)	10.3 (8.3)	−0.065 (6.23)	−13.3 to 13.1	−12.28 to 12.15	0.782

ICC: Intraclass Correlation Coefficient.
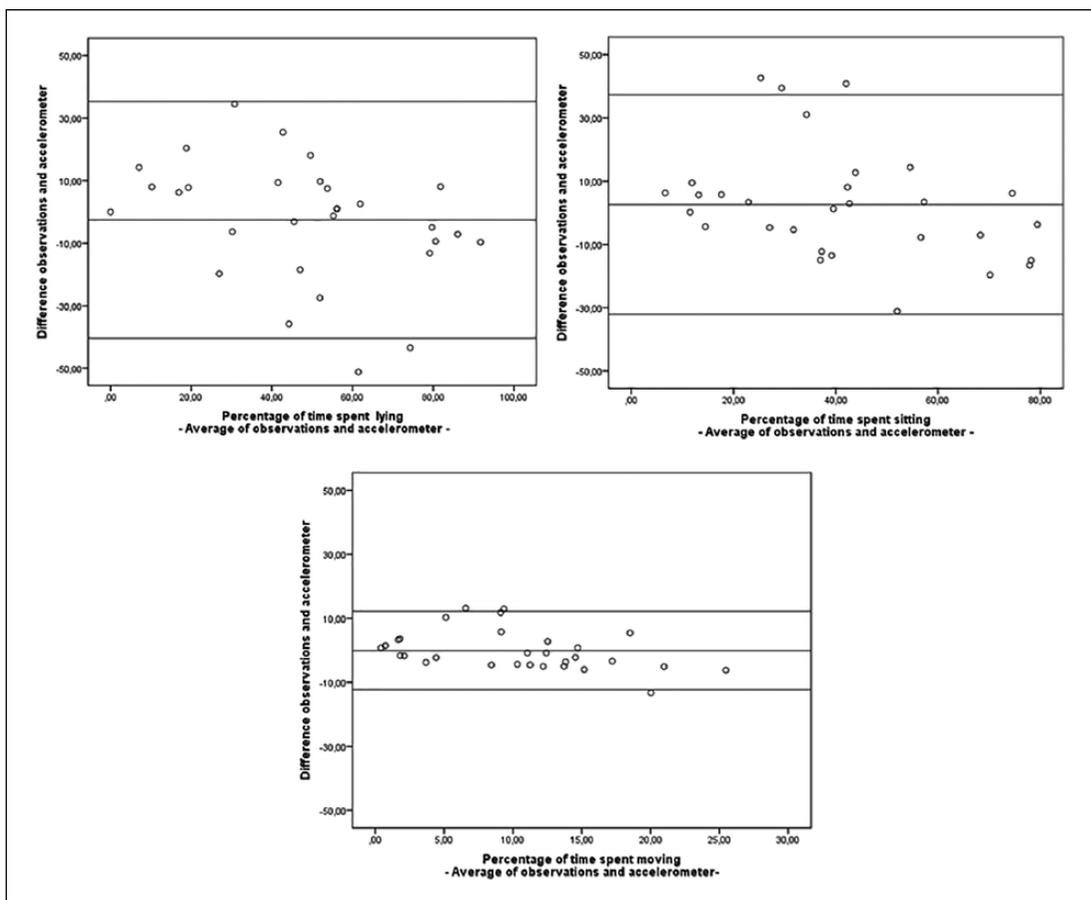*Percentage of time (from 9 AM to 4 PM) per physical activity level.

Figure 2. Bland–Altman plots for the observations and the accelerometer.
The X axis represents percentages of time spent lying, sitting and moving. On the Y axis the middle line represents the mean difference between the two measures, the upper and lower lines represent the limits of agreement (mean difference ± 2 SD).

activity levels, Bland–Altman plots show large variation above and below the mean with differences of ⩾20% being common. Furthermore, the upper and lower limits of agreement are large for all three levels.

Discussion

This study shows that the level of agreement between the behavioural mapping method and the Dynaport MoveMonitor to measure inpatient physical activity, categorized into lying, sitting and moving, is strong on group level. On patient level, the variation between both measures is large.

The behavioural mapping method is a rich source of data. Besides measuring physical activity, it can also be used to map the physical and social environment in which the physical activity takes place. For example, it can show the percentage of time that patients spend in their patient room, or the percentage of time a nurse or physician is present. In addition, this method allows to evaluate the number of patients in bed during lunchtime or the main physical activity while family or visitors were present. The combination of collecting objective physical activity data and contextual data makes this method very useful to map the mobility culture in hospital wards. This information can be used as a starting point for the design of interventions or implementation projects.[21] In addition, it can be used as an outcome measure to evaluate the impact of interventions like shared lunching or the involvement of family or visitors to assist in the mobilization of a patient.[6,15,21–23] This method also has several downsides. The majority of behavioural mapping studies assess physical activity only during working hours (between 8 AM and 5 PM). Monitoring patients for a period of 8 hours or more is not very feasible due to the accompanying workload. Furthermore, the privacy of patients is hampered by observing a patient every 10 minutes. This method is therefore not suitable for routine monitoring of physical activity. Accelerometers might be more suitable for that purpose.

Several accelerometers are used to measure physical activity of hospitalized patients.[17,24,25] The validity of accelerometers for this purpose is variable and depends on the chosen outcome measure and target population. While some accelerometers are unable to discriminate between lying and sitting, others have more difficulty to distinguish between sitting and standing.[17] An additional challenge for the use of accelerometers is the willingness of inpatients to wear the accelerometer. Up to 45% of patients a priori decline to wear an accelerometer for a full day, and up to 25% of patient withdraw during the day.[24,26] The low inclusion and retention of participants in inpatient accelerometer studies may therefore introduce selection bias. On the other hand, with the increasing number of technological innovations in healthcare, it seems likely that accelerometers will become available for use in hospital settings. When they will be implemented for routine monitoring, they might have several benefits above the behavioural mapping method, provided that they have a high user comfort. The superiority of one of the two measurements, for example on terms of covered time periods, would be an interesting question for future research.

To determine the level of agreement between the two measures in this study, Bland–Altman method was used.[19] This is a fairly simple method to visualize agreement to evaluate the bias between two measures and to estimate an agreement interval. The absolute difference between the two investigated measures in some individual cases was large (Table 1). The largest difference between the observations and the accelerometer for the time spent lying was 51.2%. In this specific case, the patient was observed lying for 87.1% of the time, while the accelerometer indicated the patient as lying for 35.9% of the time. This might be explained by the angle of the back-rest of the bed. With a rising upright angle, the chance that the accelerometer registered this as 'sitting' instead of 'lying' increases, while this would still be classified as 'lying' according to our classification of physical activity levels. Sensitivity analyses could provide detailed insight into the levels of agreement per specific physical activity, instead of the physical activity classifications. The choice was made to combine physical activities into levels to make a

more clear distinction between active and passive behaviour and the most common inpatient activities. Furthermore, on group level, the results show a very low bias with mean differences below 2.6% and a strong relationship between the two measures with ICCs above 0.78. These results indicate that, on group level, the chosen physical activity levels are appropriate to objectively classify inpatient physical activity (Table 1).

For agreement studies, a sample size of at least 32 is recommended.[27] Our sample size of 30 is therefore a limitation of this study.

In conclusion, we state that, on group level, the behavioural mapping method agrees strongly with the Dynaport MoveMonitor in classifying inpatient physical activity into time spent 'lying', 'sitting' and 'moving'. However, on patient level, the variation between both measures is large. Therefore, the overall level of agreement is considered reasonable.

Clinical messages

- On group level, the level of agreement between behavioural mapping and the Dynaport MoveMonitor is strong. However, on patient level, the variation between both measures is large.
- Patients admitted to a hospital spent the majority of their day sedentary, with 90% of the time spent lying or sitting.

Supplemental material

Supplemental material for this article is available online.

ORCID iD

Karin Valkenet ![iD] https://orcid.org/0000-0002-4715-685X

Lotte van Delft ![iD] https://orcid.org/0000-0002-9397-8934

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