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Comparative analysis of actigraphy performance in healthy young subjects

Giannina J. Bellone [a,b,1], Santiago A. Plano [a,b,c,1], Daniel P. Cardinali [b,c], Daniel Pérez Chada [d], Daniel E. Vigo [b,c,e,*], Diego A. Golombek [a,c,*]

[a] Chronobiology Laboratory, Universidad Nacional de Quilmes (UNQ) Bernal, Buenos Aires, Argentina
[b] Applied Neuroscience Laboratory, Institute for Biomedical Research (BIOMED), School of Medical Sciences Universidad Católica Argentina (UCA), Buenos Aires, Argentina
[c] Consejo Nacional de Investigaciones Científicas y Tecnológicas (CONICET), Argentina
[d] Sleep Clinic, Hospital Universitario Austral, Pilar, Buenos Aires, Argentina
[e] Research Group on Health Psychology, Department of Psychology, KU Leuven, Leuven, Belgium

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ABSTRACT

Sleep-related health disorders are increasing worldwide; diagnosis and treatment of such sleep diseases are commonly invasive and sometimes unpractical or expensive. Actigraphy has been recently introduced as a tool for the study of sleep and circadian disorders; however, there are several devices that claim to be useful for research and have not been thoroughly tested. This comparative study provides activity, sleep and temperature information regarding several of the most commonly used actigraphers: Micro-Mini Motion Logger; Act Trust; Misfit Flash; Fitbit Flex & Thermochron.

Twenty-two healthy young subjects were assessed with five different commercial actigraphs (Micro-Mini Motionlogger Watch, Condor Act Trust, MisFit Flash and Fitbit Flex) and a temperature recorder (Thermochron), and also completed a sleep diary for a week. There were not significant differences in the analysis of rest-activity pattern between devices. Temperature rhythm comparison between the Act Trust and the Thermochron showed significant differences in rhythm percentage ($p < 0.05$) and mesor ($p < 0.0563$) but not in amplitude or acrophase.

Although data accessibility and ease of use was very different for the diverse devices, there were no significant differences for sleep onset, total sleep time and sleep efficiency recordings, where applicable. In conclusion, depending on the type of study and analysis desired (as well as cost and compliance of use), we propose some relative advantages for the different actigraphy/temperature recording devices.

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1. Introduction

Sleep disorder diagnosis is usually based on Electroencephalography (EEG) and Polysomnography (PSG) recordings that involve unpractical and invasive sleep assessment, high costs, and usually demand a great effort from the patient [1–4]. An easier and cheaper alternative to assess circadian sleep disorders is the Daily Sleep Diary in which the person performs a subjective record about his/her sleep habits, including sleep onset and offset. While the Diary is practical to identify general sleep patterns and weekday/weekend differences, it is not a reliable instrument because personal sleep assessment is clearly affected by subjective recollections [1,5,6].

In recent years, with the spread of mobile telephony, the ease to connect to the internet wirelessly and the development of online applications, different companies have started to offer portable devices for the monitoring and recording of sleep. While these devices were initially used for investigation purposes, this type of portable technology started to be commercialized so that athletes could personally monitor their activity patterns, including distance and speed [7–10].

There are currently more than 200 different portable activity trackers, which can be easily purchased. The main objective here is to offer comfortable tools for health measurements (biometrics) and easier data management (information-surveyed records).

Activity or Sleep (activity/sleep trackers) monitors are portable, non-invasive and relatively cheap devices developed to track and quantify different movement patterns through accelerometers that measures the force of inertia generated when a mass is affected by a change in velocity. Actigraphy is based on the monitoring of movements during sleep or activity for long periods of time and, thanks to the use of specific computer algorithms, small devices can

* Corresponding authors.
[1] Both authors contributed equally to this work.
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Table 1.
Main features of the nine appliances of our initial screening.

#	Brand	Model	Style	App	Software	Sync	Waterproof	Battery	On display info	Alarm
1	Ambulatory monitoring	Micro-mini Motionlogger actigraph	Watch	No	Yes	IR to USB interface	Yes	Watch Battery 1 DL2430 (125 days)	No	No
2	Beddit	Beddit	Sensor placed on the mattress	Android/ i OS	No	Bluetooth	No	Has to be plugged	No	No
3	Condor instruments	Act trust	Watch	No	Yes	USB using a dock as interface	Yes	USB charge (up to 3 months)	No	No
4	Fitbit	Flex	Wristband	Android/ i OS	Yes	Bluetooth & Cable	No. Only splash.	USB charge	Lights	Yes
5	Hexoskin	Hexoskin Smart	Shirt	Android/ i OS	Yes	Bluetooth	Yes	USB charge	No	No
6	Maxim integrated	Thermochron DS1921G	iButton	No	Yes	Simple Serial Port Interfaces to Most Micro-controllers for rapid data transfer	No	Disposable device	No	No
7	Misfit	Misfit flash	Watch/ Multiwear	Android/ i OS	No	Bluetooth	Yes	Watch battery	Lights	No
8	Withings	Pulse OX	Watch/ Multiwear	Android/ i OS	No	Bluetooth	No	USB charge	On display	Yes
9	Withings	Activité Pop	Watch	Android/ i OS	No	Bluetooth	Yes	Watch battery	On display	Yes

offer information regarding individual sleep patterns. Many software applications are able to record, analyze and score physical activity and, in turn, infer sleep/wake characteristics which allow to diagnose and even prevent sleep-related disease [2,3,11–18].

In addition to movement, many of these devices include sensors that can record other variables such as temperature, heart rate, light exposure, oxygen saturation, perspiration, and respiration. Indeed, actigraphy is being increasingly established as the technology of choice for clinicians and circadian/sleep researchers. A recent survey estimated that about one fourth of such studies use actigraphy rather than polysomnography.8.

However, the use of most commercially available actigraphy devices has not been fully validated for clinical or research applications and, in addition, some of the most commonly used motion trackers claim to record sleep accurately, a statement that remains to be tested.

The objective of the present study is to compare different actigraphy and temperature portable devices in the general population. While some devices like Micro-Mini Motion Logger and Thermochron have been commonly used in sleep or circadian research, others (Condor Act Trust, Fitbit Flex or Misfit Shine) have been introduced more recently and have not necessarily been thoroughly tested. Two of these actigraphy monitors (Micro Mini-Motion Logger and Condor Act Trust) have been developed specifically for the assessment of circadian rhythms, while the Fitbit and Misfit devices are motion loggers whose main application is to trace physical activity programs. Our aim was to perform an initial comparison of these technical resources and their relative advantages and weaknesses for sleep and circadian research.

2. Materials and methods

2.1. Participants

A total of 22 (11 males, 11 females) healthy volunteers (21–34 years old) participated in the study. All of them were notified of the study description and objective, and signed an informed consent form. A written instructive portfolio with a detailed description of the study and the devices was given to all participants.

Subjects were asked to complete a demographic questionnaire and a general health questionnaire to discard any physical or psychological disease that might interfere with the study. The Munich Chronotype Questionnaire (MCQ) [19], was used to identify potentially extreme larks or owls.

On the first day of the recordings, the devices were placed and started by one of the investigators, who recovered all apparatus one week later.

2.2. Actigraphy and temperature recorders

We initially tested nine commercially available devices, based on diverse recording principles, as follows:

- Act Trust (CAT; Condor Instruments, São Paulo, Brazil)
- Beddit, (Beddit, Espoo, Greater Helsinki, Finland)
- Fitbit Flex, (FF; Fitbit, San Francisco, California, USA)
- Hexoskin Smart (Hexoskin, Montréal, Quebec, Canadá)
- Micro-Mini Motionlogger Watch (MM; Ambulatory Monitoring Inc., Ardsley, New York, USA)
- Misfit Flash (MF; Misfit, San Francisco, California, USA)
- Thermochron (TH; Maxim Integrated, San José, California, USA)
- Withings Activité Pop (Withings, Issy-les-Moulineaux,Île-de-France, France)
- Withings Pulse OX, Withings (Withings, Issy-les-Moulineaux, Île-de-France, France)

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