Sleep Assessment in Large Cohort Studies with High-Resolution Accelerometers

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KEYWORDS

• Accelerometers • Actigraphy • Sleep-wake differentiation • Periodogram-based sleep detection • Cohort studies • German National Cohort

KEY POINTS

- Large prospective studies are needed to identify sleep characteristics as possible determinants of personal health.
- Accelerometers can be a practical replacement for polysomnography in large observational studies.
- State-of-the-art accelerometers can estimate population-based average sleep times reasonably, at least for populations without high prevalence of sleep problems.
- Further algorithm development is required, as conventional classification approaches do not exploit major aspects of the acceleration data and work for wrist-worn devices only.
- Accompanying quality assurance procedures are necessary for accelerometer recordings in large cohort studies.

INTRODUCTION: SLEEP AND HEALTH

Insomnia and other sleep disturbances are discussed to be associated with impaired functioning during the day and higher risks for work or traffic accidents.[1–4] Beyond impacts on daytime performance, there is evidence on associations between insomnia, sleep apnea, or general sleep characteristics (such as shortened or prolonged sleep duration) with risk factors for major diseases,[5–9] morbidity,[10–16] and mortality.[15,17–21] However, the explanatory value of many studies on these associations is limited because of restrictions of the underlying study designs, or limitations in methods used for the assessment of the respective exposures. For example, a cross-sectional design, relying on self-reported information on sleep, residual confounding, and measurement artifacts might limit the results.[22–24] Therefore, it is premature to infer causal relationships from the current body of literature. Hence, additional large prospective studies, such as cohort studies, are needed that address sleep characteristics as possible determinants of personal health in more differentiated ways.

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ASSESSMENT OF SLEEP IN MEDICINE AND RESEARCH

Cardiorespiratory polysomnography (PSG) has been regarded as the gold standard in sleep medicine since 1968.[25–28] However, the applicability of PSG for the assessment of sleep characteristics in large prospective studies is limited due to its intricacy and costs.[29] Beyond that, PSG may produce first-night effects[30–32] and may lead to a selection bias because not every participant agrees with staying overnight in a sleep laboratory,[12,33] whereas participants might differ systematically from nonparticipants. Additionally, PSG settings might influence sleep depending on individual factors.[34–37] Therefore, conclusions based on PSGs might be limited with regard to sleep under unattended conditions at home.

As an alternative to PSGs, movement-based methods, such as actigraphy (or accelerometry) have been established since 1974.[38–41] They are also used for measuring physical activity and other physiologic signals in ambulatory settings.[42] Advantages of accelerometry over PSG are described as lower costs, higher availability, easy recording of multiple nights, and lower influence on natural sleep.[43–46] Nevertheless, movement-based methods seem to overestimate sleep and to underestimate wakefulness.[43,47,48] Their accuracy varies between different sleep variables[49] and depends on population-specific characteristics, being reduced the more sleep is disturbed.[43,47] In clinical settings, accelerometers are thus recommended only as an adjunct in the evaluation of circadian rhythm disorders, the assessment of sleep patterns in healthy adult populations, and in inpatients with certain suspected sleep disorders, such as delayed sleep phase syndrome or shift work disorder. They are not recommended as diagnostic instruments for routine diagnosis.[50,51]

The validity of movement-based devices also depends on device-specific technical characteristics and the algorithm used for data analysis. Technological progress leads to advanced devices with higher temporal resolution, higher acceleration resolution, and separate recording of all 3 directions (see later in this article), whereas many published and still used algorithms are several years old.[52,53] We refer to **Box 1** for short descriptions of several algorithms published between 1992 and 2013. Most algorithms do not take high resolutions into account or use aggregated data only.[54–57] As an early exception, in 2004, Hedner and colleagues[58] described an algorithm for a single-axis actigraph with a sampling rate of 100 Hz, reporting a reasonable sensitivity and specificity in patients with sleep apnea. For using this algorithm with more recent 3-axis devices, the applicability and validity would have to be tested. In conclusion, there seems to be a lack of algorithms for the deduction of sleep characteristics from recent high-resolution 3-axis accelerometers that are actually used in large observational studies.

SLEEP ASSESSMENT IN POPULATION-BASED STUDIES

This section gives a none-exhaustive overview of some important population-based studies with sleep assessments until 2016. One of the first articles on the frequency of sleep disturbances in a general population was published by Bixler and colleagues[59] in 1979. Since then, many population-based studies have included more or less comprehensive sleep assessments based on self-reported data (questionnaire or interview data).[60–64] Since 1988, objective measurements on sleep also have been applied with a special focus on sleep-related disorders, see **Table 1**. Initially, the focus was on sleep-disordered breathing (SDB),[65–68] whereas most recent cohort studies assess information on sleep as potential exposures or outcomes of interest among many others.[62,69–74]

THE GERMAN NATIONAL COHORT STUDY: A LARGE PROSPECTIVE OBSERVATIONAL STUDY

The German National Cohort (GNC) is an ongoing cohort study with objective measurements on sleep. This prospective observational study has been designed to provide a resource for population-based health and disease research in Germany, with a focus on major chronic diseases; that is, cardiovascular diseases, cancer, diabetes, neurodegenerative/psychiatric diseases, musculoskeletal diseases, respiratory and infectious diseases, and their preclinical stages or functional health impairments.[74] Study centers across Germany aim at including a total of 200,000 subjects (100,000 men, 100,000 women, 20–69 years of age) randomly sampled from the general population during 4 to 5 years since 2014. The overall duration is planned for 25 to 30 years. The baseline assessment includes a personal interview, self-completion questionnaires, medical examinations, samples taken for a bio bank, and an accelerometer (GT3X+; ActiGraph, Pensacola, FL) worn at the hip for 7 days.[74,86] A random subsample of 40,000 participants receives an intensified examination program (see later in this article), and