

Title	An Epidemiological Sleep Study Using a Large-scale Database of Body Acceleration Data in a Japanese Population - Age, Gender, and Seasonal Effects
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論 文 内 容 の 要 旨

氏 名 (李 俐)

論文題名

An Epidemiological Sleep Study Using a Large-scale Database of Body Acceleration Data in a Japanese Population - Age, Gender, and Seasonal Effects
 (身体加速度ビックデータベースの利活用による日本人の睡眠疫学研究
 — 加齢、性差、季節性の影響)

論文内容の要旨

The recent development and prevalence of IoT (Internet of Things) wearable devices enable us to collect large-scale biological signals (e.g., wrist acceleration data, heart rate) which are objectively measured in daily life. The utility of such bigdata is thought to have a great potential for establishing a new type of epidemiological research, referred to as ‘ecological epidemiology’. The realization of such new research could provide unprecedented health- and disease-related knowledge at the population and/or at the worldwide levels in a real-time fashion. In this thesis, with an assumption of a future scenario in which biological bigdata are available by IoT devices, a blueprint of ecological epidemiology was provided by showing utilities of biological bigdata (specifically, tri-axial trunk acceleration collected from about 70,000 individuals) in sleep studies. The thesis has consisted of three studies as follows.

First, sleep–wake classifiers using machine learning approaches was developed. Briefly, we first conducted simultaneous measurements of Holter monitoring and Actigraphy (Ambulatory Monitoring Inc., Ardsley, NY; a reliable assessment of habitual sleep) and then trained classifiers [support vector machine (SVM), k -nearest neighbor, and k -means clustering], in which local statistics derived from Holter acceleration data were as feature vectors inputting machines and sleep–wake states derived from actigraph data were as supervised data. The SVM-based classifier showed the highest agreement in sleep–wake estimation with actigraph data (accuracy = $94.4 \pm 3.8\%$, specificity = $94.2 \pm 5.2\%$, sensitivity = $94.8 \pm 3.9\%$, and F1-score = $92.0 \pm 4.5\%$). We further developed an algorithm to score sleep parameters and then validated their accuracy; seven sleep parameters, in-bed time (IBT), get-up time (GUT), time-in-bed (TIB), sleep latency (SL), wake time after sleep onset (WASO), total sleep time (TST), and sleep efficiency (SE), were nicely coincident with those of actigraph without any significant difference. These algorithms enable us to obtain large-scale data of objective sleep parameters in a Japanese population.

Second, by using the derived objective sleep data, an epidemiological sleep study on age- and gender-effects on Japanese sleep habits was conducted. To this end, age-related variations of sleep parameters from adolescents to the elderly (10–89 years old) were analyzed, by which a variety of considerable results were obtained. For example, we found a U-shaped association with increasing age in sleep durations assessed by TIB and TST for the first time. In addition, a progressive reduction in sleep quality with age (more evident after the middle-aged), mainly caused by the increase of WASO. Further, gender comparisons showed that TST was shorter in women than in similarly aged men, which is much evident after the age of 30 years. This was associated with later bedtimes and age-related deterioration of sleep quality in women; women over age 50 demonstrated a more significant reduction in SE is related to the increase of nighttime awakening durations. Those age and gender differences are thought to be attributed to several intricately intertwined causes, including biological aging, as well as socio-cultural and socio-familial factors in Japan.

Third, seasonal variations of sleep parameters and further identified meteorological factors [e.g., ambient temperature (T_a), humidity, and sunlight] contributing to the seasonality were examined. Sleep parameters (TST, SL, SE, and WASO) demonstrated significant seasonal variations, showing the worsening of sleep quality in summer compared with the remaining seasons. While the IBT did not show clear seasonality, the GUT varied seasonally, with a nadir during summer. Further, we identified that T_a had a practically meaningful association with sleep quality, indicating that sleep quality worsened with the increase of T_a . This association would partly explain seasonal variations in sleep quality among seasons, while bedtime were affected by social rhythms in daily life.

In conclusion, epidemiological insight into Japanese sleep habits (age, gender, and seasonal influences on sleep) were obtained by this study, which have not been reported so far by objective and reliable approaches. Furthermore, the current attempts had valuable contributions to establish ecological epidemiology in the field of sleep studies.

論文審査の結果の要旨及び担当者

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論文審査の結果の要旨

本学位論文は、定性的調査手法に基づいて発展してきた従来の睡眠研究を、IoT技術と機械学習を含む最新の統計手法を活用することで、睡眠疫学とも言える新しいステージに発展させる基盤の確立、およびその基盤を日本全国から集められた約7万人の24時間ホルター心電図計に付随する3軸体幹加速度データに適用して得られた日本人の睡眠に関する新しい知見をまとめたものである。特に、7万件という数はこれまで日本で実施されてきた客観的睡眠実態の研究としては過去最大の規模であることは特筆に値する。本研究の1つ目の成果は、日常生活の中で計測されたホルター心電図付随加速度計によって計測された身体加速度と睡眠研究のゴールドスタンダードとして用いられるアクチグラフによる睡眠状態の同時計測を実施し、得られたデータを、機械学習を主軸とした様々な手法で統計解析することで、被験者個人に対する睡眠指標（入眠・起床時刻、総合睡眠時間、睡眠効率、睡眠潜時、中途覚醒時間など）を高精度で推定可能な手法を開発したことである。次に、開発手法を用いて、睡眠に関わる種々の興味深い現象の存在を定量的に明らかにした。例えば、女性は男性に比べ睡眠時間が平均で約30分短く、それが30歳以上で顕著で、かつそれが男女差の無い起床時刻に対して女性の就寝時刻が男性よりも遅いことによることを明らかにした。また、加齢に伴う睡眠の質の低下も男性よりも女性の方が顕著であることも示した。これらは欧米における類似調査とは異なる現象であり、日本特有の社会的・文化的・家族的要因が複合関与していることを示唆する。さらに、日本人の睡眠特性の季節性の変化を定量的に明らかにした。特に、睡眠の質が夏場に低下すること、およびその主要な要因が室内温度であって湿度等の他の要因の影響は限定的であること、また起床時間は日の出時刻によって決まることなどを明らかにした。以上のように、本論文は、睡眠研究およびヘルスケアIoTの今後の発展に対して寄与するものであり、博士（工学）の学位論文として価値のあるものと認める。