Abstract
We spend almost one third of our life in sleep. Sleep is one of the main contributors to our life and wellbeing. Sleep disorders are known to have adverse health effects but studies have also shown that too little or too much sleep is correlated with a greater risk of death. Sleep trackers have introduced new tools for sleep related studies by providing detailed, long-term sleep data. In this study, data collected with a wearable wellness device, Oura ring, is used to reveal how people sleep from the point of view of duration, consistency and timing. It is shown that, on average, Oura users sleep approximately 7 hours per night and that following a consistent sleep schedule is associated with more efficient sleep.

ACM Classification Keywords
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Author Keywords
Sleep; Wearable Sensors; Oura Ring; Population Based Study.

Introduction
Sleep is one of the main pillars of our health and wellbeing. Both short and long duration of sleep has been associated...
with obesity, diabetes, hypertension and cardiovascular diseases [2] and even with greater risk of death [4]. The official recommendation of the National Sleep Foundation is 7–9 hours of sleep for adults [6], an amount that is not achieved approximately by 40 percent of population in Western societies [9]. Nevertheless, the duration of the sleep is not the only quantity affecting the perceived quality of sleep but it can be divided into dimensions of quantity, continuity and timing, for example [3]. While continuity and timing are not well studied possibly due the difficulty of assessing them with questionnaires, the recent development of wearable and environmental sleep trackers can enable more versatile analysis of all three dimensions. For example, a recent case study [1] studied the relation of sleep to cognitive performance by revealing that sleeping later in one’s circadian cycle effects negatively the day-time performance while sleeping earlier does not.

In this article, sleep duration as well as the role of go-to-bed time and sleep consistency as contributors of sleep quality, are assessed in real-life settings. The actual data set consists of sleep data from Oura ring users [7]. The Oura ring (Figure 1) is a scientifically validated, wearable sleep tracker which objectively estimates go-to-bed time and sleep stages based on nocturnal PPG (250 Hz), 3-D accelerometer (50 Hz) and min-by-min skin temperature [5]. The associated Oura App also displays an optimal bed-time window for those users that are considered very good sleepers according to the Oura Sleep Score metrics.

Study
This study was divided into three categories. The first one was based on a population of 9333 persons while the second category used a sub-sample of those, named very good sleepers (n=2170). The third one looked at data from a single good sleeper to provide an example of daily variations that a single person can have compared to population based averages.

In the largest population three different metrics was considered interesting: 1) overall sleep duration, 2) consistency of time spent in bed vs sleep efficiency, and 3) consistency of time in bed vs total sleep. Sleep efficiency was determined as the ratio of total sleep duration in a night compared to total amount of time in bed. As a criteria for consistency, the difference between a 75th percentile and 25th percentile of time in bed was used, which includes the variation of one half of the nights of a single user.

The definition of a very good sleeper was based on an optimal bed time criteria defined by the Oura ring. The optimal bed time criteria was an individual value based on the user’s good quality nights — Sleep Scores higher or equal to 85 — and sleep schedules — wake-up and bed-time schedules that matches those good quality nights. The good quality nights were defined using a parameter named Sleep Score in which information of Total sleep time, Efficiency, Tranquility, amount of REM sleep, amount of Deep sleep, Latency and Timing (related to circadian clock) are combined (see Figure 2).

For the very good sleepers we studied what kind of characteristics in sleep schedules associate with the highest quality sleep. In practice, we considered the time people were going to bed vs. when should they go to bed to get their best sleep, as well as how consistent they were in their go-to-bed times.

For the single good sleeper we run an analysis over 587 nights to reveal how consistent the sleep schedule is within the limits used in this study (25th and 75th percentile) and how much variation a single person can have in sleeping habits.
Results and discussion

The results are presented for the three different populations in different subsections starting with the largest population and ending with single person based results.

Population based results

In the largest population based results three different metrics were considered as interesting: overall sleep duration, consistency vs sleep efficiency, and consistency vs total sleep. To be included into this population a user needed at least 10 Oura recorded nights available constituting a population of 9333 persons and including approximately 1.8 million nights.

From the histogram in Figure 3 we can see that half of the Oura users sleep, on average, less than 7 hours per night. This is slightly higher proportion of population than seen in questionnaire based studies where 40 percent of population was having inadequate amount of sleep [9]. There can be at least three explanations: 1) it has been shown that self assessment tends to give a more positive result than the objective measured values [8], 2) in particular, sleep related questionnaires may not distinguish between time spent in bed and actual sleep duration, and 3) the users of sleep trackers do sleep less than the overall population. Nevertheless, regardless of the reason half of the Oura users need more sleep.

Figure 5: Consistency vs. efficiency.

Very good sleepers

While for the larger population the median sleep amount was on average 7 hours, the very good sleepers (n = 2170) on the other hand slept on average 7.35 hours. As seen in Figure 6, also the very good sleepers should go to bed approximately half and hour before their median values to ensure their best sleep quality. On the other hand, half of the population were consistent sleepers (consistency less than 1.4 hours) and only one percent of population (22 persons) had consistency over 3 hours.

The fact that the good sleepers sleep more and are consistent in their sleep habits is not very surprising while it was already stated that the very good sleeper definition was based on ability to have good quality nights and sleep schedules related to that. Nevertheless, the fact that only 23.3 percent of the whole population was considered as very good sleepers strengthens the relation found between sleep quality and consistency.

Single person based results

While in previous results the 25th and 75th percentiles were used as boundaries it meant that half of the nights were excluded from the analysis. Although, this was a reasonable selection while in [1] it was also stated that one bad night does not effect highly negatively to people’s performance, there was an interest also to study what kind on nights people can have outside this "normal night" category.

Figure 7 illustrates the correlation between a go-to-bed-time and sleep score for a subject having data from 587 nights.
It can be seen that the subject is normally consistent with the go-to-bed-times (1.2 hour difference between 75th and 25th percentile) and the median go-to-bed-time is approximately 22:40. Nevertheless, there can also be seen a variation of 10 hours and a high correlation between the late go-to-bed-times and lower sleep scores.

**Conclusion**

Sleep is essential for humans to survive everyday challenges. Different sleep disorders limit our capabilities but even inadequate or excessive sleep can harm our performance and correlates with different diseases and even death. The positive aspect is that people are getting conscious about the importance of sleep and its effects on their overall wellbeing, for which we can, at least partly, thank the current development of comfortable sleep trackers.

In this study we revealed some facts on how people sleep based on sleep data gathered with a wearable sleep and wellness device called the Oura ring. It was shown that on average half of the Oura users were having insufficient amount of sleep compared to NSF recommendations. Moreover, lack of sleep consistency was found to correlate with shorter sleep duration and lower sleep efficiency. In future studies, demographic information, such as sex and age, should be included in the analysis. Especially interesting would be to see how chronotypes affect the duration and quality of sleep.

**REFERENCES**


