Sleep wearables and the future of underwriting

Introduction

Insurers worldwide are grappling with the ever-increasing pace and volume of data available in many markets, and how to use these to differentiate their products and practices in increasingly commoditised global environments. Insurance pricing and risk management are examples of such environments. Insurers are quickly appreciating that, in order to achieve greater efficiencies, it is essential to be able to make use of a wider variety of data sources to enhance underwriting and how insurance products are constructed, sold and managed. Automated underwriting and using different (better) rating factors with the potential to accurately track risk and improve mortality and morbidity, if optimised, are at the forefront of many of these emerging changes.

It is estimated that, in the connected world we live in, each of us generates more than half a gigabyte of new data every day across everything from our social media platforms, communication channels, and transactions through our financial institutions, to our healthcare claims, retail purchases, and wearable device activities. The owner of this data (the customer) typically has little sight of this data, has limited ability to collect and store it centrally and cannot make use of it for their own benefit. Financial institutions, and in this case insurers, can facilitate this in order to understand their customers better to move past outdated underwriting and risk management practices and more effectively assess, quantify and monitor insurance risk.

An example of this is the ability to understand an individual's sleep habits. Long has the importance of sleep been known, with researchers highlighting that sleep may not only be one of the three pillars of health but the foundation on which the other two pillars, exercise and healthy eating are built. Ultimately, sleep impacts all causes of mortality and has linkages to dread diseases.

Sleep and biological functions

To understand the extent of this foundational role that sleep plays in one's health, wellness and longevity, a detailed literature review was performed on the impact of sleep on the various body systems. Below is a summary of key findings of this review.

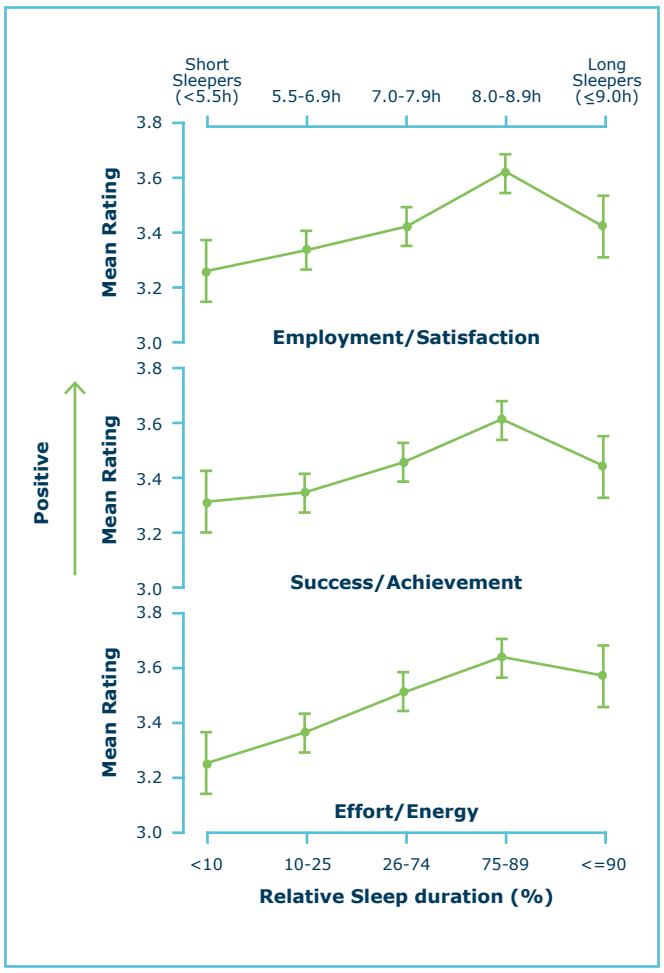
Individuals reporting less than seven hours of sleep a night are almost three times more likely to become infected by a rhinovirus as found by Cohen et al. (2009). Additionally, a sleep shortage can also lead to increases in accidents, more sickness and absences from work (Hafner et al., 2016) as well as an increase in the risk o f musculoskeletal injury in athletes sleeping less than 8 hours (Fox et al., 2019).

Further studies completed by Prather et al. (2021), Benedict & Cedernaes (2021) and Czeisler (2015) indicate that sleep plays a role in vaccines and vaccine protocol. Short (too little) sleep lowers vaccine effectiveness regardless of whether the lack of sleep is prior to taking the vaccine, the night after taking it or if the short sleep patterns are observed in the weeks following the administering of the vaccine.

Several nights of just four hours of sleep in otherwise healthy individuals impairs blood sugar regulation to such an extent that they would be classified as pre-diabetic (Czeisler, 2015) and hormonal (endocrine) systems suffer as well. Healthy young males sleeping just four hours a night for four nights will have a level of testosterone equivalent to that of someone 10 years their senior. Women are also impacted, as studies have shown that women sleeping less than eight hours have a 17% reduction in follicular-stimulating hormone, are 30% more likely to have abnormal menstrual cycles, and may have reduced fertility, relative to those obtaining sufficient sleep (Walker, 2021).

Sleeping patterns outside of what is considered to be healthy ranges also impact mental health and quality of living. The impact of sleep on mental health and quality of life also indicates that it is not only short sleep that may be indicative of underlying conditions, but long sleep as well.

A study completed by Groeger et al. (2004) found that quality of life tends to reflect as an upside-down U when considered against increasing sleeping durations. They found that a person's (1) Enjoyment or Satisfaction, (2) Success or Achievements, and (3) Effort and Energy levels all make an upside-down U-shape on a five-point rating scale (with eight hours of sleep a night at the centre) for quality of life.



In their 2007 study, Wallander et al. found that different forms of mental illness were much more commonly diagnosed out of cohorts of sleep extremes with clinical depression and suicide being higher in individuals outside of the recommended sleep range. They also suggested that sleeping durations can be an indication of underlying psychological illness and a need for care.

However, it is not always easy to identify where sleep is the underlying cause for a condition or one of the effects from another. The impact of sleeping patterns on weight management can be thought of as a cycle which can help to illustrates this.

Tiredness from short sleep will lead to lower energy levels, less motivation for physical activities and a craving for alternative food energy sources which all contribute to increased obesity risk (Taheri, 2016). Additionally, studies have found that when monitoring the same individuals under normal circumstances and restrictive sleep durations (Broussard et al., 2016), reductions in sleep significantly increase the ghrelin levels in the gut, leading to an increased feeling of hunger and their increase in the consumption of calories. Al Khatib et al. (2017) concluded that sleep deprivation leads to increased energy intake and will have no effect on energy expenditure – in other words a person will eat more but not use more energy.

Today such high calorie food cravings can lead to an increase in highly processed food intake due to the easy access to takeout or comfort food. This, combined with no further energy burning, contributes to increases in obesity and struggles with weight maintenance. Increased intake of ultra-processed foods can also lead to lower cognitive performance, learning difficulties and a poorer memory (Noll et al., 2021). There is also a positive dose–response relationship between the consumption of fast food and the risk of depression as well as the ability to deal with stressful situations in a positive manner (Sa'nchez-Villegas et al., 2011).

Highly processed food intake can therefore lead to increased feelings of stress which, in turn, has been highlighted as one of the potential causes of sleep reduction – closing the loop on a potentially negative short sleep cycle.

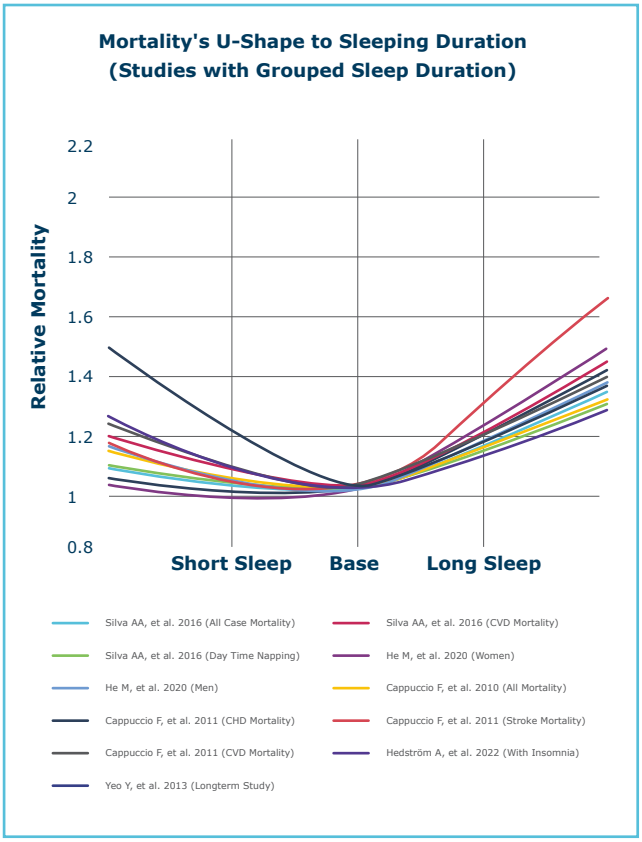
This highlights the need to be able to assess individuals in a holistic manner which, from an actuarial perspective, can enable life insurers to provide mechanisms to improve their overall quality of sleep, quality of life, and improved health outcomes targeted at the actual cause of the negative spiral. For example,

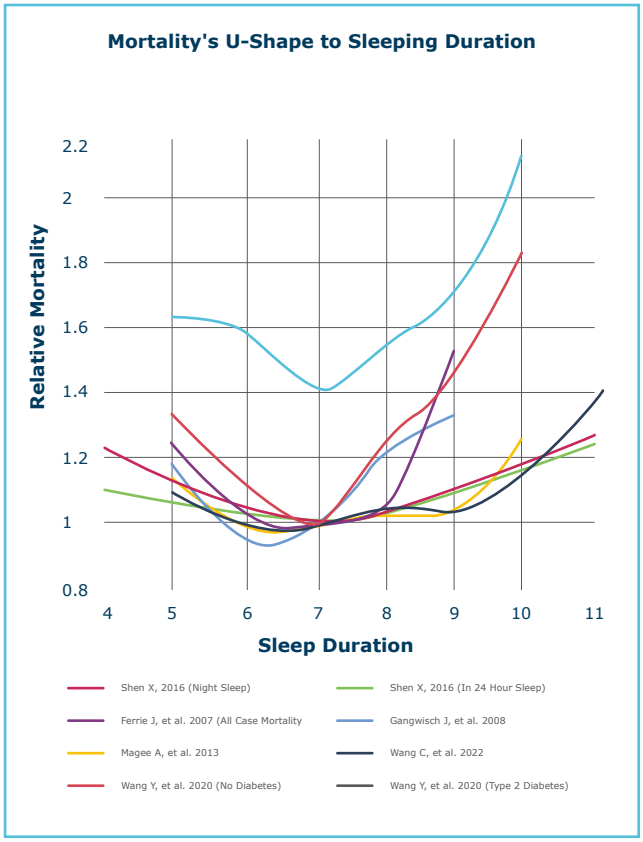
- was the individual originally struggling to deal with high stress levels which led to reductions in sleep and increases in weight; or
- do they not have time to prepare or have access to healthy food choices resulting in the original negative sleep spiral; or
- was poor sleep as a result of poor sleep hygiene the original cause of the poor weight management cycle?

Sleep and mortality

Given the impact of sleep duration on morbidity what is the resulting impact over the long-term on mortality?

Below are the findings from 12 studies on the impact of sleep habits on mortality. The overall impact of sleep on mortality typically presents as a U-shaped or J-shaped curve with seven to eight hours of sleep being the turning point and considered a healthy base. Both sides of this point, whether it be increasing the sleep per day or decreasing it, will increase all-cause mortality and illness.





When considering the impact of sleeping patterns on mortality it is important to appreciate that sleep has a short-term impact as well as longer term consequences. Over short durations the lack of sleep increases the risk of accidents, both vehicular and workplace related. Extended periods of short sleep negatively impact morbidity, resulting in worse health outcomes and negatively impacting mortality in the long-run.

Cappuccio (2018) stated that most studies miss the important relationship between ill-health and sleeping durations, namely that short sleep durations can be the cause of ill-health but longer sleeping durations are more likely a consequence of undetected underlying pre-existing ill-health. In the study by Magee et. al. (2013) they attempted to link pre-existing conditions and illnesses before the study commenced. The study concluded that sleep duration does not affect mortality significantly, but rather identifies poor health at baseline.

Sleep and underwriting

Despite the above-noted importance of sleep as a determinant of morbidity and longevity, accurate data on sleep patterns were historically not available outside of polysomnography (PSG) performed in a clinical setting (Rundo & Downey, 2019). Given the onerousness of undergoing PSG, this meant that there was no widespread commercially viable ability to collect this data. But all this has quickly changed in recent years with sleep data now being readily available and reliable with the improvements to the accuracy and cost-effectiveness of modern wearable wellness tracking devices. This offers insurers access to significant volumes of temporal data of extended periods for individuals which can provide an accurate view on the sleeping patterns of applicants and policyholders over time.

Apart from giving a picture of an individual's current state of wellbeing, sleep is also one of the easier dimensions to improve and could yield significant value in both improvements in absolute longevity and the quality of life through risk management programmes designed to improve sleep quality. This combination of biological importance, general scientific consensus on the impact and importance of sleep availability and trackability of data as well as the potential benefit to consumers make sleep data analysis one of the most interesting and exciting potential new rating factors and new sources of underwriting information to be considered for use by insurers.

Exploratory Analysis

The findings from the literature review performed illustrate the compelling risk assessment benefits to life insurers of being able to use sleep data in the assessment and management of mortality and morbidity risk. One of the authors of this paper is the Co-Founder and CEO of Elevate Life, which sells fully-underwritten risk cover products. As such, the authors had the access and incentive to undertake the analysis of how sleep data can be used to enhance life insurance underwriting and risk management techniques. This work was first presented at the 2022 All Actuaries Summit in Melbourne.

The research question of focus in the analysis undertaken is set as follows: "Identifying techniques whereby sleep tracker data can be used in life insurance underwriting to generate observable outcomes to improve risk classification/management."

It is important to note that the investigation that the authors chose to perform was an exploratory analysis (Elman et al., 2020). The reason for this is that this type of investigation has not been explored previously in depth and as such there are no existing methodologies or frameworks in place to leverage from. In addition, the research questions to be explored are to be guided by related research as well as being designed to be purposely open-ended and flexible. This allows for the findings of the exploratory analysis to guide further exploration where appropriate (Swedberg, 2020). The goal of such an exploratory analysis is to lay the foundation that will be used to inform the inputs into the models and protocols that will comprise this new way to underwrite and manage mortality and morbidity risk.

The analysis in question is designed to use metrics recorded from wearable devices and trackers to measure policyholders' quality of sleep. As a result, it is necessary to evaluate whether sleep data from trackers can provide an accurate measure of sleep quality. To ascertain this, the authors did further literature reviews on (1) how sleep metrics measured by trackers compare to PSG, (2) the intra-device consistency of trackers, and (3) the inter-device reliability between different trackers (Menghini et al., 2021; Jeon et al., 2015). The outcomes of these literature reviews showed that sleep data from trackers do provide an accurate measure of sleep quality (Kolla et al., 2016; Liang & Chapa Martell, 2018). By using their accelerometer and HR, trackers provide strongly correlated results to those of PSG for the metrics they measure, despite some overestimation of sleep duration and time spent in sleep phases. The consistency of a number of the same tracking devices equipped to the same subject showed no significant recording differences between the devices when investigated over any extended period (Mouritzen et al., 2020). Different wearable tracking devices were observed to show wide variations compared to one another. However, research confirmed that the common devices that most frequently presented among the most accurate were those developed by Fitbit (Chinoy et al. 2021; Liang & Ploderer, 2020).

Before any analysis on the effect of bad sleep could be considered, the authors needed to define what measurable outcomes to analyse that indicate good and bad sleep. The above literature reviews confirmed the following consensus quantitative measurements of sleep quality, namely: duration of nightly sleep between seven and nine hours, good sleep continuity of no more than one wake up per

night, and well-timed sleep (consistent wake up and bedtimes) to achieve the optimal time in each sleep phase, i.e. a good circadian rhythm.

Data collection and methodology

The data used in the analysis came from that which Elevate Life captures as part of its rewards programme. Elevate Life policyholders can share their wellness data (which includes that from wearables and trackers) through the ElevateMe web application that all policyholders get access to, and this is used to provide them with monthly wellness goals. If these goals are achieved the policyholder will get monthly cashbacks based on their premium amounts.

All data collected adheres to South Africa's POPIA legislation. ElevateMe Portal users consent to their data being used for benchmarking purposes. All data was fully anonymised so that policyholders could not be identified in any results of this study. The starting cohort considered for analysis was all underwritten policyholders onboarded during the period of 1 April 2021 to 31 March 2022 and who had connected a Fitbit tracker to their ElevateMe Portal. These requirements made 17.2% of all policyholders underwritten admissible for inclusion in the exploratory analysis.

Furthermore, all policyholders who had not automatically tracked sleep data for a continuous period of 60 days or more, pre or post their underwriting during the study period, were excluded. This reduced the total number of policyholders that could be included in the analysis to 7.8%.

The sleep data collected from the Fitbit devices was then cleaned, and all policyholders whose Fitbit tracker data did not record sleep data for the following three metrics: (1) sleep duration, (2) sleep start and end times, and (3) number of wakeups were excluded. This ensured that the devices generating this data were sufficiently new and tracked all the quantitative key metrics needed to assess sleep quality. This left a final subset of 6.3% of all policyholder's underwritten during the study period.

It should be noted that Fitbit devices provide six months of historical data upon initial syncing. This allows for the analysis of sleep data to be compared to initial underwriting to assess the accuracy of both identification and severity of any disclosures as well as voluntary or involuntary non-disclosures. Continuous wearable data post initial underwriting allows for analysis of the use of sleep data for the identification of new diagnoses and ongoing successful management of existing diseases.

The remaining data collected on each policyholder included the full upfront underwriting information to determine all the disclosures that had an impact on their premium. This included the application form and all medical tests performed. In addition, all other wellness data that was available for the policyholder shared in their ElevateMe Portal was collected and summarised.

The methodology then undertaken to analyse each policyholder included in the study was to prepare a data profile for each. The first step was to identify the period before and/or after the date of the initial underwriting of each policyholder's policy to be considered in the study. This was based on the period of data available on them meeting the requirements set out in the data collection stage.

The second step of the methodology was to generate a profile for each policyholder of the key metrics to be considered in the analysis by using their initial underwriting info, demographic information, and available sleep data. The first part of generating this summary was to outline for each policyholder their major health disorders, demographics and the mean and standard deviation of sleep duration, sleep start time, and number of wake ups for their identified time period. This was designed to provide the starting point to observe key sleep data averages to compare them against specific health disclosures and demographic characteristics.

The third step of the methodology was to provide further context of each policyholder's profile by plotting each of the sleep metric's point values for their specific time period before and/or after the date of the initial underwriting of their policy. These trends were again compared against the disclosures from their underwriting assessment (and considering their demographic characteristics) to explore the enhanced picture these trends in their sleep metrics could illustrate about their risk profile.

Finally, the profile on each policyholder was expanded to incorporate any other wellness data synced by the policyholder to their ElevateMe Portal in order to identify potential causes of (and/or the effects of) the risk drivers illustrated by their sleep patterns.

Findings and Discussion

Two policyholder profiles prepared using the above methodology are detailed below to illustrate the nature of the findings of the exploratory analysis and the understanding such profiling of sleep habits can provide in the initial underwriting stage as well as the ongoing management of their of their morbidity and mortality risk.

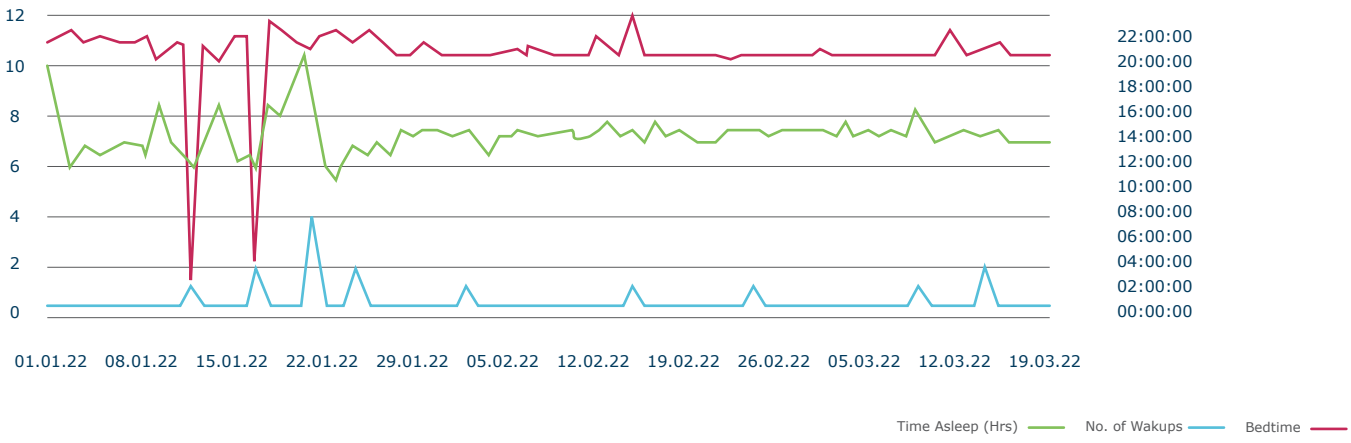
Figure 1:
Summary data profile of Policyholder 1

Policyholder #1

The key metrics of this policyholder are outlined in Figure 1 below. This policyholder's profile shows that she has acute depression and hypothyroidism. While her average sleep duration of 7.15 hours is sufficient, the standard deviation sleep duration of 1.24 hours, which outlines the range in time within which the participant fell asleep, is very large as well as their variation in bedtime and number of wake ups. This immediately points to concerning sleep habits, especially for someone with a mental health disorder.

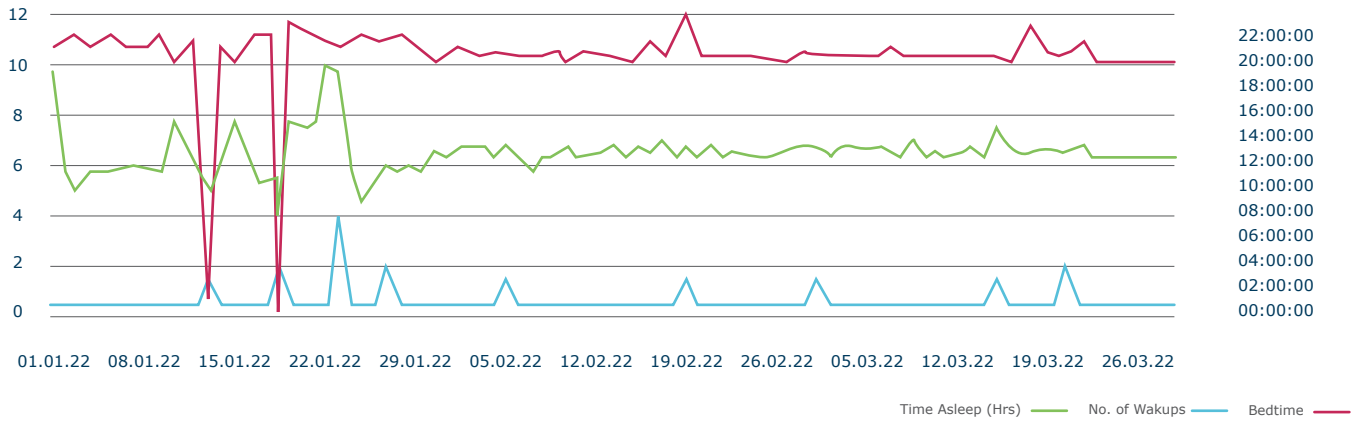
When observing this policyholder's sleep trends for a period of three months immediately following their initial underwriting the above concerns were confirmed by strong evidence of sporadic sleep duration, inconsistency in bedtimes and many nights with more than one wake up during the night as seen in Figure 2.

Figure 2:
Sleep duration, bedtimes and number of wake ups for Policyholder 1 between 5 October and 31 December 2021



However, when looking at the three-month period following this from 1 January 2022, there was a marked improvement in this policyholder's sleep patterns. Variation in all sleep measures improved quite suddenly from the end of January 2022 as seen in Figure 3.

Figure 3:
Sleep duration, bedtimes and number of wake ups for Policyholder 1 between 1 January and 31 March 2022

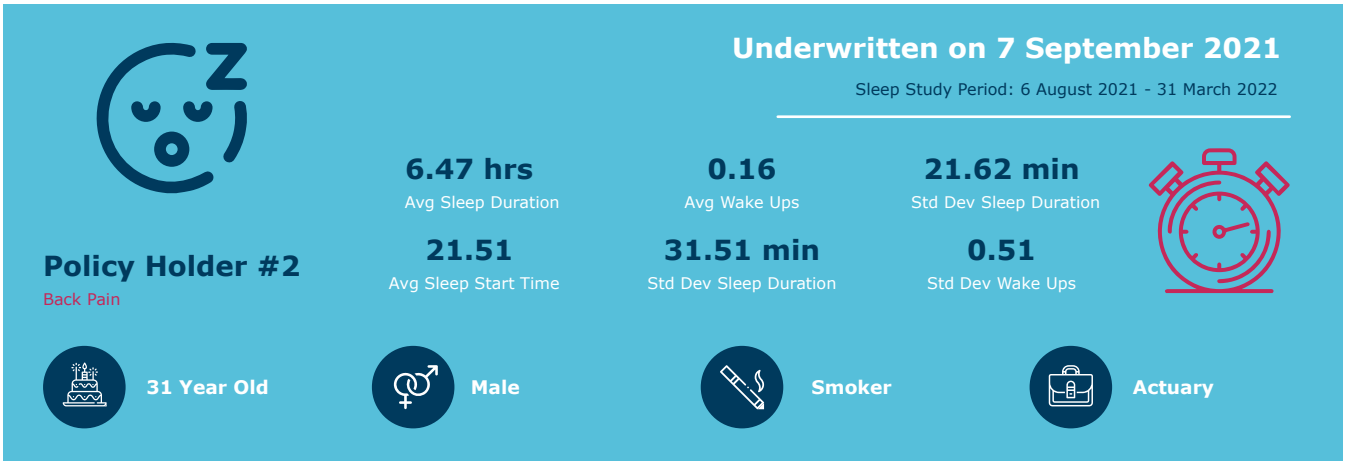


When considering the broader data available on this policyholder shared for these periods through their ElevateMe Portal, it was observed that their medical scheme claims history pointed to sporadic treatment and management of her mental health disorder during the course of 2021. In 2022, her treatment became more regular and consistent. She started to see her physiologist regularly and consistently took medication to treat her disorder. The marked improvement in her sleep being correlated to her improved management of her disorder points to the cause and effect power of considering sleep trends. The poor sleep habits were pointing to an underlying condition that was poorly managed. This is the exact phenomenon as outlined above by Cappuccio (2018). The intervention designed at improving this condition had the effect of improved sleep, showing the effectiveness and success of the intervention to improve her overall wellbeing.

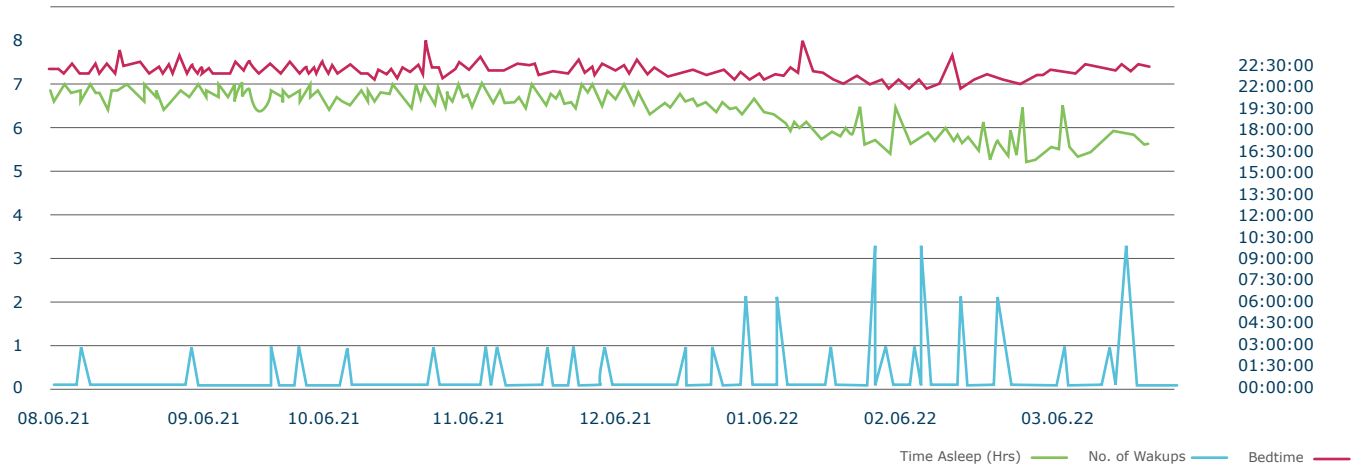
Policyholder #2

The findings from a second policyholder can be observed in Figure 4 and show that he had back pain but with good observed sleep habits. Sleep duration, consistency and continuity all showed to be at good levels with low volatility for each.

Figure 4: Summary data profile of Policyholder 2



However, over the course of the study period, the quality of sleep was observed to decline for this policyholder. By March 2022, he was sleeping markedly less, more sporadically, and consistently getting to bed later as seen in Figure 5.



When looking at other data that formed part of this policyholder's profile, it was observed that their financial situation significantly worsened during the course of December 2021 and continued through to 2022. This was observed through his credit score dropping considerably during 2022 due to missed payments and multiple requests for more credit from the bank. This policyholder is another example of how looking at an individual from a holistic perspective can provide life insurers the ability to understand more completely policyholders' ongoing levels of morbidity and mortality risk.

Conclusion and next steps

The literature reviews and case study performed in this research illustrate the power of using sleep data generated from wearable devices to enhance the risk assessment and management of life insurance policyholders. The steps to be followed by the authors to continue this work include further exploration of sleep data within policyholder profiles, followed by operationalising these findings by defining the protocols that will be used to assess risk with this new data source and approach. Ongoing monitoring and enhancing of the protocols will be essential to ensure refinement and that these techniques can effectively start to replace traditional risk assessment practices.

While sleep data was the focus of this research, the work in this area must be done as part of a broader exercise to understand policyholders more holistically. In this way meaningful improvements in life insurance risk analysis can be achieved compared to current traditional approaches. The successful move to such a holistic approach will mark a substantial jump forward in actuarial risk management practices. Improved mortality and morbidity experience in the life insurance industry could be achieved through more accurate and less onerous initial underwriting, a better understanding of an insurance book's risk over time as well as the ability to better intervene in risk behaviours to improve policyholder wellbeing.

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