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When a gold standard isn't so golden: Lack of prediction of subjective sleep quality from sleep polysomnography

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ABSTRACT

Background: Reports of subjective sleep quality are frequently collected in research and clinical practice. It is unclear, however, how well polysomnographic measures of sleep correlate with subjective reports of prior-night sleep quality in elderly men and women. Furthermore, the relative importance of various polysomnographic, demographic and clinical characteristics in predicting subjective sleep quality is not known. We sought to determine the correlates of subjective sleep quality in older adults using more recently developed machine learning algorithms that are suitable for selecting and ranking important variables.

Methods: Community-dwelling older men (n = 1024) and women (n = 459), a subset of those participating in the Osteoporotic Fractures in Men study and the Study of Osteoporotic Fractures study, respectively, completed a single night of at-home polysomnographic recording of sleep followed by a set of morning questions concerning the prior night's sleep quality. Questionnaires concerning demographics and psychological characteristics were also collected prior to the overnight recording and entered into multivariable models. Two machine learning algorithms, lasso penalized regression and random forests, determined variable selection and the ordering of variable importance separately for men and women.

Results: Thirty-eight sleep, demographic and clinical correlates of sleep quality were considered. Together, these multivariable models explained only 11–17% of the variance in predicting subjective sleep quality. Objective sleep efficiency emerged as the strongest correlate of subjective sleep quality across all models, and across both sexes. Greater total sleep time and sleep stage transitions were also significant objective correlates of subjective sleep quality. The amount of slow wave sleep obtained was not determined to be important.

Conclusions: Overall, the commonly obtained measures of polysomnographically-defined sleep contributed little to subjective ratings of prior-night sleep quality. Though they explained relatively little of the variance, sleep efficiency, total sleep time and sleep stage transitions were among the most important objective correlates.

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Abbreviations: EEG, electroencephalogram; EMG, electromyogram; EOG, electrooculogram; IDIS, Iowa Drug Information Service; Lasso, least absolute shrinkage and selection operator; MrOS, osteoporotic fractures in men study; OLS, ordinary least squares; PSQI, Pittsburgh Sleep Quality Index; SE, sleep efficiency; SOF, study of osteoporotic fractures; TST, total sleep time; WASO, wake after sleep onset; PSG, polysomnography.

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1. Introduction

Although the issue of subjective "sleep quality" is frequently encountered in research and treatment, the correlates that may contribute to these subjective estimates remain poorly understood. Clinically, subjective sleep quality is fundamental to complaints of insomnia and non-restorative sleep, two conditions associated with considerable morbidity and impairment, and relevant to sleep health in general. Dissatisfaction with "sleep quantity or quality" is a central feature of Insomnia Disorder in the DSM-5, and it is well known that a number of individuals with insomnia will report poor sleep quality even when objectively-measured sleep appears relatively normal (Edinger et al., 2000; Salin-Pascual, Roehrs, Merlotti, Zorick, & Roth, 1992). Subjective sleep quality is also central to complaints of non-restorative sleep, which was included as a subtype of insomnia until publication in the DSM-5. Research by Roth and colleagues has shown that complaints of non-restorative sleep are stable and separable from those of difficulty initiating or maintaining sleep, though still associated with comparable levels of functional impairment (Roth et al., 2010). In the general population, non-restorative sleep complaints are quite common (Ohayon, 2005) and associated with a variety of physical and mental conditions (Walsh et al., 2011).

Given the clinical significance of subjective sleep quality, understanding the biological and psychological parameters that influence perceived sleep quality is important to inform interventions. In both young and older individuals, a variety of objective correlates of better sleep quality have been posited, including increased duration of polysomnographically-determined stage N2 (Baekeland & Hoy, 1971; O'Donnell et al., 2009; Westerlund, Lagerros, Kecklund, Axelsson, & Akerstedt, 2014) and N3 sleep (Riedel & Lichstein, 1998; Westerlund et al., 2014; Hoch, Kupfer, Berman, Houck, & Stack, 1987), decreased N1 sleep (Bonnet & Johnson, 1978; O'Donnell et al., 2009; Riedel & Lichstein, 1998), decreased wakefulness at night (Baekeland & Hoy, 1971; Bonnet & Johnson, 1978; Hoch et al., 1987), increased sleep efficiency (Akerstedt, Hume, Minors, & Waterhouse, 1994a), and fewer transitions from sleep to wake (Laffan, Caffo, Swihart, & Punjabi, 2010). It is important to note, however, that many of these studies are small and limited to good-sleeping adults or to clinical populations such as those with insomnia. This study improves upon prior work by examining sleep quality in a very large sample of community-dwelling older adults who have both normal and disturbed sleep.

Previous research attempting to understand sleep quality is also limited by investigating only a limited number of correlates in predictive models. As recognized by Buysse and colleagues some 25 years earlier, sleep quality is likely to be a multifaceted construct that is difficult to characterize by any single correlate (Buysse, Monk, Hoch, Yeager, & Kupfer, 1991). Though there have been calls to examine sleep quality using multivariable analyses with a wider range of predictors (Krystal & Edinger, 2008), no studies have yet been completed. The present research takes an important step towards clarifying subjective sleep quality by considering a large number of sleep, demographic and clinical correlates together using recently developed analytical techniques for multivariable analysis.

Mounting evidence suggests that estimates of subjective sleep quality must be interpreted in light of age and sex differences. There are age-dependent changes in sleep that predispose older individuals to poor objective sleep quality, including increased fragmentation and wakefulness at night (Ohayon, Carskadon, Guilleminault, & Vitiello, 2004). Moreover, multiple studies suggest that the prevalence of sleep disorders—including insomnia, periodic limb movements, and sleep disordered breathing—increase with age (Ancoli-Israel et al., 1991a, 1991b; Bloom et al., 2009; Ohayon, 2002), though there may be some leveling off or improvement by the seventh decade (Grandner et al., 2012; Young et al., 2002). Interestingly, although objective sleep deteriorates and rates of sleep disturbances increase, some studies indicate that older individuals rate their sleep quality similarly to or better than younger cohorts (Buysse et al., 1991; Zilli, Ficca, & Salzarulo, 2009). It is therefore important to understand the objective correlates of perceived sleep quality in older individuals. This question must also be considered in light of sex differences in sleep quality reports. Women report higher rates of insomnia (Zhang & Wing, 2006) and non-restorative sleep (Ohayon, 2005) compared to men. Women are also more likely to report worse subjective sleep parameters relative to objective sleep parameters (van den Berg et al., 2009; Vitiello, Larsen, & Moe, 2004). Finally, sleep architecture itself appears to differ between men and women, with men obtaining more light sleep and less slow wave sleep, a discrepancy that widens with increasing age (Redline et al., 2004).

Subjective sleep quality may be assessed through a variety of means, often via retrospective self-report inventories such as the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) or via ordinal or visual analog scales included on prospective sleep diaries (Buysse, Ancoli-Israel, Edinger, Lichstein, & Morin, 2006). The present research focused on ordinal sleep diary ratings of two dimensions of subjective sleep quality from the prior night: Sleep Depth (light to deep) and Sleep Restfulness (restless to restful). Research suggests both dimensions are important. Åkerstedt and colleagues reported that sleep restfulness was strongly associated with subjective sleep quality (Akerstedt, Hume, Minors, & Waterhouse, 1994b) and, in a subsequent factor analysis, that sleep restfulness and sleep quality loaded strongly onto the same factor (Keklund & Akerstedt, 1997). In validating a morning questionnaire assessing the prior night's sleep, Ellis and colleagues determined that sleep depth was also relevant (Ellis et al., 1981). Hence, Sleep Depth and Sleep Restfulness were used as two non-exclusive measures of sleep quality.

The overall aim of this investigation was to determine the correlates of subjective sleep quality in older men and women, as well as to evaluate the relative importance of each correlate in predicting subjective sleep quality. Given the large number of potential variables that may explain subjective sleep quality, we used modern machine learning methods to determine which variables were important in predicting subjective sleep quality, as well as the ordering of this importance, using statistical techniques designed to reduce bias. We focused our analyses on a sample of community-dwelling older adults, and we ran all analyses separately and in parallel between men and women as we expected sex differences to emerge.

2. Methods

2.1. Study population

Male participants in these analyses were enrolled in the Osteoporotic Fractures in Men Study (MrOS). At baseline, a total of 5994 men aged 65 or older were recruited between 2000 and 2002 from six areas of the United States: Birmingham, Alabama; Minneapolis, Minnesota; Palo Alto, California; Pittsburgh, Pennsylvania; Portland, Oregon; and San Diego, California. Assessment of sleep occurred at two separate time points. These analyses used data collected at the Sleep Visit 2, which took place from 2009 through 2012. A total of 1055 men participated across all six sites, of whom 1026 (97%) had polysomnographic data available and were included in final analyses.

Female participants in these analyses were enrolled in the Study of Osteoporotic Fractures (SOF). At baseline, a total of 9704 Caucasian women aged 65 or older were recruited between 1986 and