Associations among Sleep, Diet, Quality of Life, and Subjective Health

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Objective: We set out to improve understanding of the health behaviors of older adults by examining the interrelationships of a low-fat diet and subjective measures of sleep. **Methods:** Older adults (N = 126) completed a paper-and-pencil questionnaire about sleep, health behaviors, quality of life, and subjective health. **Results:** Path analysis revealed sleep quality was related to daytime functioning, which was positively interrelated with quality of life and subjective health. The positive relationship between low-fat diet and quality of life may be connected to increased daytime functioning. **Conclusion:** Together with a healthy diet, sleep seems to play a role for older adults in maintaining a functional and healthy lifestyle, improved quality of life, and a positive perception of health.

Key words: sleep quality; older adults; older adult health; low-fat diet; subjective health; quality of life
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Older adults are among the population groups with declining health, and the quality of life of these groups is not always optimal, in part, due to health complaints and sleep problems that increase with age.[1-3] The occurrence of many sleep problems, such as insomnia, which often coexists with illness, medication use, or sleep apnea, and is associated with cardiovascular disease and obesity, is increasingly common among older adults.[1,4] In older populations, insufficient sleep duration[5] and poor subjective sleep quality[6] have been associated with higher chronic disease risk factors, including cardio-metabolic risk, hypertension, cardiovascular disease, diabetes, obesity, and depression.[7] Therefore, sleep has gained attention in research, and it has been recommended that health authorities raise awareness of sleep as an important health behavior.[8] Previous studies suggest that the association between sleep problems and health is essential to explore further, particularly with aging populations.[9]

According to the World Health Organization,[3] the demographic changes in populations, including persons living to an increasingly old age, means the number of older adults with health-related problems continues to grow.[10] Thus, interest in optimizing the chances for good health and quality of life of older adults is increasing.[3,11] Because it is known that a healthy lifestyle benefits older adults, and engaging in more than a single health behavior increases well-being,[2,12] many studies have already investigated traditional health behaviors,[13] such as physical activity and fruit and vegetable intake,[14-16] and how they are linked to health status;[14-20] however, little is known about the associations of health problems and chronic disease issues with sleep. Thus, the purpose of this study was to examine the associations of sleep duration, subjective sleep quality, daytime functioning, and a low-fat diet, on subjective health and quality of life. Better understanding of these associations enables interventions that are responsive to promoting lifestyle improvements for older adults.

Whereas most health-related behaviors studied

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among older adults have focused on persons aged 65 and above,[21] younger older adults aged 50 and above are a particularly important group of interest for several reasons: (1) risk or morbidity and mortality due to chronic diseases is most likely to occur in 'early old age' (before the age of 70);[22] and (2) multiple unhealthy behaviors significantly increase mortality risk in this age group.[23] Therefore, more attention to their lifestyle is needed, as is information on health status and health behaviors that can assist in promoting lifestyle improvements.[3]

Theoretical Background

Most existing theoretical frameworks in this area describe only single health behaviors, eg, the Theory of Planned Behavior (TPB)[24] and the Health Action Process Approach (HAPA).[25,26] However, there is, a theoretical framework that provides options for fostering a healthy lifestyle with more than a single health behavior, to prevent and manage chronic diseases such as obesity and diabetes. This framework is Lippke's *Compensatory Carry-Over Action Model (CCAM)*.[12]

Whereas model testing and compensatory or carry-over mechanisms within CCAM are not the aims of this study, our objective is driven by the theoretical and evidence-based assumptions of CCAM, which can be studied individually. CCAM suggests: (1) different health behaviors interrelate (in this case, subjective measures of sleep – sleep duration, sleep quality, daytime functioning and low-fat diet interrelate); and (2) a healthy lifestyle consisting of more than a single health behavior increases well-being and quality of life (in this case, subjective measures of sleep – sleep duration, sleep quality, daytime functioning, and a low-fat diet increase quality of life and subjective health).

Most of the populations aiming to enhance their quality of life do so by heightening the chances for health via lifestyle improvements, and thus, engage in regular health behaviors.[27] Therefore, quality of life serves as a higher-level goal, because most people aim to improve their quality of life, and this can be understood as a main predictor of decision-making and actual behavior.[12]

In addition, individuals experience various types of stressors during the adoption and maintenance of health behaviors. For instance, if an individual has set a goal and fails to achieve this goal (eg, due to daily hassles, work stress, or chronic stressors), their well-being is influenced. Also, sleep problems often are associated with stress and emotional health, which then impact one's health and well-being.[28] In one study, researchers found that increases in sleep quality were associated with decreases in stress.[29] Therefore, subjective health (perceiving oneself as healthy) may result in the decrease of stress with the increase of well-being, and previous evidence has shown that greater subjective health is associated with lower stress levels.[30]

Sleep, Low-Fat Diet, Subjective Health, and Quality of Life

Based on the theoretical background of the associations among sleep, diet, subjective health, and quality of life, previous studies have been conducted. For example, Bayán-Bravo et al[31] compared traditional health behaviors (ie, non-smoking, physical activity, and healthy diet) and non-traditional health behaviors (ie, sleeping 7 to 8 hours a day, less sedentariness, strong social network), and found that being physically active, sitting less, and getting adequate sleep were associated with improved health-related quality of life in older adults. Similarly, another study showed that engaging in a greater number of negative lifestyle behaviors, like poor diet, physical inactivity, and greater sedentariness were closely related to lower subjective health and health-related quality of life; the association between poor lifestyle behaviors and quality of life particularly decreased when subjective sleep quality was included into the analyses.[13]

For sleep duration, it is important to note that sleeping either too little or too much is associated with poor sleep quality and poor subjective well-being in early old age.[32] Faubel et al[33] found that excessive sleep duration (too little – less than 5 hours or too much – more than 10 hours) is one indication of poor quality of life in the elderly. The healthy range of good sleep for adults is an average of 7 to 8 hours per night.[31] Sleeping for too long of a duration yielded a more negative association with poor quality of life than sleeping too little;[31] however, most studies have found that insufficient sleep duration has more negative health consequences than a longer sleep duration, and sleep quality improves with increasing sleep duration.[34] In any case, examining the association of sleep du-

ration and subjective sleep quality in linear terms is imperative.

The outcomes of poor subjective sleep quality and insufficient sleep duration may be related to morbidity, obesity, weight gain, and increased hunger and appetite.[35-37] Due to an imbalance of energy intake and energy expenditure, insufficient sleep duration has been found to be related to diet and eating patterns,[38] leading individuals to consume more energy-rich foods, like high-fat foods or refined carbohydrates, and fewer fruits and vegetables. This has been reviewed in clinical trials showing that among mostly healthy individuals, a healthy diet, like consuming fruits and vegetables and a general low-fat diet, can improve sleep quality.[39]

Boehm and Kubzansky[40] found that sufficient sleep duration, good subjective sleep quality, and a healthy diet were positively related to psychological well-being and negatively associated with cardiovascular disease. One study discovered that people with sleep problems tended to have greater fat mass, higher intake of saturated fatty acids, and less physical activity.[41] Compared to people with sufficient sleep duration, people with insufficient sleep duration were more likely to be heavier, gain more weight over time, and have a decreased ability to lose weight.[38] These persons reported poor subjective sleep quality and experienced excessive daytime dysfunction, including sleepiness and lack of enthusiasm to get things done during the day,[38] which in turn influenced quality of life.

A substantial amount of research has examined the relationship between sleep and diet, and the association between sleep duration and sleep quality among older adults as mentioned earlier. Despite this, little is known about the associations of sleep duration and sleep quality with daytime functioning, which in turn, influence older adults' subjective health and quality of life, and subsequently their participation in multiple health behaviors. To explain the association between sleep and quality of life in specific age groups, it has been suggested that science needs to look beyond the association between sleep duration and/or sleep quality and quality of life.[8] Because problems like insufficient sleep duration and poor sleep quality (which are common occurrence for older adults) tend to reduce daytime functioning (ability to perform normal daily tasks), exploring the relation of sleep to daytime functioning is essential.[42-44] For instance, insufficient sleep duration and poor subjective sleep quality are related to daytime sleepiness, which causes decreased ability for daytime functioning and accomplishment of tasks.[45] Insufficient sleep duration is related to poor perception of health status[46] and lower quality of life among adults aged 45 to 95 years.[47] Poor sleep quality predicted more daytime sleepiness, which then predicted poorer self-rated health.[48]

Slater and Steier[49] explained excessive daytime sleepiness as initiated by insufficient sleep duration, poor sleep quality, and increasing age, which together create negative impacts on subjective health and quality of life. According to one study, sleep problems like insomnia impaired daytime functioning cognitively, emotionally and physically.[50] Moreover, poor subjective sleep quality was associated with a decreased ability for daytime functioning and lower overall quality of life.[50,51] Excessive daytime sleepiness also has been associated with greater body mass index (BMI), and increased likelihood of being overweight or obese.[53,54] Moreover, excessive daytime sleepiness has been positively related to high-fat intake,[55] both of which negatively impact health and quality of life.[54,55]

Therefore, the outcomes of daytime dysfunction suggest that they may be related to poor sleep quality, and subsequently, to lower quality of life. Another study showed similar results, raising awareness that the association of sleep (duration, quality), daytime functioning, and quality of life should be explored,[56] because they can be influenced by interventions that promote good sleep and lifestyle improvements for older adults.[49] Consequently, sleep duration and subjective sleep quality should relate to daytime functioning, and could potentially relate to older adults' quality of life and subjective health.

Research Questions

To examine the interrelations of multiple health behaviors (eg, low-fat diet and subjective measures of sleep – duration, subjective sleep quality, and daytime functioning), subjective health, and quality of life, the following research questions were studied:

Are sleep duration, subjective sleep quality

and consuming a low-fat diet related to daytime functioning?

Are sleep duration, subjective sleep quality and consuming a low-fat diet related to subjective health and quality of life in older adults, via daytime functioning?

METHODS

Settings and Participants

A total of 126 older adults aged 50 and older (M_{age} = 71.85, SD = 10.13) were recruited from 4 different senior daycare and sports clubs. Only persons who met the following inclusion criteria were approached to participate in the study: (1) aged 50 or older, like previous studies that recruited older adults aged 45 to 95 years[47] or aged 53 to 97 years;[57] (2) no cognitive impairments with average literacy enabling them to complete a questionnaire without help; and (3) German language proficiency.

Among participants, 61.9% (N = 78) were female and 38.1% (N = 48) were male. In addition, 67.5% were married and/or in a long-term relationship and 78.6% were retired. Finally, 53.2% reported one or more chronic diseases, such as type 2 diabetes, hypertension, or cardiovascular disease.

Procedure

Researchers were assigned to a different senior daycare or sports club and arranged appointments. During data collection, the researchers provided an information sheet (containing the aims and information of the current study), and a consent form. A clinical trial registration was conducted at ClinicalTrials.gov, which included a description of the study, its objectives, designs, methods, and interventions.[58] Only the data collected in Germany have been used and analyzed, because country difference is not the focus of this study, and the data collection in other countries is not yet completed for analysis.

After we obtained informed consent forms from all individuals in the study, we gave them paper-and-pencil questionnaires, including socio-demographic variables in the first section and selected lifestyle measures in the second. At the end of the study, participants received a debriefing statement with the contact details of the researchers. All information and materials involved in the study contained code numbers instead of names, to ensure anonymity and encourage honest responses.

Measures

Because this study was carried out in Germany, we used a German version of the questionnaire, which has been validated in previous studies.[59,60] However, all items given below as examples are the English measures. Data collection was limited to self-report.[61]

Socio-demographic variables. Socio-demographic characteristics included age, sex, year of birth, occupation, education level, marital status, and living arrangements, as well as information about health and chronic disease conditions.

Subjective measures of sleep. The Pittsburgh Sleep Quality Index (PSQI)[62] was used for subjective measures of sleep. This is an effective instrument particularly for older adults, and was used as an initial assessment and ongoing comparative measures across the healthcare field and rehabilitation. Of 7 domains, 4 were selected and the participants were asked to respond based on their experience during the past month: sleep duration – hours of actual sleep; subjective sleep quality – rated from '*Very bad*' to '*Very good*'; and daytime functioning – how easy it is to keep up enthusiasm to get things done, rated from '*Very difficult*' to '*Very easy*'; and use of medication – how often participants too medicine (prescribed or "over the counter") to help with their sleep, rated from '*Never*' to '*Always*' which has been used only as control variable. The term 'daytime functioning' was used instead of 'daytime dysfunction' based on the PSQI, because this study focused on the positive aspect of older adults' function, as Dewald-Kaufmann et al's study did.[43] Previous studies that adopted the PSQI across different age groups globally demonstrated strong validity and reliability.[13,62]

Subjective health and quality of life. The 12-item Short-Form Health Survey (SF-12) is a measure used to evaluate health-related quality of life, predominantly for well-being in physical and emotional dimensions of life, which is specifically useful for clinical studies.[63,64] In this study, the item of general health status was used to assess participants' subjective health, by asking: "In general, how would you describe your health state now?" rated from '*Very bad*' to '*Very good*'. To assess older adults'

Table 1
Means, Standard Deviations, and Correlations of the Major Study Variables

Variables	1	2	3	4	5	6	7	8	9	10	11
Low-fat diet	-	-	-	-	-	-	-	-	-	-	-
Sleep duration	.02	-	-	-	-	-	-	-	-	-	-
Subjective sleep quality	<-.01	.30**	-	-	-	-	-	-	-	-	-
Daytime function	.26**	.23*	.37**	-	-	-	-	-	-	-	-
Subjective health	0.16	.10	.36**	.52**	-	-	-	-	-	-	-
Quality of life	.28**	.08	.30**	.47**	.64**	-	-	-	-	-	-
Control Variables											
Age	-.09	.03	-.06	-.13	-.21*	-.05	-	-	-	-	-
Use of medications	.02	-.13	-.14	-.16	-.21*	-.06	.19*	-	-	-	-
Chronic disease	-.05	.06	.02	-.07	-.16	-.04	.13	.30**	-	-	-
Employment status	.05	-.05	.09	.04	.22*	.05	-.60**	-.09	-.06	-	-
Marital status	.08	.11	-.04	.01	.21*	.17	-.43**	-.23*	-.11	-.19*	-
Mean	4.02	7.09	2.94	2.95	3.45	3.89	71.85	1.43	0.54	0.21	0.68
Standard deviation	1.44	0.96	0.57	0.69	0.89	0.75	10.13	0.82	0.50	0.41	0.47
Range (Min.-Max.)	1–5	4.50–9.00	2–4	1–4	1–5	2–5	50–95	1–4	0–1	0–1	0–1
N (sample size)	126	120	121	119	125	125	125	121	124	126	125

**** p < .01**
*** p < .05, two-tailed significance levels of correlations**

Note.
Chronic disease included as dichotomous variable, 0 indicates 'no chronic disease' and 1 indicates 'with one or more chronic disease'.
Employment status included as dichotomous variable, 0 indicates 'working' and 1 indicates 'retired'.
Marital status included as dichotomous variable, 0 indicates 'without a partner or widowed or divorced' and 1 indicates 'married or long-lasting relationship'.

quality of life, we asked: "How would you describe your quality of life now?" rated from '*Very bad*' to '*Excellent*'. For these 2 domains of well-being, we calculated Pearson's r to be 0.65.

Low-fat diet. The assessment of participants' fat consumption was included, which was a modification of the stages algorithm previously developed for physical activity and fruit and vegetable intake. It has been used in previous studies.[65,66] Participants were asked: "Do you consistently eat low-fat foods (eg, less fat from animals, less peanuts, chips and crackers, as well as less ready-made meals)?" They could answer based on a 5-point Likert rating scale: '*No, and I do not intend to do so*'; '*No, but I'm thinking about it*'; '*No. but I intend to do so*'; '*Yes, for a short period of time*'; '*Yes, for a long period of time*'. The algorithm was designed for stages of change ranging from a pre-contemplation to maintenance stage. The stages of change have been included as a linear item in analyses in previous studies.[65-67] The reliability and validity of this measure in a previous study,[65] together with all the measures of that study was found to be high with Cronbach's alpha > .70.

Data Analysis

All analyses were performed with IBM SPSS 24 for preliminary analyses, and AMOS 24 for main analyses. In the preliminary analysis, bivariate correlation determined the interrelations among the main variables – subjective health, quality of life, stages of low-fat diet, sleep duration, subjective sleep quality, and daytime functioning, as well as

age, use of medication to help with sleep, health status and chronic disease, employment status, and marital status. Chronic disease, employment status, and marital status were included as the dichotomous variables, to be able to include them as continuous variables in the analysis.[68] Also, we used Pearson's r values to measure the effect size of the relationships among variables, to minimize incorrect inferences, biased results, and less precise estimates.[68]

Prior to our main analyses, we tested for outliers and multicollinearity among variables; all variables were within an acceptable range of variance inflation factors (VIF) and without correlations (Pearson's r) higher than .85.[69] Analyses confirmed multicollinearity did not affect any of the significant effects reported below, and multivariate normality was assumed.

As the proposed model is linear, missing values (0%-5.6%) were estimated with the full-information maximum likelihood (FIML) method, which exhibits the least bias.[70] We performed path analysis was performed to investigate the comparative strength of direct and indirect relationships among multiple observed variables.[71]

To answer the research questions, we performed a path analysis containing only observed variables, with sleep duration and subjective sleep quality as exogenous variables, and daytime functioning, subjective health, low-fat diet, and quality of life as endogenous variables. Stages of change is included as a variable in the path analysis, as in previous studies.[67,72] The analysis controlled for age, use of medication to help with sleep, health status and chronic disease, employment status, and marital status, and chronic disease; employment status and marital status were included as the dichotomous variables.

RESULTS

Preliminary Analyses

To inspect the descriptive and interrelations among variables, the main continuous variables were used in an inter-correlation analysis (Table 1). Among study participants, minimum sleep duration was 4 hours and 30 minutes, and maximum sleep duration was 9 hours. Not all participants had sufficient sleep according to guidelines; some had less than 7 hours of sleep (28.6%), but most participants (66.6%) slept 7 to 8 hours, and only 4 persons (3.2%) slept more than 8 hours. Thus, all participants were considered in the analysis to generate possible linear regression outcomes.

Main Analyses

The exploratory path analysis model displayed in Figure 1 was tested, with age, use of medication for sleep, marital status, employment status, and health and chronic disease conditions included as control variables. The model fits the data acceptably, with chi-square, $\chi^2(6, N=126) = 7.76$, $p = .26$; normed chi-square, $\chi^2/df = 1.29$, comparative fit index (CFI) = .99, Tucker-Lewis index (TLI) = .92, root mean squared error of approximation (RMSEA) = .048 (Model 1), as shown below.

It is essential to identify the positive correlation between subjective sleep quality and sleep duration (b = .29, B = .16, SE = .05, p = .002). Subjective sleep quality (b = .33, B = .40, SE = .10, p < .001) and consuming a low-fat diet (b = .25, B = .12, SE = .04, p = .001) were significantly interrelated with daytime functioning, but sleep duration (b = .13, B = .10, SE = .06, p > .05) yielded non-significant results.

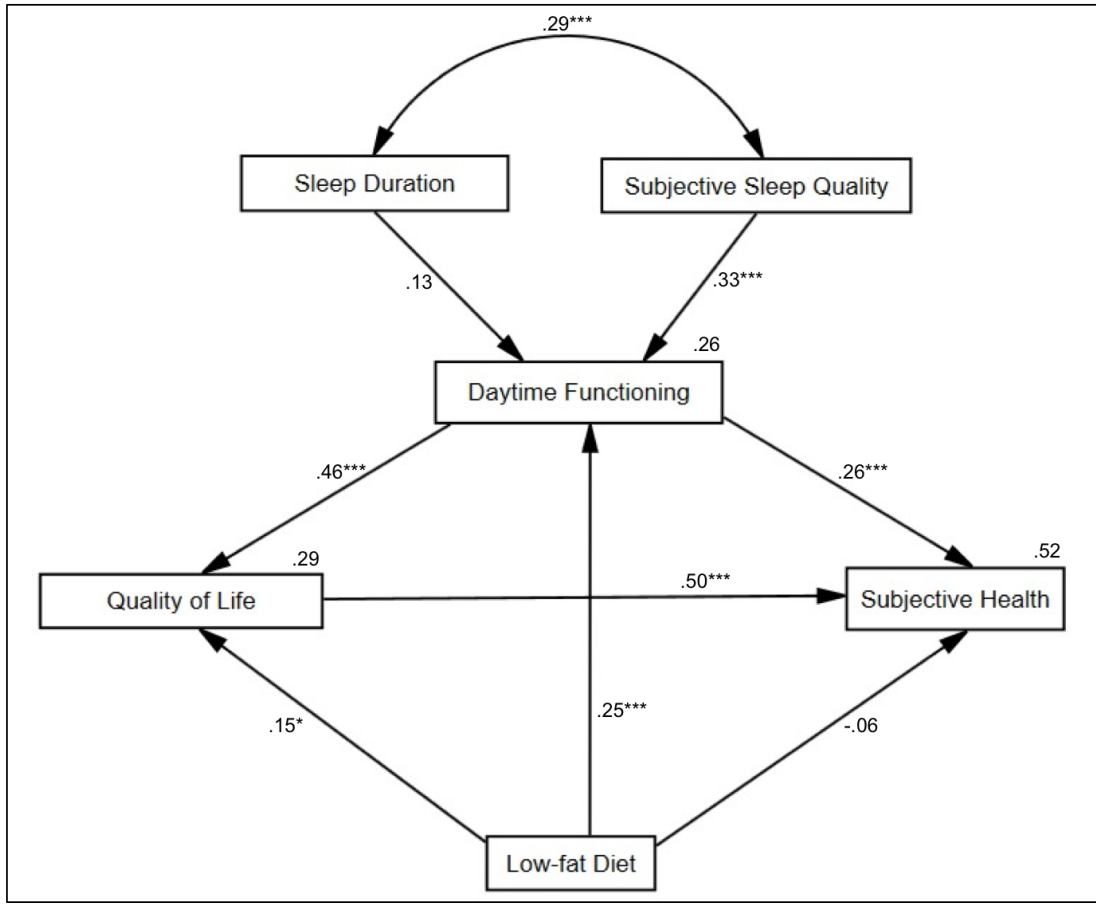
Quality of life was significantly and positively interrelated with subjective health (b = .50, B = .59, SE = .09, p < .001). Furthermore, daytime functioning was significantly positively interrelated with quality of life (b = .46, B = .50, SE = .09, p < .001) and subjective health (b = .26, B = .34, SE = .10, p < .001). Also, consuming a low-fat diet was borderline significantly interrelated with quality of life (b = .15, B = .08, SE = .04, p = .06), but was not significantly related to subjective health (b = -.06, B = -.04, SE = .04, p > .05).

The examined predictors accounted for 26% of the variance of daytime functioning, 29% of the variance of quality of life, and 52% of the variance of subjective health. Therefore, Model 1 in Figure 1 with the best model fit among other possible models, as final proposed path diagram.

DISCUSSION

To identify lifestyle improvements for older adults with more than single health behaviors, a substantial amount of research is now focusing on health promotion and disease prevention, aiming for bet-

Figure 1
Path Diagram for Proposed Model Predicting Older Adults' Subjective Health and Quality of Life with Standardized Coefficients



*****p< .01. significance levels of regression weights**
***p = .06**

Note.
Standardized beta weights; chi-square, $\chi 2$ (6, N = 126) = 7.76, p = .26; normed chi-square, $\chi 2/df$ = 1.29, comparative fit index (CFI) = .99, Tucker-Lewis index (TLI) = .92, root mean squared error of approximation (RMSEA) = .048.

ter efficiency in chronic disease management.[73] Sleep is increasingly acknowledged as an essential lifestyle contributor to health, especially with sleep problems increasing with age;[1,8] yet, little is known about its associations with other more common or traditional health behaviors, such as healthy diet and the possible positive health outcomes. Whereas the adoption of multiple health behaviors remains a challenge, particularly for the population of older adults,[74] in this study, we examined how sleep as a non-traditional health behavior might relate to low-fat diet as a traditional health behavior, as well as to subjective health and quality of life among adults ≥50 years old.

From the preliminary correlational findings, sleep duration, subjective sleep quality, daytime functioning, and consuming a low-fat diet significant interrelated with each other; however, low-fat diet was not correlated with sleep duration and subjective sleep quality. This finding was not consistent with previous studies, possibly because only low-fat

diet was assessed in this study, but no other types of diet and eating patterns, like fruit and vegetable consumption.[38] Also, almost more than half of the older adults in this study reported having one or more chronic diseases, which may be the reason for the non-significant finding, as previous studies only examined healthy individuals, and different health conditions may produce different outcomes.[39]

With the consideration that insufficient sleep duration is usually related to poor sleep quality, which yielded negative health outcomes with poor quality of life,[32,33] we found that subjective sleep quality among older adults improved with increasing sleep duration, which is in line with previous studies.[5,31,34] Other than the health benefits of sufficient sleep duration and better subjective sleep quality, little is known about their associations with another important subjective measure of sleep – daytime functioning (often measured by the antonym 'daytime sleepiness').

When an individual is experiencing a lack of sleep, which is presumably connected with poor sleep quality and higher tendency of craving for high-fat diet, he/she is likely to feel sleepy during the day and lack motivation to perform daily tasks, which in turn, might lead to poor work performance and restricted life goals.[50] According to one of the assumptions of CCAM,[12] different health behaviors interrelate. Therefore, we asked whether a low-fat diet, subjective sleep quality, and sleep duration interrelated with daytime functioning. Despite the outcome that sleep duration was not significantly interrelated with daytime functioning, consuming a low-fat diet and subjective sleep quality were. These findings strengthen past research that found better subjective sleep quality[32-44] and consuming a low-fat diet[38,45,54] led to better daytime functioning. In contrast, sleep duration was not significantly associated with daytime functioning, which may be due to sleep duration becoming habitual and having less impact on daytime functioning.[44] It also may be due to sleep quality playing a more significant role than sleep quantity.

A healthy lifestyle requires more than a single health behavior to increase well-being and quality of life, as suggested in CCAM model.[12] In this study, we asked whether a low-fat diet, subjective sleep quality, and sleep duration interrelated with subjective health and quality of life in older adults, via daytime functioning. Despite the outcome that sleep duration was not directly interrelated with daytime functioning, subjective sleep quality was significantly interrelated with daytime functioning, which in turn, was significantly and positively interrelated with quality of life and subjective health, as found in earlier research.[13,46,47]

Sleep problems have been associated with weight gain and a tendency to consume high-fat food.[35-37,41] Together, with the assumptions that these sleep problems are associated with daytime functioning, which may have an impact on health and overall quality of life.[38,45,51,54,55] In our study, we found that consuming a low-fat diet was significantly interrelated with quality of life, and that daytime functioning may mediate this relationship. Although a low-fat diet was not directly related to subjective health, it was related to increased daytime functioning, which was positively related to subjective health. In other words, individuals may function better when consuming a low-fat diet, and individuals perceive better health when they function better. Our findings expand the understanding of the role of sleep and consuming a low-fat diet via daytime functioning in predicting older adults' quality of life and subjective health.

In other words, having good sleep quality might lead to having more enthusiasm to get things done during the day (ie, daytime functioning), which could be interpreted as being more active with having less daytime sleepiness. This also may be related to being less likely to consume high-fat food, as found previously.[38,54] One health behavior alone might not be sufficient to explain why and how one's well-being and quality of life increases or decreases;[2,12] thus, our reported outcomes may add value to identifying the health benefits of non-traditional heath behaviors, such as sleep quantity and quality, as well as daytime functioning, which have been less studied that some other health behaviors, particularly among older adults.

To provide contributions to understanding the associations of sleep, subjective health, and quality of life, many studies have examined sleep through its duration and its quality. Yet, most studies considered the length of time an individual slept to be a sufficient measurement, although it varies and is subjective, and the outcomes are generally based on several factors like age and health conditions. For

example, adolescents need longer sleep duration than older adults,[8] and sleep disturbance is common during illness onset or while suffering health problems.[75] Although it may be true that individuals with chronic disease experience poor subjective sleep quality, thereby influencing their quality of life,[76] these bidirectional associations may be valid; however, in the current study, we only examined the associations of health behaviors (in this case, sleep and low-fat diet) with older adults' quality of life and subjective health to understand the possible underlying mechanisms, although not the cause. Thus, we analyzed the results by controlling age and whether persons experienced chronic disease, as well as use of medication to help with sleep, employment status, and marital status. Retirement or the transition to retirement, for example, is related to longer sleep duration and changes in sleep timing,[77] and sleep problems mediate the relationship between marital status or relationship distress and subjective health.[78]

Overall, the results suggest sleep plays an important role in living a functioning healthy lifestyle and having an increased subjective health and quality of life.

Study Strengths and Limitations

To our knowledge, this is among first studies of older adults that examined more than a single health behavior with the associations of sleep (not only quantity and quality, but also daytime functioning) and low-fat diet, with subjective health and quality of life. Secondly, the investigation included adults aged 50 and above, which included both middle-aged and elderly adults, as these have previously been widely examined in separate categories. This age group of 50 and above is a relevant time when threat or death due to non-communicable diseases often occurs.[22,23] A further strength of this study is our use of path analysis that enabled the exploration of possible associations among variables, including direct and indirect relationships, which are useful for untangling the complicated interrelations among variables and recognizing the most significant pathways relating to an outcome.[69,79] Although causality is not possible via path analysis, the findings are useful in understanding their associations with their underlying mechanisms, which may be beneficial for improving the tailoring of interventions to meet the needs of individual health status.

There are also limitations of this study that should be recognized. The sample size was small. Although it was sufficient for this relatively non-complex path analysis, including more variables and a larger sample to model this complex process would be strengthen the conclusions able to be drawn. Our data were collected only once without follow-up; thus, a longitudinal study was not possible, which could have been useful in the study of healthy aging, and observing stronger correlations and changes over time. In addition, we only assessed low-fat diet, which may be insufficient for measuring diet quality; thus, other types of possible diet and eating patterns, like fruit and vegetable consumption,[38] or other variables should be included in the future research. The items of subjective health and quality of life were listed in the questionnaire one after another, which may have introduced bias, as perceived health may indicate quality of life, or vice versa. We used self-report measures, which may lead to over- or underestimation of actual health behaviors. For example, adults with obesity underreported the actual amount of high-calorie foods.[80] Finally, health behaviors such as sleep and daytime functioning are complex, and the model proposed here most likely does not account for all relevant factors. It does, however, suggest that sleep plays some role, suggesting the need for further investigation.

With a heightened risk of morbidity and mortality, most health promotion interventions address risk factors as categorically distinct health behaviors; yet, they often occur together.[2] Therefore, future research should be directed towards including multiple health behaviors[81] and uncovering other possible factors to close knowledge gaps. For example, similar to stages of change in healthy diet and physical activity behaviors, future studies could examine stage-specific variables of sleep to obtain more information of possible mechanisms,[82] such as the relationship of sleep with intention, self-efficacy, and planning.[83] Other possible variables, such as optimism and other non-traditional health behaviors (eg, sedentary behavior and social support) as suggested in other studies,[31,84] should be considered. Additional confounding variables, such as pain, a major factor in disability or health-related

quality of life,[64] should be included in future research. We also recommend a longitudinal design to examine the changes over time.

Our findings enhance the understanding of the relationship between sleep and diet, along with subjective health and quality of life, which is particularly applicable for initiating and maintaining a day-to-day functional healthy lifestyle. Thus, our results could be beneficial in planning interventions to promote sleep adequacy and healthy lifestyle across age groups.[49] Also, our findings may inform health-related research and practice, which could be effectively applied to prevent disease, improve general health, enhance chronic disease management, and reduce healthcare costs.

IMPLICATIONS FOR HEALTH BEHAVIOR OR POLICY

As adults aged 50 and over are the main target of this current study, the following implications may be more applicable to this target group, even though sleep has been suggested as an important health behavior to all populations.[8] Our findings went beyond sleep duration and quality, and included daytime functioning, which researchers, practitioners, and policymakers may need to consider for ensuring the health and well-being of older adults.

The US Centers for Disease Control and Prevention[8] has mentioned the need to raise awareness of sleep as health behavior, Sleep may be an important component of health, because its duration, quality, and its related outcomes, such as daytime functioning, have not been well reviewed. Thus, subjective measures of sleep should be investigated further, particularly its associations with other traditional health behaviors, such as physical activity and diet, because multiple health behavior change studies in older adults are in demand. More data are needed to inform whether such multiple behavior change approaches produce better health results and are more cost effective compared to single health behavior change approaches.[74]

Given the associations of sleep and daytime functioning as seen in this study, sleep seems to play a role in performing tasks and overall functioning during the day, and thus, may be the key in increasing productivity in learning or at the workplace. Because sleep is not only associated with decreasing stress and increasing well-being (in this case, subjective health), it also plays an essential role in memory consolidation, learning, and emotion regulation. For example, a pilot study suggested sleep health promotion program for college students is feasible and acceptable to implement, and can constructively improve knowledge about sleep and sleep behavior itself.[85] Another study found that poor sleep quality predicted daytime sleepiness and was associated with increased risk of common mental disorders among college students; thus, health promotion programs that raise awareness of good sleep habits during the college years are needed.[86] Also, resilience among service members has been increased through promotion of healthy sleep,[87] which then strongly suggested the need of further development and enhancement of policies that have a direct impact on sleep. The initial but major step is through training or education opportunities. As a further example, people in the workplace can learn the importance of sleep and take appropriate actions, like having sufficient sleep duration and consuming a low-fat diet, which may improve sleep quality and daytime functioning. Consequently, our findings could be useful to policymakers and educators alike in raising the awareness of sleep health, particularly as it relates to subjective health and quality of life.

During patient healthcare visits, providers should make inquiries about sleep quality and quantity, and help in pinpointing sleep problems and raising awareness of the need to sleep well. Sleep also should be included as a variable in intervention design or stress management to meet the needs of individuals and enhance their overall health and well-being.

Human Subjects Approval Statement

Ethical approval was applied for and received from the German Psychological Society (Deutsche Gesellschaft für Psychologie, DGPs). A clinical trial registration was conducted at ClinicalTrials.gov on June 29, 2015, with Protocol ID is FP7/2007-2013 and ClinicalTrials.gov ID is NCT02502292. Therefore, procedures of this study are in accordance with ethical standards for human research.

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Conflict of Interest Disclosure Statement

The authors declare that they have no conflict of interest.

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