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Do stress, health behavior, and sleep mediate the association between loneliness and adverse health conditions among older people?

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ABSTRACT

Introduction: Prior research has established an association between loneliness and a variety of negative health conditions among older people. However, little is known about the mechanisms underlying this association.
Objective: Building on the Loneliness Model, Hawkley and Cacioppo (2010) identified possible pathways through which loneliness may affect the development of adverse health conditions. The present study was designed to test the pathways proposed by Hawkley and Cacioppo.
Methods: The sample consisted of 8593 elderly ranging from 65 to 102 years of age participating in the 2013 Public Health Survey "How are you?".
Results: Findings show that loneliness was significantly associated with cardiovascular disease, diabetes, and migraine. In addition high perceived stress, physical inactivity, daily smoking, and poor sleep mediated the association between loneliness and adverse health conditions. Moreover, findings demonstrate several gender differences in the association between loneliness and various adverse condition and the indirect mechanisms affecting these associations.
Conclusion: The findings largely support the pathways proposed by Hawkley and Cacioppo.

Loneliness is a common, yet painful emotional experience affecting individuals of all ages. It is thought to accelerate the rate of physiological decline, which makes it an important research area among older people (65+ years) (Cacioppo and Cacioppo, 2014; Hawkley and Cacioppo, 2007). Loneliness among older people is well-investigated, and it is a widely held stereotype that it is more prevalent in this age group than among other age groups (Peplau et al., 1982; Pinquart and Sørensen, 2001). Nonetheless, loneliness is generally not more frequent among older people, and 5–15% of older men and woman actually report often being lonely (Pinquart and Sørensen, 2001; Victor et al., 2000). The oldest old (75+ years and above) are, however, more prone to feelings of loneliness (Dykstra et al., 2005; Hawkley and Cacioppo, 2007; Pinquart and Sørensen, 2001), which may reflect that they are faced with a general increase in widowhood, sickness, physical immobility, and limited social opportunities. Large cross-national variations in the prevalence of loneliness in old age have been documented, and among European elderly the prevalence has been found to range from 3 to 34% across different nations (Yang and Victor, 2011). The prevalence of loneliness in northern European nations such as Denmark, Germany, Sweden and The United Kingdom has been found to be low compared to eastern and southern European nations (Yang and Victor, 2011).

1. Loneliness in old age

Loneliness is an unpleasant emotional state and a result of a discrepancy between desired and achieved levels of social contact (Peplau and Perlman, 1982). Loneliness is not synonymous with social isolation, but is related to both the amount of social contact (quantity) as well as the features (quality) defining social relationships, as for instance intimacy and confidentiality. Furthermore, loneliness in old age is associated with a variety of serious health consequences and therefore appears to be an important psychosocial risk factor of relevance for age-related health problems (Hawkley et al., 2008).

Social life changes radically in old age; for some older people,

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widowhood and retirement have large implications for loneliness and overall well-being (de Jong Gierveld, 1998; Victor et al., 2000). For instance, losing a spouse is equivalent to losing an attachment figure (Weiss, 1973) and entail loss of intimacy and closeness, which may explain why widows are more prone to feelings of loneliness. Even though the risk of loneliness in old age seems great, many older people live a satisfying social life where they continue to take part in social activities and maintain social relationships. However, some individuals still experience profound feelings of loneliness in old age, and a large body of research indicates that such individuals are at greater risk of developing poor health.

2. Loneliness and adverse health conditions in old age

The Loneliness Model (Cacioppo and Hawkley, 2009; Hawkley and Cacioppo, 2010) is a highly specific model, which seeks to explain mechanisms that promote and perpetuate feelings of loneliness. Building on the Loneliness Model, Hawkley and Cacioppo (2010) propose that persistent feelings of loneliness are a risk factor for broad-based morbidity and mortality. Based on this proposal, Hawkley and Cacioppo (2010) delineate possible pathways through which loneliness may affect the development of adverse health conditions. Furthermore, the association between loneliness and adverse health conditions is thought to be particularly relevant in old age (Cacioppo and Cacioppo, 2014).

According to the Loneliness Model, hypervigilance for social threats serves as a fundamental agent in the process through which loneliness affects health because it is, among other things, involved in the production of maladaptive cognitive bias regarding social interaction. Cognitive bias causes the lonely individual to perceive the social world as threatening, and patterns of inappropriate social behavior are produced in response to this perception (Hawkley and Cacioppo, 2010). Inappropriate social behavior often evokes negative reactions from peers, which confirms the maladaptive cognitive bias. Hawkley and Cacioppo (2010) have labeled this process "self-reinforcing loneliness loops" and argue that such loops contribute to the development of chronic loneliness. This process is furthermore thought to represent a dispositional tendency which activates a series of neurobiological, physiological, and behavioral mechanisms that are assumed to contribute to the development of adverse health conditions (Hawkley and Cacioppo, 2010). Specifically, through maladaptive hypervigilance, loneliness is assumed to affect health by producing elevated stress, creating patterns of health-compromising behavior, and by affecting physiological repair and maintenance processes such as sleep (Hawkley and Cacioppo, 2007, 2010). As such, Hawkley and Cacioppo (2010) argue that stress, health-compromising behavior (e.g., physical inactivity, smoking and poor diet) as well as sleep may constitute possible pathways between loneliness and adverse health conditions. However, the pathways described by Hawkley and Cacioppo (2010), are generic, and specific mediators and health outcomes still need to be identified. Moreover, studies that have put the theoretical notions into empirical testing are sparse.

Loneliness has been found to predict several adverse health conditions, including poor self-rated health (Luo et al., 2012), increased blood pressure (Hawkley et al., 2008), increased risk of mortality (Holwerda et al., 2012; Perissinotto et al., 2012; Steptoe et al., 2013), decline in activities of daily living and mobility (Perissinotto et al., 2012), the onset of dementia (Holwerda et al., 2014) and cardiovascular disease (Hawkley et al., 2003; Hawkley et al., 2008; Momtaz et al., 2012).

Furthermore, studies suggest that loneliness could potentially affect other diseases such as diabetes and migraine. However, the direct associations have yet to be examined. Poor social relations have been linked to diabetes (Hempler et al., 2013), and loneliness has also been associated with the metabolic syndrome, which refers to a clustering of factors that have been shown to increase the risk of diabetes among others (Whisman, 2010). Likewise, migraine has been associated with psychosocial difficulties such as poor social functioning (Raggi et al., 2012), and frequent headaches have been associated with having few confidants and a small network size (Cohen and Henry, 2011). Together this may suggest that loneliness could potentially affect the development of migraine or frequent headaches.

One previous study has demonstrated that elevated stress, health-compromising behavior, and poor sleep have an indirect effect on the association between loneliness and health. Segrin and Passalacqua (2010) investigated the potential pathways, identified by Hawkley and Cacioppo (2010), and found that the association between loneliness and poor self-rated health was mediated by several factors (high perceived stress, medical adherence, sleep, and exercise). However, their study was limited due to a small sample size ($n = 265$) and the use of a convenience sample. Furthermore, the study provided only a single, self-rated measurement of health status and did not investigate specific disease conditions.

Moreover, gender differences have not previously been a subject of investigation in relation to the loneliness-health association and the mechanisms affecting the association. However, older women tend to be lonelier than older men (Cohen-Mansfield et al., 2009; Dykstra et al., 2005; Rieke and Bird, 2005; Pinquart and Sørensen, 2001), and many health conditions or diseases are more prevalent among one gender than another (National Center for Health Statistics 2012). For instance, gender differences exist in the prevalence of manifestations of cardiovascular disease (Leening et al., 2014). Moreover, men overall have higher rates of diabetes than women (Wild et al., 2004), whereas more women experience migraine and/or frequent headaches than men (Lipton and Bigal, 2005; Lyngberg et al., 2005). Taken together, the investigation of gender as a potential moderator of the loneliness-health association appears to be a relevant research avenue.

3. The aim of the present study

Although loneliness clearly predicts adverse health conditions (Cohen-Mansfield et al., 2009; Luo et al., 2012), the mechanisms through which loneliness may affect health have not been sufficiently investigated. Building on the theoretical foundation of the Loneliness Model, Hawkley and Cacioppo (2010) offers a generic description of the loneliness-health association. However, the proposed pathways has not yet been fully operationalized or examined empirically.

The aim of the present study was to further validate the hypothesized pathways by examining a broad range of mechanism in relation to three disease conditions in old age among Danish elderly (see Fig. 1). Furthermore, the study aimed to investigate the loneliness-health association across gender to determine possible variations.

The investigated health outcomes were cardiovascular disease, diabetes, and migraine. Cardiovascular disease was included in the study on the grounds of results from previous studies (Hawkley et al., 2003; Hawkley et al., 2008; Momtaz et al., 2012). To the best of our knowledge loneliness has not previously been associated with diabetes or migraine. Nevertheless, the two conditions were included in the study because previous research have associated loneliness-related conditions with diabetes (Hempler et al., 2013) and migraine/frequent headaches (Cohen and Henry, 2011; Raggi et al., 2012), respectively. Furthermore, we investigated potential mediators from three domains: stress, health behavior, and

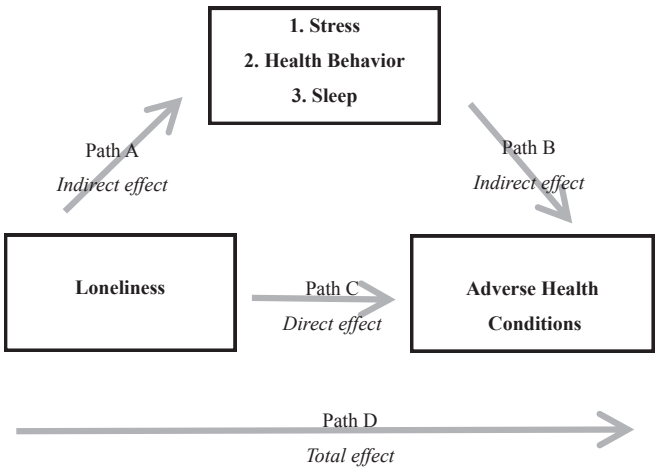

Fig. 1. Model of indirect effects.

sleep. The mediators represent a broad range of the indirect mechanisms described by Hawkley and Cacioppo (2010).

Based on the proposed pathways, described by Hawkley and Cacioppo (2010), along with the results of previous studies, it was hypothesized that:

1. Loneliness would be associated with cardiovascular disease, diabetes, and migraine among older people.
2. High perceived stress, health-compromising behavior, and poor sleep would exert an indirect effect on the association between loneliness and all of the chosen health conditions.

Due to the scarcity of previous research it was difficult to develop clear expectations regarding the effect of the mechanisms across gender.

4. Method

4.1. Participants and procedure

The data in the present study were obtained from the 2013 Danish Public Health Survey "How are you?" (Larsen et al., 2014). Denmark is administratively divided into five regions. The survey was conducted in the Central Denmark region, where approximately 1,270,000 (22%) Danish citizens are settled (Danish Regions, 2014). The population of the Central Denmark region is characterized by a demographic composition (gender, age and civil status) that is similar to the total Danish population (Statistics Denmark, 2015). Furthermore, the latest National Public Health Survey (2013; Christensen et al., 2014) demonstrated that the population of the Central Denmark region is comparable to the total Danish population on health-related and social factors. Every person living in Denmark has a unique 10-digit central personal registry number (CPR number) for identification. Using the CPR number, a random sample of individuals was drawn from the CPR Registration System. Participants received a letter of introduction that briefly described the purpose and content of the survey. They were then invited to fill out the enclosed paper questionnaire and informed about the voluntariness of participation and the confidentiality of their responses. Furthermore, a mixed mode approach was used to collect the data. Each participant could fill out the enclosed paper questionnaire or use a unique web-access to fill out the questionnaire electronically. To enhance the representativeness of the study weights were applied to account for potential differences in selection probabilities and response rate. These weights were constructed using a model-based calibration approach based on register information from Statistic Denmark (Särndal and Lundström, 2005).

The present sample consisted of 8593 elderly persons aged 65–103 years with a response rate of 67%. 94% of the sample filled out the paper questionnaire. All participants were of Danish origin; participants of other ethnic origin were excluded as the response rate of elderly participants of other ethnic origin than Danish was low. The mean age of the sample was 73 years, and the majority of the participants were between the age of 65 and 74 years (64%), 28% were between the age of 75 and 84 years, and 7% of the participants were older than 84 years. 51% of the participants were female. Only 9% of the participants were still employed, and 31% stated to live alone.

4.2. Measures

4.2.1. Independent variable

4.2.1.1. Loneliness. Data on loneliness were gathered using a Danish version of the Three-Item Loneliness Scale (Hughs et al., 2004; Lasgaard, 2007). This scale is developed with reference to large population-based surveys, and it is based on the widely used Revised UCLA Loneliness Scale (20 items; Russell et al., 1980; Hughs et al., 2004). It has been demonstrated that the two scales correlate strongly ($r = .82$) and have good internal consistency, and both scales have high concurrent and discriminant validity (Hughs et al., 2004). In the present sample, the Three-Item Loneliness Scale demonstrated good internal consistency; Cronbach's alpha = .72.

The Three-Item Loneliness scale contains the following three questions: *How often do you feel isolated from others? How often do you feel you lack companionship? How often do you feel left out?* The items are rated on a three-point Likert scale. The sum of the items (ranging from 3 to 9) was used as a global measure of loneliness. Higher scores on the scale indicated greater loneliness (Hughs et al., 2004).

4.2.2. Dependent variables

4.2.2.1. Cardiovascular disease, diabetes, and migraine. Data on chronic diseases (cardiovascular disease, diabetes, and migraine) were collected using a revised version of a survey instrument recommended by the World Health Organisation for use in national health surveys (Burata et al., 2003). Respondents were asked if they had any of the selected diseases or if they had had any of the diseases and were still affected by these diseases.

4.2.3. Mediating variables

4.2.3.1. Perceived stress. Data on stress were assessed using the 10-item Perceived Stress Scale (10-PSS; Cohen and Williams, 1988). The scale measures the degree to which one perceives aspects of one's life as being uncontrollable, unpredictable, and stressful. Each item is rated on a five-point Likert scale (*Never*, *Almost never*, *Sometimes*, *Fairly often*, and *Very often*), and a higher total score reflects greater stress (ranging from 0 to 40). The scale has been shown to have good internal consistency (Roberti et al., 2006). In the present sample, Cronbach's alpha was .81. The scale was dichotomized prior to analysis classifying participants belonging to the top 10-percentile (>18) of the 10-PSS total score as being high in perceived stress.

4.2.3.2. Health behaviors. The participants were asked about four types of health behavior: daily smoking, alcohol problems, weekly physical activity, and dietary habits. Participants who smoked on a daily basis were classified as smokers. Alcohol problems were

assessed using the CAGE-C, which consists of six questions about problem drinking and potential alcohol problems, such as "(In the past 12 months) Have you ever felt you should cut down on your drinking?". Having an alcohol problem was defined as two or more positive answers in questions 1–5, or one positive answer in questions 1–5 in addition to having an alcohol intake on 4 or more days per week (question 6) (Zierau et al., 2005). Participants were classified as physically inactive if they were only physically active between 0–30 min minutes weekly, as the Danish Health and Medicines Authority recommence at least 30 min of physical activity a day (Kiens et al., 2007). Dietary habits were assessed using the Diet Quality Score (DQS; Toft et al., 2007), which was developed to identify the quality of the diet in relation to cardiovascular risk. The scale consist of 25 items, which include questions regarding type of bread spread, fats used for cooking and how often the participants consumed selected food items (including fish, meat, fruits and vegetables). The total score classifies the participants into three groups with high, medium, and low dietary quality. Low dietary quality (i.e., an unhealthy diet) is defined by a low amount of fruit, vegetables and fish and a high amount of saturated fat.

4.2.3.3. Sleep. Each participant was asked to rate his or her general sleep quality on a four-point Likert scale (*Really good*, *Good*, *Fair*, and *Bad*). Participants who stated to be sleeping badly were considered as having poor sleep quality. Furthermore, the open-end-question, *"In the past four weeks: How many hours and minutes did you approximately sleep on a weekday?"* assessed the participant's sleep duration. In the present study, less than 6 h and more than 9 h of sleep per weekday were considered as poor sleep duration in conformity with the guidelines from The American Institute of Medicine and previous studies (Cappuccio et al., 2010; Perry et al., 2013; Tsai et al., 2014).

4.2.4. Data analysis

Multiple mediation analyses were conducted to determine the indirect effect of the seven selected mediators on the association between loneliness and each of the three dependent variables. Thus, three models of mediations were conducted: Model A (cardiovascular disease), Model B (diabetes), and Model C (migraine). Moreover, each model was tested independently for male and female participants. The Stata-command, khb, was used to conduct multiple mediation analysis (Breen et al., 2013; Kohler et al., 2011). The command decomposes the total effect into direct effect (the effect of the independent variable on the dependent variable when controlling for mediating variables) and indirect effect (the effect of the independent variable on the dependent variable through mediating variables).

5. Results

Table 1 summarizes direct and indirect effects of loneliness and mediators on cardiovascular disease (Model A), diabetes (Model B), and migraine (Model C).

5.1. The association between loneliness and cardiovascular disease

In Model A, loneliness significantly predicted cardiovascular disease (total effect). However, loneliness did not predict cardiovascular disease when the seven mediators (direct effect) were included (Table 1). As shown in Table 2, high perceived stress, daily smoking, physical inactivity and poor sleep duration were significant mediators in the association between loneliness and cardiovascular disease. Alcohol problems, unhealthy diet and poor sleep quality did not affect the association. Loneliness had the strongest indirect effect on cardiovascular disease through high perceived stress and physical inactivity.

5.2. The association between loneliness and diabetes

In Model B, loneliness significantly predicted diabetes (total effect), but, loneliness did not predict diabetes when the seven mediators (direct effect) were included (Table 1). As Table 3 shows, physical inactivity, poor sleep quality and poor sleep duration were significant mediators in the association between loneliness and diabetes. High perceived stress, daily smoking, alcohol problems and unhealthy diet did not affect the association significantly. Loneliness had the strongest indirect effect on diabetes through physical inactivity.

5.3. The association between loneliness and migraine

In Model C, loneliness significantly predicted migraine (total effect). However, loneliness did not predict migraine when the seven mediators (direct effect) were included. As shown in Table 4, high perceived stress and poor sleep quality were significant mediators in the association between loneliness and migraine. Daily smoking, unhealthy diet, alcohol problems, physical inactivity, and poor sleep duration did not affect the association significantly. Loneliness had the strongest indirect effect on migraine through high perceived stress.

5.4. Gender

As Table 1 shows, loneliness did predict cardiovascular disease among male and female participants (total effect). However, loneliness did not predict cardiovascular disease in male or female participants, when the seven mediators were included (direct effect). Among the male participants, loneliness had an indirect effect on cardiovascular disease through high perceived stress (total effect = 34%, $p = .005$), daily smoking (total effect = −2%, $p = .014$), physical inactivity (total effect = 22%, $p < .001$) and poor sleep duration (total effect = 6%, $p = .01$). Alcohol problems (total effect = 1%, $p = .383$), unhealthy diet (total effect = − 3%, $p = .288$), and poor sleep quality (total effect = 8%, $p = .200$) were not significant mediators. Among the female participants, loneliness had an indirect effect on cardiovascular disease through physical inactivity (total effect = 22%, $p = .005$) and poor sleep duration (total effect = 8%, $p = .031$). High perceived stress (Total effect: 29%, $p = .056$), daily smoking (total effect = 1%, $p = .303$), alcohol problems (total effect = 0%, $p = .958$), unhealthy diet (total effect = 1%, $p = .752$), and poor sleep quality (total effect = 8%, $p = .142$) were not significant mediators.

As Table 1 also shows, loneliness did predict diabetes among the female participants, but not among the male participants (total effect). Furthermore, loneliness did not predict diabetes among the female participants when the seven mediators were included (direct effect). Among the female participants, loneliness had an indirect effect on diabetes through high perceived stress (total effect = 36%, $p = .028$) and physical inactivity (total effect = 30%, $p = .001$). Daily smoking (total effect = −1%, $p = .532$), alcohol problems (total effect = 0%, $p = .393$), unhealthy diet (total effect = −6%, $p = .153$), poor sleep quality (total effect = 11%, $p = .063$) and poor sleep duration (total effect = 5%, $p = .322$) were not significant mediators.

As shown in Table 1, loneliness did predict migraine among both male and female participants (total effect). However, loneliness did not predict migraine when the seven mediators were included in male and female participants (direct effect). Among the male participants, loneliness had an indirect effect on migraine through poor sleep quality (total effect = 17%, $p = .023$). High perceived

Table 1
Direct and indirect effect of loneliness and mediators on cardiovascular disease (Model A), diabetes (Model B), and migraine (Model C).

Effect	*OR*	*SE*	*Z*	*p*	*95%* CI		*Men*			*Women*		
					Lower	Upper	*OR*	*SE*	*p*	*OR*	*SE*	*p*
Model A												
Total effect	1.15	.04	4.21	<.001	1.08	1.23	1.15	.05	.002	1.14	.05	.004
Direct effect	1.05	.04	1.29	.195	0.98	1.12	1.05	.05	.335	1.05	.05	.359
Indirect effect	1.10	.02	5.87	<.001	1.07	1.13	1.10	.02	<.001	1.09	.02	<.001
Model B												
Total effect	1.15	.05	3.08	.002	1.05	1.26	1.14	.08	.059	1.19	.07	.005
Direct effect	1.05	.05	1.02	.306	0.95	1.16	1.08	.08	.292	1.04	.07	.532
Indirect effect	1.10	.02	4.47	<.001	1.05	1.14	1.16	.03	.037	1.14	.04	<.001
Model C												
Total effect	1.26	.06	4.69	<.001	1.14	1.38	1.23	.10	.009	1.25	.08	<.001
Direct effect	1.11	.06	1.86	.062	0.99	1.23	1.13	.10	.149	1.09	.08	.247
Indirect effect	1.13	.03	5.44	<.001	1.09	1.19	1.08	.03	.006	1.15	.04	<.001

Note. *OR* = Odds ratio. *SE* = standard error.

Table 2
Model A: Contribution of each mediator on the association between loneliness and cardiovascular disease.

Mediating variable	*B*	Standard error	*p*	Contribution (%) to the indirect effect	Contribution (%) to the total effect
High perceived stress	.37	.11	.001	46.99	31.44
Daily smoking	−.23	.09	.013	−2.60	−1.74
Alcohol problems	.07	.09	.440	0.06	0.04
Unhealthy diet	−.07	.10	.496	−1.66	−1.11
Physical inactivity	.42	.08	<.001	34.88	23.34
Poor sleep quality	.24	.12	.051	11.92	7.98
Poor sleep duration	.26	.08	.001	10.41	6.97

Note. *B* = Unstandardized regression coefficient.

Table 3
Model B: Contribution of each mediator on the association between loneliness and diabetes.

Mediating variable	*B*	Standard error	*p*	Contribution (%) to the indirect effect	Contribution (%) to the total effect
High perceived stress	.18	.16	.247	22.66	14.62
Daily smoking	.13	.14	.925	.15	.10
Alcohol problems	−.27	.15	.074	−0.24	−0.02
Unhealthy diet	−.15	.16	.339	−3.67	−2.37
Physical inactivity	.64	.12	<.001	52.23	33.71
Poor sleep quality	.34	.17	.038	17.34	11.19
Poor sleep duration	.29	.12	.016	11.52	7.44

Note. *B* = Unstandardized regression coefficient.

Table 4
Model C: contribution of each mediator on the association between loneliness and migraine.

Mediating variable	*B*	Standard error	*p*	Contribution (%) to the indirect effect	Contribution (%) to the total effect
High perceived stress	.56	.17	.001	51.87	28.66
Daily smoking	.18	.16	.259	1.53	0.85
Alcohol problems	−.36	.19	.055	−0.23	−0.13
Unhealthy diet	−.15	.18	.405	−2.75	−1.52
Physical inactivity	.21	.15	.157	12.55	6.94
Poor sleep quality	.80	.18	<.001	29.53	16.32
Poor sleep duration	.26	.14	.065	7.48	4.14

Note. *B* = Unstandardized regression coefficient.

stress (total effect = 28%, p = .051), daily smoking (total effect = −2%, p = .243), alcohol problems (total effect = −2%, p = .161), unhealthy diet (total effect = 0%, p = .980), physical inactivity (total effect = 0%, p = .962), and poor sleep duration (total effect = −1%, p = .804) were not significant mediators. Among the female participants, loneliness had an indirect effect on migraine through high perceived stress (total effect = 28%, p = .017), daily smoking (total effect = 3%, p = .011), poor sleep quality (total effect = 14%, p = .001) and poor sleep duration (total effect = 10%, p = .004). Alcohol problems (total effect = 0%, p = .982), unhealthy diet (total effect = −1%, p = .722), and physical inactivity (total effect = 10%, p = .190) were not significant mediators.

6. Discussion

As anticipated, loneliness was significantly associated with cardiovascular disease, diabetes, and migraine. The findings of the present study thereby confirm previous studies that established an association between loneliness and cardiovascular disease (Hawkley et al., 2003; Hawkley and Cacioppo, 2010; Momtaz et al.,

2012; Whisman, 2010). However, the associations between loneliness and diabetes and between loneliness and migraine have not previously been documented. Furthermore, the present study finds that high perceived stress, health-compromising behaviors in particular physical inactivity, and poor sleep mediates the association between loneliness and adverse health conditions. As such, the present study contributes to the operationalization and validation of the proposed pathways (Fig. 1), described by Hawkley and Cacioppo (2010) by identifying specific mediators and health outcomes. Finally, the present findings suggests, that there are gender differences in the association between loneliness and various adverse conditions as well as the indirect mechanisms affecting these associations.

Our findings suggest that the pathways outlined by Hawkley and Cacioppo (2010) can at least partly explain the association between loneliness and the three investigated health conditions. Indeed, stress, physical inactivity and sleep seem to affect the loneliness-health association among older people. Furthermore, the study demonstrates that the proposed pathways, described by Hawkley and Cacioppo (2010) affect distinct health conditions.

In line with the findings by Segrin and Passalacqua (2010), the present study finds that high perceived stress mediated the association between loneliness and adverse health conditions. High perceived stress was indeed found to be the strongest of the seven examined factors in the present study, and affected the loneliness-health association across gender. This may indicate that stress plays a unique role in the loneliness-health association. Health-compromising behaviors were also found to mediate the association between loneliness and adverse health conditions. Especially physical inactivity had a large indirect effect on the association, accounting for 23–33% of the total effect. This confirms previous findings by Segrin and Passalacqua (2010), who found that less exercise mediated the effect on the association between loneliness and poor self-rated health. Daily smoking also mediated the association; however, the indirect effect was marginal. Hawkley and Cacioppo (2010) suggest that in lonely people, health behavior is affected by mechanisms related to hypervigilance, which over time diminishes self-regulation, eventually creating patterns of health-compromising behaviors such as physical inactivity, unhealthy eating, and smoking. The findings of the present study demonstrate that not all health-compromising behaviors affect the loneliness-health association among older people. Rather, only physical inactivity appears to have a strong impact on the association between loneliness and the three investigated health conditions.

Poor sleep (poor sleep quality or short sleep duration) was found mediate the association between loneliness and adverse health conditions. This confirms previous findings (Segrin and Passalacqua, 2010). The present study therefore supports the notion that it may be important to consider sleep when trying to understand the mechanisms that connect loneliness with adverse health conditions. According to Cacioppo and Cacioppo (2014), loneliness causes the brain to remain somewhat vigilant during sleep, resulting in poor sleep patterns. Thus, by causing poor quality or poor sleep duration, loneliness affects the body's normal restorative processes, which has important implications for health.

Neither alcohol problems nor unhealthy diet were found to mediate the association between loneliness and the adverse health conditions. Furthermore, daily smoking was found to have only a marginal indirect effect on the loneliness-health association. Therefore, these three health-compromising behaviors appear to be of little importance to the loneliness-health association among older people. We are aware of no prior studies that have examined a broad range of health-compromising behaviors as mediators of the loneliness-health association in old age, and so this novel finding requires replication. Moreover, the potency or importance of the mechanisms may vary across a lifespan (Hawkley and Cacioppo, 2007). For instance, it may be speculated that a combination of loneliness, severe alcohol problems, and poor diet in young and middle age increases the risk of premature death in old age.

Variations between genders were detected in the present study. Among women loneliness were associated with all the tested health outcomes, whereas loneliness was only associated with cardiovascular disease and migraine among men. Hence, gender might be an important moderator of the association between loneliness and diabetes. Moreover, significant differences were detected between genders with regards to the examined mediators. However, the differences in the contribution of the mediators to the total effect were marginal with regard to both cardiovascular disease and migraine. This could indicate that the identified mediators affect the loneliness-health association across gender. However, further research is needed to replicate these novel findings and to further explore possible gender differences.

6.1. Limitations

There are several limitations worthy of consideration in the present study. First, it is important to note that the findings are based on cross-sectional data, which implies that no conclusions about the temporality or causation can be made. Indeed, loneliness predicts poor health (Holwerda et al., 2012; Holwerda et al., 2012; Luo et al., 2012), but it may also originate from poor health (Luo et al., 2012; Cohen-Mansfield et al., 2009). The data reported here therefore do not allow causal inference between loneliness and poor health. Second, according to Hawkley and Cacioppo (2010), the physiological effects of loneliness are thought to unfold gradually. For instance, the physiological strains of elevated stress evolve over years, just like the physiological consequences of an inactive lifestyle or long-term sleep problems, may not become evident until after several years. These mechanisms cannot be described or explained using the present data, and future longitudinal research is therefore very much needed. Finally, there is concern as to whether the sample includes the weakest and sickest elderly in Denmark, given that the response rate among the oldest old was low. These people, who may be institutionalized or hospitalized, may not be rightfully represented.

6.2. Implications and further research

With these limitations in mind, the findings of the present study make a relevant contribution to the literature by shedding light on the mechanisms that affect the loneliness-health association among older people. The present findings contribute to the operationalization and validation of the hypothesized pathways identified by Hawkley and Cacioppo (2010), building on the Loneliness Model, by identifying specific mediators in relation to three different health outcomes in a large, representative sample. The findings of the present study indicate that the loneliness-health association is in general constituted by perceived stress, physical inactivity, and poor sleep which may therefore be relevant targets of future research as well as future prevention or intervention initiatives among lonely individuals. Furthermore, the prevalence of loneliness among Danish elderly has been found to be substantially lower than the prevalence among collectivistic nations in the eastern and southern Europe (Yang and Victor, 2011). Results from the present study may therefore only be representative of other northern European counties. Future research would benefit from a longitudinal perspective that can clarify and explain the association between loneliness and adverse health conditions over time, not least because the effect of stress, health compromising behavior, and sleep problems is thought to unfold gradually over time.

7. Conclusion

The findings of the present study showed that loneliness was significantly associated with cardiovascular disease and migraine for men and women and with diabetes for women (but not men). As anticipated, high perceived stress, certain health-compromising behaviors (predominately physical inactivity), and poor sleep were found to be mediators in the association between loneliness and the three investigated health outcomes. The findings therefore support the pathways identified by Hawkley and Cacioppo (2010) while contributing with additional knowledge on the complexity of the loneliness-health association. The present study furthermore indicates that there is much need for prevention and intervention towards loneliness among older people, and for further research in this area.

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