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1 TITLE Short Sleep Duration and Poor Sleep Quality Increase the Risk of Diabetes in
2 Japanese Workers with no Family History of Diabetes

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1 ABSTRACT

2 OBJECTIVE

3 To investigate whether a difference in risk for diabetes exists in Japanese workers regarding
4 sleep duration/quality and the presence or absence of a family history of diabetes (FHD).

5 RESEARCH DESIGN AND METHODS

6 The researchers conducted a prospective occupational-based study of local government
7 employees in Sapporo, Japan. Between April 2003 and March 2004, 3,570 non-diabetic
8 participants aged 35 to 55 years, underwent annual health-checkups and completed a
9 self-administered questionnaire which included information on sleep duration/quality and
10 FHD at baseline. Having diabetes was defined as taking medication for diabetes or a fasting
11 plasma glucose level of ≥ 126 mg/dl at follow-up (2007 – 2008).

12 RESULTS

13 A total of 121 (3.4%) new cases of diabetes were reported. In multivariate logistic regression
14 models of workers without FHD, and after adjustment for potential confounding factors, the
15 odds ratio (95% CI) for developing diabetes was 5.37 (1.38 - 20.91) in those with a sleep
16 duration of ≤ 5 h compared to those with >7 h. Other risk factors were 5.03 (1.43 - 17.64);
17 awakening during the night, 6.76 (2.09 - 21.87); self-perceived insufficient sleep duration,
18 3.71 (1.37 – 10.07) and unsatisfactory overall quality of sleep. In subjects with FHD these
19 associations were either absent or weaker.

1 CONCLUSIONS

2 The present study shows that poor sleep is associated with a higher risk of developing
3 diabetes in workers without FHD. Promoting healthy sleeping habits may be effective for
4 preventing the development of diabetes in people without FHD.

5

1 Modern society encourages late-night activities such as watching television; using the
2 computers or Internet, 24-7 entertainment, as well as demanding shift-work or night work
3 which further promotes such activities. According to a survey by the National Sleep
4 Foundation (2010), about one-fourth of participants stated that their current work schedule
5 prevented them from getting enough sleep [1]. One study reported that the average sleep
6 duration for Finnish people had decreased by about 18 minutes during a period of 33 years
7 (1972 to 2005), while sleep complaints such as difficulty in falling asleep or awakening
8 during the night had increased, especially among the employed middle-aged population [2].
9 According to a 2006 Survey of Japanese adults on “Time Use and Leisure Activities”,
10 average sleep duration was the shortest it has been for the past two decades [3]. Furthermore,
11 another report showed that a fifth of Japanese adults habitually used alcohol or medicine to
12 help them fall asleep [4].

13 It has been reported that poor sleep is associated with higher HbA1c levels in subjects
14 with type 2 diabetes [5-6]. Some prospective studies have reported that extreme sleep
15 duration [7-10] and poor sleep quality, such as difficulty in sleep initiation [11-13] and sleep
16 maintenance [12, 14-15], are associated with a higher risk of impaired glucose tolerance or
17 developing type 2 diabetes. However, those at greatest risk of developing diabetes from poor
18 sleep remains to be elucidated. A recent meta-analysis indicated that no significant difference
19 existed between men and women regarding sleep duration/quality and diabetes, with the

1 exception of short sleep duration in women [16]. One multiethnic cohort study found that the
2 risk in non-Hispanic Caucasians and Hispanics differed to that in African Americans [10].
3 However, the sleep-diabetes association in Asians is controversial with few studies published
4 [12-13].

5 Type 2 diabetes is well-known as a disease involving a complex combination of genetic,
6 environmental, and behavioral factors. In 2004, the Center for Disease Control and
7 Prevention in the USA developed Family Healthware, a family history screening tool, to
8 prevent common chronic diseases, including diabetes. They subsequently reported that a
9 family history of diabetes (FHD) was associated with a two-six-fold risk of developing
10 diabetes compared to no FHD. Three academic centers are now trying to determine whether
11 personalized prevention messages tailored to familial risk will motivate people at risk to
12 change their lifestyles or screening behavior [17]. FHD is considered to be an indicator for
13 intervention to prevent the development of diabetes in a high risk population. However, it is
14 not clear whether the sleep-diabetes association should also be an indicator for intervention.
15 Furthermore, whether people without FHD have any specific risks for developing diabetes
16 according to their daily lifestyle has not been ascertained.

17 The aim of this paper was to investigate whether a difference in risk for diabetes exists in
18 Japanese workers regarding sleep duration/quality and the presence or absence of a family
19 history of diabetes (FHD).

1 RESEARCH DESIGN AND METHODS

2 This is a prospective occupational-based study which took place in Sapporo, Hokkaido
3 prefecture, Japan. We contacted a total of 10,423 (men: 8,229, women: 2,194) local
4 government employees, aged between 35 to 60 years, who were to undergo their annual
5 health-checkup between April 2003 and March 2004. We then excluded participants aged 56
6 years or over, because they were due to retire during the follow-up period. The total number
7 of respondents was 4,195 (men: 3,073, women: 1,122). After completing their check-up,
8 participants submitted a self-administered questionnaire that had received previously and
9 included questions on sleep duration/quality, medical history, family history, lifestyle and
10 potential diabetes risk factors, as well as working conditions. A total of 208 participants with
11 a previous diagnosis of diabetes and/or a Fasting Plasma Glucose level (FPG) of ≥ 126 mg/dl
12 at baseline, 7 who had no information on FPG, and 21 who failed to complete all questions
13 on sleep were excluded. Follow-up data of 3,576 participants (90.3 %) who had undergone
14 their health-checkup and completed a further questionnaire on medical history and FHD
15 between April 2007 and March 2008 were obtained. Of these, 6 participants without FPG
16 were excluded from the final analysis.

17 The Ethical Committee for Medicine at Hokkaido University approved recruitment of
18 participants, as well as consent and field procedures prior to the survey. Written informed
19 consent was obtained from all participants before participation in the study.

1 Outcome and Exposures

2 The development of diabetes was defined as having been prescribed medication for
3 diabetes after the first health-checkup and/or a FPG ≥ 126 mg/dl at the follow-up
4 health-checkup.

5 Information on sleep was obtained from a self-administered questionnaire. Sleep
6 duration was assessed by the question 'How long on average, in hours and minutes, do you
7 normally sleep'. It was then further categorized into ≤ 5 h, 5-6h, 6-7h, >7 h. Because only 69
8 (1.9 %) participants slept for more than >8 h, they were combined into the >7 h category to
9 increase statistical power. Sleep quality was assessed by the Athens Insomnia Scale (AIS), the
10 consistency, reliability, and validity of which has been ascertained as a screening or diagnosis
11 tool for insomnia [18]. We used the AIS to assess sleep conditions. Another major sleep
12 questionnaire is the Pittsburgh Sleep Quality Index (PSQI), but we selected the AIS because
13 it has fewer questions and is quicker to answer. A recent study on sleep quality reported
14 similar results between PSQI and AIS [19]. AIS consists of eight items: the first five of
15 which pertain to sleep induction, awakening during the night, final awakening earlier than
16 desired, total sleep duration (not quantity but perceived sufficiency), and overall quality of
17 sleep (sleep satisfaction), the subsequent three items refer to sense of well-being, functioning,
18 and sleeping during the day. Participants were requested to score on a scale of 0 to 3, with 0
19 signifying no problem at all, 1 signifying a minor or slight problem, 2 signifying marked or

1 considerable problems, and 3 signifying serious problems or being unable to sleep at all.
2 Answers were based on any sleep difficulties participants may have experienced at least three
3 times a week during the previous month. For the analyses, we used the total score obtained
4 from all items to assess the severity of comprehensive sleep quality. A higher score expressed
5 a more aggravated sleep quality. We also investigated each of the five main items to
6 determine the extent of the risk of diabetes for each item separately. Because few participants
7 (less than 1% for each symptom, respectively) had serious problems (a score of 3), results
8 were transformed into dichotomous variables, where a score of 0 or 1 represented ‘no
9 difficulty’, and a score of 2 or 3 represented ‘difficulty or suffering’ in order to increase
10 statistical power.

11 FHD was obtained from the self-reported questionnaire. FHD was defined as having (or
12 having had) a first-degree relatives with diabetes. We did not ask for specific information on
13 diabetes type, since it was possible for participants to be mistaken. Type 1 diabetes is rare in
14 Japan (childhood incidence; 2.1 - 3.5 /100,000 /yr), while type 2 diabetes is common (adult
15 prevalence; 4 - 11 %) [20].

16 Potential Confounding Factors

17 Many potential confounders existed. BMI was calculated by height and weight via
18 health-checkup data of participants at baseline. Smoking was categorized into never, past,
19 current. Drinking was categorized into no (never or rarely) or yes (often or regularly).

1 Physical exercise was categorized into ≥ 150 minutes per week or less. Education was
2 grouped into more than high school or less. Sedentary work by grouped into the following
3 categories: $< 25\%$, $25 - 50\%$, $50 - 75\%$, and $\geq 75\%$, and then transformed into dichotomous
4 variables $\geq 75\%$ or less. Occupational stress which is significantly associated with insomnia
5 was assessed using two major job stress models, the demand-control model (DCM) and the
6 effort-reward imbalance model (ERI). Descriptions of the association between insomnia and
7 occupational stress assessed by both models are detailed in a previous study [21]. For the
8 analyses, DCM was redefined as demand-control ratio; demands scores and controls scores
9 were summed up separately, after which the demands score was divided by the control score.
10 An alternative model, the ERI was redefined as effort-reward rate; efforts scores and rewards
11 scores were summed up separately, after which the effort score was divided by the reward
12 score for analyses. In both models, high scores meant a more stressful job situation for the
13 individual.

14 Analysis

15 The Mann-Whitney U-test and Fisher's exact test were used to compare participants who
16 did and not develop diabetes, along with characteristics and sleep duration/qualities. All
17 analyses were performed separately for participants without or with FHD. To examine how
18 the association of sleep duration/quality and the development of diabetes was affected by
19 other factors, we calculated the risk [odds ratio (OR), 95 % CI] in different logistic regression

1 models. Model 1 was adjusted for age, sex, and FPG, Model 2 included additional adjustment
2 for established lifestyle risk factors for diabetes: BMI, smoking, drinking and physical
3 exercise, while Model 3 included additional adjustment for education and occupational
4 factors: working hours per week, shift work, rate of sedentary work, DCM, and ERI. The risk
5 of developing diabetes was calculated separately in these models along with sleep duration,
6 total AIS score, and each of AIS's five main items in participants without/with FHD. $p < 0.05$
7 was considered statistically significant. All analyses were performed using PASW Statistics
8 18 (SPSS Inc. Chicago. IL).

9 RESULTS

10 The number of participants without FHD was 2,862 (80.2 %). Having FHD was
11 significantly associated with approximately twice the risk of developing diabetes after
12 adjustment for age, sex, FPG, and lifestyle and occupational factors [OR 1.94 (95 % CI; 1.19
13 - 3.16), $p < 0.01$]. Interaction between FHD and sleep duration/quality in the multivariate
14 logistic model was not statistically significant.

15 Table 1 shows the comparison between participants who did and did not develop diabetes
16 with regards to characteristics and sleep duration/quality at baseline. Those with and without
17 FHD were analyzed separately. In both groups, participants who developed diabetes were
18 older, with a higher mean FPG, and higher mean BMI. In participants without FHD, those
19 who developed diabetes were significantly more often male, smokers, and more likely to

1 have perceived insufficient total sleep duration than those who did not. In participants with
2 FHD, those who developed diabetes had a significantly lower mean ERI than those who
3 didn't.

4 Table 2 shows the ORs for developing diabetes in participants without FHD in each
5 regression model along with sleep duration/quality. Sleep duration of ≤ 5 h was significantly
6 associated with a higher risk for diabetes compared to the reference of >7 h. However,
7 additional adjustment for diabetes-related lifestyle factors reduced this risk, but after further
8 adjustment for education and occupational factors, the risk increased once more. Total AIS
9 score was unequivocally associated with a significant increase in risk in all models. For each
10 of the five main AIS items, awaking during the night, insufficient total sleep duration, and
11 unsatisfactorily overall quality of sleep were significantly associated with an increased risk of
12 diabetes, but difficulty in sleep induction and final awakening earlier than desired were not.
13 The OR for awakening during the night was slightly higher in model 2, but significantly
14 higher in model 3. Perceived insufficient total sleep duration had the highest ORs among the
15 five items in all models. Even after additional adjustment for self-reported sleep duration, the
16 OR decreased only slightly and the significance remained [5.18 (1.50 - 17.85), $p < 0.01$]. The
17 ORs for unsatisfactorily quality of sleep were similar in all models.

18 In contrast, in those participants with FHD (table 3), neither sleep duration nor sleep
19 quality were significantly associated with risk of diabetes. Overall, ORs were smaller than for

1 participants without FHD.

2 In the present study, the OR for diabetes according to sleep duration/quality increased in
3 subjects without FHD (Table 2) after adjustment because many potential confounders
4 influenced the results. In particular, a difference in the distribution of FPG in sleep duration
5 and quality was observed.

6 Because only 14 women developed diabetes, the number was not sufficient for statistical
7 analysis to be performed on sex differences.

8 CONCLUSIONS

9 This report is one of few to document differences with regards to FHD and the
10 association between sleep and diabetes. It presents new findings in that short sleep duration
11 and poor sleep quality are significantly associated with an increased risk of diabetes in
12 Japanese workers without FHD, but not in those with FHD. This discrepancy in the risk of
13 developing diabetes may be explained by studies on the pathogenesis of type 2 diabetes in
14 people with familial risks. Cusi [22] noted that insulin resistance in both muscle and hepatic
15 tissue are genetically determined and fully established early in life in those with FHD.
16 Participants with FHD in the present study may have already lapsed into insulin resistance by
17 the time they reached the age of between 35-55 years, and poor sleep duration/quality would
18 not alter or diminish the risk of diabetes. Based on this hypothesis, short sleep duration/ poor
19 quality of sleep might be more influential in the early phase of the process of impaired

1 glucose metabolism or developing diabetes, before obvious clinical abnormalities appear.

2 In the present study, sleep duration ≤ 5 h was significantly associated with a higher risk of
3 developing diabetes only in those participants without FHD, after adjustment for potential
4 confounders. In an earlier study of 6,509 Japanese workers aged 19 to 69 years, no significant
5 association between short sleep and developing diabetes was observed [13]. In the present
6 study too, the association was not seen in all participants [1.64 (0.58 - 4.61, $p = 0.35$)]. One
7 epidemiological study from Sweden [15] and three from the USA [8-10] have shown an
8 association between short sleep and higher risk for developing diabetes. One possible
9 explanation of the discrepancy between these results and our results is that the effect of short
10 sleep on risk differs with ethnicity. One multiethnic study demonstrated that the risk in
11 non-Hispanic Caucasians and Hispanics differed to that in African Americans [10]. Another
12 possible explanation is duration of follow-up. One meta-analysis demonstrated that the risk of
13 developing diabetes with regards to poor sleep tended to increase with the duration of
14 follow-up [16]. The average duration of 4.2 years in a previous Japanese study [13] and four
15 years in the present study, might be shorter than that necessary to reach a significant
16 association. Some studies have reported that long sleep duration also was associated with
17 increased risk [7-10]. We did not analyze the risk regarding long sleep duration, because few
18 workers in our study slept for >8 h.

19 An increase in total AIS score was significantly associated with an increased risk of

1 developing diabetes. One cross-sectional population-based study reported that insomnia
2 combined with objectively measured sleep duration of ≤ 5 h was associated with a higher risk
3 of diabetes compared to normal sleep with >6 h, but only insomnia, poor sleep quality or
4 short sleep duration not alone were not statistically significant [23]. However, in our
5 prospective study, the OR of total AIS score after adjustment for additional self-reported
6 sleep duration remained significant [1.14 (1.02 – 1.28), $p = 0.02$] in those without FHD. This
7 means that increasingly poor sleep quality may be associated with an increased risk of
8 developing diabetes independent of sleep duration in those without FHD.

9 A significant association between difficulty initiating sleep and a higher risk of diabetes
10 has been reported in some studies [11-13], however, two studies also found no such
11 association [14-15]. The present study supports the latter, irrespective of FHD. The
12 discrepancy in these results may be explained by differences in measurement of difficulty
13 initiating sleep; frequency (never, sometimes, or often), yes/no, or degree of severity. All
14 studies having a positive result measured frequency or yes/no in symptoms. AIS measures
15 degree in severity of symptoms at least 3 times a week. Frequency of difficulty initiating
16 sleep might be a more predictable risk than the degree of symptoms.

17 Difficulty maintaining sleep has also been reported to be a significant risk factor for
18 developing diabetes [12, 14-15], and the association is likely to be consistent with either
19 measurement of frequency or degree. The mechanism involved in this association has not

1 been fully explained. One recent laboratory study demonstrated that all-night selective
2 suppression of falling into a deep sleep without change of sleep duration led to a 25%
3 decrease in insulin sensitivity [24]. The present results support the theory that difficulty in
4 maintaining sleep or having persistently shallow sleep could result in the induction of insulin
5 resistance and consequent the development of diabetes.

6 Perceived insufficient total sleep duration had the highest OR for diabetes even in those
7 with FHD without reaching statistical significance. Mallon et al. [15] reported that out of 38
8 men, 3 with a sleep duration ≤ 5 h had sufficient individual sleep duration and did not develop
9 diabetes during 12-year follow-up. One cross-sectional study in African Americans with type
10 2 diabetes found that a perceived sleep debt was more strongly correlated with higher HbA1c
11 levels compared with sleep duration in patients without complications, but this association
12 was not seen in those with complications or taking insulin [5]. This combined with our results
13 suggest that perceived sufficiency of sleep duration is an important factor for predicting
14 future aggravation of glucose metabolism in both healthy subjects and those with incipient
15 diabetes. Unsatisfactorily overall quality of sleep was associated with a significantly higher
16 risk in those without FHD. Thus individual optimum sleep duration may exist with perceived
17 sufficiency or satisfaction which prevents the development of diabetes.

18 There are several limitations to our study. One limitation is that participants were
19 relatively healthy local government employees, who were mostly men aged between 35 and

1 55 working in a city, with a relatively homogeneous socioeconomic status. Consequently, our
2 results are not applicable to the general population. Another limitation is the lack of objective
3 sleep measurement with polysomnography or actigraphy, so some misclassifications may
4 have occurred. A report described a moderate correlation between self-reported sleep duration
5 and measured sleep duration using wrist actigraphy ($r = 0.47$), the former was more likely to
6 overestimate the latter by 0.8 hours on average, and this overestimate escalated particularly
7 with shorter sleep duration [25]. Therefore, the risk of diabetes by short sleep duration might
8 be overestimated. However, using AIS as measurement of sleep quality has been already been
9 validated as an invaluable tool in sleep research and clinical practice [18]. We did not obtain
10 information on sleep disorders such as apnea which has been associated with a higher
11 prevalence of type 2 diabetes in adults [26]. FHD was gained by a self-reported questionnaire.
12 Regarding self-reported family history of diabetes, one Japanese study confirmed the validity
13 of self-reporting in Japanese subjects with <5 % discordance [27], however, we must not
14 overlook the potential for familial diabetes to also develop in the future. Another limitation is
15 that we could not control for diet in individuals. Taheri et al. [28] found that participants with
16 short sleep duration had reduced leptin levels and elevated ghrelin, both of which are related
17 to an increase in appetite and consequently an increasing BMI. Further study is needed to
18 clear the association between quality of sleep, calorific intake and weight, and the
19 contribution of dietary constituents to the sleep-diabetes relationship in FHD.

1 In conclusion, sleep duration ≤ 5 h, awakening during the night, perceived insufficient
2 total sleep duration, and unsatisfactorily overall quality of sleep were each found to be
3 associated with a future independent risk of diabetes in Japanese workers without FHD. It is
4 well known that people with a FHD are more likely to develop diabetes than those who don't;
5 and from our observations so far, seem to be more conscious of their risk and thus take active
6 measures to prevent the disease. However, those without FHD, should also be made aware
7 that they have their own risks for diabetes, such as poor sleep, and take active measures to
8 reduce this risk. Consequently, the present study proposes that public health strategies for
9 diabetes prevention need to consider the presence or absence of FHD.

10 Author Contributions

11 T.K. wrote the manuscript and researched data. E.Y. researched data, contributed to the
12 discussion and reviewed/edited the manuscript. H.S contributed to the discussion and
13 reviewed/edited the manuscript. Y.S, M.K researched data and contributed to the discussion.
14 E.O. contributed to the discussion. And R.K. researched data and reviewed/edited the
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1 Table 1. Baseline characteristics and sleep duration/quality for risk of diabetes according to FHD

	Without FHD		With FHD	
	No diabetes	Diabetes	No diabetes	Diabetes
Number	2788 (98.4)	74 (2.6)	661 (93.4)	47 (6.6)
Sex (male)	2202 (79.0)	68 (91.9)**	496 (75.0)	39 (83.0)
Age (years)	46.2 ± 6.1	50.3 ± 4.0***	46.5 ± 5.9	49.1 ± 4.5***
FPG (mg/dl)	90 ± 8	111 ± 10***	91 ± 10	109 ± 11***
BMI (kg/m ²)	23.3 ± 3.0	25.7 ± 3.2***	23.6 ± 2.9	25.6 ± 3.1***
Smoking				
Non Smoker	942 (33.8)	11 (14.9)**	210 (31.8)	9 (19.1)
Former Smoker	640 (23.0)	22 (29.7)	155 (23.4)	12 (25.5)
Current Smoker	1206 (43.3)	41 (55.4)	296 (44.8)	26 (55.3)
Drinking (often or more))	1963 (70.6)	52 (71.2)	467 (70.9)	34 (72.3)
Physical exercise (≥150 min/week)	471 (16.9)	15 (20.3)	111 (16.8)	9 (19.1)
Education (more than high school)	1315 (47.2)	30 (40.5)	310 (46.9)	17 (36.2)
Working hours	44.5 ± 9.9	43.3 ± 8.6	44.6 ± 8.7	43.2 ± 5.3
Shift-work	689 (24.7)	18 (24.3)	156 (23.6)	11 (23.4)
Sedentary work ≥75 %	1011 (36.4)	22 (29.7)	216 (32.9)	13 (27.7)
Demand-Control rate	0.73 ± 0.18	0.71 ± 0.16	0.75 ± 0.18	0.72 ± 0.14
Effort-Reward rate	0.22 ± 0.12	0.22 ± 0.11	0.23 ± 0.12	0.20 ± 0.07*
Sleep duration				
>7 h	547(19.6)	13 (17.6)	117 (17.7)	10 (21.3)
6 - 7 h	1207 (43.3)	39 (52.7)	304 (46.0)	18 (38.3)
5 - 6 h	811 (29.1)	15 (20.3)	186 (28.1)	18 (38.3)
≤5 h	223 (8.0)	7 (9.5)	54 (8.2)	1 (2.1)
Total AIS score	3.8 ± 3.0	4.4 ± 3.5	4.1 ± 3.2	3.6 ± 2.7
AIS items				
Difficulty in sleep induction	129 (4.6)	3 (4.1)	34 (5.1)	2 (4.3)
Awakening during the night	101 (3.6)	4 (5.4)	26 (3.9)	2 (4.3)
FAED	165 (5.9)	4 (5.4)	40 (6.1)	2 (4.3)
Insufficient total sleep duration	219 (7.9)	11 (14.9)*	53 (8.0)	4 (8.5)
Overall quality of sleep	227 (8.1)	9 (12.2)	76 (11.5)	3 (6.5)

2 Abbreviations: FHD; Family history of diabetes, FPG; Fasting plasma glucose level, AIS; Athens Insomnia
3 Scale, FAED; Final awakening earlier than desired. Data are mean ± SD or n (%). *P*-values correspond to
4 Mann-Whitney U-test for continuous variables or Fisher's exact test for categorical variables. Statistical
5 significance: * *p* < 0.05, ** *p* < 0.01, *** *p* < 0.001.

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1 Table 2. Odds ratio (95 % CIs) for diabetes according to sleep duration/quality (participants without FHD)

	Model 1	Model 2	Model 3
Sleep duration			
>7 h	1.00	1.00	1.00
6 - 7 h	1.87 (0.84 - 4.13)	1.97 (0.80 - 4.02)	1.57 (0.64 - 3.83)
5 - 6 h	1.63 (0.66 - 4.02)	1.57 (0.63 - 3.90)	1.38 (0.50 - 3.79)
≤5 h	5.46 (1.73 - 17.21)**	4.42 (1.30 - 15.03)*	5.37 (1.38 - 20.91)*
Total AIS score [†]	1.15 (1.06 - 1.25)**	1.14 (1.04 - 1.24)**	1.16 (1.05 - 1.30)**
AIS items [‡]			
Difficulty in sleep induction	0.98 (0.23 - 4.07)	0.47 (0.08 - 2.65)	0.66 (0.10 - 4.29)
Awakening during the night	3.66 (1.15 - 11.61)***	3.81 (1.16 - 12.52)*	5.03 (1.43 - 17.64)*
FAED	1.36 (0.44 - 4.18)	1.44 (0.46 - 4.51)	1.74 (0.53 - 5.68)
Insufficient total sleep duration	8.06 (3.41 - 19.05)***	7.60 (3.05 - 18.93)***	6.76 (2.09 - 21.87)**
Overall quality of sleep	2.82 (1.15 - 6.94)*	3.04 (1.21 - 7.63)*	3.71 (1.37 - 10.07)**

2 Abbreviations: FHD; Family history of diabetes, AIS; Athens Insomnia Scale, FAED; Final awakening earlier
 3 than desired. [†]Total AIS score is a continuous variable. [‡]Each item in AIS represents the OR for sleep difficulties
 4 compared to no difficulties. Model 1: adjusted for age, sex, and Fasting plasma glucose level, Model 2: adjusted
 5 for model 1 plus BMI, smoking, alcohol intake, and physical exercise, Model 3: adjusted for model 2 plus
 6 education, working hours, shift-work, rate of sedentary work, and occupational stress. Statistical significance: *
 7 $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

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1 Table 3. Odds ratio (95 % CIs) for diabetes according to sleep duration/quality (participants with FHD)

	Model 1	Model 2	Model 3
Sleep duration			
>7 h	1.00	1.00	1.00
6 - 7 h	0.66 (0.27 - 1.66)	0.60 (0.24 - 1.53)	0.74 (0.29 - 1.90)
5 - 6 h	1.19 (0.47 - 3.03)	0.98 (0.37 - 2.59)	1.18 (0.43 - 3.24)
≤5 h	0.23 (0.03 - 2.01)	0.21 (0.02 - 1.96)	0.25 (0.03 - 2.42)
Total AIS score [†]	0.95 (0.83 - 1.07)	0.92 (0.81 - 1.05)	0.95 (0.82 - 1.11)
AIS items [‡]			
Difficulty in sleep induction	0.97 (0.19 - 4.85)	0.77 (0.14 - 4.19)	0.97 (0.17 - 5.43)
Awakening during the night	1.27 (0.23 - 7.12)	1.12 (0.20 - 6.77)	1.69 (0.26 - 11.06)
FAED	0.41 (0.07 - 2.26)	0.37 (0.06 - 2.21)	0.32 (0.05 - 1.98)
Insufficient total sleep duration	2.76 (0.79 - 9.61)	2.35 (0.66 - 8.37)	3.33 (0.78 - 14.10)
Overall quality of sleep	0.70 (0.19 - 2.53)	0.57 (0.15 - 2.13)	0.60 (0.15 - 2.35)

2 Abbreviations: FHD; Family history of diabetes, AIS; Athens Insomnia Scale, FAED; Final awakening earlier
3 than desired. [†]Total AIS score is a continuous variable. [‡]Each item in AIS represents the OR for sleep difficulties
4 compared to no difficulties. Model 1: adjusted for age, sex, and Fasting plasma glucose level, Model 2: adjusted
5 for model 1 plus BMI, smoking, alcohol intake, and physical exercise, Model 3: adjusted for model 2 plus
6 education, working hours, shift-work, rate of sedentary work, and occupational stress.