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RESEARCH

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Assessing the level of device-measured physical activity according to insomnia symptoms in 1,354 individuals with diabetes: the HUNT Study, Norway

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Abstract

Background Insomnia symptoms that influence daytime functioning are common among adults with type 2 diabetes. However, no previous study has examined if levels of physical activity differ among adults with diabetes with and without insomnia symptoms. Thus, the aim of this study was to assess the difference in total physical activity (TPA) and moderate-to-vigorous physical activity (MVPA) levels in individuals with diabetes with and without insomnia symptoms.

Methods This cross-sectional study included 1,354 participants with any type of diabetes who participated in the Norwegian HUNT4 Study, 2017-19. Participants were defined to have 'insomnia symptoms' if they reported difficulty initiating and/or maintaining sleep ≥ 3 nights/week during the last 3 months. MVPA (defined as moderate/brisk walking [> 4.0 km/h], running, and cycling), and TPA (MVPA including slow walking [≤ 4.0 km/h]) were determined from two accelerometers worn on the thigh and lower back. Analyses were stratified by age and sex.

Results The median age was 67 years and 491 (36%) had insomnia symptoms and 37 (3%) had insomnia disorder. Among women, 28% with one or more insomnia symptoms fulfilled the recommended minimum level of physical activity, as compared to 34% in women without insomnia symptoms. The corresponding proportions in men were 48% and 45%. Women above 65 years with insomnia symptoms performed less TPA (-73 min/week, 95% CI -122 to -24) and MVPA (-33 min/week, 95% CI -50 to -15), compared to women without insomnia symptoms in the same age group. There was no clear difference in physical activity levels according to insomnia symptoms in men or women below 65 years. Women and men with insomnia disorder had substantially lower TPA (women: -192 min/week, 95% CI -278 to -106; men: -276 min/week, 95% CI -369 to -193) and MVPA (women: -37 min/week, 95% CI -63 to -11; men: -67 min/week, 95% CI -83 to -50) than those without insomnia symptoms.

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Conclusions This study showed that women above 65 years with insomnia symptoms and individuals with insomnia disorder performed less physical activity, suggesting that these subgroups may suffer from additional challenges that prevent them from engaging in regular physical activity.

Keywords Diabetes mellitus, Sleep, Physical activity, Insomnia

Background

Diabetes is an increasing public health challenge and currently more than 60 million people in Europe live with diabetes (both type 1 and 2 diabetes) [1]. Regular engagement in moderate-to-vigorous intensity physical activity (MVPA) is a cornerstone of diabetes management to prevent complications and premature mortality [2, 3]. The importance of physical activity for glycemic control in people with diabetes is well-established [4, 5]. Adults living with diabetes are recommended to follow the general World Health Organization (WHO) guidelines of at least 150–300 min of moderate intensity or 75–150 min of vigorous intensity (or an equivalent combination) aerobic physical activity week [6, 7]. However, only 35–60% of adults with diabetes meet the current recommendations for aerobic physical activity [8–11]. To increase physical activity levels in people with diabetes, it is essential to identify modifiable factors that are associated with engagement in physical activity [8, 12].

Insomnia symptoms are common in adults with type 2 diabetes [13] with an overall reported prevalence of 39% [14]. Healthy sleep behavior is considered a relevant component in the management of type 2 diabetes [12], but the evidence is scarce and mainly justified due to its influence on improved glycemic control [12]. Insomnia symptoms are associated with adiposity, glucose dysregulation, and impaired daytime functioning in individuals with diabetes [13, 15], which might affect the ability to engage in physical activity. In previous studies, not restricted to individuals with diabetes, adults with insomnia symptoms were less active than adults without insomnia [16, 17]. Moreover, sleep quality, time it takes to fall asleep after turning the lights out, and sleep efficiency predict levels of physical activity the following day [18–20], possibly explained by daytime sleepiness or fatigue [21]. To date, there is a lack of studies that describe the levels of physical activity according to insomnia symptoms in people with diabetes.

It is well-documented that there are age- and sex-related differences in both physical activity [22, 23] and the prevalence of insomnia symptoms [24, 25]. However, it is unclear whether the association between insomnia symptoms and physical activity differs according to age and sex among individuals with diabetes. Since healthy sleep behavior, and in particular physical activity are of importance in the management of type 2 diabetes, it is relevant to describe the association between sleep and physical activity further to help identify groups of individuals with diabetes who may need particular attention and support. Thus, the aim of this study was to explore the association between insomnia symptoms and device-measured physical activity among individuals with diabetes. Specifically, we aimed to assess the levels of device-measured physical activity (total physical activity (TPA) and MVPA) according to insomnia symptoms, stratified by age and sex.

Methods

Design and setting of the study

The study was cross-sectional, and the reporting of the study followed the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) checklist [26].

This study utilized data from the fourth survey of the Norwegian Trøndelag Health Study (HUNT4) carried out in 2017-19 [27]. Approximately 103,800 inhabitants aged 20 years or older residing in the northern part of the Trøndelag County were invited. Among the 56,042 (54.0%) participants who accepted to participate in HUNT4, 31,295 (56%) also wore two tri-axial AX3 accelerometers (Axivity, Ltd., Newcastle, United Kingdom) for seven days. Of these, 1,358 (4.3%) reported diabetes (including all types of diabetes), had at least one valid day with accelerometer data, and complete information on insomnia symptoms. The participants filled in comprehensive questionnaires on lifestyle and health-related factors and attended a clinical examination. All participants provided written informed consent prior to participation and ethical approval was granted by the Regional Committee for Medical and Health Research Ethics, Mid-Norway (reference no. 635300).

In the present study, we included those who answered 'yes' to the question 'Have you had, or do you have diabetes?'.

Device-measured physical activity

Physical activity was assessed for seven days. One accelerometer was placed centrally on the right thigh approximately 10 cm above the upper border of patella, and one were positioned centrally on the third lumbar segment (L3) on the lower back. The accelerometer data was sampled at 50 Hz and a range±8 g. An eXtreme Gradient Boosting (XGBoost) machine learning classifier was trained to predict key daily physical activity types (i.e., walking, running and cycling) and postures (i.e., sitting, lying down, standing) during free-living [28, 29]. Separate

machine learning classifiers were trained to predict slow (≤4.0 km/h), moderate (4.1–5.4 km/h), and brisk (≥5.5 km/h) walking speeds, as well as no-wear time.

We included the following physical activity variables: (i) TPA min/week, defined as slow-, moderate-, and brisk walking, running and cycling, (ii) MVPA min/week, defined as moderate-, and brisk walking, running, and cycling, and (iii) adherence to the World Health Organization (WHO) recommendations for physical activity [6], i.e., the proportion of individuals who performed at least 150 min moderate physical activity per week, or at least 75 min of vigorous physical activity per week, or an equivalent combination of the two.

In supplementary analyses, physical activity was defined according to metabolic equivalent of task (MET) min per week. The MET values were defined according to the compendium of physical activities [30, 31]: exercise intensity walking=4.3 (code 17200), moderate intensity walking=3.5 (code 17190), running=6.0 (code 12029), and cycling=7.5 (code 01015). These four physical activity types were added together to a total volume of physical activity (METs/week). Weekly MET-min was computed by multiplying the estimated MET value of each physical activity type by the minutes spent in the physical activity type. Based on this, (i) total MET-min/week, (ii) MVPA MET-min/week, and (iii) adherence to the WHO recommendations for physical activity (500 MET-min/week) were determined [6].

Insomnia symptoms

Insomnia symptoms were identified by four questions: 1) "How often during the last three months have you had difficulty falling asleep at night?", 2) "How often during the last three months have you woken up repeatedly during the night?", 3) "How often during the last three months have you woken too early and couldn't get back to sleep?", and 4) "How often during the last three months have you had impaired daytime functioning (socially or professionally) due to the sleep problems?", with three response options for each question: "Never/seldom", "Sometimes" and "≥3 times a week". Participants were classified with *insomnia* disorder if they answered, "≥3 times a week" on at least one of the questions 1–3, and "≥3 times a week" on question 4. The information retrieved from these four questions approximates the information necessary to diagnose insomnia according to current diagnostic classification systems which were used in this study to define insomnia disorder [32]. People who reported at least one insomnia symptom "≥3 times a week" were defined as having insomnia symptoms (i.e., not fulfill the insomnia diagnosis). Participants who did not fulfill the insomnia diagnostic classification, but who reported "≥3 times a week" to at least one of questions 1–3 were classified as having "insomnia symptoms", and those who reported none were defined as "without insomnia symptoms".

Other variables

Information on age and sex was obtained by linking each participant's record in the HUNT Study to information from Norwegian National Registry, using the unique identification numbers allocated to all Norwegian residents. Educational level was categorized into "Primary school", "High school", and "University". In addition to the question regarding diabetes status, participants reported their age at diabetes onset, which was used to calculate the duration (years) of diabetes. Participants smoking status were categorized into "Never smoked", "Former smoker", and "Current smoker". Perceived bodily pain during the last four weeks was collapsed into the following categories: "No pain", "Mild pain", "Moderate pain", and "Severe pain". Participants were asked whether they suffered from long-term (at least one year) illness or injury of a physical or psychological nature that impairs their daily life functioning, which was categorized into "No impairment", "Slight impairment", "Moderate to severe impairment".

At the clinical examinations, participants' height and weight were measured which were used to calculate body mass index (BMI) (kg/m^2). BMI was categorized into (1) Underweight/Normal weight (BMI<25.0), (2) Overweight (BMI≥25.0-<30.0), and (3) Obese (BMI≥30.0), as defined by the WHO [33]. Participants were asked how often during the last three months they had experienced breathing stops during sleep with the response options "Never/seldom", "Sometimes" and "≥3 times a week".

Statistical analysis

Prior to commencing the analyses, a statistical analysis plan was made publicly available [34]. This statistical analysis plan did not specify stratification on age (<65 years/≥65 years) and sex (men/women), however, this was included due to expected differences on these factors. Cross-tabulations were conducted to describe characteristics of the participants with diabetes stratified by insomnia symptoms, and were summarized as numbers with proportions, mean with standard deviation (SD) or median with interquartile range (IQR).

Multiple linear regression models were used to investigate the association between insomnia symptoms and TPA min/week, while multiple quantile regression models were used to investigate the association between insomnia symptoms and MVPA min/week due to the non-normal distribution of MVPA. Participants with insomnia symptoms were compared with participants without insomnia symptoms stratified on age and sex. Due to the descriptive design of this study, the fully adjusted analyses were only controlled for educational

level to see if the unadjusted analyses masked any disparities in the distribution of MVPA among individuals with and without insomnia symptoms. This adjustment strategy was chosen since adjustments should be carefully considered in studies that cannot answer causal questions [35, 36]. We did not use approaches to deal with missing data since we had complete data on age and sex, and few observations with missing values on education (<1%). In sensitivity analyses, we repeated the main analyses (1) using total MET-min/week and MVPA measured in MET-min/week, (2) excluding those with ≤3 valid measurement days, and (3) excluded individuals who reported self-reported breathing stops to account for the overlap between obstructive sleep apnea and insomnia [37]. Precision of the estimates was assessed by 95% confidence intervals (CI) and robust variance estimates were used. All statistical analyses were performed in STATA/BE 17.0.

Results

Among the 1,358 participants with diabetes, 493 (36%) reported insomnia symptoms while 37 (3%) were classified with insomnia disorder according to current diagnostic classification system. The proportion of females was higher among participants with insomnia symptoms, and a higher proportion of participants with insomnia symptoms was obese, had moderate-to-strong bodily pain, and moderate to severe physical impairment, compared to participants without insomnia symptoms (Table 1). Supplementary Table 1 shows the characteristics of the participants stratified on insomnia disorder. Among women ≤65 years, 43% met the minimum recommendations for MVPA, while among women above 65 years, 26% of those without insomnia symptoms and 12% of those with insomnia symptoms met the recommended minimum. Among men, the proportion meeting the recommendations for MVPA were similar between those with and without insomnia symptoms in both age groups (Supplementary Table 2).

Table 2 shows that women above 65 years with insomnia symptoms accumulated 448 min/week (SD 265) of TPA, while those without insomnia symptoms accumulated 537 min/week of TPA. Among men, those with and without insomnia symptoms accumulated similar weekly TPA. When compared to women above 65 years without insomnia symptoms, women with insomnia symptoms in the same age group accumulated less TPA (-73 min/week, 95% CI -122 to -24). There was no association between insomnia symptoms and TPA among women below 65 years. Among men, there was no association between insomnia symptoms and TPA in either age group.

Women and men with insomnia disorder accumulated less TPA compared to women and men with good sleep, i.e. median difference was −192 min/week (95% CI -278 to -106) among women and −276 min/week (95% CI -369 to -193) among men, respectively (Supplementary Table 3).

Table 3 shows that median MVPA among participants above 65 years with and without insomnia symptoms was 54 (IQR 17 to 148) and 77 min/week (IQR 27 to 160), respectively. The corresponding numbers for those below 65 years were 137 (IQR 80 to 238) and 128 min/week

Table 1 Characteristics of 1,358 participants with diabetes stratified by insomnia symptoms

Charactertistic	Insomnia symptoms[a]	
	No	Yes
No. of participants	865	493
Age, median (IQR)	66.8 (56.9–73.1)	67.6 (58.5–73.8)
Sex (female), no. (%)	359 (42)	250 (51)
Duration of diabetes (years), median (IQR)	10.1 (4.9–17.5)	11.4 (5.6–18.5)
Educational level, no. (%)		
Primary school	153 (18)	79 (16)
High school	452 (52)	258 (53)
University	259 (30)	153 (31)
Current smoker, no. (%)	69 (8)	50 (10)
Body mass index, mean (SD)	29.3 (4.9)	30.1 (5.3)
Obese (BMI ≥ 30), no. (%)	214 (25)	146 (30)
Moderate to strong bodily pain, no. (%)	322 (37)	290 (59)
Moderate to severe physical impairment, no. (%)	119 (14)	129 (26)
Self-reported breathing stops, no[b] (%)	38 (4.4)	37 (7.5)
Insomnia disorder[c], no. (%)	-	37 (7.5)

Abbreviations: IQR=interquartile range; SD=standard deviation

[a] People who reported at least one insomnia symptom minimum 3 times a week during the last 3 months were defined as having insomnia symptoms

[b] Experienced breathing stops minimum 3 times a week the last 3 months

[c] People who reported at least one insomnia symptom minimum 3 times a week accompanied by impaired daytime functioning the last 3 months were defined as having insomnia disorder

Table 2 Mean difference in total physical activity (min/week) according to insomnia symptoms among participants with diabetes

	< 65 years				≥ 65 years			
			Mean difference				Mean difference	
	n	**Mean (SD)**	**Crude**	**Adjusted (95% CI)[a]**	***n***	**Mean (SD)**	**Crude**	**Adjusted (95% CI)[a]**
Total sample								
No insomnia symptoms	382	673 (263)	0	Reference	483	546 (262)	0	Reference
Insomnia symptoms[b]	216	641 (255)	-32	-18 (-62 to 25)	277	510 (265)	-36	-24 (-69 to 13)
Women								
No insomnia symptoms	171	638 (241)	0	Reference	188	537 (255)	0	Reference
Insomnia symptoms	131	590 (224)	-48	-44 (-98 to 9)	121	448 (221)	-89	-73 (-122 to -24)
Men								
No insomnia symptoms	211	702 (276)	0	Reference	295	553 (267)	0	Reference
Insomnia symptoms	85	722 (280)	19	21 (-49 to 91)	156	559 (287)	6	12 (-40 to 63)

n = 1,354

Abbreviations: TPA = total physical activity; CI = confidence interval; SD = standard deviation

Coefficients and 95% CI represent median difference in TPA min/week compared to those without insomnia symptoms

[a] Adjusted for age (continuous) and educational attainment (primary school, high school, university)

[b] People who reported at least one insomnia symptom minimum 3 times a week during the last 3 months were defined as having insomnia symptoms

Table 3 Median difference in total moderate-to-vigorous physical activity (min/week) according to insomnia symptoms among participants with diabetes

	< 65 years				≥ 65 years			
			Median difference				Median difference	
	n	**Median (IQR)**	**Crude**	**Adjusted (95% CI)[a]**	***n***	**Median (IQR)**	**Crude**	**Adjusted (95% CI)[a]**
Total sample								
No insomnia symptoms	382	137 (80 to 238)	0	Reference	483	77 (27 to 160)	0	Reference
Insomnia symptoms[b]	216	128 (65 to 213)	-9	0.1 (-22 to 23)	277	54 (17 to 148)	-23	-19 (-35 to -2)
Women								
No insomnia symptoms	171	111 (68 to 208)	0	Reference	188	60 (18 to 138)	0	Reference
Insomnia symptoms	131	119 (57 to 189)	-2	-6 (-20 to 33)	121	28 (8 to 73)	-32	-33 (-50 to -15)
Men								
No insomnia symptoms	211	86 (34 to 173)	0	Reference	295	87 (35 to 173)	0	Reference
Insomnia symptoms	85	84 (31 to 183)	-2	-6 (-49 to 37)	156	84 (31 to 183)	-3	-3 (-33 to 28)

n = 1,354

Abbreviations: MVPA = moderate to vigorous physical activity; CI = confidence interval; SD = standard deviation

Coefficients and 95% CI represent median difference in MVPA min/week compared to those without insomnia symptoms

[a] Adjusted for age (continuous) and educational attainment (primary school, high school, university)

[b] People who reported at least one insomnia symptom minimum 3 times a week during the last 3 months were defined as having insomnia symptoms

(IQR 65 to 213), respectively. In sex-stratified analyses among those below 65 years, there were no differences in MVPA between those with and without insomnia symptoms. Among women above 65 years, those with insomnia symptoms accumulated 28 min/week (IQR 8 to 148) of MVPA, while those with without insomnia symptoms accumulated 60 min/week (IQR 18 to 138), corresponding to a median difference of -33 min/week (95% CI -50 to -15). There was no association between insomnia symptoms and MVPA among men above 65 years or among women and men below 65 years. Median MVPA was significantly lower in men and women with insomnia disorder when compared with those without insomnia symptoms (men: -67 min/week, 95% CI -83 to -50, women: -37 min/week, 95% CI -63 to -11) (Supplementary Table 4).

Sensitivity analyses

Similar associations were observed when weekly TPA and MVPA were estimated with METs (data not shown). Moreover, excluding participants with < 3 valid measurement days from the analysis had negligible influence on the results. Finally, excluding individuals with self-reported breathing stops had negligible influence on the results, however, the estimates became somewhat attenuated when comparing women above 65 years without insomnia symptoms with women with insomnia symptoms in the same age group (-53 min/week, 95% CI -103 to -3).

Discussion

We found that women with insomnia symptoms who were 65 years or older performed less TPA and MVPA, compared to women without insomnia symptoms in the same age group. Independently of age and sex, participants suffering from insomnia disorder performed less TPA and MVPA than participants without insomnia symptoms, suggesting that levels of TPA and MVPA decline with increasing insomnia severity.

Our results, showing that 36% of the participants with diabetes had insomnia symptoms or insomnia disorder are comparable to the prevalence reported in a meta-analysis [14] where 39% of individuals with type 2 diabetes reported insomnia symptoms. We are not aware of any study that has investigated physical activity level in individuals with insomnia and diabetes, and whether this association differs between age and sex groups. When comparing those with and without insomnia symptoms, we found no difference in MVPA levels among men, or among the youngest women. Women above 65 years with insomnia symptoms performed 73 min/week less TPA and 33 min/week less MVPA than women without insomnia symptoms. The explanation behind these findings remains uncertain but could be related to age- and sex specific differences in sleep [38]. For instance, compared to men, older women have longer sleep latency, shorter sleep, and are more likely to report daytime sleepiness [39]. Moreover, the observed age- and sex-related differences in our study could be explained by the postmenopausal stage. This life stage is associated with higher symptom burden (e.g., insomnia, fatigue, joint pain, depression) that can impair the ability to participate in physical activities [40–42]. This could also explain why women are undertreated and appear to benefit less than men when it comes to lifestyle interventions and pharmacological treatments for managing type 2 diabetes [43–45]. Notably, we found that participants suffering from insomnia disorder performed substantially lower levels of both TPA (-226 min/week) and MVPA (-64 min/week) compared to participants without insomnia symptoms. As TPA only includes slow walking in addition to MVPA, this suggests that physical activity in participants with insomnia disorder is primarily covered by slow walking. Since few participants reported insomnia disorder (3%), we could not conduct age-stratified analyses on insomnia severity.

It is uncertain whether 33 min less MVPA/week (corresponding to 4–5 min/day) among the oldest women are of importance for diabetes management. Recent research has shown that repeated 1–5 min daily bouts of MVPA [46–48], is a feasible alternative to reach health-related benefits for adults who are challenged or unable to adhere to the recommendations [48]. Few middle-aged and older adults perform high intensity physical exercise [49–51] and high intensity exercise may not be appealing to inactive adults with diabetes [52–54]. Although speculative, targeting healthy sleep behaviors could be beneficial because even small improvements in physical activity have positive impact on several parameters that are relevant in diabetes management, including glucose control, physical impairment, depression, and quality of life [48, 55–59]. These results are supported by studies on older adults and pain-afflicted individuals showing that nightly variations in sleep quality predict physical activity behavior the following day [18, 60]. However, an experimental study [16] found that a 4-week behavioral treatment for insomnia in the general population did not change device-measured physical activity despite significant improvements in insomnia, highlighting the need to identify whether targeting healthy sleep behaviors will increase physical activity levels in people with diabetes. Additionally, the causation could be the other way around as well, suggesting that if we target physical activity, this maybe improve sleep behaviors in individuals with diabetes.

Strengths and limitations

The strengths of the current study include the large study sample of individuals with diabetes with device-measured physical activity and the assessment of insomnia which enabled us to define insomnia disorder and symptoms in concordance with current diagnostic classification systems [32]. In particular, the use of a robust machine learning model to detect physical activity types in a free-living setting enabled us to investigate the perspectives of engagement of weekly MVPA.

This study has some limitations that should be mentioned. Although the study sample was large, only 37 individuals suffered from insomnia disorder according to current diagnostic classification systems [32], and the observed differences should therefore be interpreted with caution. Notably, the prevalence of insomnia disorder (3%) is likely to be underestimated due to the strict definition of daytime impairment (i.e., at least three times a week) [61]. Moreover, participants volunteered to wear accelerometers for seven days. It is therefore possible that our sample comprised a healthier group of individuals with diabetes leading to a possible overestimation of adherence to recommendations. Moreover, it was not possible to distinguish between types of diabetes among participants, however, as type 2 diabetes accounts for 85–90% of diabetes cases in high-income countries, the findings of this study will primarily be applicable to this group [62].

In the current study, 40% of the participants adhered to the recommendations of at least 150–300 min moderate physical activity per week, or at least 75–150 min of vigorous physical activity per week, or an equivalent

combination of the two. This is comparable to a recently published Danish study where 37% with diabetes adhered to the recommendations of minimum 150 min MVPA/week [8]. Furthermore, one week of physical activity measurement might not reflect the individual's habitual physical activity behaviors. It should be noted that the median age in our study was 67 years and a large proportion of those with insomnia symptoms were obese, suffered from bodily pain, or had moderate to severe physical impairment, which are all factors that may have impact on the individual's sleep quality [63, 64] and engagement in physical activity [9, 65]. Since the aim of this cross-sectional study was to describe levels of physical activity according to insomnia symptoms, future prospective studies are warranted to examine if insomnia is associated with changes in physical activity behavior, or if targeting insomnia symptoms leads to changes in MVPA in individuals with diabetes.

Conclusion

This study indicates that having insomnia symptoms are associated with reduced engagement in daily physical activity in women above 65 years with diabetes. Notably, only 28% of women with insomnia symptoms achieved the recommended weekly MVPA level, in contrast to the 45% adherers among men with insomnia symptoms. Moreover, individuals suffering from insomnia disorder performed less physical activity than individuals without insomnia symptoms, suggesting that individuals with insomnia disorder represent a group that may suffer from additional challenges that prevent them from engaging in regular physical activity. Future studies should investigate characteristics and facilitators as well as sex differences among those with insomnia symptoms who manage to reach the recommended levels of physical activity. Also, studies should investigate if addressing insomnia symptoms, and in particular insomnia disorder, as part of diabetes management improves physical activity and subsequently overall health outcomes.

Abbreviations

CI	Confidence interval
IQR	Interquartile range
HUNT	Trøndelag Health Study
TPA	Total physical activity
MET	Metabolic equivalent of task
MVPA	Moderate to vigorous physical activity
OR	Odds ratio
SD	Standard deviation
WHO	World Health Organization

Supplementary Information

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Supplementary Table 1: Characteristics of 1,358 participants with diabetes stratified by insomnia symptoms

Supplementary Table 2: Association between insomnia and meeting the minimum recommendations for moderate-to-vigorous intensity physical activity

Supplementary Table 3: Mean difference in total physical activity (min/week) according to insomnia symptoms among participants with diabetes

Supplementary Table 4: Median difference in moderate-to-vigorous physical activity (min/week) according to insomnia symptoms among participants with diabetes

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Author contributions

Substantial contributions to the design of the work; or the acquisition, analysis, or interpretation of data for the work: S.R.M., E.S.S., P.J.M., S.T.S., and A.K. did the statistical analysis. Drafting of the manuscript: SRM. Revising the work critically: E.S.S., P.J.M., S.T.S., B.O.Å., T.I.L.N., A.K. Final approval of the version to be published: S.R.M., E.S.S., P.J.M., S.T.S., B.O.Å., T.I.L.N., A.K. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

All participants in the HUNT Study gave a written informed consent upon participation. This study was approved by the Regional Committee for Medical and Health Research Ethics (reference no. 635300).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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