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Association between physical activity over a 10-year period and current insomnia symptoms, sleep duration and daytime sleepiness: a European population-based study

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ABSTRACT

Objectives To explore the relationship between physical activity over a 10-year period and current symptoms of insomnia, daytime sleepiness and estimated sleep duration in adults aged 39–67.

Design Population-based, multicentre cohort study.

Setting 21 centres in nine European countries.

Methods Included were 4339 participants in the third follow-up to the European Community Respiratory Health Survey (ECRHS III), who answered questions on physical activity at baseline (ECRHS II) and questions on physical activity, insomnia symptoms, sleep duration and daytime sleepiness at 10-year follow-up (ECRHS III). Participants who reported that they exercised with a frequency of at least two or more times a week, for 1 hour/week or more, were classified as being physically active. Changes in activity status were categorised into four groups: persistently non-active; became inactive; became active; and persistently active.

Main outcome measures Insomnia, sleep time and daytime sleepiness in relation to physical activity.

Results Altogether, 37% of participants were persistently non-active, 25% were persistently active, 20% became inactive and 18% became active from baseline to follow-up. Participants who were persistently active were less likely to report difficulties initiating sleep (OR 0.60, 95% CI 0.45–0.78), a short sleep duration of ≤6 hours/night (OR 0.71, 95% CI 0.59–0.85) and a long sleep of ≥9 hours/night (OR 0.53, 95% CI 0.33–0.84) than persistently non-active subjects after adjusting for age, sex, body mass index, smoking history and study centre. Daytime sleepiness and difficulties maintaining sleep were not related to physical activity status.

Conclusion Physically active people have a lower risk of some insomnia symptoms and extreme sleep durations, both long and short.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ The longitudinal study design, in which the exposure (physical activity) is measured 10 years prior to the sleep outcomes, enables an investigation into whether the consistency of physical activity over time has an impact on current symptoms of insomnia, sleep duration and daytime sleepiness.
- ⇒ Data were collected using standardised and validated procedures and instruments, increasing its internal validity.
- ⇒ Data were obtained from nine European countries, increasing the external validity of our findings.
- ⇒ One limitation of our study is that sleep variables are only available at the follow-up, which precluded testing their effect on baseline physical activity.
- ⇒ Insomnia symptoms, sleep durations and daytime sleepiness data were obtained by questionnaire and no sleep disorder diagnoses from medical providers or objective assessments were available.

INTRODUCTION

Disturbed sleep is common in the general population and impacts health and quality of life.[1–3] Chronic sleep disturbances are associated with cardiovascular disease, metabolic dysfunction, psychiatric disorders and increased mortality.[4–6]

Physical activity and sleep

Regular exercise is associated with better health and several studies suggest that physical activity (PA) is beneficial to sleep and may improve symptoms of chronic insomnia.[7–10] It is, however, unclear how significant these benefits are and which factors may have a moderating effect on them.[11] The positive association between PA and sleep may be subject to multiple moderating factors such as gender, age, body mass index (BMI), fitness level, general health and the characteristics of the type of exercise in question. Therefore,

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sleep and PA probably influence each other through complex, reciprocal interactions including multiple physiological and psychological pathways.[7]

PA and daytime sleepiness

There is evidence that more PA is associated with less daytime sleepiness.[12–17] Cross-sectional studies have shown that low PA is associated with an increased likelihood of excessive daytime sleepiness (EDS)[14–16] and that subjects participating in exercise are less likely to have EDS.[12 17] In older adults, increasing PA by doing home exercises has been shown to improve EDS and reduce the prevalence of insomnia symptoms,[13] while another study showed that increasing PA protected women from future insomnia.[18] Other studies have contradictory findings. In an epidemiological study of 4405 Koreans, daytime sleepiness was more common among those in the top quartile of PA compared with those in the lowest quartile group.[19] Among patients with obstructive sleep apnoea, increased PA was associated with a lower severity of disease and a 28% decrease in EDS.[20] The daily association between PA and sleep duration was described in 2021, based on a systematic review and meta-analysis of 33 peer-reviewed papers, which showed that, on the night following increased PA, there was a lower total sleep time.[21]

Limitations of previous studies

There is a lack of epidemiological data from long-term follow-up studies of large cohorts exploring the association of PA with sleep length, daytime sleepiness and insomnia symptoms. Previous research on PA and sleep-related outcomes has several important limitations. Most studies are cross-sectional or have a short follow-up interval, preventing the possibility of elucidating whether increased PA improves sleeping outcomes or whether reduced PA is a consequence of sleep problems. Finally, the effects of PA on sleep length, daytime sleepiness and insomnia symptoms have not been studied simultaneously.

Aims of the current study

Therefore, the aim of the present study was to assess the inter-relationship between PA, based on frequency, duration and intensity, and symptoms of insomnia, self-reported sleep durations and daytime sleepiness among middle-aged subjects from 21 centres in nine countries at two moments in time, 10 years apart, providing important longitudinal follow-up data.

MATERIALS AND METHODS

Subjects

We studied participants from the second and third follow-up surveys of the European Community Respiratory Health Survey (ECRHS II and III, www.ecrhs.org), an international, population-based, multicentre cohort study of asthma and allergic disease, which was first carried out in 1990. Detailed descriptions of the methods used for ECRHS I and ECRHS II have been published elsewhere.[22 23] Briefly, participating centres randomly selected samples from subjects aged 20–44 in order to track them for asthma, allergy and lung disease (see: www.ecrhs.org). Participants completed a short postal questionnaire about asthma and asthma-like symptoms and, from those who responded, a random sample was selected to undergo a more detailed clinical examination. In ECRHS II, subjects who had participated in the clinical phase of ECRHS I (performed between 1991 and 1994) were invited to participate in the follow-up study. The clinical phase of ECRHS II was carried out between 1998 and 2002. ECRHS III is the second follow-up study and was carried out from February 2011 to January 2014.[22–24] The present study is based on data from ECRHS II and III (see figure 1 for the flow chart).

Health, habits and measurements

Subjects answered the core ECRHS questionnaires, which included questions on lifestyle, respiratory symptoms, smoking history and general health. 'Current smokers' were defined as those who smoked tobacco regularly during the last month. 'Former smokers' were defined as smokers who denied having smoked regularly in the month prior to the examination. Those who reported no regular smoking at the time of or prior to the examination were defined as 'never smokers'. The participants' height and weight were measured and their BMI was calculated.[24]

Assessment of PA

PA was assessed in ECRHS II and III using replies from questionnaires. The assessment of PA in ECRHS has previously been described in detail, including how both the frequency and duration of PA were used to divide the population into categories.[22] In brief, participants were asked how often and for how many hours per week they usually exercised to the point that they became out of breath or sweaty. Participants who exercised two or more times a week, for at least 1 hour/week, were classified as physically active. Changes in activity status from baseline to follow-up were categorised into four PA groups: persistently non-active (non-active at both baseline and follow-up), became inactive (active at baseline and non-active at follow-up), became active (non-active at baseline and active at follow-up) and persistently active (active at both baseline and follow-up).

Sleep questionnaires and measurements

Sleep-related symptoms were assessed using the Basic Nordic Sleep Questionnaire,[25] where participants were asked about the frequency of insomnia symptoms. Answers were provided on a scale of 1–5: (1) never or very seldom, (2) less than once a week, (3) once to twice a week, (4) three to five times a week, (5) every day or almost every day of the week. Insomnia symptoms were defined using answers to three questions from the Basic Nordic Sleep Questionnaire: 'I have difficulties falling asleep at night' (difficulties initiating sleep), 'I wake up

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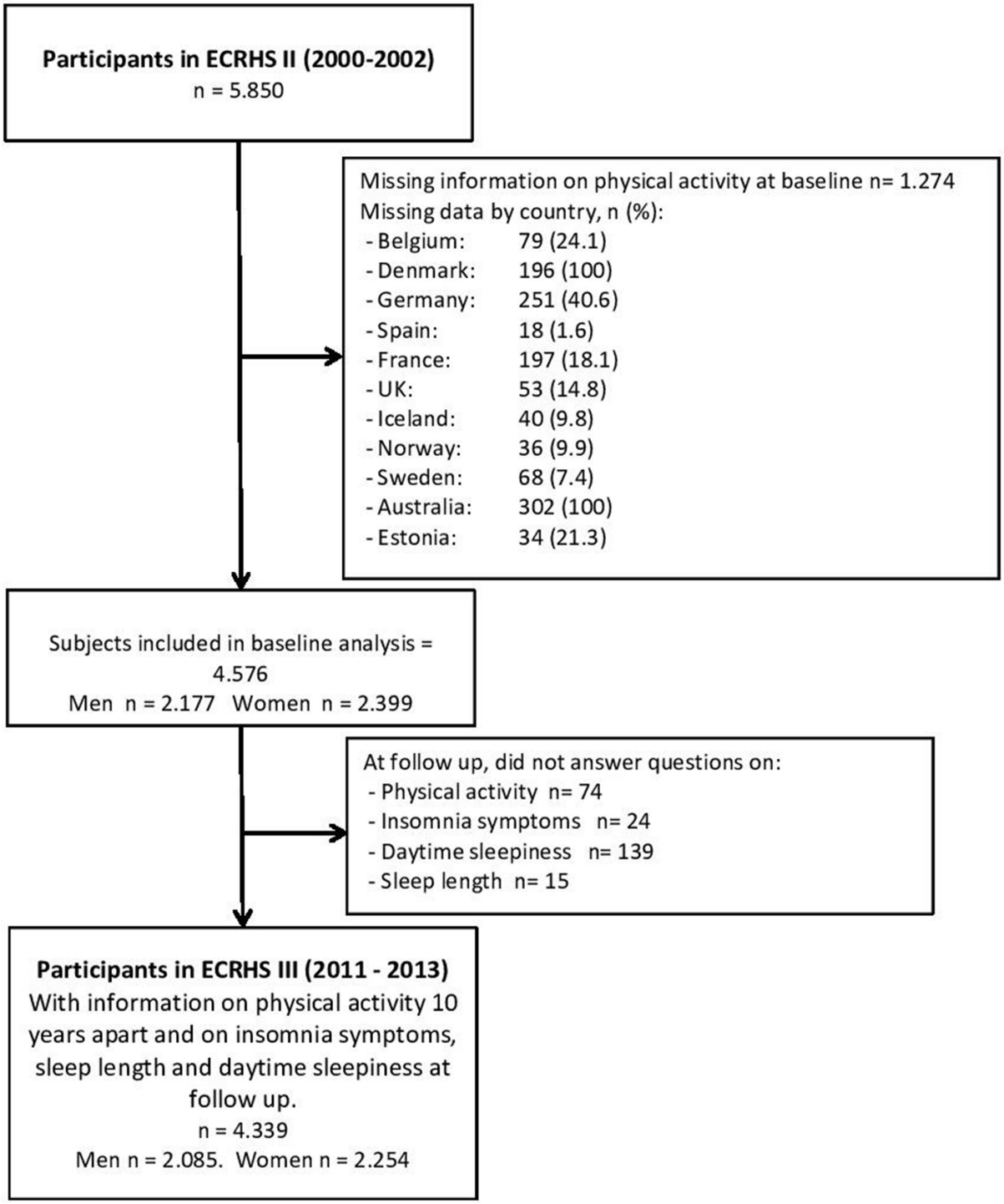

Figure 1 Flow chart of the study population in the European Community Respiratory Health Survey (ECRHS).

often during the night' (difficulties maintaining sleep) and 'I wake up early in the morning and can't fall back asleep' (early morning awakenings). Those who reported these symptoms of insomnia ≥3 times a week (scores 4 and 5) were considered to have the corresponding insomnia subtype. Daytime sleepiness was evaluated using the Epworth Sleepiness Scale (ESS), a brief questionnaire that measures daytime sleepiness based on the likelihood of falling asleep in eight different situations.[26] Participants with an ESS score >10 were considered to have EDS. Participants were asked the question: how much sleep do you estimate that you get on average each night? According to their answers, they were classified as: short sleepers (≤6 hours/night), normal sleepers (6–9 hours/night) or long sleepers (≥9 hours/night).

Patient and public involvement

The study's design did not involve patients or the general public. However, all participating patients were informed of the research objectives and their informed consent

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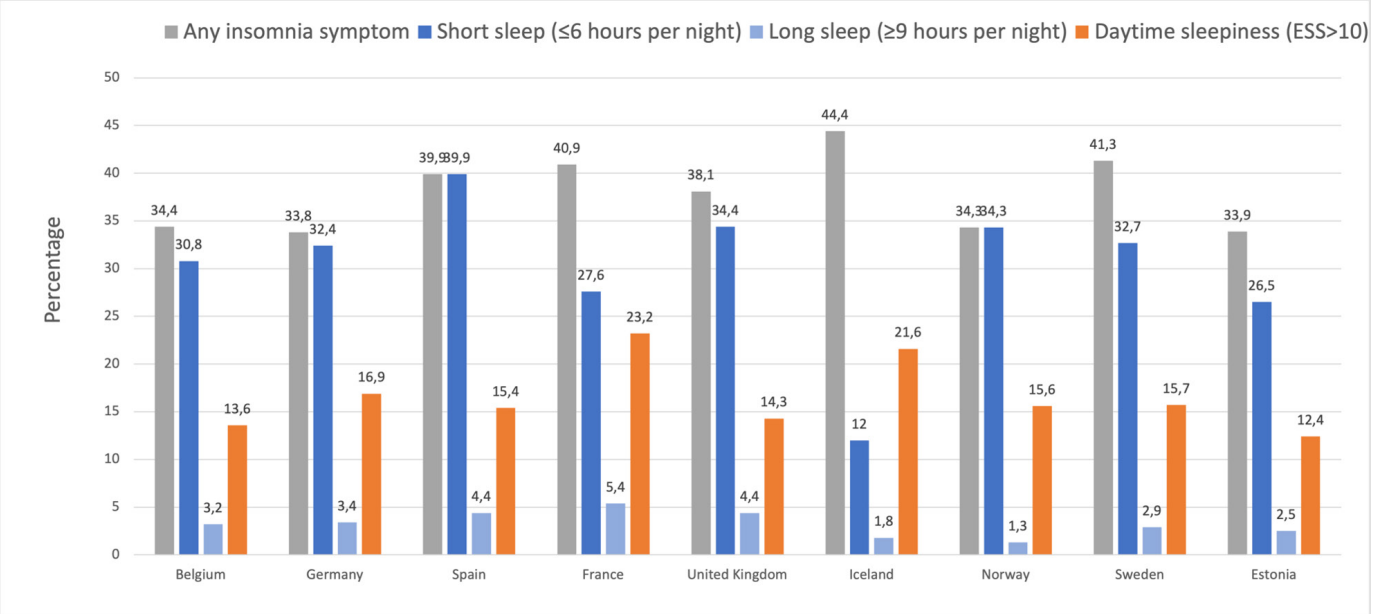

Figure 2 Prevalence of any insomnia symptom, short sleep duration (≤6 hours/night), long sleep duration (≥9 hours/night) and daytime sleepiness (Epworth Sleepiness Scale (ESS) score >10) by country.

was obtained. The survey was completed by participants voluntarily and no input from patients was sought in interpreting or writing up the results. The results of the research will not be disseminated to the patients.

Statistical analysis

Data are presented as numbers and percentages or mean±SD, depending on distribution. For bivariate analysis, the χ^2 test and one-way analysis of variance were used for nominal and continuous variables. Logistic regression was used for multivariable analyses to estimate the association between PA and sleep-related outcomes. The model was adjusted for potential confounders including age, sex, BMI, smoking history and study centre. In the analysis, all variables, including study centre (n=21), were treated as fixed effects. STATA V.16 was used for all statistical analyses.

RESULTS

Participants and level of PA

From a total of 5850 participants in ECRHS II, we excluded those with missing data and included a total of 4339 participants (48% men) (see figure 1). Figure 2 shows the prevalence of insomnia symptoms, short and long sleep durations and daytime sleepiness among subjects in the different countries included in the study. From baseline to 10 years later, 36.9% of participants were persistently non-active, 17.9% became physically active at follow-up, 20.3% of participants became inactive and 24.9% were persistently active (table 1). There were geographical differences in the level of PA between the ECRHS countries (figure 3). Participants in Norway were most likely to be persistently active, while participants in Spain, followed by Estonia, were most likely to be persistently non-active (figure 3).

Table 1 Characteristics and general health of the participants by the level of physical activity

	Persistently non-active	Became inactive	Became active	Persistently active	P value
General characteristics					
n, %	1601 (36.9)	881 (20.3)	775 (17.9)	1082 (24.9)	
Men, %	44.3	49.0	46.8	53.7	<0.001
Age, years	55.0±7.2	54.5±7.1	53.4±7.2	53.7±7.2	<0.001
Body mass index, kg/m^2	27.6±5.2	27.1±4.9	27.1±4.8	27.0±4.4	0.007
Currently working, %	82.7	85.8	88.9	90.4	<0.001
Smoking history, %					
Never	42.4	43.4	44.3	47.6	<0.001
Former	34.4	39.8	37.5	40.0	
Current	23.2	16.9	18.2	12.4	

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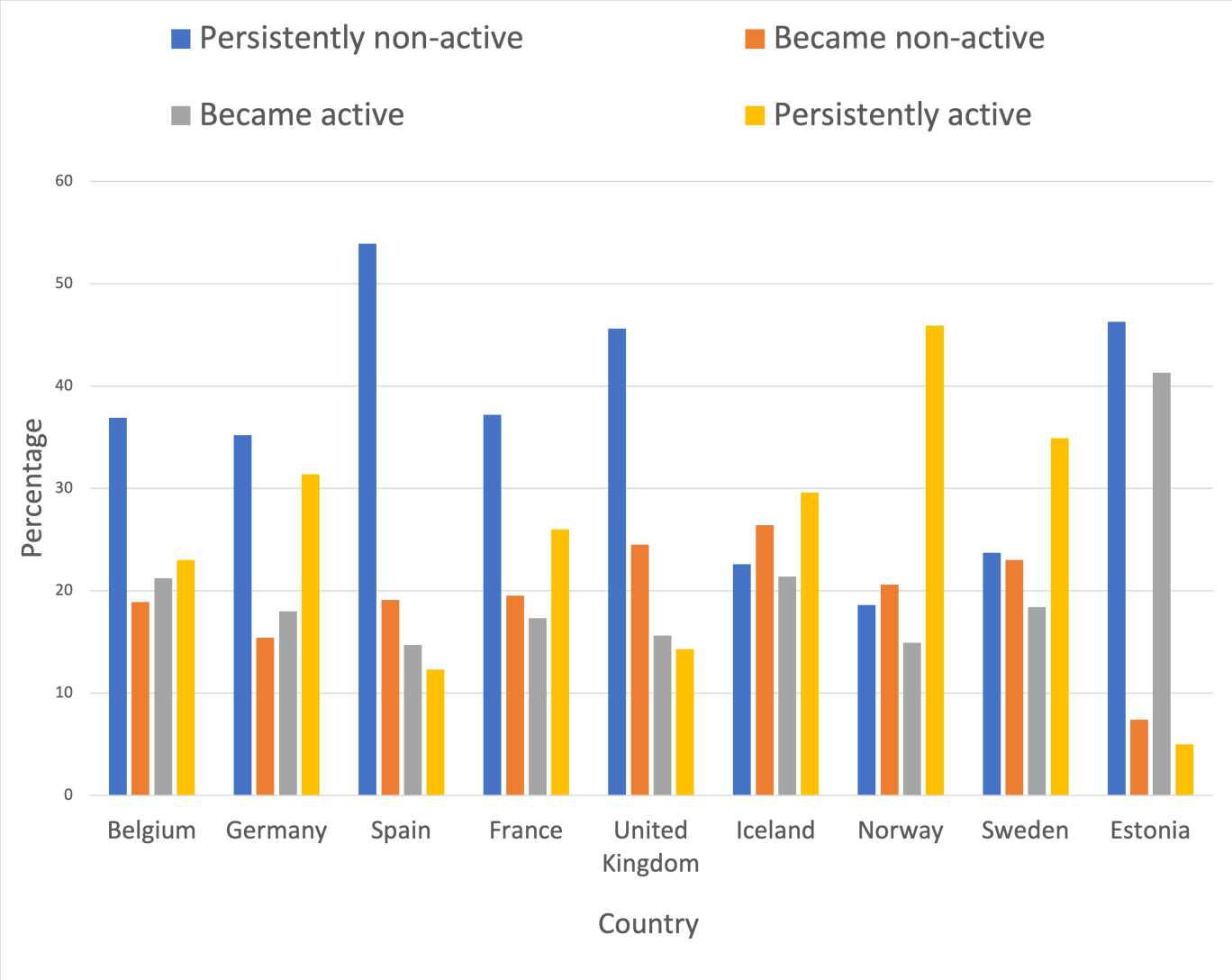

Figure 3 Activity levels by country.

General characteristics and health

Persistently active participants were more often men, they were younger and they had a slightly lower BMI (table 1). They were also less likely to be current smokers and more likely to be currently working (table 1).

Insomnia symptoms

In unadjusted analysis, there was a significant difference in reporting difficulties initiating sleep, early morning awakenings and any insomnia symptom where those persistently active were least likely to report these symptoms. Also, persistently active subjects were the least likely to report having two or three insomnia symptoms (table 2). After adjusting for age, sex, BMI, smoking history and study centre, this negative association remained significant for difficulties initiating sleep (OR 0.58 (0.42–0.77)), any insomnia symptom (OR 0.78 (0.65–0.94)) and reporting two (OR 0.60 (0.43–0.82)) and three (OR 0.63 (0.41–0.98)) insomnia symptoms (table 3). Additionally, in adjusted analysis, persistently active subjects were significantly less likely to report difficulties initiating sleep (OR 0.80 (0.66–0.97)) (table 3). There were also independent associations between insomnia symptoms and age, female gender and BMI (table 4).

Sleep duration and daytime sleepiness

In unadjusted analysis, there was a significant difference in short and long sleep durations between levels of activity. Those who were persistently active were most likely to be normal sleepers while the persistently non-active were least likely to be in that category (70.9% vs 59.2%, respectively) (table 2). After adjusting for age, sex, BMI, smoking history and study centre, these results remained significant for persistently active subjects. They were significantly more likely to be normal sleepers (OR 1.55 (1.29–1.87)) and significantly less likely to be short sleepers (OR 0.71 (0.58–0.85)) or long sleepers (OR 0.48 (0.28–0.80)) (table 3). Additionally, those who became active were more likely to be normal sleepers than those who were persistently non-active (OR 1.21 (1.00–1.47)) (table 3).

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Table 2 Insomnia symptoms, sleep duration and daytime sleepiness by level of physical activity

	Persistently non-active (n=1601)	Became inactive (n=881)	Became active (n=775)	Persistently active (n=1082)	*P value
Insomnia symptoms					
Difficulties initiating sleep (%)	15.4	14.0	11.7	8.2	**<0.001**
Difficulties maintaining sleep (%)	31.9	32.1	33.0	28.5	0.128
Early morning awakenings (%)	18.2	18.3	15.0	13.2	**0.002**
Any insomnia symptom (%)	41.0	41.5	39.5	34.9	**0.006**
Number of insomnia symptoms (%)					
0	58.4	58.2	61.0	64.9	**0.001**
1	23.2	25.2	24.0	23.8	
2	11.9	10.6	10.0	7.8	
3	6.6	6.1	5.1	3.6	
Sleep duration					
Sleep time (hours)	6.8±1.1	6.8±1.0	6.9±1.0	6.9±0.9	0.234
Sleep time, %					**<0.001**
Short sleepers (≤6 hours)	35.9	31.9	20.7	26.9	
Normal sleepers (6–9 hours)	59.2	64.6	66.9	70.9	
Long sleepers (≥9 hours)	4.9	3.5	3.4	2.2	
Daytime sleepiness					
Epworth Sleepiness Scale score	6.8±4.1	7.2±4.1	6.9±4.1	6.9±3.8	0.106
Epworth Sleepiness Scale score >10 (%)	17.2	19.4	17.7	15.6	0.176

Data are presented as mean±SD or % where indicated. Significant differences are in bold (p<0.05).
*P value from Pearson's χ^2 test (numerical variables) and one-way analysis of variance (continuous variables).

However, there was not a significant association between the mean ESS score or percentage with an ESS score >10 and level of PA (tables 2 and 3). Daytime sleepiness was also independently associated with smoking (table 4).

DISCUSSION

The main results of this study were that participants who reported being physically active at the start and end of a 10-year follow-up period were less likely to report insomnia symptoms at the follow-up. We also found that subjects who are persistently active are more likely to sleep the recommended 6–9 hours. This association remained statistically significant after adjusting for sex, age, smoking history and BMI. We also found that persistently active participants were more often men, were younger, had a slightly lower BMI and were less likely to be current smokers and more likely to be currently working.

Our results are in line with previous studies that have shown the beneficial effect of PA on symptoms of insomnia,[9 10] but the current study additionally shows the importance of consistency in exercising over time, because the association was lost for initially active subjects who became inactive. A recent meta-analysis examining the effects of acute and regular exercise on a range of sleep variables showed that acute exercise (less than 1 week of exercise) has a small beneficial effect on many objective measures of sleep, such as total sleep time, insomnia symptoms and sleep quality.[7] Furthermore, this meta-analysis found greater benefits from regular exercise for both subjective and objective sleep parameters over time. Regular exercise had small beneficial effects on total sleep time and sleep efficiency, small-to-medium beneficial effects on sleep onset latency and moderate beneficial effects on sleep quality.[7]

There are two recent systematic reviews and meta-analyses on the effects of PA on sleep[7] and insomnia,[9] both substantially reviewing the same randomised controlled studies. Banno *et al* included nine studies with a total of 557 participants.[7] The majority of participants exercised three times or less per week and the follow-up interval was 4 months or shorter in all the studies except one. Their conclusion was that exercise could improve sleep, but that higher quality research was needed.[7] Five studies on insomnia, and, additionally, six on insomnia symptoms, showed shorter sleep latency and higher sleep efficacy, but the authors also acknowledged the small size of the literature and severe methodological limitations, often based on selection bias.[9] In addition, most previous studies are cross-sectional, which can also be considered a limitation.

Furthermore, a recent systematic review of PA and sleep showed that moderate exercise had a more promising outcome in terms of sleep quality than vigorous exercise.

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Table 3 Independent association between the level of physical activity and medical disorders, insomnia symptoms, daytime sleepiness and sleep duration expressed as adjusted* ORs (95% CI) with the persistently non-active group as reference

	Became inactive (n=881)	Became active (n=775)	Persistently active (n=1082)
Insomnia symptoms			
Difficulties initiating sleep	0.97 (0.75–1.25)	0.82 (0.62–1.08)	**0.58 (0.42–0.77)**
Difficulties maintaining sleep	0.96 (0.80–1.17)	1.04 (0.85–1.27)	**0.80 (0.66–0.97)**
Early morning awakenings	1.09 (0.87–1.38)	0.86 (0.63–1.03)	0.80 (0.63–1.03)
Any insomnia symptom	1.02 (0.85–1.22)	0.95 (0.78–1.14)	**0.78 (0.65–0.94)**
Number of insomnia symptoms			
1	1.07 (0.86–1.32)	0.99 (0.79–1.24)	0.91 (0.74–1.12)
2	0.89 (0.66–1.20)	0.86 (0.63–1.17)	**0.60 (0.43–0.82)**
3	1.09 (0.74–1.59)	0.94 (0.62–1.42)	**0.63 (0.41–0.98)**
Daytime sleepiness			
Epworth Sleepiness Scale score >10	1.17 (0.94–1.47)	1.00 (0.78–1.27)	0.87 (0.69–1.10)
Sleep duration			
Short sleepers (≤6 hours)	0.89 (0.73–10.7)	0.85 (0.69–1.03)	**0.71 (0.58–0.85)**
Normal sleepers (6–9 hours)	1.18 (0.98–1.42)	**1.21 (1.00–1.47)**	**1.55 (1.29–1.87)**
Long sleepers (≥9 hours)	0.74 (0.47–1.17)	0.84 (0.53–1.33)	**0.48 (0.28–0.80)**

Bold text indicates statistical significance.
*Adjusted for age, sex, body mass index (BMI), smoking history and centre.

It is therefore important to study further the impact of the intensity of PA, in the context of age and gender, when exploring any beneficial impact on sleep.[27]

This study has a long follow-up period (10 years) and indicates strongly that consistency in PA might be an important factor in optimising sleep duration and reducing the symptoms of insomnia. Most other studies have had a much shorter follow-up period,[7] which makes it more difficult to assess the consistency of activity over time.

Our results indicate that those who maintain a consistent level of PA are also less likely to be both short (<6 hours) and long sleepers (>9 hours). Those who are physically active in general are also more likely to engage in a

Table 4 Associations between age, sex, BMI and smoking history and sleep-related symptoms

	Age	Sex	BMI	Smoking history
Insomnia symptoms				
Difficulties initiating sleep	**1.02 (1.01–1.03)**	**2.16 (1.77–2.64)**	**1.02 (1.01–1.05)**	**0.81 (0.66–0.99)**
Difficulties maintaining sleep	**1.04 (1.03–1.05)**	**1.80 (1.56–2.07)**	**1.01 (1.00–1.03)**	1.09 (0.95–1.26)
Early morning awakenings	**1.02 (1.01–1.03)**	**1.52 (1.28–1.80)**	1.01 (1.00–1.03)	1.02 (0.85–1.21)
Any insomnia symptom	**1.03 (1.02–1.04)**	**1.75 (1.53–1.99)**	**1.02 (1.01–1.03)**	1.07 (0.93–1.22)
Number of insomnia symptoms				
1	**1.03 (1.01–1.04)**	**1.47 (1.26–1.71)**	**1.02 (1.00–1.03)**	1.15 (0.98–1.34)
2	**1.04 (1.02–1.06)**	**2.11 (1.69–2.64)**	**1.02 (1.00–1.05)**	1.01 (0.80–1.26)
3	**1.04 (1.02–1.06)**	**2.62 (1.93–3.53)**	1.03 (0.99–1.06)	0.89 (0.66–1.20)
Daytime sleepiness				
Epworth Sleepiness Scale score >10	0.99 (0.98–1.00)	0.95 (0.81–1.12)	1.01 (0.99–1.03)	**1.28 (1.08–1.52)**
Sleep duration				
Short sleepers (≤6 hours)	1.01 (0.99–1.02)	0.88 (0.77–1.00)	**1.03 (1.02–1.05)**	**0.83 (0.72–0.96)**
Normal sleepers (6–9 hours)	**0.99 (0.98–0.99)**	1.08 (0.95–1.23)	**0.96 (0.95–0.98)**	**1.20 (1.05–1.38)**
Long sleepers (≥9 hours)	**1.03 (1.01–1.06)**	1.35 (0.96–1.89)	1.02 (0.99–1.06)	0.95 (0.67–1.34)

*Bold text indicates statistical significance.
BMI, body mass index.

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healthier lifestyle,[28] which can likewise have an effect on sleep. Lifestyle factors, such as a healthy diet and being physically active, are probably part of a phenotype that characterises those individuals who are generally engaged in a healthy lifestyle. A recent review highlighted the importance of focusing on the combination of sleep, diet and exercise when exploring healthy longevity.[29]

The three groups reporting low PA in either of the ECRHS surveys, or at both points in time, all report a very similar prevalence of insomnia symptoms, extreme sleep lengths and daytime sleepiness. This is somewhat surprising, especially given that those who were active in the follow-up survey but not at the baseline have a very similar symptom profile to those who were inactive in both surveys. Our study found that consistency in a behaviour such as PA for more than a decade is strongly related to a lower incidence of insomnia and a more 'normal' sleep length. Important information concerning 'the healthy phenotype' would be missed if the PA data were available only at baseline or at follow-up but not at both timepoints.

In a recent review based on 22 randomised controlled trials concerning the effects of regular exercise (lasting at least 2 months on a regular basis) on self-reported sleep quality, insomnia and daytime sleepiness, it was found that regular PA improved subjective sleep quality, insomnia severity and daytime sleepiness as measured with the ESS.[30] These results regarding insomnia symptoms are in line with our study, but the results on daytime sleepiness differ from our results. The reason for this discrepancy could be due to different study populations, as there were only two studies in this review that measured daytime sleepiness using the ESS; one study assessed this among the elderly, 60 years and older,[13] and the other among overweight and obese men.[31] Another recent review of 32 randomised controlled trials on the effects of exercise on improving sleep disturbances showed that exercise is beneficial in improving sleep quality, symptoms of insomnia, restless legs, sleep apnoea and daytime sleepiness. However, exercise only had significant effects on sleepiness if it had lasted for more than 12 weeks, while the exercise period did not matter in regard to the association to sleep quality and insomnia symptoms.[32]

Another recent study showed that high or increasing levels of PA could protect women from future insomnia.[18] Therefore, exercise seems to have a stronger association with sleep quality and insomnia than with sleepiness, which is in line with our results. However, almost all previous studies have the limitation that the definition of sleepiness is limited to the estimate that the likelihood of falling asleep but not the general feeling of sleepiness that we have shown is also an important part of sleepiness.[33 34] Another recent review exploring the associations of exercise, sleep and cognitive function among older adults showed that PA is associated with improved cognitive function but the association of sleep and cognitive function seems to be U shaped, as too much or too little sleep is negatively associated with cognitive function.[35] We did not explore cognitive function in the current study but it would be interesting for future studies to explore further how cognitive function is affected by the association of PA and sleep.

This study has several strengths such as the population-based nature, the longitudinal study design and the large sample collected in the same manner at many centres in nine different countries. Another strength is the use of standardised and validated procedures and instruments. The long follow-up period is also a strength since data on PA are collected 10 years apart and subjects are categorised according to change in PA. This study is, however, not without limitations. It is not possible to know whether those who are active at both timepoints have been continuously physically active throughout the study period or only at these two timepoints. Furthermore, PA was only measured using a questionnaire. Another limitation of our study is that sleep variables are only available at the follow-up, and we only have information on insomnia symptoms but not the diagnosis of insomnia disorder. Sleep length and daytime sleepiness are also based on subjective data. Therefore, even though the measurement of PA is longitudinal, it may not be entirely appropriate to describe the associations between PA and sleep outcomes as longitudinal. Also, there are potential implications of residual confounders that can influence both PA and sleep which were not explored in the current study (eg, mental health, musculoskeletal disorders/chronic pain) which could influence the study findings.

In conclusion, PA over time is associated with lower prevalence of insomnia symptoms and with sleeping between 6 and 9 hours/night.

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