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Associations of endurance, muscle strength, and balanced exercise with subjective sleep quality in sedentary workers: A cross-sectional study

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Abstract.
BACKGROUND: The optimal exercise combination for improving sleep quality among sedentary workers is unclear.
OBJECTIVE: To reveal what combination of exercises contributes to good sleep quality.
METHODS: In this cross-sectional study, we enrolled 5,201 sedentary workers who underwent health examinations in 2019. Data on sleep quality, basic attributes, energy expenditure, and lifestyle aspects such as exercise and physical activity, supper time close to bedtime, and alcohol intake were obtained. The subjects reported their exercise habits by selecting up to three forms of exercise from a list of 182 options, which were classified into three types: endurance (e.g., jogging), muscle strength (e.g., bench pressing), and balanced types which combined both endurance and muscle strength characteristics. (e.g., walking). These forms were then categorized into eight combination patterns: endurance only; muscle strength only; balanced only; endurance and muscle strength; endurance and balanced; muscle strength and balanced; all types; and absence of any exercise habits. Binary logistic regression analysis was used to examine the associations between the exercise combination patterns and sleep quality.
RESULTS: Good sleep quality was significantly associated with "endurance" (OR = 1.419; 95%CI 1.110–1.814), "balanced only" (OR = 1.474; 95%CI 1.248–1.741), and "endurance and balance" (OR = 1.782; 95%CI 1.085–2.926) exercise patterns. No significant associations were found between the combinations that included muscle strength exercises and sleep quality.
CONCLUSION: The endurance or balanced-type exercises, or a combination of both, may help to improve the sleep quality of sedentary workers as part of occupational health management.

Keywords: Sedentary behavior, sleep, sleep quality, exercise, occupational health, work, physical endurance

1. Introduction

Many people in today's society spend much of their time doing sedentary work, such as desk work and/or work on computers [1–3]. Sedentary behaviour requires only a minimal level of energy expenditure and an excess of this kind of inactivity

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can lead to poor sleep quality [4, 5], which is associated with depression [6], suicide [7], cardiovascular disease [8], and increased medical costs [9]. Therefore, good-quality sleep is important, and should be promoted among sedentary workers.

There is robust evidence that sedentary work and an overall sedentary lifestyle contribute to the development of serious health problems such as cardiovascular disease and cancer [10]. In light of the health risks of poor-quality sleep [6–9], promotion of good-quality sleep among sedentary workers is of importance in a company as a form of occupational health management, in addition to the prevention of the above-mentioned fatal diseases [11]. To enhance the sleep quality of sedentary workers, company managers and healthcare professionals, such as occupational physicians, need to make practical suggestions.

Exercise is a safe and inexpensive option for improving sleep quality [12]. Past studies have revealed that the intensity [13], duration [14], and frequency [15] of exercise and exercise forms, especially among sedentary workers [16, 17], are associated with sleep quality. Also, past reviews regarding the associations between the form of exercise and sleep quality indicated that high-quality sleep is associated with cardio exercise [18], tai chi programs [19], and yoga [20, 21].

However, although exercise may be performed in various combinations, the association between exercise, including combinations, and sleep quality in sedentary workers has yet to be clarified. Previous studies have reported that each form of exercise has its own characteristics, and the forms differ depending on the required oxygen consumption, cardiac output, and blood pressure [22]. Thus, it is reasonable to assume that such differences in characteristics of exercise forms may be related to sleep quality. Identifying the exercise combination that would best contribute to improving sleep quality in sedentary workers can be beneficial for developing evidence-based interventions; in light of the busy schedule of modern full-time workers [23], such identification is beneficial for occupational health management.

The present study aimed to reveal the association between exercise, in various combinations, and sleep quality in sedentary workers. Of the forms of exercise that previous studies have shown to be associated with good sleep quality [18–21], aerobic exercise in general and tai chi may have an endurance-type load, and yoga may have a balanced load, in terms of oxygen consumption, cardiac output and blood pressure [22]. In light of these previous studies, we hypothesised that exercise with such a balanced- and endurance-type load, either alone or in combination with other forms of exercise, might be associated with good sleep quality.

2. Methods

2.1. Study design and participants

In this cross-sectional study, 11,476 workers who participated in a health examination conducted in 2019 by the Koriyama Health Promotion Foundation, one of the leading regional health examination providers in Fukushima Prefecture, Japan, were selected as potential subjects. Of these, individuals who answered that their work style was "sedentary," and had no missing data regarding basic attributes, and no missing/unclear responses to the questionnaire about their lifestyle, were included in the analysis. Finally, 5,201 subjects were enrolled in the present study.

2.2. Measurement

2.2.1. Basic attributes

The health examination included basic attributes such as sex, age, height, and weight, and a detailed questionnaire about their lifestyle, such as alcohol intake amount, dinner time, habitual physical activity, exercise, and sleep quality. The responses to the questionnaire and basic attributes were recorded in the Koriyama Health Promotion Foundation's database and used for the present study.

The questionnaire consisted of items developed and standardised by the Ministry of Health, Labour and Welfare in Japan and those created by the health examination provider of the present study; these questionnaires had been used in previous epidemiological studies [24–27], as it was assumed that there was consensus on the appropriateness of the items. The questionnaires and the items used in this study were considered appropriate for the present epidemiological study.

2.2.2. Lifestyle

Regarding lifestyles, yes-no or multiple-choice questions were asked, according to past studies which examined the relationship between lifestyle and sleep quality [24–26]. The daily alcohol intake amount was assessed by the question, 'How many glasses of alco-

Table 1
List of 182 exercise forms

A-C: aerobics, Aikido (Japanese martial art), American football, aqua-aerobics, archery, badminton, balance disc, ballet, Balleton (aerobic exercise programs that combine ballet, yoga, and fitness), ballroom dancing, baseball, basketball, basketball refereeing, batting, beach volleyball, belly-dancing, bench pressing, bike trials, billiards, blowgun, BMX, boat paddling, Body Attack, Body Combat, Body Pump, Bodyblade, bodyboarding, bound tennis (indoor tennis which uses smaller courts and racquets than usual tennis), bowling, boxercise, boxing (match), boxing (sparring), canoeing, catch, Centenarian gymnastics (low-intensity exercise for elderly people), cheerleading, Chokin exercise (muscle exercise for frailty prevention easily performable at home), circuit training, clay shooting, Core Rhythms, cricket, croquet, Cross-training (machine training using equipment for all body muscles), curling, Curves circuit training (original circuit training combining strength training, aerobic exercise, and stretching), cycling.
D-J: dancing (flamenco; general; hip-hop; hula; traditional; the “Awa-odori,” traditional Japanese slow dancing; the “yosakoi”, traditional Japanese dancing with small wooden instruments; with folk songs), dodgeball, drumming, duathlon, elliptical exercise machine, farm work, fencing, field hockey, figure skating, fishing, floorball, foot-massaging using bamboo board, frisbee, full-body workouts using video software, futsal (indoor soccer), gardening, gateball (Japanese croquet), golf, golf practice, handball, hiking, horseback riding, Hua jia quan (exercise based on traditional Chinese martial arts), hula-hooping, ice hockey, ice skating, indiaca, indoor field hockey, in-line skating, Japanese dancing, javelin throwing, jet skiing, Jikyo-jutsu (exercises consisting of relaxed, full-body movements, developed in Japan), jogging, judo, juggling, jumping rope.
K-R: karate, kart racing, kayaking, kendo (Japanese art of modern swordsmanship), kyudo (Japanese art of archery), lacrosse, leg exercise machine, liangong (Chinese-style gymnastics with a focus on stretching), lifting the dumbbells, marching, medicine ball, mountain biking, mountain climbing, mountain hiking, mountain stream fishing, naginata (Japanese martial arts), Nordic walking, occlusion training, others, paragliding, park golf, petanque, physical education class in school, pilates, playing musical instruments, pole vault, push-ups, Qigong (traditional Chinese medicine that optimizes physical and mental conditions through exercise and meditation that incorporates slow movements and breathing techniques), racewalking, racquetball, radio calisthenics, recreational activities, refereeing, rifle shooting, rock-climbing, roller skates, rollerblades, rowing, rugby.
S-Y: scuba diving, shorinji kempo (Japanese martial arts using bare hands and weapons), shot-putting, sit-ups (machine), sit-ups (own weight), sit-ups (roller), skateboarding, skiing, skimboarding, slow jogging, snowboarding, soccer/football, softball, square dancing, squash, squatting, stair stepping, stationary bike, stepper (machine training using steps for cardio workout), stretching, stretching (using towel), sumo wrestling, surf-fishing, surfing, swimming, synchronized swimming, table tennis, tai chi, tap dance, teaching in sport club activities, tennis (standard), tennis (using a soft rubber ball), three B gymnastics (Japanese gymnastics for health using props such as ball, light kettlebell, and bands), trampoline, trekking, triathlon, tug of war, TV gymnastics program, unicycling, volleyball, wakeboarding, walking, walking (faster pace than usual), walking in water, water polo, water skiing, weight training (using training machines), weightlifting, windsurfing, workouts using resistance bands, workouts using twist board, yachting, yoga.

Note: The exercise forms are listed in alphabetical order and separated for readability.

hol do you have every day?’, with response options of ‘<1 glass’, ‘1–2 glasses’, ‘2–3 glasses’ and ‘≥ 3 glasses’, after following definition of one glass of different alcohol types: the alcohol content of a glass (180 ml) of refined sake (rice wine) is 15% (ethanol content 20 g), which is equivalent to that of 500 mL of beer, 80 mL of shochu, 60 mL of whiskey, or 240 mL of wine. The habit of dinner time close to bedtime was confirmed by the following question with yes-no response: ‘Do you have dinner within 2 hours of bedtime 3 times or more per week?’ Habitual physical activity levels were measured by the following question with yes-no response: ‘Do you routinely engage in walking for 1 hour or more or an equivalent amount of other type of physical activity every day?’

2.2.3. *Exercise forms*

We requested participants to select up to three forms of exercise from a list of 182 options based on the METs codes [28], as shown in Table 1, for their regular exercise engagement. The list included intentional exercises like sports and routine activities such as “farm work” to collect a broad range of information on exercise engagement. We excluded participants who chose activities such as “physical education class in school,” “teaching in sports club activities,” and “others” from the analysis, because these activities are general and make it difficult to identify the specific exercise that the subjects engage in. Participants who selected “none” were classified as having no exercise habits.

2.2.4. *Amount of exercise*

Regarding the amount, for each exercise form selected, the subjects also answered the weekly frequency they engaged in exercise, as well as the length of each session in minutes.

2.2.5. *Sleep quality*

To assess subjective sleep quality (SSQ), we asked whether participants felt they received sufficient and restorative sleep by asking, ‘Do you feel adequately rested after your sleep?’ with 2 response options: ‘yes’ and ‘no’. ‘Yes’ responses were categorized as having good SSQ.

Table 2
Exercise types and forms

Types	Forms
Endurance	aerobics, aqua-aerobics, badminton, ballet, ballroom dancing, baseball, basketball, belly-dancing, cross-training (machine training using equipment for all body muscles), cycling, dancing (flamenco, general, hula, and/or with folk songs), futsal (indoor soccer), handball, hula-hooping, ice hockey, Japanese dancing, jogging, juggling, jumping rope, marching, mountain climbing, mountain hiking, Nordic walking, playing musical instruments, soccer/football, softball, squash, stationary bike, stepper (machine training using steps for cardio workout), swimming, table tennis, tai chi, tennis (standard), tennis (using a soft rubber ball), trampoline, trekking, volleyball, walking in water.
Muscle strength	Aikido (Japanese martial art), batting, bench pressing, body pump, judo, karate, kendo (Japanese art of modern swordsmanship), kyudo (Japanese art of archery), lifting the dumbbells, occlusion training, push-ups, shorinji kempo (Japanese martial arts using bare hands and weapons), sit-ups (using a machine, a roller, or the subject's own weight), skateboarding, snowboarding, squatting, sumo wrestling, weight training (using training machines), weightlifting, windsurfing.
Balanced	billiards, bowling, boxercise, boxing (sparring), canoeing, catch, circuit training, Curves circuit training (original circuit training combining strength training, aerobic exercise, and stretching), dancing (hip-hop; the "yosakoi", traditional Japanese dancing with small wooden instruments; the "awa-odori," traditional Japanese slow dancing), dodgeball, drumming, farm work, fishing, golf, golf practice, centenarian gymnastics (low-intensity exercise for elderly people), medicine ball, Pilates, radio calisthenics, rock-climbing, skiing, stair stepping, stretching, surfing, three B gymnastics (Japanese gymnastics for health using props such as ball, light kettlebell, and bands), TV gymnastics program, walking, walking (faster pace than usual, yoga.

Note: The exercise forms are listed in alphabetical order.

2.3. *Statistical analysis*

2.3.1. *Age group and body mass index (BMI)*

Age groups of the subjects were '<40', '40–49', '50–59', and '≥ 60' years. BMI was calculated using weight and height according to the World Health Organization criteria; subjects with a BMI of <25 were considered 'not overweight' and those with a BMI of ≥ 25 were considered 'overweight' [29].

2.3.2. *Energy expenditure*

To estimate exercise intensity, energy expenditure per week (kilocalories) was calculated using the following formula in the METs table [28]: multiplying the MET of the selected exercise with each subject's weight in kilograms, duration in hours, engagement frequency per week, and 1.05. When a subject selected two exercise forms or more, the energy expenditures for each form were added together and then used in the analysis. The above-mentioned formula to calculate energy expenditure per week was as previously reported [30, 31].

2.3.3. *Exercise types and their combination patterns*

We employed Levine et al.'s classification system [22], which divides exercises into dynamic and static components. Dynamic refers to how much oxygen an individual uses, while static refers to how much force an individual applies. We classified the 97 exercise forms our subjects selected into three types based on which component is dominant or if they are equal: 'endurance', 'muscle strength', and 'balanced' (Table 2). We also classified exercise forms not included in Levine et al.'s classification [22] into three types according to the said components.

We used these three types of exercise to classify the subjects' exercise habits into eight combination patterns: 'endurance only'; 'muscle strength only'; 'balanced only'; 'endurance and muscle strength'; 'endurance and balanced'; 'muscle strength and balanced'; 'all types'; and 'no exercise habits'. For example, an individual who engaged in both 'weight training using training machines' (muscle strength type) and 'walking' (balanced type) was classified as having a 'muscle strength and balanced' pattern.

2.4. *Analytic procedure*

Subject characteristics were summarised using descriptive statistics. The associations between SSQ and exercise combination patterns were investigated by employing the chi-square test for discrete variables and the Mann-Whitney's *U* test for continuous variables.

We used binary logistic regression analysis to examine the associations between exercise combination patterns and SSQ after adjusting for confounders such as basic attributes. Subjects with no exercise habits served as the reference group, and associations between SSQ and exercise combination patterns were verified through subsequent comparisons. The explanatory variables comprised basic attributes, lifestyles, and exercise combination patterns, and the response variable was good SSQ. We developed three models following these steps: a crude model (Model 1) to examine the initial one-on-one relationships between explanatory and response variables; an adjusted model for age and sex (Model 2); and a multivariate-adjusted model (Model 3) which incorporated all factors in Models 1 and 2 irrespective of their significance. In all models, we employed a direct method for input of variables. Model 3 is our final logistic regression model. The Hosmer-Leme show test indicated a good fit for Model 3 ($p = 0.769$).

We assessed multicollinearity in Model 3 using the variance inflation factor (VIF). The VIFs for the exercise combination patterns, sex, age, BMI, alcohol intake amount, habits of having dinner close to bedtime, habitual physical activity, and energy expenditure were 1.325, 1.188, 1.025, 1.036, 1.131, 1.067, 1.081 and 1.372, respectively. All the VIF values were below 10, with the mean being less than 6, demonstrating no evidence of collinearity.

Significance level was set as 5% throughout all analyses. In the multivariate analysis, odds ratio (OR) and 95% confidence interval (CI) were calculated for basic attributes and lifestyle in relation to SSQ. All statistical analyses were performed using SPSS statistics V.26 (IBM, Armonk, New York, USA) in July 2022.

2.5. *Ethical considerations*

This study was approved by the Ethics Committee of the Fukushima Medical University, Fukushima, Japan with application number General 2020–006 in April 21, 2020. Informed consent was obtained in the form of opt-out on the web-site at April 21, 2020. All data were anonymized by the health examination provider. The first author's affiliation received and analysed such data for the current study. All methods were performed in accordance with the Declaration of Helsinki.

3. Results

The characteristics of the subjects are presented in Table 3. Regarding basic attributes, the largest age groups were 40–49 years and 50–59 years. About 30% of the subjects engaged in habitual physical activity, and the median and 25th percentile energy expenditures were zero. For the exercise combination patterns, other than the subjects who reported no habits, the most common patterns were in the order of 'balanced only,' 'endurance only,' and 'muscle strength only'. Sleep quality was reported as good by 64.9% of the subjects.

The results of the bivariate analysis are presented in Table 4. All basic attribute and lifestyle variables showed significant associations with SSQ. The exercise combination patterns were associated with sleep quality ($p < 0.001$).

As shown in Table 5, in Model 3, good SSQ was significantly prevalent among the subjects who had the patterns 'endurance only' (OR = 1.419; 95%CI 1.110–1.814), 'balanced only' (OR = 1.474; 95%CI 1.248– 1.741) and 'endurance and balance' (OR = 1.782; 95%CI 1.085–2.926), compared to those without exercise habits. Among the variables adjusted for confounders, no significant associations with SSQ were found in alcohol intake amount (OR = 1.035; 95%CI 0.958–1.118) or energy expenditure (OR = 1.00008; 95%CI 0.99997–1.00019).

4. Discussion

The present study examined the associations between exercise combination patterns and sleep quality in sedentary workers. As we had hypothesized, good SSQ was more common in subjects who engaged in exercise patterns that included balanced-type, such as 'balanced only' and 'endurance and balanced,' and good SSQ was also associated with the 'endurance only' pattern. Notably, no associations were found between the patterns of enhancing muscle strength and sleep quality. These results suggest that engagement in muscle strength training may not be a practical option for sleep quality improvement. For sedentary workers who report poor sleep quality, it may be practical to suggest endurance- or balanced-type exercises such as jogging, walking and stretching, or a combination of both types.

In the population of the current study, the core age groups were 40–49 and 50–59 years. These age groups are also the core age groups of sedentary workers in Japan [32]; thus, our study population is representative of the general population. The results that the median and 25th percentile of energy expenditure were zero are explained by the finding that 3,019 of the total of 5,201 subjects reported "no exercise habits." This may have skewed the distribution of energy expenditure toward zero.

The results of the bivariate analysis indicate associations with the SSQ for all basic attributes and lifestyle variables. Multivariate analysis was required

Table 3
Characteristics (N = 5,201)

Variables	Values
Sex	
Male	2740 (52.7)
Female	2461 (47.3)
Age ± SD (years)	50.1 ± 8.9
< 40	547 (10.5)
40–49	2045 (39.3)
50–59	1783 (34.3)
≥ 60	826 (15.9)
BMI (25–75 percentile)	23.2 (20.9–25.9)
Overweight	1674 (32.2)
Not overweight	3527 (67.8)
Alcohol intake amount per day	
< 20g	3307 (63.6)
20–39 g	1238 (23.8)
40–59 g	473 (9.1)
≥ 60 g	183 (3.5)
Dinner time close to bedtime	
Present	1541 (29.6)
Absent	3660 (70.4)
Habitual physical activity	
Present	1445 (27.8)
Absent	3756 (72.2)
Energy expenditure by exercise per week (25–75 percentile)	0 (0–414)
Exercise combination patterns	
Endurance only	493 (9.5)
Muscle strength only	270 (5.2)
Balanced only	1100 (21.1)
Endurance and muscle strength	84 (1.6)
Endurance and balanced	106 (2.0)
Muscle strength and balanced	104 (2.0)
All types	25 (0.5)
No exercise habits	3019 (58)
Subjective sleep quality	
Poor	1824 (35.1)
Good	3377 (64.9)

Note: *n* (%) for discrete variables and median for continuous variables.

to examine these associations in detail, adjusted for confounding factors.

The logistic regression analysis revealed significant associations of good SSQ with the exercise combination patterns "endurance only," "balanced only," and "endurance and balance" after adjusting for the confounding factors. In other words, none of the patterns associated with good SSQ included a muscle strength type exercise. The results were consistent with past studies, showing that balanced-type exercise such as Pilates [16] and endurance-type exercise such as aerobics [17] contribute to good sleep quality in sedentary workers. Exercise type and combination may be a powerful contributing factor to good sleep. Despite previous studies which revealed regular physical activity [33] and multicomponent workplace wellness programmes [34] may not associate with sleep quality, our study found an association between types of exercise and sleep quality. Our more detailed analysis of exercise types than these previous studies may have allowed us to obtain accurate results on the association between exercise and sleep quality in sedentary workers.

It may be reasonable to explain the mechanism of our results in physiological terms. Previous studies have reported that nocturnal exercise stimulates melatonin secretion [35], regular exercise increases adenosine concentration and body temperature [35], and physical activity decreases cortisol [36]. These previous studies provided physiological evidence that exercise and physical activity improve sleep quality. Our results suggest that such physiological effects may be associated with balanced- and endurance-type exercise.

In our results, there appears to be no benefit from muscle-strengthening exercises for sleep quality improvement. However, as previous studies have shown, muscle strengthening has benefits

Table 4
Bivariate analysis between subjective sleep quality and factors

Variables	Subjective sleep quality		p-value
	Poor ($n = 1824$)	Good ($n = 3377$)	
Sex			< 0.001*
Male	888 (32.4)	1852 (67.6)	
Female	936 (38)	1525 (62)	
Age group (years)			< 0.001*
< 40	203 (37.1)	344 (62.9)	
40–49	761 (37.2)	1284 (62.8)	
50–59	654 (36.7)	1129 (63.3)	
≥ 60	206 (24.9)	620 (75.1)	
Overweight			0.003*
Present	635 (37.9)	1039 (62.1)	
Absent	1189 (33.7)	2338 (66.3)	
Alcohol intake amount per day			0.004*
< 20g	1203 (36.4)	2104 (63.6)	
20–39 g	390 (31.5)	848 (68.5)	
40–59 g	156 (33)	317 (67)	
≥ 60 g	75 (41)	108 (59)	
Dinner time close to bedtime			< 0.001*
Present	677 (43.9)	864 (56.1)	
Absent	1147 (31.3)	2513 (68.7)	
Habitual physical activity			< 0.001*
Present	429 (29.7)	1016 (70.3)	
Absent	1395 (37.1)	2361 (62.9)	
Energy expenditure by exercise per week (kcal)	0 (0–241)	0 (0–490)	< 0.001*
Exercise combination patterns			< 0.001*
Endurance only	137 (27.8)	356 (72.2)	
Muscle strength only	92 (34.1)	178 (65.9)	
Balanced only	301 (27.4)	799 (72.6)	
Endurance and muscle strength	22 (26.2)	62 (73.8)	
Endurance and balanced	23 (21.7)	83 (78.3)	
Muscle strength and balanced	31 (29.8)	73 (70.2)	
All types	9 (36)	16 (64)	
No exercise habits	1209 (40)	1810 (60)	

Note: *n* (%). * indicates statistical significance by chi-square test for discrete variables and Mann-Whitney's U test for continuous variables.

in preventing the work-related problem of musculoskeletal disorders in sedentary workers such as welders [37], office workers [38], and long-term computer users in the recent COVID-19 pandemic [39]. Therefore, concerning work-related problems in sedentary workers, occupational health professionals need to explore ways to reconcile the benefits of muscular exercise in preventing musculoskeletal disorders with the advantages of endurance- and balanced-type exercise in improving sleep quality. Importantly, our results showed no association between muscle-strength type exercise and sleep quality; statistically, muscle-strength type exercise neither helped nor worsened sleep quality. Previous study suggested that high-intensity muscle-strength exercise reduces sleep quality [40]. In light of this literature, occupational health professionals can improve coping with work-related problems and poor sleep, which are common in sedentary workers. A high-intensity muscle-strength exercise should be avoided, balanced or endurance-type exercise or moderate-intensity muscle-strength exercise may be an option for such workers. For balanced- and endurance-type exercise, as shown in Table 2, endurance-type exercise includes jogging, and balanced-type exercise includes walking and stretching; since these are relatively easy to combine, they may be promising options for improving sleep quality in sedentary workers. Given the current busy schedule of workers and the increase in sedentary work and lifestyle under the COVID-19 pandemic [1–3, 23, 32], these exercise proposals are considered to be practical for achieving sleep quality improvement as part of occupational health management.

A limitation of the present study is that we did not investigate when the subjects performed the exercise. Although night-time exercise decreases sleep quality

Table 5
Logistic regression analysis for the association between presence of good subjective sleep quality and exercise combination patterns

Variables	ORs (95%CI)		
	Model 1	Model 2	Model 3
Exercise combination patterns			
No exercise habits	Reference	Reference	Reference
Endurance only	1.736 (1.407, 2.141)*	1.701 (1.378, 2.101)*	1.419 (1.110, 1.814)*
Muscle strength only	1.292 (0.994, 1.679)	1.288 (0.990, 1.674)	1.144 (0.873, 1.501)
Balanced only	1.773 (1.524, 2.063)*	1.677 (1.439, 1.955)*	1.474 (1.248, 1.741)*
Endurance and muscle strength	1.882 (1.151, 3.078)*	1.794 (1.095, 2.938)*	1.467 (0.863, 2.494)
Endurance and balanced	2.410 (1.510, 3.847)*	2.307 (1.443, 3.686)*	1.782 (1.085, 2.926)*
Muscle strength and balanced	1.573 (1.027, 2.409)*	1.555 (1.014, 2.385)*	1.306 (0.832, 2.049)
All types	1.187 (0.523, 2.696)	1.097 (0.482, 2.496)	0.814 (0.341, 1.944)
Confounding factors			
Sex (female)	0.781 (0.697, 0.876)*	N/A	0.741 (0.653, 0.842)*
Age group	1.178 (1.104, 1.258)*	N/A	1.108 (1.035, 1.186)*
BMI (overweight)	0.832 (0.737, 0.939)*	0.787 (0.695, 0.890)*	0.817 (0.720, 0.926)*
Alcohol intake amount	1.043 (0.971, 1.120)	0.997 (0.924, 1.075)	1.035 (0.958, 1.118)
Dinner time close to bedtime (absent)	1.717 (1.519, 1.940)*	1.791 (1.578, 2.031)*	1.722 (1.514, 1.958)*
Habitual physical activity (absent)	0.715 (0.627, 0.815)*	0.719 (0.630, 0.820)*	0.797 (0.694, 0.916)*
Energy expenditure by exercise per week	1.0003 (1.0002, 1.0004)*†	1.0003 (1.0002, 1.0004)*†	1.00008 (0.99997, 1.00019)†

*indicates statistical significance by logistic regression analysis. †Odds ratios and confidence intervals are rounded off to three decimal places. However, the differences regarding energy expenditure by exercise per week were so narrow, that they are rounded off to four decimal places in Models 1 and 2, and to five decimal places in Model 3. Model 1, crude model; Model 2, sex-and-age-adjusted model; Model 3, multivariate adjusted model. N/A indicates 'not applicable', because sex and age were input consistently in Model 2 and thus their ORs and 95% CI were omitted.

[41], our study did not include such information in the analysis. Future work should examine appropriate exercise timing for sedentary workers. Another limitation of this study is that other sleep-related health conditions, such as sleep apnoea and morbid obesity, were not included in the analysis. Such conditions also need to be investigated in future studies.

5. Conclusion

The subjects in the current study had good sleep quality when they engaged in endurance exercise, balanced-type exercise, or a combination of the two. In other words, none of the exercise patterns associated with good sleep quality included a muscle strength type exercise. Company managers and healthcare professionals need to be aware of ineffectiveness of muscle strength exercise on sleep quality improvement, and suggest endurance or balanced-type exercises (e.g., jogging, walking, stretching), or a combination of both, for sedentary workers who report poor sleep quality as part of occupational health management.

Ethical considerations

This study was approved by the Ethics Committee of the Fukushima Medical University, Fukushima, Japan with application number General 2020–006 in April 21, 2020.

Informed consent

Informed consent was obtained in the form of opt-out on the website on April 21, 2020.

Conflict of interest

The authors Rieko Miura, Youko Funayama and Kimitaka Tajimi were employees of the Koriyama Health Promotion Foundation, where the data of the present study was recorded.

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