Recreational Underwater Exercise Facilitates the Sleep Continuity in Physically Untrained Males

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Abstract

ODA, S., MIZUNO, T., NAKAGAWA, K. and MORIYA, K., Recreational Underwater Exercise Facilitates the Sleep Continuity in Physically Untrained Males. Adv. Exerc. Sports Physiol., Vol.7, No.2 pp.59-63, 2001. In this paper, we examined the effects of recreational underwater exercise (UWE) on sleep. Physically untrained male college students participated in the UWE program in the evening at a health resort facility. UWE was performed in thermoneutral water (34 ℃) and the subjects followed an instructor's directions. The program was divided into two sessions. An aqua trim exercise consisted of slow gymnastic exercises and an aqua aerobic exercise consisted mostly of rapid aerobic dances. After UWE, the subjects were studied with nocturnal polysomnography at home. The nocturnal sleep data following UWE were compared with those following a day of routine activity in which exercise was not practiced on the control night. Heart rate during UWE showed that the intensity of exercise was low to moderate. From sleep results, the time in stage 1 ($p=0.03$) and sleep disturbance (movement time and stages W and 1 combined, $p=0.03$) on the UWE night were significantly shorter than those on the control night. On the other hand, no significant differences were found in the time of SWS (slow wave sleep) or REM (rapid eye movement) sleep. These results indicate that recreational UWE of low to moderate intensity may improve the sleep continuity rather than cause changes in the sleep pattern.

Key words: underwater exercise, recreation, mood states, sleep, awakening

Introduction

In several recent epidemiological studies, various sleep disorders among young adults have been demonstrated, such as difficulty in falling asleep, frequent mid-sleep awakenings and not feeling refreshed in the morning (5, 13, 14). Young adults with sleep complaints tend to have physically non-active lifestyles. Several studies have found that physically active young adults have better sleep habits than those who have a more sedentary lifestyle (9, 16). These findings indicate the importance of a physically active lifestyle for getting a good nocturnal sleep.

Therefore, numerous studies have examined the effects of exercise on subsequent nocturnal sleep (3, 7, 29, 30). However, there has been little agreement to support the hypothesis that physical exercise improves the following night's sleep. The majority of researches appear to use exercise protocols and limit their study strictly controlled pertaining to intensity and/or energy consumption, in order to understand on the physiological aspect of the influence of exercise on sleep. These highly controlled exercise protocols may clarify the relationship between physiological response and sleep, however, sleep may be influenced not only by physiological changes but by other factors as well. It is worth noticing here that there are strong links between sleep disorders in young adults and their moods. There is agreement that sleep is disturbed by negative moods, such as anxiety or depression (13, 14). These findings suggest that sleep may also be improved by exercise-induced mood benefits, as many studies showed (2, 19, 20). However, few studies have focused on the effects of exercise-induced mood benefits on sleep. Kupfer et al (12) failed to demonstrate that either changes in sleep or moods after exercise were significantly worthy of note, and did not support their hypothesis at all. It is likely that this failure was due to the use of a monotonous running/jogging protocol, which is a monotonous type of laboratory exercise. If an exercise is too tedious or too strenuous, useful benefits may only be observed among those people with a high level of motivation or perseverance. It is felt that more enjoyable exercise ought to be recommended in order to improve mood and sleep, especially for physically untrained subjects. This enjoyable feeling is also effective for inducing subjects to continue the exercise.

Unfortunately, there have been no studies that examined the effect of enjoyable exercise on sleep. We therefore focused on recreational underwater exercise (UWE), which is performed at health resorts and leisure facilities as appropriate exercise for improving both mood and sleep. We emphasize that this UWE was devised for general enjoyment. In a previous study (19), we have already reported that a significant increase in scores of positive mood (i.e. vigor) and a decrease in scores of negative mood (i.e. tension and anxiety, and depression and dejection) after UWE, assessed by profile of mood states (POMS).

Another reason that we focus on UWE is the various unique benefits of water, which have been reported elsewhere (8, 10, 24, 26). For example, buoyancy may reduce

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weight stress on the joints and may allow problem-free exercise for those who are unable to participate in traditional walking or low-impact aerobic programs due to their physical limitations. In fact, UWE has been widely used to improve fitness in older adults, and as a therapy for chronic diseases, orthopedic rehabilitation, and so on.

Above all, the purpose of this study is to examine the effects of recreational UWE on sleep. We will also discuss the physiological and psychological mechanisms behind the results observed.

Methods

Subjects

Eight healthy male college students participated in this experiment. Informed consent was obtained from the subjects. None of the subjects regularly engaged in physical exercise and their fitness levels were not taken into consideration. They agreed to refrain from alcohol, caffeine, illegal drugs and high-intensity physical activity for 24 h before data collection. The data for six subjects with a mean (±SD) age of 23.0±1.1 years were used for the statistical analysis, since these for two subjects were partially missing.

Design

To assess the effects of UWE on sleep, each subject was studied for two nights of sleep. One was a control night study conducted on the night after a day of routine activity in which the subject refrained from physical exercise. The other was UWE night study, which was conducted on the night following UWE in the evening. Both studies were counterbalanced in order and performed at least one day apart, after one night of adaptation to reduce any possible "first night effect" as Agnew et al (1) suggested. On this adaptation day, all subjects participated in the same UWE program. Electrocardiogram (ECG) data were recorded for each subject as an intensity index of UWE.

Experimental Procedure

In the UWE night study, the subjects arrived at the laboratory at 17:00 and were taken to a commercial health resort (Sapporo Therme, Sapporo, Japan) by car, where they participated in the UWE program from 18:30 to 19:30. Upon arrival, the subjects changed into their swimsuits and sat on chairs beside the exercise pool to wait for the start of the UWE program. The water temperature and depth were set at 34℃ and 120 cm, respectively. The subjects always exercised together, alongside other participants in the program. They followed the instructor's directions and movements with music when practicing UWE.

The program was divided into two sessions: an aqua trim session for the first 20 min and an aqua aerobics session for the last 30 min. The typical movements of both sessions are illustrated in our previous article (19). For most of the first aqua trim session, subjects engaged in slow gymnastic exercises using a pole, while the instructor directed them to breathe slowly. In addition, the subjects jumped occasionally, often twisting themselves. After stretching and cooling down, the session ended. After a 10 min break, the aqua aerobic session commenced, during which the subjects mostly practiced rapid aerobic dances. Towards the middle of this session, the subjects danced while moving quickly and jumping. They stretched themselves and cooled down again at the end of the session.

Upon completion of the UWE program, the subjects returned to the laboratory where they were fitted with electrodes for polysomnography (PSG) measurements. With these preparations completed, the subjects were taken home. In order to reduce undue stress, all the PSG recordings were carried out in the confines of the normal domestic sleeping environment for subjects (28). They were instructed to adhere to their normal routine in the evening and to go to bed and get up at their usual time.

For the control night, the subjects arrived at 20:00 for the fitting of PSG electrodes. Sleep recording was carried out using the same procedure as on the UWE night. The subjects were instructed to adhere to a similar normal routine lifestyle except for the exercise. They were also instructed to write an activity diary for screening.

Measurements

1) ECG recordings during UWE

ECG recordings during UWE, which were taken in the adaptation study, used the chest-lead method. ECG electrodes were attached to the subjects after treatment with skin preparation gel (Skin Pure, Nihon Kohden, Tokyo, Japan) and rubbing ethanol. Waterproof pads (Tegaderm TM Transparent IV Dressing, 3M Health Care, USA) were used to cover the electrodes. ECG data were recorded with 1 mV/10 mm calibration, a time constant of 0.5 s and a 100 Hz low-pass filter using a multi-telemeter system (WEB-5000, Nihon Kohden, Tokyo, Japan) and cassette data recorder (MR-40, TEAC, Tokyo, Japan).

2) PSG recordings

PSG recording and scoring methods were according to the standardized procedure (22). The monitoring montage consisted of four electroencephalogram (EEG) channels (C3, C4, P3, P4), a bilateral electrooculogram (EOG), submental chin electromyogram (EMG), and chest-leaded ECG. PSG data were recorded using a multi-telemeter system (WEB-5000, Nihon Kohden, Tokyo, Japan) and cassette data recorder (XR-510, TEAC, Tokyo, Japan). EEG data were recorded with 50 μV/8 mm calibration, a time constant of 0.3 s and a 30 Hz low-pass filter. EOG data were recorded with 50 μV/10 mm calibration, with a time constant of 1.5 s and a 30 Hz low-pass filter. EMG data were recorded with 50 μV/10 mm calibration, a time constant of 0.03 s and a 30 Hz low-pass filter. ECG data were recorded with 1 mV/10 mm calibration, a time constant of 0.5 s and a 100 Hz low-pass filter.

Data Analysis

From ECG data recorded during UWE, the mean heart rate (HR) was obtained every minute using a time series analysis system (Maximal Entropy Methods for Time Series Analysis, MemCalc, Ver. 2.5, GMS, Tokyo, Japan). Furthermore, to estimate the individual intensity of the UWE program, relative HR reserve (%HR_{res}) was calculated using the following equations: $\%HR_{res} = (HR_{exercise} - HR_{rest}) / (HR_{max} - HR_{rest}) \times 100$. $HR_{max} = 220 -$ age (years). We defined HR_{rest} as the minimum HR value during pre-exercise rest (19). We therefore obtained mean, trough and peak %HR_{res} during both sessions of UWE.

PSG data were analyzed using a Medilog sleep analysis computer (DEE−1100, Nihon Kohden, Tokyo, Japan) as well as by visual scoring, with a 30 s sleep epoch. The sleep variables analyzed were as follows: (1) Time in bed (TIB: the duration of the lights-out period). (2) Sleep period time (SPT: the time from sleep onset to final waking). (3) Total sleep time (TST). (4) Sleep efficiency (SE: TST/TIB). (5) Sleep onset latency (SOL: the period from lights-out to the start of the first minute of continuous stage 2 or deeper sleep). (6) Movement time (MT). (7) Wake time after sleep onset (WASO: stage W + MT). (8) Sleep disturbance time (WASO and stage 1 combined). (9) Time in each of the sleep stages 1, 2, 3, 4, and REM (rapid eye movement). (10) Slow wave sleep (SWS: stages 3 + 4). All of the above were based on shorter SPT for each subject. (11) Mean HR during TIB was also scored.

We used a paired t-test for comparing the sleep variables between the control night and the UWE night. Differences were considered significant at $p < 0.05$.

Results

1) Subject characteristics and %HR_{res} data

Table 1 shows individual physical data collected on the subjects prior to the experiment, and mean, trough and peak %HR_{res} data for each of the two sessions of UWE. Average %HR_{res} for all subjects changed every minute during UWE as plotted in our previous article (19). Mean %HR_{res} was about 20% during the aqua trim session, while mean and peak %HR_{res} reached at about 30% and 50% during the aqua aerobics session. Furthermore, the data reveal large individual differences in exercise intensity, especially during the aqua aerobics session.

2) PSG data

There was no difference in bedtime between the UWE night [0:06 (SD 44.2 min)] and the control night [0:08 (SD 42.7 min)]. Table 2 shows mean scores of sleep variables for six subjects over both UWE and control nights. There are no significant differences in all the sleep time variables (TIB, SPT, TST), SOL and SE. However, significant differences were obtained in sleep continuity variables. On the UWE night, a shorter time in stage 1 was observed in comparison with that on the control night [$t(6) = 2.55$, $p = 0.03$]. Although the time of stage W and WASO tended to be smaller on UWE night ($p < 0.10$), sleep disturbance time was significantly shorter on UWE night [$t(6) = 2.29$, $p = 0.03$], as compared with that on the control night. On the other hand, sleep pattern variables (stages 2, 3, 4 and REM, and SWS) showed no significant differences between both nights. Mean HR during sleep also did not differ significantly in both nights (Table 2).

Discussion

In this study, we investigated the effects of recreational UWE in the evening on following nocturnal sleep. Although PSG results indicate no significant improvement in the parameter of sleep depth (stages 3, 4 and SWS) or REM sleep, an improvement in the sleep continuity (shorter time in stage 1 and sleep disturbance) after UWE was observed. Previous studies have failed to observe the effects of physical exercise on the sleep continuity and have hardly discussed the matter at all (30). To understand the improvement in sleep continuity, not only the tradi-

Table 1 Mean, trough and peak %HR_{res} during two sessions of the underwater exercise. HR_{rest} was defined as the minimum HR value during pre-exercise rest (19). $\%HR_{reserve}$ $(\%HR_{res}) = (HR_{exercise} - HR_{rest}) / (HR_{max} - HR_{rest}) \times 100$. $HR_{max} = 220 -$ age (yrs).

Subject	HR_{rest} (bpm)	%HR_{res} during Aqua trim (%)			%HR_{res} during Aqua aerobics (%)		
		Mean	Trough	Peak	Mean	Trough	Peak
M.A	51.2	23.6	12.0	39.5	50.3	32.9	70.6
T.Y	55.1	16.2	7.8	28.2	36.7	13.4	58.9
H.T	56.6	20.3	12.3	31.1	34.7	14.4	50.1
T.S	66.0	17.8	10.3	25.4	33.1	3.9	55.2
A.S	44.6	16.4	8.7	25.1	24.6	7.4	38.3
S.O	77.1	20.8	15.6	34.7	22.9	7.4	40.1
Mean	58.4	19.2	11.1	30.7	32.2	13.2	52.2
SD	11.5	2.9	2.8	7.3	9.9	10.4	12.1

Table 2 Comparison of PSG sleep variables between the underwater exercise night and the control night (n=6, TIB: time in bed, SPT: sleep period time, TST: total sleep time, SOL: sleep onset latency, MT: movement time,WASO: wake time after sleep onset, sleep disturbance: WASO and stage 1 combined, SWS: slow wave sleep, HR: mean heart rate during TIB.)

		Control night		Underwater exercise night			
Sleep variables	Unit	Mean	SD	Mean	SD	t value	t-test results
Bedtime	hours (SD; min)	2408	42.7	2406	44.2		
(1)TIB	min	455.8	20.1	437.7	55.5	0.73	n.s.
(2)SPT	min	437.3	21.9	419.4	52.6	0.89	n.s.
(3)TST	min	428.6	24.4	414.6	52.9	0.65	n.s.
(4)Sleep Efficiency	%	94.0	2.2	94.7	1.7	0.71	n.s.
(5)SOL	min	17.8	7.9	16.8	7.5	0.21	n.s.
(6)MT	min	3.3	2.0	3.1	1.3	0.25	n.s.
(7)WASO	min	8.8	6.5	4.8	1.8	1.60	$P < 0.10$
(8)Sleep Disturbance	min	17.3	7.0	10.8	1.8	2.29	$p = 0.03$
(9)Stage W	min	5.4	5.7	1.8	0.9	1.66	$p < 0.10$
Stage 1	min	8.5	2.4	5.9	1.0	2.55	$p = 0.03$
Stage 2	min	184.3	25.1	189.3	18.2	0.63	n.s.
Stage 3	min	36.3	15.8	41.8	16.1	0.83	n.s.
Stage 4	min	44.9	27.1	45.7	24.6	0.08	n.s.
Stage REM	min	127.5	28.5	122.8	29.3	1.13	n.s.
(10)SWS	min	81.2	33.8	87.5	26.3	1.50	n.s.
(11)HR	beats · min^{-1}	51.7	4.8	53.0	7.2	1.06	n.s.

n.s.=not significant

tional physiological aspects, but also the unique benefits and psychological aspects of UWE require consideration.

Almost all previous studies examined the effects of exercise on sleep have focused on SWS in particular, which might be related to recovery from fatigue, restorative processes or energy build-up (3, 29, 30). Although SWS appearance is likely facilitated by body and brain heating due to high intensity or long sustained exercise (11, 15), there are many studies in which sleep disturbance was observed after high intensity exercise (3, 6, 7, 17, 28, 30). As Buguet et al (3) suggested, strong stress may disturb nocturnal sleep in a day when the exercise load is too heavy for an individual. In some studies, an elevated excretion level of the stress hormone, such as catecholamine (28) or cortisol (17), was observed in subjects whose sleep had been disturbed. Bunnell et al (4) also reported significant elevation of norepinephrine excretion and/or HR and cardiac output during sleep after exhaustive exercise. Furthermore, Youngstedt et al (30) found that WASO time extended in nocturnal sleep following exercise in which higher body heating was induced. These results indicate that stress reactions against an exhaustive exercise in the daytime continued even during nocturnal sleep. In this study, the results of $\%HR_{res}$ indicate that the intensity of UWE is low to moderate, so it is unlikely that the subjects experienced extreme stress. Furthermore, we should be focusing on the large individual differences observed in the $\%HR_{res}$ data. These differences may be due, not only to varying individual fitness levels, but also to water viscosity. It is known that faster movements create more resistance in water and streamlined movements less in water because of its viscosity. It is therefore likely that subjects unconsciously opted to move according to their fitness level in the water. They might have a “comfortable fatigue”as a result of a flexible exercise load. So far, we infer that recovery against moderate physical activation facilitates the sleep continuity. Since we did not record the intermediate HR between UWE and sleep, it is unclear how physical activation continue after UWE. However, we could not find significant differences between the mean HR on either control or UWE night, so the low level of physiological arousal after UWE might not disturb the sleep continuity on the night following UWE.

Another study found that the number of MT (sleep disruptions) during sleep was significantly higher on the night after exhaustive exercise than on the control night (27). It is supposed that MT might increase by muscle fatigue and soreness following the high training load. There is thus a second explanation involving muscle fatigue. Untrained people often feel muscle pain after acute or strong exercise, and this discomfort will often disrupt sleep (27). Richards (23) suggested that this pain could increase sleep latency and increase the number and length of mid-awakenings. However, in the case of exercise in water, buoyancy may reduce the load on the lower limbs and viscosity may suppress intensity of movement and activate almost all immersed body muscles (10, 24). These findings indicate that muscle pain or fatigue during UWE might be low to moderate. On the other hand, it is likely that immersion in water might be useful in recovering from fatigue or relaxing muscles. Nakamura et al (18) reported that a tepid water (30℃) bath resulted in a greater removal of blood lactate after submaximal exercise. Richards (23) suggested that muscle relaxation was effective for promoting sleep. These studies indicate that moderate muscle fatigue and relaxation caused by UWE in thermoneutral water have a possibility to improve the sleep continuity.

Since it is reported that subjects disrupted frequently their sleep by noise showed lower performance and more sleepiness on the following daytime as compared with those of normal days (25), a shorter time of sleep disruptions observed on the UWE night must increase their quality of life. The effects detected on the UWE night are thought more useful for people with sleep disorders than subjects who did not manifest any sleep disorders.

At last, we wish to emphasize the psychological causes of sleep improvement. As described in the introduction, negative moods such as anxiety and/or depression may also disturb sleep (13, 14). In our previous study (19), the decreases in mood scores of anxiety and depression were observed immediately following UWE. This mood change may be acquired not only through the typical mechanism of physical activity, but also through the emotional enjoyment of UWE. It is unclear whether this mood improvement continues during sleep. However, Raglin et al (21) showed that anti-anxiety effects were sustained for a longer period following exercise, and might support the contention that better mood continued during the evening and into the sleep period. These data support the hypothesis that the improvement in sleep continuity after UWE reflects the benefits of mood improvement.

In conclusion, we observed a significant improvement in sleep continuity after recreational UWE. We have discussed various possible mechanisms for this effect, but the causes remain unclear. They may be clarified by additional research employing traditional and brand-new physiological approaches, including the idea that changes in body temperature relate to sleep quality. Although this study focuses on untrained young male adults, we should examine whether the benefits observed here can also apply to people with a lower fitness level, to older adults, or to people who are unable to participate in traditional walking or low-impact aerobic programs on land due to their physical limitations.

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