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Original Article

Effect of Aerobic Training on Sleep Problems in Children with Down Syndrome

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Abstract:
Purpose: To ascertain the aerobic training efficacy on sleep issues in Down syndrome children. **Methods**: Thirty children with Down syndrome (21 boys and 9 girls), ranging in age between 7 and 12 years old, took part in the current research. They were randomly allocated into 2 groups of equal number. The control group (A) received a selected physiotherapy programme only, while the study group (B) received the same selected physiotherapy programme as group A, besides aerobic training on a treadmill. Children in both groups attended three treatment sessions a week over the course of three successive months. Sleep was evaluated through the Children's Sleep Habits Questionnaire (Arabic version) prior to and following three consecutive months of treatment. **Results**: A statistically significant decline was demonstrated in the eight subscale scores and the total score of the Children's Sleep Habits Questionnaire in group B in comparison to group A. **Conclusion**: Aerobic training in addition to a selected physiotherapy programme for three months can improve bedtime resistance, sleep-onset delay, sleep duration, sleep anxiety, night wakings, parasomnias, sleep-disordered breathing, and daytime sleepiness among Down syndrome children.

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1. Introduction:

Down syndrome (DS), often called trisomy 21, is the most prevalent chromosomal abnormality and the leading cause of mental disabilities. It affects 1 in 319 to 1 in 1000 live births, and its occurrence rises with maternal age and varies with population **[1].**

Children with DS may experience problems during their sleep **[2].** These problems include obstructive sleep apnea (OSA), excessive daytime sleepiness, and difficulties in sleep initiation and maintenance **[3].** Chronic sleep disturbances are complex and can be dangerous to overall health. Sleep difficulties have been linked to attention deficit hyperactivity disorder, mood and anxiety disorders, autism spectrum disorders, cardiovascular disease, obesity, and a variety of neurocognitive problems. They may cause distress to families as well **[2].**

There are many methods used to evaluate a child's sleep, such as polysomnography, videosomnography, actigraphy, motility monitoring, parental report questionnaires, and direct observation. Cost, degree of interference, usability, and the type of data they offer are all different across these methods **[4,5].**

The Children's Sleep Habits Questionnaire (CSHQ) is a good instrument for sleep screening to identify behavioural and medical sleep troubles in school-aged children **[6].** The CSHQ and its subscales show better psychometric properties among children with DS **[7].**

The American College of Sports Medicine defines aerobic exercise as any activity that utilizes large muscle groups, can be maintained over time, and has a rhythmic nature **[8].** Sleep organizations see exercise as an important part of non-pharmacological therapy for poor sleep. Exercise has also been regarded as an easy, affordable, and safe substitute to traditional therapies for sleep problems **[9].** Exercise and sleep have an effect on each other, and exercise is widely thought to enhance sleep quality through a number of physiological and psychological mechanisms **[10].**

This research aimed to find out the aerobic training effectiveness on sleep problems in DS children.

2. Methods:

A randomized controlled trial was executed at the Department of Physical Therapy, Quesna Central Hospital, Menoufia, Egypt.

2.1. Subjects:

The number of children required for this study was 30 (15 children for each group). G*Power software (version 3.1) was used to calculate the sample size with a power of 80%, an α-level of 0.05, and an effect size of 1.08.

Thirty children with DS (trisomy 21) from both genders, ranging in age from 7 to 12 years and in weight from 37 to 66 kg, were recruited from Eltarbeya Elfekreya School for children with special needs. Children were capable of understanding and following easy instructions given visually and verbally (intelligence quotient (IQ) ranged from 50 to 70%, according to their school reports) and were able to walk on their own. Their overall scores on the Arabic version of the CSHQ were more than 41. Children who had visual or hearing defects, musculoskeletal disorders, acute or chronic respiratory diseases, cardiac anomalies or diseases, or a history of recent surgery were excluded. Also, we excluded children who were practicing a specific sport or exercise or who were receiving medications known to affect sleep.

Children were divided randomly and equally into 2 groups, which are the control group (A) and the study group (B). All parents of children involved in the present study were told about the aim, procedures, and possible benefits of the current research and signed a consent form, including their agreement to participate, before the beginning of study procedures. This study was carried out following the approval from the Research Ethics Committee of the Faculty of Physical Therapy at Cairo University in Egypt (No.: P.T.REC/012/004243).

2.2. Randomization:

Thirty-four children with DS were evaluated for eligibility. Two children were excluded as they didn't meet the inclusion criteria, and two children were excluded as their parents refused to participate in the study. After we had taken the baseline measurements, the randomization process was performed using sealed, opaque envelopes. The researcher prepared 15 sealed, opaque envelopes labelled as group A and another 15 sealed, opaque envelopes labelled as group B. Then, each child was instructed to draw an envelope containing one of the two groups. The flowchart illustrating participants entered into the study is represented in **Figure 1.**

2.3. Methods:

2.3.1. Evaluation:

The Arabic version of the CSHQ was used to assess sleep for all the participating children before and after three months of treatment. The CSHQ is a retrospective, parent-reported survey that has been used in several studies to evaluate sleep behaviour in young children. 33 out of its 45 original questions were categorized into 8 subscales, which are bedtime resistance, sleep-onset delay, sleep duration, sleep anxiety, night wakings, parasomnias, sleep-disordered breathing (SDB), and daytime sleepiness **[6].** Asaad and Kahla prepared the Arabic version of the CSHQ through a translation and retranslation process. Minor modifications to the translation have been made to make it more appropriate for use in Egyptian culture **[11].**

2.3.2. The Arabic version of the Children's Sleep Habits Questionnaire:

A printed form of the Arabic version of the CSHQ was completed by one parent of each child or by an educated family member if both parents were not educated. Each parent was asked to complete demographic data, recall the child's sleep behaviours occurring throughout the last week or within a recent, more usual week if the last week was not representative for some reason, and rate the frequency of each item on a three-point rating system ranging from 'usually' (5–7 times/week) and 'sometimes' (2–4 times/week) to 'rarely' (0 or 1 time/week). Responses were reviewed by the investigator with the parent who completed the questionnaire in a face-to-face interview. The total score and each subscale score were counted by the investigator because the child may have a sleep disturbance in a particular area and not have an elevated total score. Each item is scored from 1 to 3 (usually = 3, sometimes = 2, and rarely = 1). The scoring of some items (1, 2, 7, 9, 10, and 26) is reversed (usually = 1 and rarely = 3) to make a higher score representative of more disturbed sleep, as these items ask about the normal sleep behavior. The total score is computed as the sum of all the items answered on the eight subscales (items 4 and 6 are included in two subscales, so they are counted once in the total score). The total score exceeding 41 suggests the presence of a sleep disturbance. Higher scores indicate greater overall sleep disturbance.

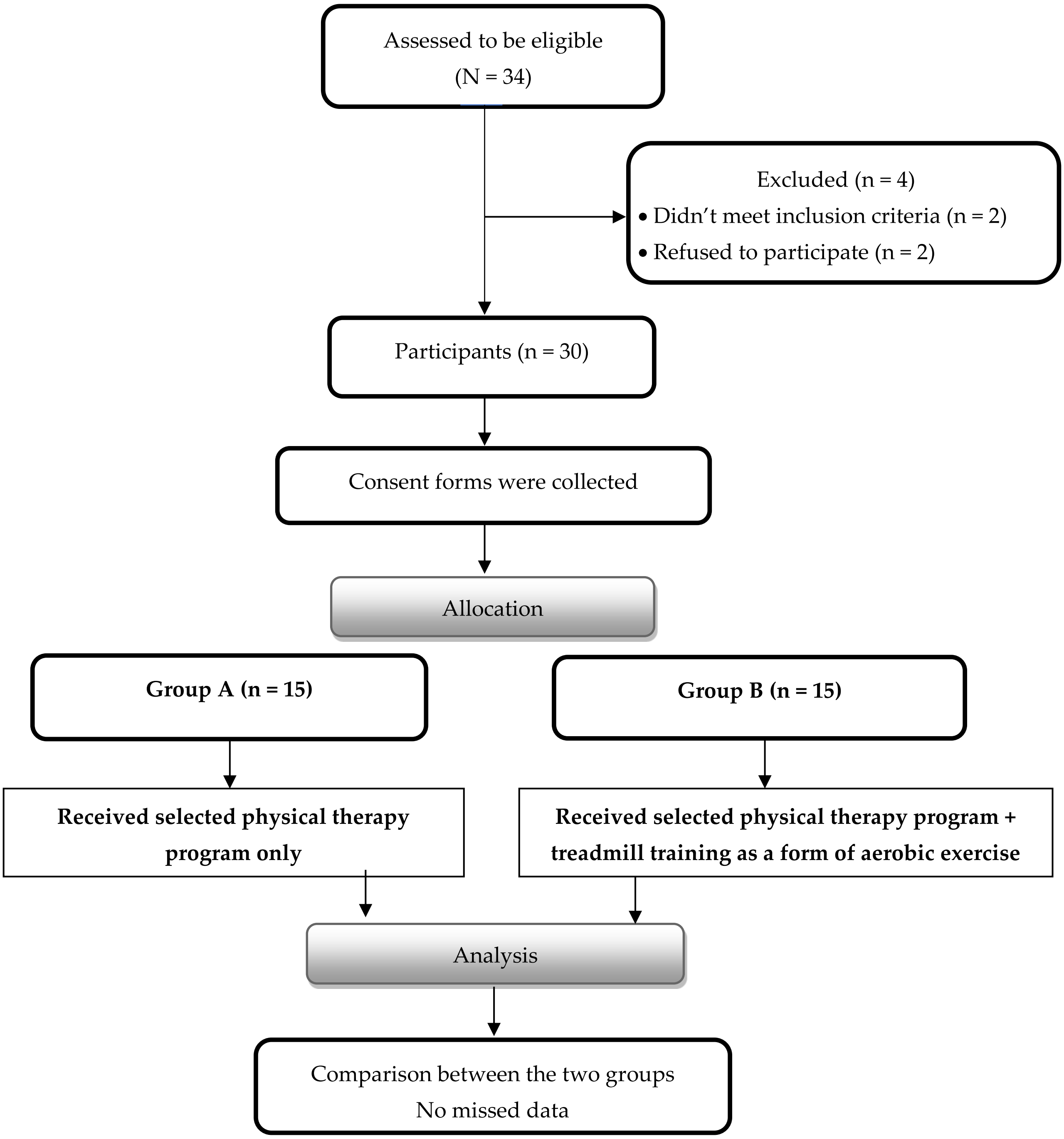

Figure 1. Flowchart illustrating participants entered into the study.

2.3.3. Treatment sessions:

Children in the two groups in the present study received a selected physiotherapy programme; besides, children in the study group received aerobic training by using a treadmill.

The control group (A): This group of children received a selected physiotherapy programme, according to Eid et al. **[12].** The frequency of sessions was 3 times weekly for 3 months in succession. Each session lasted for 1 hour, and each exercise was performed in 3 sets, with 10 repetitions in each set, with 30–60 seconds of rest between each set per session. Each session included balance and postural control exercises for 15 minutes and gait training exercises for 45 minutes. The balance and postural control exercises included maintaining erect standing on a balance board with anteroposterior and mediolateral disturbances and active stooping and recovery from the standing position. The gait training exercises included forward, backward, and sideways walking between two lines and walking with obstacles using different diameters and heights of wedges and rolls.

The study group (B): This group of children received the same treatment programme given to the control group for 15 minutes, plus aerobic training using a treadmill (Phantom AC6069, Taiwan) for 45 minutes. Treadmill training consisted of three phases, which are the warming-up phase, followed by the active phase, followed by the cooling-down phase. The parameters of each phase were adjusted according to Ibrahim and Abdullah **[13].** The warming-up phase was adjusted at a speed of 1.7 km/h for 5 minutes. The active phase was adjusted at a starting speed of 2.7 km/h for 35 minutes (three-minute stages); the speed was raised progressively every 3 minutes by 0.1 km/h. During the cooling-down phase, the speed was returned to 1.7 km/h for 5 minutes.

Before starting the treatment sessions, all children in the study group were familiarized with the treadmill through three familiarization sessions.

During the performance of treadmill training, the following procedures were followed: Each parent was instructed to be in front of his/her child to attract him/her to complete the treadmill training time without any pauses. The therapist stood beside each child and asked him/her to be in the upright posture, put his/her feet on the treadmill belt, look forward as much as possible, close his/her mouth, and breathe from his/her nose. Training started with each child holding the handrails with two hands and then with one hand until he/she was able to walk without support.

Statistical Analysis:

The collected sleep data from groups A and B were analyzed statistically in order to compare the aerobic training impact on sleep troubles in DS children. The mean and standard deviation were calculated as descriptive statistics for all the data. Age, weight, height, and IQ were compared between groups using the Unpaired t-test. To compare the distribution of sexes among groups, the Chi-squared test was utilized. The Shapiro-Wilk test was used to verify the normal distribution of the data. The homogeneity among groups was tested using Levene's test for homogeneity of variances. To compare the CSHQ among groups, the Unpaired t-test was used. The CSHQ was compared in each group before and after treatment using the Paired t-test. For all statistical tests, the level of significance was set at $p < 0.05$. The statistical package for social studies (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA) was used to carry out all statistical analyses.

3. Results:

3.1. Subject Characteristics:

The basic characteristics of the participants in groups A and B are displayed in **Table 1**. There were no obvious differences among groups in age, weight, height, IQ, or sex ($p > 0.05$).

Table 1. Comparison of children's characteristics between groups A and B.

	Group A	Group B			
	Mean ± SD	**Mean ± SD**	**MD**	**t-value**	**p-value**
Age (years)	10.93 ± 1.28	11.07 ± 1.38	-0.14	-0.27	0.78
Weight (kg)	38.27 ± 7.12	37.80 ± 9.36	0.47	0.15	0.88
Height (cm)	130.53 ± 3.20	129.93 ± 3.53	0.60	0.49	0.63
IQ (%)	57.67 ± 6.97	58.80 ± 5.62	-1.13	-0.49	0.62
Sex, n (%)					
Girls	4 (27%)	5 (33%)			
				(χ^2 = 0.16)	0.69
Boys	11 (73%)	10 (67%)			

SD, Standard deviation; MD, Mean difference; χ^2, Chi-squared value; p-value, Probability value.

3.2. Effect of Treatment on CSHQ

3.2.1. Within-group comparison

There were noticeable reductions in bedtime resistance, sleep-onset delay, sleep duration, sleep anxiety, night wakings, parasomnias, SDB, daytime sleepiness, and the total score of group B after treatment in comparison to that before treatment ($p < 0.001$), while there were no noticeable changes in group A ($p > 0.05$), as shown in **Table 2 and Table 3.**

3.2.2. Between-group comparison:

There were no clear variances among groups before treatment ($p > 0.05$). Comparison among groups after treatment revealed a clear decline in bedtime resistance, sleep-onset delay, sleep duration, sleep anxiety, night wakings, parasomnias, SDB, daytime sleepiness, and the total score of group B when compared with that of group A ($p < 0.01$, and all effect sizes were large), as illustrated in **Table 2 and Table 3.**

Table 2. Mean bedtime resistance, sleep-onset delay, sleep duration, sleep anxiety, and night wakings before and after treatment of groups A and B.

	Pre-treatment	**Post-treatment**				
	Mean ± SD	**Mean ± SD**	**MD**	**% of change**	**t-value**	**p-value**
Bedtime resistance						
Group A	14.53 ± 2.85	14.40 ± 2.80	0.13	0.89	1.47	0.16
Group B	13.67 ± 3.44	11 ± 3.38	2.67	19.53	6.01	0.001
MD	0.86	3.4				
t-value	0.75	3.01				
	p = 0.45	***p = 0.006***				
		EF = 1.1				
Sleep-onset delay						
Group A	2.47 ± 0.74	2.40 ± 0.73	0.07	2.83	1.00	0.33
Group B	2.40 ± 0.83	1.60 ± 0.74	0.8	33.33	4.58	0.001
MD	0.07	0.8				
t-value	0.23	2.97				
	p = 0.82	***p = 0.006***				
		EF = 1.09				
Sleep duration						
Group A	5.87 ± 2.07	5.73 ± 2.05	0.14	2.39	1.47	0.16
Group B	5.67 ± 1.76	3.53 ± 0.64	2.14	37.74	6.09	0.001
MD	0.2	2.2				
t-value	0.28	3.96				
	p = 0.77	***p = 0.001***				
		EF = 1.45				
Sleep anxiety						
Group A	10.53 ± 1.51	10.47 ± 1.46	0.06	0.57	1.00	0.33
Group B	10.60 ± 1.64	7.67 ± 1.88	2.93	27.64	6.99	0.001
MD	-0.07	2.8				
t-value	-0.12	4.56				
	p = 0.9	***p = 0.001***				
		EF = 1.66				
Night wakings						
Group A	7.20 ± 0.94	7.13 ± 0.92	0.07	0.97	1.00	0.33
Group B	7 ± 1.51	4.60 ± 0.99	2.4	34.29	8.29	0.001
MD	0.2	2.53				
t-value	0.43	7.29				
	p = 0.66	***p = 0.001***				
		EF = 2.65				

SD, Standard deviation; MD, Mean difference; p-value, Probability value; EF, Effect size.

4. Discussion:

Physical inactivity is widespread among people with DS **[14].** Prolonged sedentary behaviour is linked to a higher chance of insomnia and sleep disturbance **[15].** The current study was carried out to explore the aerobic training effectiveness on sleep difficulties among children with DS. The ages of the participating children in the running study ranged between seven and twelve years. This age range was chosen according to Carter et al. **[16],** who used the CSHQ and found that sleep issues are widespread in school-aged children with DS.

Based on the results of the existing research, there was a clear decrease in bedtime resistance, sleep-onset delay, sleep duration, and night wakings in group B than in group A. These four subscales are related to each other. Kruk et al. **[17]** and Alnawwar et al. **[18]** explained that physical activity stimulates the release of a hormone that regulates the cycles of sleep and wakefulness, which is called melatonin. Therefore, exercise can help one fall asleep more quickly and sleep better. Physical activity also decreases stress, which is a common barrier to falling and staying asleep. Exercise also helps to regulate body temperature, which is important for sleeping since a rise in body temperature during exercise promotes a subsequent decline in body temperature that occurs 30 to 90 minutes after exercise, making it easier to fall asleep. From the previous explanation, sleep duration was improved as a result of the improvement in sleep continuity and the decrease in night wakings.

Because of the limited number of studies that explained the impact of aerobic training on sleep disorders in DS children, we cited the results in another population.

Table 3. Mean parasomnias, SDB, daytime sleepiness, and total score before and after treatment of groups A and B.

	Pre-treatment	**Post-treatment**				
	Mean ± SD	**Mean ± SD**	**MD**	**% of change**	**t-value**	**p-value**
Parasomnias						
Group A	10.27 ± 1.39	10.13 ± 1.41	0.14	1.36	1.47	0.16
Group B	10.93 ± 1.03	8.60 ± 1.06	2.33	21.32	10.04	0.001
MD	-0.66	1.53				
t-value	-1.49	3.37				
	p = 0.14	***p = 0.002***				
		EF = 1.22				
SDB						
Group A	5.53 ± 0.99	5.33 ± 0.90	0.2	3.62	1.87	0.08
Group B	5.27 ± 1.39	3.07 ± 0.26	2.2	41.75	6.20	0.001
MD	0.26	2.26				
t-value	0.61	9.37				
	p = 0.54	***p = 0.001***				
		EF = 3.42				
Daytime sleepiness						
Group A	12.80 ± 1.74	12.67 ± 1.72	0.13	1.02	1.47	0.16
Group B	12 ± 2.73	9.40 ± 1.50	2.6	21.67	5.99	0.001
MD	0.8	3.27				
t-value	0.95	5.54				
	p = 0.34	***p = 0.001***				
		EF = 2.03				
Total score						
Group A	69.20 ± 6.13	68.27 ± 5.55	0.93	1.34	1.76	0.10
Group B	67.53 ± 9.11	49.47 ± 6.82	18.06	26.74	16.02	0.001
MD	1.67	18.8				
t-value	0.58	8.28				
	p = 0.56	***p = 0.001***				
		EF = 3.02				

SD, Standard deviation; MD, Mean difference; p-value, Probability value; SDB, Sleep-disordered breathing; EF, Effect size.

The present findings coincide with the outcomes of the previous study conducted by Mendelson et al. **[19],** who found improvements in sleep duration and quality in the form of sleep continuity and sleep efficiency in obese adolescents after 12 weeks of structured exercise training, which was a mixture of aerobic exercise and resistance training. The current results also accord with the outcomes of the previous research by Brand et al. **[20],** who conducted a pilot study on ten children with autism spectrum disorder whose ages ranged from 7 to 13 years and found that regular aerobic exercise training and motor skill training for 3 weeks improved objective sleep, such as sleep efficiency, wake time after sleep onset, and sleep onset latency, but no variations were noticed for total sleep time or the number of awakenings after sleep onset. The reason for the non-improved parameters may be due to the short intervention period.

The possible explanation of the minor changes that took place in bedtime resistance, sleep-onset delay, sleep duration, and night wakings in group A is that the regular physical activity made the children more active during the day, which built sleep pressure and helped them feel sleepy by bedtime. In the long run, their sleep/wake cycles were regulated.

Other subscales were evaluated in this study: sleep anxiety and parasomnias. Our study's findings revealed that there were apparent decreases in sleep anxiety and parasomnias in group B than in group A. These two subscales are related to each other. Regular physical activity has been proven to provide antidepressant and anxiolytic effects and to guard against the negative effects of stress **[21].** Previous research has demonstrated that physical exercise reduces stress and bad emotions by secreting serotonin and dopamine and increases mental health **[22].**

The existing outcomes are consistent with the outcomes of the previous study by Abd El-Kader and Al-Jiffri **[23],** who found that aerobic exercise training for six months on the treadmill can modify sleep quality and psychological well-being among subjects with chronic primary insomnia.

The slight improvement in sleep anxiety and parasomnias in group A may have occurred due to the improvement in the psychological status of the children as a result of changing their usual environment, which is a home.

The present study discussed another subscale of the CSHQ: SDB. In light of the current study's results, there was a considerable decline in SDB in group B than in group A. There are many explanations that have illustrated how exercise improves SDB; one of these explanations is that a contributing factor to the pathogenesis of SDB has been identified as fluid collection in the lower extremities and its following rostral redistribution during the night. During the day, gravity causes fluid to be retained in the lower limbs' intravascular and interstitial compartments; this fluid then moves toward the head and upper body when one lies down at night. Redistribution towards the neck causes the upper airway's luminal size to decrease and its ability to collapse to increase, which predisposes one to OSA **[24].** A sedentary lifestyle may worsen SDB, as leg skeletal muscle contraction is the key mechanism that prevents lower-limb fluid buildup **[25].** Exercise training can reduce nocturnal rostral fluid shift by activating muscle pumps, reducing fluid displacement to the neck, and potentially preventing OSA **[26].**

Another explanation is that obesity is more common in people with DS, regardless of their age **[27].** High body mass index increases the risk of severe OSA due to the accumulation of fat at the neck's level, which narrows the diameter of the upper respiratory tract during sleep **[28,29].** Obesity in the abdomen and chest wall can limit diaphragmatic expansion and rib cage inflation, respectively **[30].** Physical exercise may reduce the apnea-hypopnea index (AHI) by decreasing fat accumulation in the anatomical structures that surround the airway and tongue **[31].** Exercise can also significantly reduce abdominal adiposity without affecting weight loss **[32].**

The final explanation is that previous research revealed that long-term regular exercise may enhance upper airway muscle activation to improve upper airway diameter, lower airway resistance, and oppose pharyngeal collapse while sleeping **[33,34].**

The present finding comes in accordance with the outcomes of the previous research performed by Kline et al. **[35],** who found that exercise may be helpful for managing OSA in ways other than just aiding in weight loss, as evidenced by the moderate treatment efficacy of exercise training in the form of aerobic activity and resistance training for 12 weeks for decreasing AHI in inactive overweight/obese individuals.

The little decrease in SDB in group A may have happened because of the little improvement in their breathing as a result of increasing their physical activity.

The last subscale of the CSHQ assessed in this study is daytime sleepiness. The outcomes of the existing research proved that there was a considerable reduction in daytime sleepiness in group B compared to group A. Excessive daytime sleepiness is a major symptom of OSA **[28].** It has been linked to fragmented sleep-in patients with OSA due to frequent brain arousals that occur prior to the restoration of breathing **[36].** Sleep deprivation is a major cause of inflammation **[37].** Exercise improves inflammatory markers and may also improve the symptoms of OSA. Exercise reduces excessive daytime sleepiness by reducing inflammatory markers **[38].**

The current result coincides with the findings of the previous research executed by Ackel-D'Elia et al. **[39],** who found that 2 months of aerobic exercise training combined with continuous positive airway pressure treatment for OSA patients positively affects subjective daytime sleepiness. The existing outcome also agrees with the outcomes of the previous research carried out by Schütz et al. **[40],** who observed that two months of isolated physical exercise training in the form of aerobic and resistance exercise were able to modify subjective daytime sleepiness.

The potential explanation of the slight change that occurred in daytime sleepiness in group A is that the regular physical activity kept the children energized, which made them feel less tired during the day.

There were observational findings related to children with DS who enrolled in the current research. The parents of children in the study group observed an improvement in the sleep positions of their children after receiving treatment. Children before receiving treatment were sleeping in abnormal positions, such as sleeping in the sitting position, sleeping in the clamshell posture, or sleeping with a hyperextended neck. After receiving treatment, they could sleep in the normal position (flat). So, aerobic training can also prevent unusual sleep positions in children with DS, which was one complaint of their parents. According to Senthilvel and Krishna **[41],** there may be a connection between sleep postures and OSA, and adopting certain sleep postures may be a self-defense mechanism to prevent airway blockage. From the previously discussed results, there was an improvement in the SDB subscale of the CSHQ in the study group in comparison to the control group, and as the OSA is a form of SDB, it was also improved, resulting in an improvement in unusual sleep postures. In addition to the improvement in sleep positions, parents of DS children in the study group also observed an improvement in the communication skills of their children after receiving treatment.

From the previous discussion of the findings of the current research, we concluded that aerobic training has a positive impact on sleep in children with DS, and this is consistent with what the parents have observed in reality. Additional studies are needed on this topic to confirm our findings with a large number of DS children and to follow up on the long-term effect of the intervention after terminating the program to examine the long-term sustainability of the program. Future studies are also recommended to apply another treatment for sleep difficulties in DS children, apply appropriate therapy for sleep disturbances in DS children who have severe cognitive disabilities, and assess and treat sleep disorders in children in the other high-risk groups.

5. Conclusion:

Aerobic training can improve sleep in DS children, regardless of age and gender. The current result explained that DS children are not only impaired in gross motor, fine motor, and cognitive development but also have defects in their sleep, and this stressed the importance of the early evaluation of sleep issues in DS children in addition to the other problems, as there are few papers that studied this problem in DS children.

Author Contributions: MAB, NAZ, and SSAE formulated the idea, implemented the study design, and carried out the data analysis and interpretation; MAB was responsible for the clinical evaluation of the children, clinical application of the intervention, and writing the manuscript; NAZ and SSAE revised the final draft. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The present study was approved by the Research Ethics Committee of the Faculty of Physical Therapy, Cairo University, Egypt (P.T.REC/012/004243, 11/12/2022).

Informed Consent Statement: Written informed consent for participation in this study was obtained from the parents of the participating children.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Conflicts of Interest: None.

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