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Feasibility of inspiratory muscle training to improve pulmonary and respiratory muscle function, and for attenuating sleep apnea symptoms in children and adolescent with obstructive sleep apnea and obesity: Case report

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ABSTRACT

Background: Studies have demonstrated a potential risk of pulmonary and respiratory muscle dysfunction in individuals with obstructive sleep apnea (OSA) and/or obesity. Inspiratory muscle training (IMT) is an adjunct intervention designed to improve respiratory muscle strength, decrease severity of OSA, and to enhance sleep quality in adults with OSA. However, its effects on children with OSA and obesity are still largely unknown.

Objectives: This case report aims to show the feasibility and the effects of IMT on pulmonary and respiratory muscle function and sleep apnea symptoms of children and adolescents with OSA and obesity.

Case description: Four children and one adolescent who were diagnosed with OSA and classified as obesity underwent IMT with training load at 60% of the individual's maximal inspiratory pressure (MIP) for 12 weeks.

Results: No adverse effects occurred during evaluation and IMT. The participants' compliance with IMT varied from 77.4% to 100%. After 12-week of IMT, MIP and maximal voluntary ventilation (MVV) increased from baseline, varying from 8.0% to 83.5% and 0.1% to 36.1%, respectively. Scores in the Sleep Related Breathing Disorder-Pediatric Sleep Questionnaire (SRBD-PSQ) tended to decrease rapidly at week 3. Thereafter, participants responded differently toward the end of IMT. Changes in pulmonary function variables were not observed.

Conclusion: Improvements in respiratory muscle strength, endurance, and SRBD-PSQ scores occurred after IMT, suggesting the feasibility of IMT for increasing inspiratory muscle performance and for ameliorating sleep apnea symptoms in children and adolescents with OSA and obesity. However, pulmonary function was unaffected by IMT.

Introduction

Obstructive sleep apnea (OSA) is a sleep disorder characterized by partial or total upper airway occlusion that disrupts normal breathing and ventilation during sleep.[1] OSA is associated with morbidities that affect the cardiovascular, neurocognitive, and metabolic systems.[2] A prevalence of OSA, which has been observed as 2-3% in children of normal weight, can increase to 13-59% in cases of obesity.[1,3] In addition, obesity has been shown to be the strongest risk factor for developing OSA due to the contribution of excessive fat deposition on upper airway narrowing, chest wall compliance, and diaphragm function, which consequently reduced lung volume and capacity, and increased airway resistance. Additionally, an increased airway resistance or a reduction in pulmonary compliance which elevated work of breathing

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might cause respiratory muscle dysfunction.[4-6] The coexistence of OSA and obesity have demonstrated a pronounced reduction in vital capacity, forced expiratory volume in 1 second (FEV_1), functional residual capacity, expiratory reserve volume, and total lung capacity of children with obesity. Additionally, this is the case for moderate-to-severe OSA compared to those without OSA.[7] A recent preliminary study found that respiratory muscle strength and endurance of children and adolescents with OSA and obesity were likely to be lower than the controls, but this is not statistically different (all, $p>0.05$).[8] The maximal inspiratory pressure (MIP) of this group, which refers to respiratory muscle strength are comparable to those of children with severe obesity, were inferior to normal weight individuals and thus may be considered abnormal.[9,10] These results suggested a potential risk of pulmonary and/or respiratory muscle dysfunction in children with OSA and/or obesity. Therefore, interventions that preserve airway patency and the passage of oxygen into the lungs, as well as improve pulmonary and respiratory muscle function, are required.

Many options are available to treat OSA including noninvasive positive airway pressure, adenotonsillectomy, drug treatment, oral appliances, and weight loss/exercise. However, such interventions require weighing the pros and cons regarding particular options.[11] The inspiratory muscle training (IMT) which involves breathing exercises using a pressure-threshold device becomes of interest because it has been reported to be a convenient, practical, and time-efficient program that improves MIP, severity of OSA, and sleep quality in adults with OSA.[12] However, it is unclear whether the feasibility and effects of IMT on pulmonary and respiratory muscle function in children and adolescents with OSA and obesity is suitable for those who are more likely to have obstructed airways than adults. The purpose of this case report was to report pulmonary and respiratory muscle function and sleep apnea symptoms in five cases of children and adolescents with OSA and obesity after receiving a 12-week IMT program

Case Description

Four children and one adolescent with OSA and obesity aged 10–16 years were recruited via advertisement and flyers from the Snoring Clinic of Maharaj Nakorn Chiang Mai Hospital. The inclusion criteria were diagnoses of OSA and obesity. The assessment of OSA was performed using polysomnography (PSG) (SOMNOlab-2 AASM sleep diagnostic system, Hamburg, Germany). The subjects were classified as OSA if there was a presence of obstructive sleep-disordered breathing symptoms in combination with an AHI ≥ one episode/hour[13] and classified as obesity based on standard guidelines, respectively.[13,14] The exclusion criteria included the presence of craniofacial abnormalities, underlying conditions that affect pulmonary and respiratory muscle function (e.g., sinusitis, respiratory tract infection, and rib fracture), and medication with neuromuscular side effects. The study protocol was approved by the Research Ethics Committee, Faculty of Associated Medical Sciences, Chiang Mai University (AMSEC-64FB-001) and was registered by ClinicalTrials.gov (Thai Clinical Trials Registry: TCTR20210611007). Written informed consent was obtained from participants and their parents. The participant characteristics are shown in Table 1. Based on the AHI, cases 1, 2, 3, and 5 had mild OSA and case 4 had severe OSA. All male participants had previously undergone an adenotonsillectomy and two of these (case 2 and 5) had allergic rhinitis, while the two females had no history of tonsil or adenoid hypertrophy. They were advised to maintain their usual activities of daily living and physical activity (PA) level was monitored during the study. Routine treatment including counseling for diet, PA, and drug therapy were provided by otolaryngologists. All participants performed the anthropometric variables, MIP, pulmonary function testing (PFTs), and maximal voluntary ventilation (MVV) with a 5-minute intermission between the tests in the laboratory at a temperature of 25 °C and a relative humidity of 50.5±1.3%.

Table 1 Characteristics of participants.

Characteristics	IMT (n=5)				
	Case 1	Case 2	Case 3	Case 4	Case 5
Age (years)	10	13	10	16	10
Gender	Female	Male	Female	Male	Male
BW (kg)	57.1	67.7	49.3	121.3	47.5
Height (m)	1.40	1.55	1.45	1.71	1.39
BMI (kg/m^2)	29.13	28.18	23.45	41.48	24.58
Polysomnography indices					
AHI (events/hour)	2	2.4	3	29	4.6
ODI (events/hour)	1	3.3	5	13	1.6
SaO_2nadir (%)	89	84	84	86	81
MeanSaO_2 (%)	97	97.3	97	97	97.1
Severity of OSA based on AHI	Mild	Mild	Mild	Severe	Mild
History of tonsil or adenoid hypertrophy	No	Yes	No	Yes	Yes
Adenotonsillectomy surgery	No	Yes	No	Yes	Yes
Underlying disease	No	Allergic rhinitis	No	No	Allergic rhinitis

AHI: apnea hypopnea index, BMI: body mass index, BW: body weight, ODI : oxygen desaturation index, SaO_2nadir: oxygen saturation nadir, MeanSaO_2: mean of oxygen saturation, OSA: obstructive sleep apnea

PFTs and MVV were evaluated using the Easy on-PC spirometer, software version V03b (NDD® Medical Technologies, Switzerland), according to the standardized protocols.[15] MIP was measured using a handheld mouth pressure meter (Micro RPM, Micro Medical Ltd., Rochester, Kent, UK) as previous described.[16] The Thai translated 22-items SRBD-PSQ was used to assess sleep related breathing disorders in children.[17] Parents were instructed to complete the survey queries about snoring, daytime sleepiness, and inattention. The SRBD-PSQ score was computed by the number of 'yes' answers divided by the total items answer 'yes' and 'no''. A cut-off value of 0.33 is used to identify pediatric OSA. The intra-rater reliability of MIP, PFTs, and MVV were good to excellent (the intraclass correlation coefficient, ICC>0.9, all p<0.05), except $FEF_{25-75\%}$ which was moderate (ICC=0.642, p=0.109). Body weight and percent body fat were determined using a bioelectrical impedance analyzer (Tanita BC-418, Tokyo, Japan). Height was measured using a wall-mounted stadiometer (Health-O-Meter 402 KL, IL). The validated Thai Physical Activity Questionnaire for Children and Adolescents (PAQ-A/C) was used to evaluates level and frequency of moderate to vigorous PA over the last 7 days of participants.[18] Children and adolescents completed the questionnaire by scoring the 10-item of PAQ-C and the 9-item of PAQ-A, respectively on a five-point Likert scale (5 score = higher level of PA; 1 score = lower level of PA). The summary score is the average of all question items except the last item of each PAQ that asking for other reasons that prevented the participant from engaging in regular PA. Outcomes were measured by two independent assessors at baseline and follow-ups at weeks 3, 6, 9, and 12. At baseline, the percent predicted of FVC and FEV_1, as well as MIP and MVV of our participants was found to be lower than the references values of the children and adolescents of the same age and gender of previous studies, suggesting deficits in pulmonary and respiratory muscle function.[10,19]

Participants underwent IMT using the Powerbreathe® classic light resistance (POWERbreathe® International Ltd., Warwickshire, UK). The training protocol was comprised of a 12-week home-based IMT with an initial load at 60% of the individual's MIP as recommended by previous studies.[20,21] Previous findings indicated the beneficial effects of 8-week IMT for improving the severity of OSA and sleep quality and excessive daytime sleepiness in patients with OSA.[11,20] However, a longer period effect of IMT on the severity of OSA and respiratory muscle function have never been investigated. Each participant was asked to practice IMT at the laboratory for familiarization, and heart rate (HR) was monitored. Participants were encouraged to breathe deeply and slowly. Oxygen saturation (O_2sat) and rate of perceived exertion (RPE) were measured throughout the first training session. Training loads were adjusted at every 3-week follow-up, corresponding to 60% of the new measure MIP and a symptom-limited was imposed. The training program was supervised by a professional physiotherapist. Participants were instructed to perform 80 breaths per day (10 breaths per cycle with a 1-minute rest interval for 8 cycles), 7 days a week for 12 weeks. To promote exercise adherence and safety status, each participant received a logbook to record the exercise sessions and any adverse effects that might have occurred during or after each exercise session. Adherence to the program was done via daily phone contact and/or LINE application. Flow diagram of participants throughout this study is shown in Figure 1. At the first training session, IMT caused an increased effort from RPE 0 to 4 with HR of 84 beats per minute (bpm) and O_2sat of 98% for participant case 1. Similar response of RPE with HR of 78 bpm and O_2sat of 99% for participant case 2. IMT caused an increase in RPE from 0 to 2 with HR range of 74-86 bpm and O_2sat range of 97-99% for participants case 4 and 5. Only participant case 3 had increased in RPE from 0 to 1 with HR of 75 bpm and O_2sat range of 98-100%. The initial resistive load for IMT varied among participants and the training load tended to increase by time range of 14.3- 80%, except for participant case 5 who had a constant load at 50 cmH_2O from week 3 to week 9 and increased to 60 cmH_2O for the last three weeks (Table 3). Chest pain was reported during training at the end of week 10. After decreasing training load to 50 cmH_2O, the patient could perform IMT without chest pain until week 12. During the same time, a patient went to see the doctor and was diagnosed as having recurrent adenoid hypertrophy. He has planned to do have an adenoidectomy in a few months.

Table 3 Resistive load and training volume for inspiratory muscle traning of each participant.

	Case 1				Case 2				Case 3				Case 4				Case 5			
	wk3	wk6	wk9	wk12	wk3	wk6	wk9	wk12	wk3	wk6	wk9	wk12	wk3	wk6	wk9	wk12	wk3	wk6	wk9	wk12
Load (cmH_2O)	50	70	70	90	40	50	60	60	50	60	60	70	70	80	80	80	50	50	50	60→50
Vol (breaths)	1,600	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,120	1,360	1,040	1,680	1,680	1,680	1,200
Adherence rate	98.8%				100%				100%				77.4%				92.9%			

Vol: volume, wk: week

Noted: Participant case 5 had chest pain during training at week 10, therefore the training load was reduced from 60 cmH_2O to 50 cmH_2O.

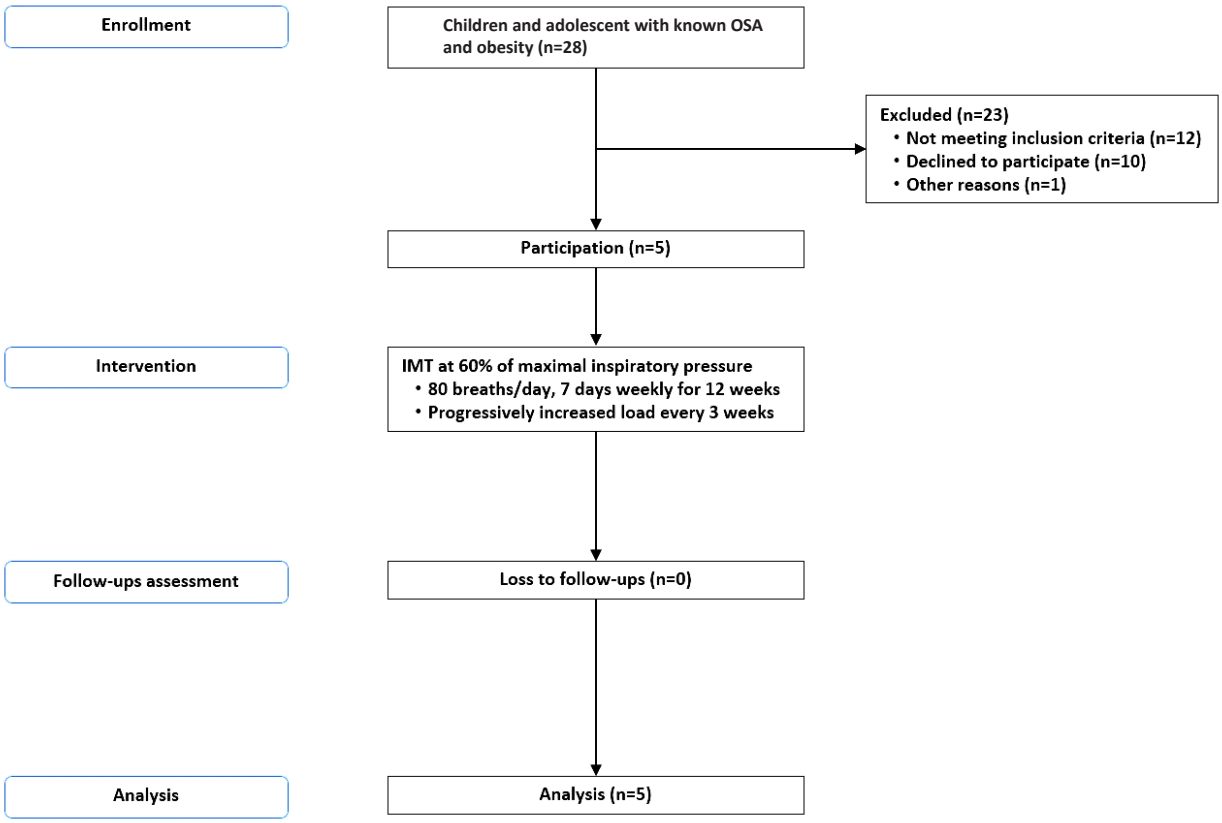

Figure 1. *Flow diagram of participants throughout intervention.*

After 12 weeks of IMT, most participants achieved adherence rate range of 92.9-100%, except participant case 4 who had low adherence to IMT (Table 3). Mean changed from baseline of MIP was 18.2 cmH_2O (20.04%), 25.6 cmH_2O (28.2%), 37.2 cmH_2O (41%), and 37.2 cmH_2O (41%) at weeks 3, 6, 9, and 12, respectively (Figure 2). Notably, MIP of participant case 5 almost unchanged from baseline values throughout the period of study. Mean changed from baseline of MVV was 4.1 L (7.1%), 2.1 L (3.6%), 4.5 L (7.8%), and 6.2 L (10.7%) at weeks 3, 6, 9, and 12, respectively (Figure 3). Sleep apnea symptoms were measured using SRBD-PSQ scores with a cut-off value of 0.33 revealed that almost participants were at high risk of OSA, except participant case 1 who had non-risk at baseline. According to the SRBD-PSQ score, participants 3 and 4 are defined as non-OSA risk after IMT at week 3 and participant case 2 at week 9. A decreased SRBD-PSQ score was observed from week 3 through the end of the study period. However, participant case 5 still had OSA (Figure 4). Variables of PFTs, anthropometry, and PAQ-C scores of all participants did not change in each period of training compared to the baseline value (Table 2). Four of the five participants informed us of their willingness to continue training after IMT completion. Some parents reported improvement of children in terms of reduced snoring after IMT.

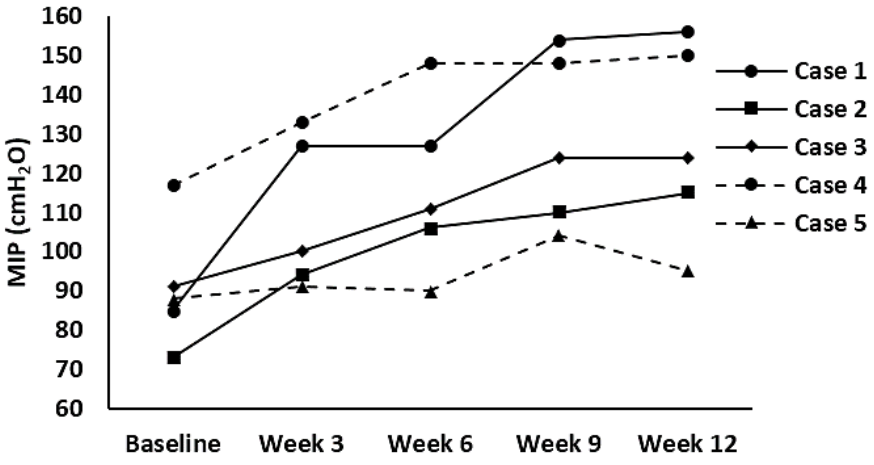

Figure 2. *Changes in the MIP from baseline to 12 weeks of IMT.*

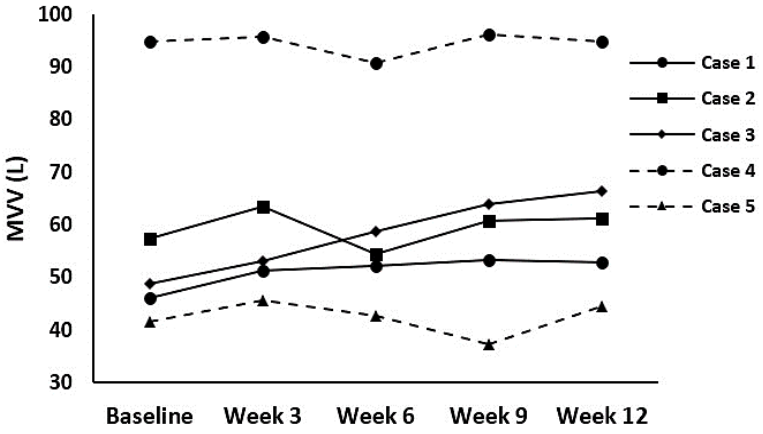

Figure 3. *Changes in the MVV from baseline to 12 weeks of IMT.*

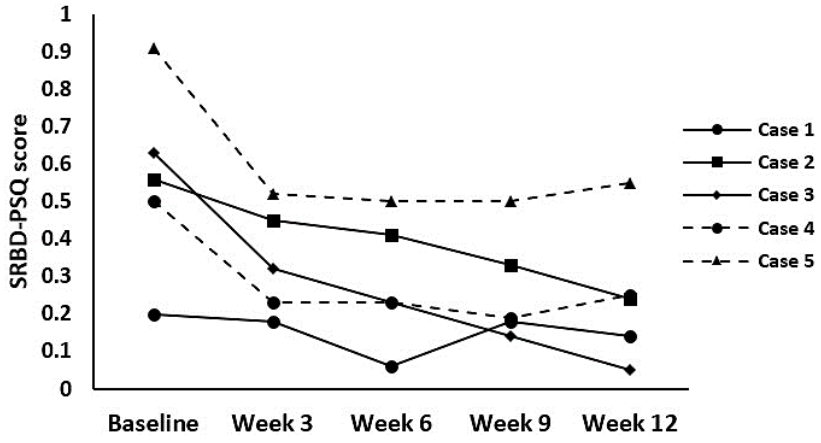

Figure 4. *Changes in the SRBD-PSQ from baseline to 12 weeks of IMT.*

Table 2 Changes in variables of pulmonary function, anthropometry and physical activity from baseline to 12 weeks of IMT.

	Baseline	Post-training			
		week 3	week 6	week 9	week 12
Pulmonary function variables					
FEV_1 (L)	2.39	2.41	2.45	2.45	2.41
	(-0.16-4.95)	(-0.01-4.82)	(-0.04-4.94)	(0.05-4.85)	(-0.16-4.99)
FVC (L)	2.80	2.86	2.90	2.87	2.82
	(-0.69-6.29)	(-0.57-6.28)	(-0.62-6.43)	(-0.49-6.22)	(-0.67-6.31)
FEV_1/FVC	0.876	0.863	0.865	0.873	0.874
	(0.71-1.04)	(0.70-1.03)	(0.71-1.02)	(0.72-1.02)	(0.73-1.01)
FEF25-75% (L)	2.72	2.71	2.82	3.00	2.87
	(0.97-4.46)	(1.54-3.88)	(1.64-4.00)	(2.10-3.89)	(1.39-4.35)
Anthropometric variables					
BMI (kg/m^2)	31.35	31.57	31.87	32.28	32.15
	(8.45-54.26)	(8.90-54.24)	(9.35-54.40)	(10.74-53.83)	(10.88-53.43)
PBF (%)	39.37	42.73	36.80	43.77	42.80
	(27.83-50.91)	(27.94-57.53)	(21.37-52.23)	(31.55-55.98)	(30.74-54.86)
Physical activity					
PAQ A/C score	1.82	2.21	2.17	1.99	2.16
	(0.27-3.38)	(0.51-3.92)	(-0.08-4.43)	(1.24-2.74)	(0.24-4.07)

Results are shown as mean and 95% confidence interval (CI), BMI: body mass index, FEF25-75%: forced expiratory flow between 25% and 75% of FVC, FEV1: forced expiratory volume in 1 second, FVC : forced vital capacity, PAQ A/C: Physical Activity Questionnaire for Children and Adolescents, PBF: percent body fat.

Discussion

Our findings showed the positive effects of the 12-week home-based IMT program on MIP, MVV, and SRBD-PSQ scores, but not for the PFTs variables. Aside from the main purposes, the observed BMI and PAQ (A/C) scores which were not altered throughout the study, affirmed that PA and BMI did not affect any positive results. These results indicated the feasibility of IMT to increase inspiratory muscle strength and endurance and for mitigating OSA symptoms in children and adolescents with OSA and obesity. In this study, initial training load varied among participants according to his/her health condition, age and gender, however IMT should be done with a symptoms limit. IMT caused an increase in RPE ranging from 1 to 4 which represented the effort as being very easy to somewhat hard and did not induce a marked decrease in O_2sat during loaded breathing. No adverse events were reported throughout the training period, except for participant 5, who experienced sharp pain on inspiration at the end of week 10. However, such a symptom immediately disappeared after reducing the training load and maintaining that load for the rest of the training period. Thus, the 12-week home-based IMT protocol of the present study was shown to be feasible and safe for further study.

In this study, the MIP was increased to week 9 of the IMT and further training up to week 12 resulted in less improvements. This was consistent with previous findings which had performed IMT for patients with chronic lung disease and healthy subjects. They found that benefits are likely to be optimal with 6-8 weeks of training.[21,22] Likewise, the MVV was increased with time, but to a lesser extent than MIP. This discrepancy may be explained by the principle of pressure-flow specificity of IMT which is proposed by Romer *et al*.[22] Moreover, each participant exhibited increased MIP and MVV at different rates, although four of five participants had mild OSA and one had severe disease (participant case 4). This reason for this discrepancy could not be determined, but could possibly be explained by the underlying disease, gender, and adherence to IMT. Three participants were male who had adenotonsillectomies prior to participating in the study, and two of them had rhinitis. At week 10 of training, one of them had recurrent adenoid hypertrophy, while participant case 4 had the lowest adherence rate of training. Such information may help researchers in designing and conducting a subsequent randomized controlled trial to establish efficacy of IMT. According to SRBD-PSQ scores, two participants were defined as non-OSA after IMT at week 3 and one at week 9. Another one showed a decrease of SRBD-PSQ scores at week 3, but OSA remained till the end of the study. These results suggested that IMT possible attributed to reduced symptoms of OSA. However, one participant was identified as non-SRBD from the beginning to the end of the study period. The inconsistent results of SRBD-PSQ score among participants suggested that further study using standard equipment such as polysomnography that assesses OSA symptoms more accurately would be more valid than SRBD-PSQ.[19]

There are several limitations in this case report that should be emphasized. The absence of a study arm involving a sham IMT intervention is relevant. Therefore, no causal inferences could be made about the IMT effects. A pilot study is warranted prior to implement on a larger scale. In addition, our IMT trial was performed on five participants who had different underlying diseases, gender, and severity of OSA. Therefore, these factors may have possibly contributed to the outcomes. Finally, a study of the long-term effects of IMT is needed to identify the optimal IMT protocol and to investigate the responses of all outcome measures.

Conclusion

Positive outcomes in inspiratory muscle strength and endurance, and SRBD-PSQ score after IMT, suggesting that IMT can be trained with the improvement of respiratory muscle function and OSA symptoms in children and adolescent with OSA and obesity.

Conflicting interests

The authors declare no conflict of interest.

Ethical approval

All procedures performed in this study involving human participants, were in accordance with the ethical standards of the institutional and/or national research committee and the 1964 Helsinki Declaration and its later amendment or comparable ethical standards. This study was approved by the Research Ethics Committee, Faculty of Associated Medical Sciences, Chiang Mai University.

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