Outcomes of an Advanced Practice Nurse–Led Respiratory Muscle Weakness Prevention Program among People with Ventilators: A Quasi–Experimental Study

Tarntana Supreeyatitikul, Apinya Siripitayakunkit, Naparat Amornputtisathaporn*

Abstract: People with ventilators are at risk of limb and respiratory muscle weakness, affecting functional status and health service costs. Evidence has shown that early mobility and inspiratory muscle training positively affect respiratory muscle strength. However, there is limited research on this topic in Thailand. Thus, this quasi-experimental study aimed to test the effectiveness of a 2-week Respiratory Muscle Weakness Prevention Program on clinical outcomes among people with ventilators led by an advanced practice nurse. Forty-nine participants were recruited from two medical intensive care units and one sub-medical intensive care unit of a university-affiliated hospital in Bangkok, Thailand, from February to September 2023. The first 25 participants were in the comparison group and completed data collection. After that, 24 participants were recruited to the experimental group and received the program. Clinical outcomes were measured by maximum inspiratory pressure, ventilation duration, weaning duration, weaning success, intensive care unit length of stay, hospital length of stay, and health service costs. Data were analyzed using descriptive statistics, independent t-test, Mann-Whitney U test, Chi-square test, Fisher's exact test, two-way repeated measures analysis of variance, and multivariate analysis of variance.

Results revealed that the experimental group significantly increased mean maximum inspiratory pressure and weaning success compared to the comparison group. The mean ventilation duration, weaning duration, intensive care unit length of stay, hospital length of stay, and health service costs in the experimental group were significantly lower than those in the comparison group. This study highlighted the benefit of an advanced practice nurse in implementing the Respiratory Muscle Weakness Prevention Program, which is evidence-based for people with ventilators. Thus, policymakers should establish the position of advanced practice nurses for people with complex problems. However, further study in other settings with a larger sample is needed before the program can be widely used.

Keywords: Advanced practice nurse, Health service costs, Maximum inspiratory pressure, Prevention program, Respiratory muscle weakness, Ventilator duration

Received 1 February 2025; Revised 19 April 2025; Accepted 21 April 2025

Author contributions:

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DOI: https://doi.org/10.60099/prijnr.2025.273422

Introduction

People with ventilators (PW-Vs) are often prone to limb and respiratory muscle weakness.[1] After an ongoing ventilator for 2-3 days, the respiratory muscle will be decreased in force-generating capacity due to muscle injury, myofibrillar damage, proteolysis, and atrophy.[1-4] The prevalence of respiratory muscle weakness (RMW) during liberation ventilation ranges from 25% to 63%.[2] RMW occurs twice as frequently as limb muscle weakness.[1] The RMW is related to the complicated weaning from ventilation,[3-4] extubation failures,[5] prolonged ventilator-dependence,[6] and increased mortality risk within one year.[1,4] Therefore, prolonged ventilation affects physical and psychological status, treatment costs, and quality of life.[4,7] Thus, shortening ventilation and weaning duration by preventing RMW is the goal in caring for PW-Vs.

Growing attention in PW-Vs has been placed on evidence-based practice that utilizes a combined rehabilitative approach to improve the weaning process and reduce ventilator duration.[8-9] Previous studies demonstrate respiratory rehabilitation interventions in PW-Vs, including conventional chest physiotherapy, airway clearance techniques, automatic mechanical system support, early mobility (EM), and inspiratory muscle training (IMT).[9-10] Most studies implemented those interventions with only one approach or combined either EM or IMT with the conventional approach.[9-10] Furthermore, respiratory muscle training is not yet the standard practice in many intensive care units (ICUs) worldwide.[3,7]

RMW prevention and treatment need novel approaches, e.g., combined interventions;[11] however, that approach may be challenging to employ. For example, there were some limitations in adopting the EM approach alone in the ICU, even though some meta-analyses and guidelines recommend the benefit of the EM approach on critically ill patients[12] because PW-Vs have a complex interplay between disease severity, hemodynamic variability, treatment strategies, and the organizational factors, e.g., nurse shortages, and time constraints.[12] Some considerations for developing the combined approach in the ICU due to PW-Vs involve safety concerns, risk assessment, ongoing clinical support, and intensive evidence-based practice interventions.[12] An advanced practice nurse (APN) plays a vital role in improving outcomes. APNs have clinical specialty skills and competencies, can coordinate care effectively with healthcare providers, develop and support, monitor the use of evidence, and significantly impact favorable outcomes.[13] Therefore, in this study, we developed and implemented a Respiratory Muscle Weakness Prevention Program (RMW-PP) synthesized from previous studies and tested its effectiveness. This program benefits PW-Vs in improving inspiratory muscle strength, ventilator duration, weaning duration, weaning success, ICU and hospital length of stay (LOS), and health service costs.

Conceptual Framework and Literature Review

Literature reviews incorporated evidence-based practice (EBP) development, APN competencies, and evidence on RMW prevention in the ICU, which served as a conceptual framework for this study. An EBP integrates the best evidence for systematic problem-solving and clinical practice decisions to improve clinical practice and health outcomes. Translation of the new EBP into practice requires obtaining relevant information from databases.[14] It is essential to critically appraise research and determine the validity and applicability of findings. One of the appraisal tools is the Johns Hopkins Evidence-Based Practice Model rating system.[15] Five levels of evidence, including Level I, indicate the evidence from an experimental study, randomized controlled trials (RCTs)/systematic reviews of RCTs, with or without meta-analysis. Level II is the evidence from a quasi-experimental study, a systematic review of a combination of RCTs and quasi-experimental studies, with or without meta-analysis. Level III includes non-experimental, exploratory, convergent,

or multiphase mixed methods and qualitative studies. Level IV consists of opinions of respected authorities and/or nationally recognized expert committees or consensus panels based on scientific evidence. In addition, Level V includes scoping reviews, integrative reviews, case reports, and opinions of nationally recognized experts based on experiential evidence.[15] The development of EBP needs to be translated into practice. It requires APNs who are at least master's prepared, can offer specialized care, and serve as change agents in the context of high healthcare needs.[16]

APN care has impacted patient outcomes regarding health status, decreased hospitalization, and health service outcomes.[13] The reasons for accomplishing this are that APNs can work and coordinate with other healthcare teams and can manage and enhance adherence to EBP protocol through substantial knowledge and research skills encompassing patient-centered care to ensure the highest standards and quality of care. APNs have several competencies, including clinical care, education, mentoring, coaching, and empowerment, that are value-added to accomplish favorable outcomes.[17] In developed countries, APNs affect the management of outcomes in various populations (diabetes, heart failure, and cancer) and different settings, e.g., primary care, transitional care, and long-term care,[13] as evidenced in Thailand. However, critical care settings have plenty of room for APNs to demonstrate their effectiveness in dealing with people with complex problems, such as those receiving ventilation.

PW-Vs may have difficulty weaning from prolonged ventilation due to the disuse of respiratory muscles within 72 hours after using the ventilator.[1-2] Inadequate management can affect patient outcomes and quality of care. It may increase economic costs from the prolonged ventilator and hospital stays.[3] Few studies have been conducted in ICUs in Thailand to prevent ventilation complications, including RMW.[18-20] The EM approach has been utilized, and the outcomes consisted of ventilation duration,[18] limb muscle strength,[19] orthostatic hypotension,[20] and maximum inspiratory pressure (MIP).[20] There had been no cost-effectiveness study or combination program to prevent RMW on PW-Vs in Thailand. Only one study demonstrated a favorable outcome for inspiratory muscle strength measured by MIP and had very low adverse events. Still, the program's acceptability from nurses and relatives was moderate due to the nurses' fear of the program's adverse events. In contrast, the relatives refused to participate due to the misconception that PW-Vs were not ready for EM.[20] Therefore, RMW prevention in the ICU has limited management, and care improvement may not be achieved. To prevent PW-Vs complications, an APN (the primary investigator: PI) developed the RMW-PP based on EBP abroad and in Thailand. A meta-analysis analyzing the characteristics of the programs found that the IMT is an appropriate approach to reduce weaning duration, and EM was found to reduce ventilation duration.[10] The RMW-PP should be applied within 1-5 days after admission to ICU. The IMT with threshold loading enhanced respiratory muscle strength by increasing respiratory muscle fibers.[21-22] The RMW-PP was a combined approach led by an APN. There is a need to test and evaluate the RMW-PP's effectiveness.

Aim and Hypotheses

This study aimed to examine the outcomes of the RMW-PP led by an APN for PW-Vs. The hypotheses were 1) the MIP of the experimental group would be higher than that of the comparison group at weeks 1 and 2 from baseline, 2) the weaning and ventilator duration, ICU, and hospital LOS of the experimental group would be shorter than those of the comparison group, 3) the weaning success rate of the experimental group would be higher than that of the comparison group, and 4) the health service costs in the experimental group would be lower than those of the comparison group.

Methods

Design: This study used a non-equivalent quasi-experimental design with a before-and-after research design and repeated measures. To prevent data contamination, we conducted the study in the comparison group first, and after completion, the experimental group received the program. This paper followed the TREND

(Transparent Reporting of Evaluations with Nonrandomized Designs) as a reporting guideline.

Sampling and Setting: This study was conducted at the two medical ICUs (MICU) and one sub-MICU of a university-affiliated hospital in Bangkok, Thailand. The two medical ICUs have 14 beds serving people with moderate and severe lung injury or hemodynamic instability. The nurse-to-patient ratio was 1:1. Also, the sub-MICU has an 18-bed service for those with mild respiratory problems who need close monitoring. The nurse and patient ratio was 1:2. The PI personally collected data from this research setting in 2022 and found that 75% were PW-Vs, with a ventilator duration average of 6-9 days; 20% were PW-Vs who had difficulty weaning, and some had failed to extubate three times. The inclusion and exclusion criteria for the participants who were using the ventilators for at least 24 hours are listed in **Table 1**. Terminal criteria were discontinued over two days of the program, transferred to any chest rehabilitation program, transferred to palliative care, or died, and the program was intended to discontinue. The sample size was determined based on a significance level of 0.05 and a test power of 0.80. The effect size was calculated from a previous study that conducted IMT on weaning duration.[23] A large effect size of 0.93 for an ANOVA test with repeated measures was used within-between interaction in the G*power analysis version 3.1.9.4 software (for two groups, with three times for measurement). The study sample size was 24 participants per group. To compensate for the attrition rate of 25%,[6] which equals six participants, we required participants up to 30 for each group. Three hundred thirty-three eligible PW-Vs were admitted from February to September 2023. To ensure that both groups were nearly equivalent in baseline characteristics, matching methods were used with the age ranges of participants that did not differ by more than five years in both groups. The number of days using ventilators before admission to the ICU was divided into three categories: less than seven days, 8-20 days, and more than 21 days. The sample flow charts throughout the study are shown in **Figure 1.** The attrition rate of the experimental group was 20%, whereas the attrition rate of the comparison group was 16.66%. Both attrition rates are considered to be at a low risk of attrition bias.[26] Also, the PI confirmed that the post hoc power analysis (β) value was equal to 0.94.

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria

- aged between 18-85 years old
- able to tolerate an upright position between 30-45 degrees
- alert and good corporation determined by a Richmond Agitation Sedation Score (RASS),[24] the score of 0—alert to -3—eye-opening to voice this screening tool was translated into Thai by Pipanmekaporn et al.[25]
- hemodynamic stability by having a systolic blood pressure (SBP) of 90-180 and/or mean arterial pressure (MAP) ≥ 65 mmHg
- no life-threatening cardiac arrhythmias
- were in a stable respiratory condition with the capability of breathing with assisted-controlled ventilation mode indicated by
  - respiratory rate ≤ 25 breaths/min
  - SpO2 ≥ 90% during activity
  - Fraction of inspired oxygen (FiO2) ≤ 0.6
  - Positive end expiratory pressure (PEEP) ≤ 10 cmH_2O
  - pressure support ventilation (PSV) mode with pressure support ≤ 15 cmH_2O
	- using a home ventilator
	- bedridden
	- pregnancy
	- history of neurological diseases
	- having neck or extremity fracture/surgery or post-abdominal surgery within 12 months
	- use of continuous renal replacement therapy
	- using extracorporeal membrane oxygenation
	- under any positioning that is related to the treatment regimen e.g., prone position for better oxygenation

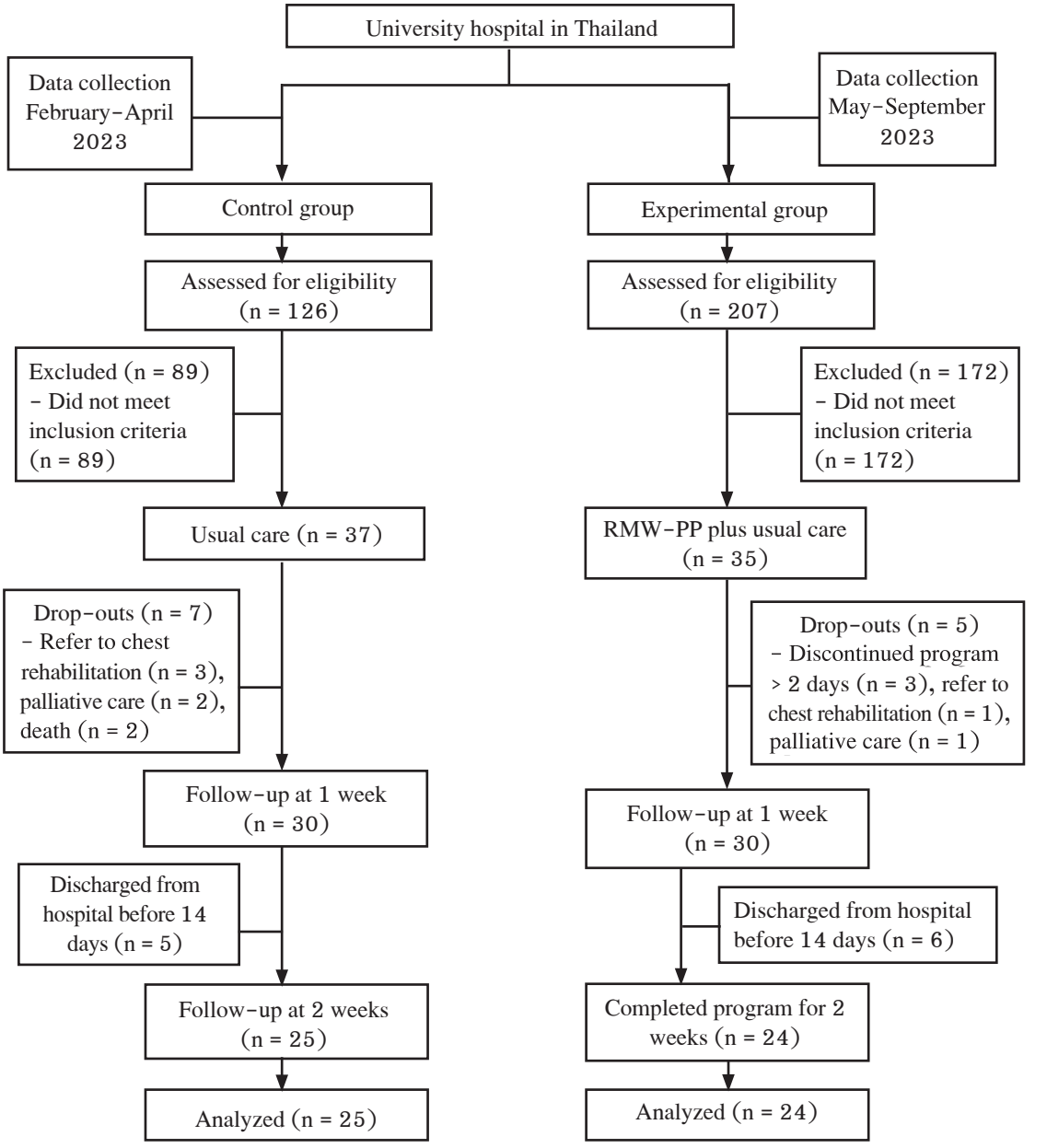

Figure 1. Flow chart of the participants throughout the study

Ethical Considerations: This research was approved by the Institutional Review Board (IRB) on Research Involving Human Subjects, Faculty of Medicine Ramathibodi Hospital, Mahidol University, with code no. MURA2022/749 and MURA2024/215. All participants and families were informed regarding the research objectives, procedures, benefits, and their rights to participate, refuse, or withdraw from the study at any time without any effects on the treatment and care they would receive from the hospital. The risks

related to the dislocation of endotracheal tubes or lines were informed; however, the PI would secure the medical equipment before starting the RMW-PP. All surrogate relatives were asked for written informed consent. The participants' information was kept confidential, reported anonymously, and used only for research purposes.

Research Instruments: The instruments were in two parts: the instrument for data collection and the RMW-PP. All instruments were validated by a panel of three experts: a critical care physiotherapy physician and two critical care nursing instructors.

The Patient Health Data Form included 1) demographic data, e.g., gender, age, marital status, educational background, and health schemes; 2) health data comprised of admission date, ICU admission date, intubation date, ventilation duration (the total days using the ventilator until discontinuing it), weaning duration (the date beginning to spontaneous breathing until discontinuing ventilator), functional status before admission, causes of admission, Acute Physiology and Chronic Health Evaluation II score, underlying associated to RMW, body mass index, medication-induced RMW, LOS in ICU, and hospital. The experts agreed with the parameters that the PI planned to collect.

A manometer, which underwent yearly quality checks by the Medical Devices Service of the research hospital, was used to measure the maximum inspiratory pressure (MIP)—the negative inspiratory force that reflects respiratory muscle function and strength. The MIP is one of the standard measurements used to determine the need for a ventilator, and it is measured according to the protocol.[27] The normal MIP value is 90 to 120 cmH_2O in ordinary people; for those who use ventilators, the appropriate MIP value is between 20 and 30 cmH_2O. A MIP value of more than 30 cmH_2O indicates a successful weaning probability. Daily MIPs in this study were measured three times, and the highest value of MIP was recorded. The PI and the chest physiotherapist in the chest clinic of a research hospital measured the MIP 15 times each. The intraclass correlation coefficient (ICC) is the degree of correlation and agreement between measurements.[28] The ICC in this study was 0.998, indicating excellent reliability.

Weaning success was defined as the number of PW-Vs that could have endotracheal tubes removed without reintubation within 48 hours, compared to the total number of PW-Vs who were weaning from ventilators in each group.

The Health Service Costs Record Form collected the total direct service costs, including 1) nursing service costs, 2) ICU room and board, 3) depreciation expenses, and 4) medical equipment costs. The PI recorded and collected the cost data, which started when PW-Vs were admitted to the ICU and continued until discharge from the hospital. The experts agreed with the items that the PI planned to collect.

Respiratory Muscles Weakness Prevention Program (RMW-PP) and Implementation

The PI developed the RMW-PP by synthesizing and integrating evidence-based knowledge from practice, including five randomized clinical trials,[6,21-22,29-30] three systematic reviews and meta-analyses,[8-9,31] one metameta-analysis,[32] a quasi-experimental study with a one-group, pretest-posttest design,[20] and the consensus of four experts.[12,33-35] All evidence was rated for its evidence level using the Johns Hopkins Evidence-Based Practice model rating system.[15] The RMW-PP is a 2-week, twice-daily activity concurrent with EM and IMT. The RMW-PP consists of three stages: (i) Preparedness for patient safety before starting the program, (ii) Supporting and strengthening respiratory muscles, and (iii) Encouraging continuity to enhance EM and Threshold IMT. The same three experts validated the RMW-PP by assessing the program's content, activities provided, arrangement, and duration, and the program was adjusted following the recommendations of the experts. The PI piloted the RMW-PP with three PW-Vs with characteristics similar to the main study. The details of RMW-PP content,

activities provided, duration, arrangement, and implementation are in **Appendix, Table A1.**

Usual care: PW-Vs received care bundles based on evidence-based practice to prevent ventilator-acquired complications, including ventilator-associated pneumonia (VAP) bundles—WHAPO: W = weaning patient, H = Hand washing, A = Aspiration prevention, P = Prevention contamination in the ventilation circuit, and O = Oral care. Also, the PW-Vs received basic nursing care for mobility, including side-to-side turning, head-of-bed elevation, no specific plan for early and intensive mobility, and respiratory muscle strength restoration. Sedation and analgesia were administered based on the PADIS guidelines—prevention and management of pain, agitation/sedation, delirium, immobility, and sleep disruption in patients in the ICU. Nurses individually started mobility according to their experiences. Usually, they did this after the PW-Vs had no critical conditions or extubation. If the PW-Vs tended to have difficulty weaning, the physician would consult physiotherapists. The IRB suggested that the PI use active control in operating, which poses fewer ethical and practical problems. Hence, the PI offered a booklet and educated them about deep breathing exercises. The participants in the comparison group practiced deep breathing exercises on their own, assuming they were not harmed.[36]

Data Collection: The PI was trained using the threshold device and method of measuring MIP with a physiotherapist at the Faculty of Medicine Ramathibodi Hospital, Mahidol University, for three weeks. This study was conducted after IRB approval from February to September 2023. The nurses in the ICU introduced the PI to the potential participants. The PI implemented the RMW-PP and collected all patient health data at baseline, the daily EM level, and mean threshold loading values. MIP at three time points: initial program, during a program at one week, and immediately after the program ended at two weeks. The ventilator and weaning durations, LOS in ICU and hospital, and health service costs were collected at two time points.

Data Analysis: Data were analyzed using a statistical software program. The patient health data were analyzed using descriptive statistics. To compare the difference between the two groups at baseline, an independent t-test was employed for continuous data, while the Mann-Whitney U test, the Chi-square test, and Fisher's exact test were used for non-normal distribution or categorical data. The means of MIP at baseline and weeks 1 and 2 were compared with two-way repeated measures ANOVA. The assumption was tested. Data indicated a test of sphericity violation assumption, so the Greenhouse-Geiser Epsilon was used to report the results. Multivariate analysis of variance (MANOVA) was used to simultaneously evaluate differences across two dependent variables, the ventilation, and weaning duration because these two dependent variables are correlated ($rs = 0.76$, p-value < 0.001). Tabachnick and Fidell suggest that the correlation (r) between variables should not be above 0.90.[37] The Shapiro-Wilk test was used to assess the normality assumption; however, the data violated this assumption; therefore, a logarithm transformation was then used to adjust the normal distribution. The Box's M test was nonsignificant (p-value = 0.034), indicating that the dependent variables' covariance matrices are equal across groups. Levene's test of homogeneity of variances was met, so the data passed the three assumptions of MANOVA. Wilks' Lambda statistical value was reported because it is suited to small sample sizes. Fisher's exact test was used to analyze the proportion of PW-Vs in both groups for differences in weaning success.

Results

Of the 49 participants, 24 were in the experimental group, and 25 were in the comparison group. Both groups were between 43 and 84 years old, and the personal characteristics and health data showed no statistically significant differences ($p > 0.05$), as shown in **Table 2.** Before implementing the RMW-PP, the PI (APN) assessed the participants' readiness daily. The participants'

readiness in both groups was within 72 hours after using ventilators. During the RMW-PP implementation, of the 24 participants in the experimental group, 21 initially began EM at level 2. When the participants could extubate the endotracheal tube, the PI stepped up the mobility to level 3 (Standing) or 4 (Walking). The PI concurrently continued to increase the threshold IMT daily (see **Figure A1, Appendix**). After week 1 of program implementation, the mean MIP sharply increased. The mean MIP of the experimental group continued to increase rapidly, measured at baseline, week 1, and week 2 immediately after the program ended. The means of the MIP of the comparison group slowly increased (see **Figure 2**).

Table 2. Personal and clinical characteristics of participants in the experimental and comparison groups (N = 49)

Characteristics	Experimental group (n = 24)		Comparison group (n = 25)		Statistic values	p-value
	n	%	n	%		
Gender						
Male	12	54.17	12	48	0.02[a]	1.000
Female	12	45.83	13	52		
Age (years)					0.020[a]	1.000
40-64	12	50	13	52		
65-85	12	50	12	48		
Mean ± SD	66.17 ± 9.97		67.24 ± 12.12		0.338[b]	0.737
Min-max	43-84		47-82			
Health scheme					2.50[a]	0.379
Universal coverage	13	54.17	8	32		
Government	10	41.67	15	60		
Social security	1	4.16	2	8		
Underlying disease related to RMW						
Yes	14	58.33	13	52	0.199[a]	0.776
No	10	41.67	12	48		
Functional status before admission					3.159[a]	0.138
Fully independence	22	91.67	18	72		
Partial independence	2	8.33	7	23		
Causes of ICU admission					1.065[a]	0.587
Respiratory infection/Sepsis	13	54.17	14	56		
Immune system disorder	10	41.67	11	44		
Metabolic disorders	1	4.16				
APACHE II scores					-0.918[b]	0.363
Mean ± SD	18.96 ± 3.47		18.08 ± 3.22			
Min-max	14-26		14-26			
Body mass index (kg/m^2)					-0.809[b]	0.423
Mean ± SD	23.67 ± 3.87		22.66 ± 4.83			
Min-max	14.30-30.00		14.80-30.00			
Medication that may cause RMW						
Corticosteroids	17	70.83	19	76	0.168[a]	0.754
Vasopressor	13	54.17	18	72	1.676[a]	0.244
NMBA	1	4.17	2	8	0.313[a]	1.000
Aminoglycoside	0	0	1	4	0.980[a]	1.000

Note: [a] = Chi-square, [b] = Independent t-test, RMW = respiratory muscle weakness, APACHE = acute physiology and chronic health evaluation, NMBA = neuromuscular blocking agent, ICU = intensive care unit

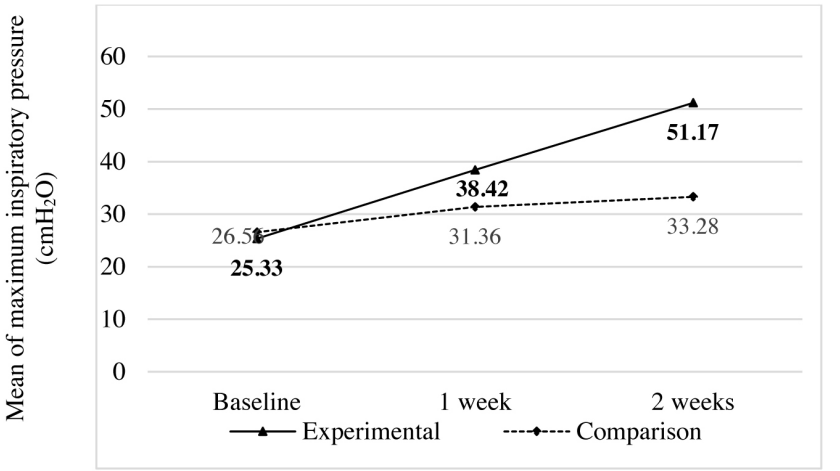

Figure 2. Comparison of the mean maximum inspiratory pressure at different time points between the experimental (n = 24) and comparison groups (n = 25)

Effectiveness of the RMW-PP

After the PW-Vs received two weeks of the RMW-PP twice daily, the results showed that the mean MIP at baseline, week 1, and week 2 between the experimental and comparison groups was statistically significant [$F(1,47) = 6.07, p < 0.017\ \eta_p^2 = 0.11$]. There was a significant interaction between time and group on MIP (**Table 3**). The least significant difference post hoc analysis was employed to assess the time difference between groups at each point. The results showed that the mean MIP at week 1 and week 2 differed significantly from the comparison group, as shown in **Table 4**.

Table 3. Comparison of mean differences in MIP between groups over time and the effect size using two-way repeated measures ANOVA (N = 49)

Source	SS	df	MS	F	p-value	Partial eta squared
Maximum inspiratory pressure						
Within-subjects effects						
Time	6509.15	1.21	5388.75	50.12[a]	< 0.001	0.52
Time x Group	2249.89	1.21	1862.62	17.32[a]	< 0.001	0.27
Error	6104.18	56.77	107.52			
Between-subjects effects						
Group	2295.84	1	2295.84	6.07[a]	0.017	0.11
Error	17773.28	47	378.16			

Note. [a] Report results using values: Greenhouse-Geisser, SS = sum of square, df= degree of freedom, MS = mean square

Table 4. Post-hoc comparison of MIP on difference time points between the experimental (n = 24) and comparison groups (n = 25)

Time/MIP MIP	Group		Mean difference	SE	p-value	95% CI for difference	
						Lower	Upper
Baseline	Experimental	Comparison	-1.227	2.637	0.648	-6.605	4.152
Week 1	Experimental	Comparison	7.057	2.789	0.015	1.445	12.668
Week 2	Experimental	Comparison	17.887	5.154	< 0.001	7.519	28.255

Note. MIP = maximum inspiratory pressure, SE = standard error, CI = confidence interval, Adjustment for multiple comparisons: Least significant difference

The effect of the RMW-PP on weaning and ventilator duration was analyzed using MANOVA. The results revealed significant differences in weaning and ventilator duration between the two groups [Wilk's lambda = 0.776, $F(2,46) = 6.62$, $p = 0.003$]. The multivariate effect size was estimated at 0.224, which explained 22.40% of the variance. The effect of the RMW-PP on each dependent variable: weaning duration $F(1,47) = 4.27$, $p = 0.044$, $\eta_p^2 = 0.083$, and ventilation duration $F(1,47) = 13.01$, $p < 0.001$, $\eta_p^2 = 0.217$ (see **Table 5**).

Table 5. Effect of the RMW-PP on weaning and ventilation duration between experimental (n = 24) and comparison groups (n = 25) using MANOVA analysis

Outcome measures	Experimental (n = 24)	Comparison (n = 25)	Univariate analysis						Multivariate analysis		
	Mean (SD)	Mean (SD)	SS	df	MS	F	p-value	η^2_p	F	p-value	η^2_p
Weaning duration	2.15 (1.72)	6.54 (15.06)	0.93	1	0.93	4.27	0.044	0.083	6.62	0.003	0.224
Ventilation duration	5.14 (3.22)	17.48 (21.02)	1.79	1	1.79	13.01	< 0.001	0.217			

Note. SD = standard deviation, SS = sum of squares, df = degree of freedom, MS = mean square, η^2_p = partial eta squared

Table 6 shows the results indicating that the experimental group had a significantly shorter ICU LOS (Median = 6.96 vs. 12.67 days) and hospital LOS (Median = 17.27 vs. 34.04 days) and had significantly lower health service costs [Median = 46,754 Baht (1,335.84 USD) vs. 110,157 Baht (3,147.36 USD)] compared to the comparison group. In addition, the weaning success of the experimental group (100% success) was a statistically significant difference from the comparison group (72% success) (Fisher's exact test $p = 0.005$).

Table 6. Comparison of patient and hospital outcomes of PW-Vs between the experimental (n = 24) and comparison groups (n = 25)

Variables	Group	Median	Interquartile rank (IQR)	Mean rank	Sum of ranks	Mann-Whitney U	p-value
LOS in ICU (day)	Experimental	6.96	5.04-8.98	17.50	420	120	< 0.001
	Comparison	12.67	7.75-23.50	32.20	805		
LOS in hospital (day)	Experimental	17.27	11.89-24.00	18.33	440	140	< 0.001
	Comparison	34.04	18.00-43.08	31.40	785		
Health service costs (USD)*	Experimental	1335.84	1127.71-1834.83	17.21	413	113	< 0.001
	Comparison	3147.36	1838.54-4771.59	32.48	812		

Note. LOS = length of stay, ICU = intensive care unit, *USD = United States Dollar (Data on January 12, 2025, 13:24 UTC; 1 USD approximately 35 Thai Baht)

Only one adverse event (0.23%) was found across the 429 sessions. One patient experienced a 3% desaturation from baseline, but this situation was transient, lasting only 1 minute, and the patient was switched to ventilation without requiring any additional treatment.

Discussion

This study yielded significant results in RMW prevention, ventilation duration, weaning duration, ICU and hospital LOS, and health service costs. The RMW-PP produced emerging evidence to guide clinical decisions and practice. The RMW-PP revealed an improvement in outcomes and demonstrated the ability of an APN to bridge the gaps between research and practice.

The RMW-PP synthesized the content and dose of intervention from the previous evidence-based approach. EM or IMT was the most effective approach for weaning or ventilation duration (Level I).[10] The RMW-PP was designed with a novel approach,[11] combining both EM

and IMT concurrently, which may lead to timely improved respiratory muscle and clinical outcomes. The RMW-PP implementation process was within 72 hours due to the daily assessment of the readiness by the APN before starting the RMW-PP. The initial program implementation was congruent with the previous study that explored early rehabilitation using EM within 72 hours, which could prevent diaphragm dysfunction and the diaphragm thickening fraction reduction viewed by ultrasonographic method (Level I).[38] The mean MIP after the RMW-PP implementation in the experimental group improved significantly compared to the comparison group, with fewer adverse events. Our findings are consistent with previous studies that showed an increase in MIP after the threshold IMT (Level I[7] and Level IV[34]), and the mobility level progressively improved (Level I).[32] However, this finding was not congruent with previous studies[22] because participants had compliance with the IMT training between 27%-100%. Hence, intervention dosages were insufficient to improve MIP, or the participants who used ventilators for more than 7 days could not improve MIP.[22] A possible explanation in this study is that the RMW-PP was implemented within 72 hours, and a significant change in respiratory strength was found at week 1 (Level IV).[6] During the RMW-PP, the APN provides coaching, mentoring, and empowerment until each session is completed. Regarding Bissett and colleagues,[3] most patients had generalized fatigue and may refuse to train. However, they suggested that psychological support may be key to successful respiratory muscle rehabilitation; future studies would need to explore the psychological aspect (Level IV).[3] In addition, the intensity of the RMW-PP using a short duration of IMT is congruent with the strength training technique (high intensity and low repetition) (Level I,[5,21] and Level IV[34]). The experimental group in this study may have achieved strength training quickly. The APN motivated and praised the participants so they felt confident and mastered the task. Furthermore, the number of contacts in the RMW-PP was 28 times, so it may be an adequate dose of the APN, indicating favorable outcomes. The more contacts and time contacts there are, the more ongoing support from the APN can build trust and enable PW-Vs to gain more confidence in practicing following the RMW-PP. Evidence revealed that IMT was associated with improved MIP in studies where treatment fidelity was at least 80% but not in those with less than 80%.[39] This was congruent with the study of APN doses that make differences in outcomes.[13] It can be concluded that the APN demonstrated her effectiveness in the clinical and health service outcomes. The APN has high clinical specialty skills and knowledge matching the PW-Vs.

The RMW-PP was proven to be enabled in the ICU setting. The outcomes of the RMW-PP were consistent with the previous studies in shortening ICU and hospital LOS (Level I),[32,39] ventilation, and weaning duration (Level I).[7,9,31-32] The RMW-PP had an expense of 4,050.12 Baht (115.72 USD) per participant, offering cost-effectiveness for this program. The health service costs (only direct costs) in the experimental group were reduced dramatically compared to the comparison group. However, this result may not be comparable to previous studies due to their different times and contexts. It is noted that the RMW-PP was a preventable respiratory muscle weakness program. The duration of the program is only two weeks, and the baseline characteristics of the participants in this study were without chronic lung disease, such as chronic obstructive pulmonary disease (COPD). People with chronic lung disease may benefit less or need other approaches, such as endurance training, and the duration of the program would be longer than 6-8 weeks (Level IV).[6]

Translating evidence into practice in an ICU setting is complex. The key success of the RMW-PP was that of an APN with advanced skills and competencies who had cooperation from the ICU healthcare team. Thus, the structure and care process should be changed to sustain this program, involving establishing the skill mix team, ICU nursing guidelines/protocol for early rehabilitation in the ICU, a safety checklist, and staff training. These essential strategies notably enhanced the quality of care of PW-Vs.

Limitations

Some limitations of this study should be addressed. Firstly, the data were collected in different periods between the two groups; we could not control the extraneous factors that may influence the outcomes. The data were collected from various areas and physicians' ward teams, giving rise to history bias, but all wards followed the standard care of the hospital's policy. Secondly, the APN did both intervention and data collection; thus, unconscious bias is inevitable. Additionally, the RMW-PP was implemented in a single tertiary hospital; thus, the generalizability is limited. The outcome measured did not cover the long-term outcome, i.e., quality of life, so more extended studies would be done, and expanding the program into multiple settings is needed.

Conclusion and Implications for Nursing Practice

The findings of this study indicate that the RMW-PP can be implemented into practice within the ICU amid the demanding environment. It sheds light on the early rehabilitation of PW-Vs in the ICU of Thailand. This program was the first one led by a highly competent APN concerned with holistic care nursing. The structure of quality improvement and care processes is crucial to enhancing the successful implementation of the RMW-PP. For the sustainability of the RMW-PP, APNs can link with a multidisciplinary team sharing responsibilities among ICU nurses and physicians, and the development of early rehabilitation protocol in ICU care, structured care plans, staff education and training, and development of technology and assistive devices for safety and risk assessment are essential components. In addition, the RMW-PP has demonstrated its financial benefits. Thus, an in-depth financial impact analysis is needed to highlight the program's annual health service cost savings. It is a challenge for policymakers to plan and drive the full scope of the APN role for people with complex health problems.

Acknowledgments

The authors gratefully acknowledge all participants in this study and the scholarship support of the Faculty of Medicine Ramathibodi Hospital, Mahidol University.

Also, the authors sincerely thank ICU nurses and nurse administrators of the Nursing Service Division for their support and encouragement in studying and data collection.

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Appendix

Table A1. The details of RMW-PP content, activities provided, duration, arrangement, and implementation

Schedule	Activities	Duration
Stage 1 Preparedness for patient safety before starting the program	1. Collaborate with a physician to correct the suspected factors induced RMW, such as nutrition status and infection, and ask for bronchodilator medication (Level V)[33]	2 minutes
	2. Establishing rapport with PW-Vs and relatives	
	3. Daily assessment of readiness criteria (Level I),[6,32] including neurological system (Level I),[8,32] respiratory system (Level I),[6,32] cardiovascular system (Level I[32] and Level II[20]) and hemodynamic stability (Level I)[6,32] to initiate EM (Level I),[30] and Threshold IMT (Level I)[6,32]	
	4. Evaluation of motor power of limb muscles (Level I),[32] and level of consciousness (RASS = 0—alert and corporate) (Level I)[8] before measuring the MIP (Level I)[6,21]	4 minutes
	5. Discuss with a physician and ensure patient readiness before program implementation (Level V)[12]	
Stage 2 Supporting, strengthening limbs and respiratory muscle (Day 1-5)	6. Patient preparations: Explain the process of IMT with a threshold device, oral hygiene, suctioning, securing the endotracheal tube and catheter, measuring the cuff pressure, recording vital signs, and providing the Fowler's position (head of the bed at least 45 degrees) (Level I)[6,21]	5 minutes
	7. The APN provided knowledge of the benefits of EM and Threshold IMT and then gave motivation and support during the activities. Select an activity that matches the participant's condition. If patient is intubated, the APN begins the EM level 1—the passive range of motion (item 7.1) or level 2—an active assisted range of motion (AAROM), sitting on the edge of the bed (item 7.2), and starting Threshold IMT (item 8).	30-40 minutes
	7.1 Empowering PW-Vs to perform EM on the bed with level 1 for 10 repetitions on both arms and legs when the patient responds to voice (RASS score = -2 to -3), able to move arm against gravity, positioning in a high Fowler's position at least 30 degrees for 20 minutes (Level I)[22,31]	
	7.2 If alert and able to move legs against gravity, the APN assisted the patient in performing EM on the bed with level 2: AAROM) 10 repetitions per exercise, sitting upright on the bed with support for 5-10 minutes (Level I).[9,32]	
	8. Coaching and mentoring PW-Vs to perform IMT with the threshold device at a load pressure of 50% MIP for the first training set, five sets of 6 breath repetitions, and rest with connected ventilation between each set for 1-2 minutes. The device is adapted and connected to the patient's endotracheal tube, and the patient is directed to continue breathing through the device (Level I,[6,9,21-22,29] and Level IV[35]).	

Table A1. The details of RMW-PP content, activities provided, duration, arrangement, and implementation (Cont.)

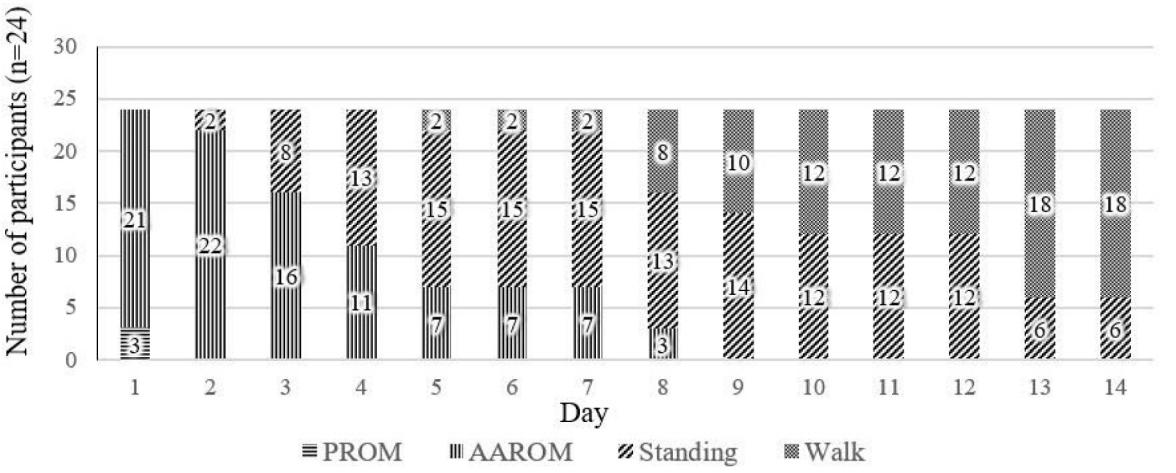
Schedule	Activities	Duration
	9. Praise, assess, and record the patient's vital signs after completing the training program, 5 and 30 minutes after rest (Level V)[34]	1 minute
Day 6th and 7th	Activities break due to prevent muscle injury (limbs and respiratory muscle) (Level I)[6]	2 days
Stage 3 Encouraging continuity to enhance of EM and Threshold IMT (Day 8-12)	10. Screened according to stage 1; if the patient intubated with endotracheal tube, the EM level and Threshold IMT training will follow item 7.1 or 7.2.	5 minutes
	11. If extubation, the APN would ask ICU nurses (Level V)[34] and a physiotherapist to assist the PW-Vs step EM to level 3 —a balance training by bedside sitting and standing with assistance (item 11.1) or level 4—continued with level 3 and added ambulation by marching in place or walking in patient's room or nearby area (item 11.2) and continue coaching and mentoring Threshold IMT according to item 12.	30-40 minutes
	11.1 Patients who were alert and able to move their arms and legs against gravity and sit upright without support may progress to EM level 3 by completing 10 repetitions per exercise. Encourage the patient to sit and stand on the edge of the bed for at least 2 minutes (Level I).[6,21]	
	11.2 Patients who were alert and able to move their arms and legs against gravity and sit upright without support may progress to EM level 4 by completing 10 repetitions per exercise. Support and encourage confidence to stationary walking or walking in his room for 10-15 minutes (Level I).[6,21]	
	12. The APN adjusted threshold load training pressure throughout the training period to ensure adequate training stimulus. It was progressively increased by 1-2 cmH_2O daily until the patient completed five sets of six breath repetitions and rest with connected ventilation between each set for 1-2 minutes (Level I).[6,21]	
	13. Praise, assess, and record the patient's vital signs after completing the training program, 5 and 30 minutes after rest (Level V)[34]	1 minute
Day 13-14	Activities break due to prevent muscle injury (limbs and respiratory muscle) (Level I)[6]	2 days
Instrument for respiratory muscle training	**Inspiratory Muscle Training Device**: is a threshold IMT—a pressure-based loading device (HS 730 Model, Respironics New Jersey, USA). It is a calibrated device with a 9-41 cmH_2O pressure range. The device can be directly connected to the endotracheal tube or tracheostomy tube. The IMT device has a spring-loaded threshold that can provide resistance training.[21] The participant should exhale completely and inhale to open a one-way value of the device for passing air through the respiratory pathway. The intensity of at least 50% of initial MIP is preset for the minimum training threshold, then increases by 1-2 cmH_2O daily.[22]	

Table A1. The details of RMW-PP content, activities provided, duration, arrangement, and implementation (Cont.)

Schedule	Activities	Duration
Program safety monitoring instrument	**The Record Form During Program Training:** a daily record to monitor the success or failure of program training. The parameters consist of neurological conditions (consciousness), hemodynamic monitoring (heart rate, SBP, MAP, new-onset arrhythmia, chest pain, or any symptoms related to an acute cardiac event), respiratory conditions (respiratory rate, oxygenation, abnormal breathing pattern (accessory muscle, paradoxical, abdominal muscle used), and adverse events occurred. All these parameters were recorded during the program implementation.	
Progressive training record form	**The Daily Mobility and Threshold Inspiratory Muscle Training Record Form.** It consisted of the start date and time of mobility and IMT training, mobility level, ventilation setting mode, FiO2, motor power, MIP each day, and total time of daily mobility.	

Note. Level I—evidence is based on a systematic review, meta-analysis, and randomized controlled clinical trial. Level II—evidence is based on a systematic review of non-randomized, controlled clinical trials, cohort studies, and case-control analytic studies.

Level IV—opinions of respected authorities and/or nationally recognized expert committees or consensus panels are based on scientific evidence. Level V—scoping reviews, integrative reviews, case reports, and opinions of nationally recognized experts are based on experiential evidence. EM = early mobilization, IMT = inspiratory muscle training, RASS = the Richmond-Agitation Sedation Scale, PROM = passive range of motion, APN = advanced practice nurse, AAROM = active-assisted range of motion, MIP = maximum inspiratory pressure



PROM = passive range of motion, AAROM = active-assisted range of motion

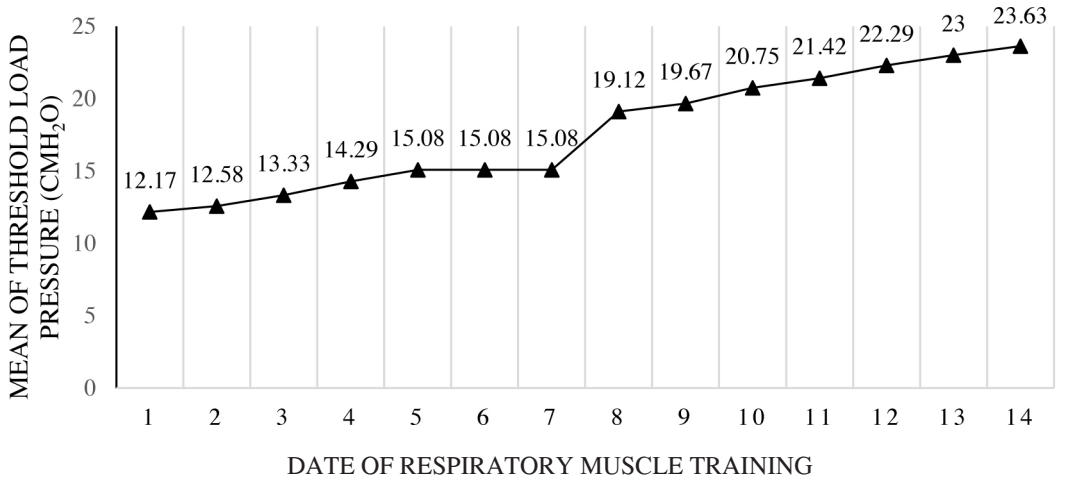


Figure A1. Daily progression of the EM level and the mean threshold load pressure for the experimental group (n = 24)

ผลลัพธ์ของโปรแกรมป้องกันการเกิดกล้ามเนื้อหายใจอ่อนแรงโดยพยาบาลผู้เชี่ยวชาญสำหรับผู้ที่ใช้เครื่องช่วยหายใจในประเทศไทย : การวิจัยกึ่งทดลอง

ธารทนา สุปรียธิติกุล อภิญญา ศิริพิทยาคุณกิจ นภารัตน์ อมรพุฒิสถาพร*

บทคัดย่อ: ผู้ที่ใช้เครื่องช่วยหายใจมีความเสี่ยงที่จะเกิดกล้ามเนื้อแขนขา และกล้ามเนื้อหายใจอ่อนแรง กระทบต่อการทำหน้าที่ของร่างกายและต้นทุนบริการสุขภาพ จากหลักฐานเชิงประจักษ์พบว่า การเริ่มเคลื่อนไหวร่างกายโดยเร็วและการฝึกกล้ามเนื้อหายใจเข้ามีผลเพิ่มความแข็งแรงของกล้ามเนื้อหายใจ อย่างไรก็ตาม การวิจัยเกี่ยวกับเรื่องนี้ในประเทศไทยยังมีน้อย ดังนั้นการวิจัยกึ่งทดลองนี้มีวัตถุประสงค์เพื่อทดสอบประสิทธิผลของโปรแกรมป้องกันการเกิดกล้ามเนื้อหายใจอ่อนแรงโดยพยาบาลผู้เชี่ยวชาญต่อผลลัพธ์ทางคลินิกในกลุ่มผู้ที่ใช้เครื่องช่วยหายใจ ระยะเวลาดำเนินโปรแกรม 2 สัปดาห์ กลุ่มตัวอย่างจำนวน 49 คนคัดเลือกจาก 2 หอผู้ป่วยวิกฤตอายุรกรรมและหอผู้ป่วยกึ่งวิกฤตอายุรกรรม 1 แห่งของโรงพยาบาลมหาวิทยาลัยแห่งหนึ่ง จังหวัดกรุงเทพมหานคร ประเทศไทย กลุ่มเปรียบเทียบจำนวน 25 คน เก็บข้อมูลครบถ้วน จากนั้นเริ่มทำโปรแกรมในกลุ่มทดลองจำนวน 24 คน ระยะเวลาเก็บข้อมูลอยู่ระหว่างเดือนกุมภาพันธ์ ถึง เดือนกันยายน พ.ศ. 2566 ผลลัพธ์ทางคลินิกที่ศึกษาได้แก่ ความดันขณะหายใจเข้าสูงสุด ระยะเวลาใช้เครื่องช่วยหายใจ ระยะเวลาหย่าเครื่องช่วยหายใจ ความสำเร็จในการหย่าเครื่องช่วยหายใจ ระยะเวลานอนในหอผู้ป่วยไอซียู ระยะเวลาในการนอนโรงพยาบาลและต้นทุนบริการสุขภาพ วิเคราะห์ข้อมูลด้วยสถิติเชิงพรรณนา การทดสอบค่าเฉลี่ยหรือค่าอันดับของกลุ่มที่เป็นอิสระต่อกัน การทดสอบไคสแควร์ การทดสอบฟิชเชอร์ การทดสอบความแปรปรวนแบบสองทางเมื่อมีการวัดซ้ำ (Two-way repeated measures analysis of variance) และการทดสอบความแปรปรวนด้วยการวิเคราะห์พหุตัวแปร (Multivariate analysis of variance)

ผลการวิจัย พบว่า กลุ่มทดลองที่ได้รับโปรแกรมมีความดันหายใจเข้าสูงสุดและ ความสำเร็จในการหย่าเครื่องช่วยหายใจเพิ่มขึ้นเมื่อเทียบกับกลุ่มเปรียบเทียบอย่างมีนัยสำคัญทางสถิติ ระยะเวลาเฉลี่ยในการใช้เครื่องช่วยหายใจ ระยะเวลาเฉลี่ยในการหย่าเครื่องช่วยหายใจ ระยะเวลาเฉลี่ยการนอนในหอผู้ป่วยไอซียู ระยะเวลาเฉลี่ยในการนอนโรงพยาบาล และต้นทุนบริการสุขภาพ ในกลุ่มทดลองลดลงเมื่อเทียบกับกลุ่มเปรียบเทียบอย่างมีนัยสำคัญทางสถิติ การวิจัยนี้เน้นให้เห็นประโยชน์ของพยาบาลผู้เชี่ยวชาญในการนำโปรแกรมป้องกันการเกิดกล้ามเนื้อหายใจอ่อนแรงมาใช้ ซึ่งพัฒนามาจากหลักฐานเชิงประจักษ์สำหรับผู้ที่ใช้เครื่องช่วยหายใจ ดังนั้น ผู้กำหนดนโยบายควรกำหนดตำแหน่งสำหรับพยาบาลผู้เชี่ยวชาญในการดูแลผู้ที่มีปัญหาซับซ้อน ในอนาคตควรมีการนำไปศึกษาในสถานที่บริบทอื่นก่อนนำโปรแกรมไปใช้อย่างแพร่หลาย

Pacific Rim Int J Nurs Res 2025; 29(3) 648-666

คำสำคัญ: พยาบาลผู้เชี่ยวชาญ ต้นทุนบริการสุขภาพ ความดันขณะหายใจเข้าสูงสุด โปรแกรมป้องกันการเกิดกล้ามเนื้อหายใจอ่อนแรง ระยะเวลาในการใช้เครื่องช่วยหายใจ

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