Original Article

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Effects of a Two-Day Pulmonary Rehabilitation Program on Patients with Acute Exacerbation of Chronic Obstructive Pulmonary Disease: A Randomized Controlled Trial

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Abstract:

Objective: To verify whether a two-day pulmonary rehabilitation program that included positive expiratory pressure (PEP) breathing, the active-cycle breathing technique (ACBT), and upper-limb exercises could improve pulmonary function and dyspnea in acute exacerbation of chronic obstructive pulmonary disease (AECOPD).

Material and Methods: Thirty-two patients were randomly assigned to either the group that received the Combination of PEP breathing, ACBT, and Upper-limb exercises (CPAU group) or the control group, which received the usual care protocol (i.e., pursed-lips breathing technique, diaphragmatic breathing technique, and chest mobilization). Slow vital capacity (SVC) and the rating of perceived exertion (RPE) were evaluated before and after the pulmonary rehabilitation program. A paired-sample t-test was used to compare within-group differences, while ANCOVA was used to compare between-group differences. A p-value of ≤0.05 was considered statistically significant.

Results: After the intervention, SVC was significantly higher in the CPAU group (p-value<0.05), whereas no statistically significant change was found in the control group (p-value>0.05). However, both groups experienced no statistically significant change in RPE after the intervention period (p-value>0.05). Regarding the comparison between the 2 groups, there were significant differences only in SVC (p-value<0.05). No adverse events were identified.

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Conclusion: The two-day CPAU program could be effectively used to increase SVC in patients with AECOPD.

Keywords: dyspnea, chronic obstructive, pulmonary disease, rehabilitation

Introduction

Dyspnea, cough, and secretion production are the main respiratory symptoms of acute exacerbation of chronic obstructive pulmonary disease (AECOPD). These symptoms often require additional therapy[1]. AECOPD is a common cause of hospitalization; it also affects pulmonary function, induces repeated instances of exacerbation, and increases mortality[2]. Acute exacerbation results in increased airway resistance and expiratory flow limitation. This leads to an increase in the residual volume of air present in the lungs on exhalation, which induces air trapping and dynamic hyperinflation[3]. Dynamic hyperinflation is known to augment the mechanical load on inspiratory muscles, which can worsen dyspnea and cause severe fatigue[4]. This exacerbation results in the patient experiencing reduced lung function, weakness of the muscles, and a lower quality of life. After an episode of exacerbation, patients require a longer recovery period after hospitalization than stable COPD patients[5], which leads to a significantly delayed regaining of pulmonary function (by up to 12 weeks); during this time, the patient is also at risk of re-exacerbation[6].

In Thailand, Chronic Obstructive Pulmonary Disease (COPD) is one of the most common causes of mortality. Chatreewatanakul, et al. and Hickman (2022)[1] found that the number of deaths due to COPD is increasing every year in the country. Moreover, patients with COPD experience exacerbation between 1 to 4 times per year[7], and 25% of COPD patients are hospitalized due to exacerbation[8]. During hospitalization, patients with AECOPD show a decrease in their daily activities and reduced muscle strength due to systemic inflammation, respiratory muscle dysfunction, and skeletal muscle dysfunction[9,10]. Furthermore, dyspnea, cough, and secretion production are heightened respiratory symptoms of clinically impactful events characterized by AECOPD[9,11]. Therefore, the combined treatment technique should be considered for implementation during the exacerbation or soon after in order to solve these problems[12].

Nowadays, different strategies for pulmonary rehabilitation (PR) are used to manage poor lung function and shortness of breath due to lung hyperinflation, sputum production, and skeletal muscle dysfunction during hospitalization. These strategies include resistance training[13], weight-lifting exercises[14], positive expiratory pressure (PEP) breathing[15], and the active-cycle breathing technique (ACBT)[11]. Resistance training (RT) involves muscle contractions performed against a specified opposing force provided by resistance[16]. Zhang et al.[17] indicated that upper limb training emphasizing resistance exercises can alleviate dyspnea associated with exercise and daily activities in patients with COPD[17]. ACBT consists of 3 main treatment elements: breathing control, thoracic expansion exercises, and the forced expiration technique (FET), which is an active method used to clear sputum from the lungs and improve pulmonary function[18]. PEP breathing involves exhaling against an expiratory resistance to temporarily increase forced vital capacity (FVC) and tidal volume (V_T), thus promoting a homogeneous distribution of ventilation throughout the lungs and improving oxygen diffusion efficiency[19]. This technique can reduce airway collapsibility and move the equal pressure point peripherally, thereby achieving improved pulmonary function and end-expiratory flow[20]. Ubolsakka-Jones et al.[21] reported that positive expiratory pressure (PEP) exercises with the BreatheMAX device can improve recovery from dyspnea in patients with COPD. Their results indicate that the BreatheMAX device

is highly effective in reducing exercise-induced dyspnea and significantly shortening recovery time. Thus, the BreatheMAX device may offer benefits in alleviating dyspnea during exacerbations in patients with pulmonary conditions.

In Thailand, most patients with AECOPD are hospitalized for an average of 2 days. Thus, a two-day PR program is frequently applied to manage acute exacerbation and unstable periods during this hospitalization. At present, there is still little evidence to recommend PR for admitted COPD patients[15,22], and no studies have evaluated the efficacy of a two-day PR program specifically on AECOPD patients. Moreover, no studies were found examining the effectiveness of the combination of PEP breathing, ACBT, and upper-limb exercises (CPAU) in cases of AECOPD. Therefore, this study aimed to assess whether a two-day PR program based on these 3 elements could improve lung function and dyspnea in AECOPD patients.

Material and Methods

Design and setting

The present study was a single-blinded, randomized, controlled trial that compared a CPAU group and a control group of patients with AECOPD. The study was conducted at Mae Chan Hospital, Chiang Rai Province, Thailand. Simple randomization with opaque envelope labels containing a number for both groups was used to allocate the participants into the 2 groups (Allocation ratio: 1:1). A list was generated and used by one of the researchers who was not involved in the evaluation processes.

Ethical statement

This research was reviewed and approved by the Ethics Committee of Mae Fah Luang University (approval code: 20183-25) and this study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all the patients.

Participants

Thirty-two participants aged 40–80 years who had been diagnosed with AECOPD by a physician were recruited from the medical ward at Mae Chan Hospital, Chiang Rai Province, Thailand, between August 2021 and March 2022. The inclusion criteria were 1) being hospitalized with AECOPD, 2) having stable cardiopulmonary function for at least one day before data collection (heart rate <100 beats/min, systolic BP 90–140 mm Hg, diastolic BP 60–90 mm Hg, and SpO_2 greater than or equal to 90%), 3) being able to breathe spontaneously, and 4) being able to communicate and cooperate for the purposes of this research. Patients were excluded if they had diseases of the musculoskeletal, neurological, and cardiovascular systems or any other comorbidities that could interfere with an exercise program. They were also excluded if they had any psychiatric illnesses.

Sample size calculation was performed using the sample size formula for 2 independent groups. The estimation was based on our pilot study, which compared the effects of the CPAU (n=5) to a control group (n=5). An effect size of 4.96 based on slow vital capacity (SVC) was used, with a significance level of 0.05 and a power of 0.90. A sample size of 16 patients was required for each group. According to these criteria, 32 patients were recruited.

Intervention

Over a two-day period, the patients in the CPAU group received a daily 60-minute session. For the PEP breathing, the patients performed deep breathing (more than tidal volume) and prolonged expiration with a steady flow using the BreatheMAX device (with I:E ratios of 1:3 or 1:4); this device comprises a plastic bottle containing water with 2 tubes passing through the lid. The outlet tube must be connected by a corrugated tube and was used for inspiratory breathing to improve chest wall expansion and respiratory muscle strength. The inlet tube extends into the bottle and

opens below the water surface. It was used for expiratory breathing to provide PEP with oscillation (Figure 1). The details of the BreatheMAX device were described by Jones et al[23]. The load setting was 5 cm H_2O for 10 breaths per set, 10 sets per treatment session, with a rest time of at least one minute between sets. The patients breathed out with effort and generated positive pressure by overcoming the water pressure in the inlet tube; this created PEP in their airways. Regarding the ACBT, a 10-minute session involved the following 3 steps. The first step, breathing control, involves the patient performing the exercise 5 times by inhaling gently through the nose and exhaling through the mouth while engaging the lower chest and diaphragm. The second step is thoracic expansion, which is performed 4 times; during this phase, the patient inhales slowly and deeply through the nose using the lower chest, holds their breath for 3 seconds, and then exhales slowly through the mouth. The final step, the FET, also performed 4 times, entails the forced expulsion of air from the airways with the glottis open, followed by a return to breathing control until the patient is ready to start another cycle[24]. The upper-limb exercises were performed with elastic bands. They consisted of biceps and triceps curls (Figure 2), with 8 repetitions per set, for 3 sets per day. To determine the suitable resistance level for the elastic band, the approach outlined by Hibberd et al.[25] was utilized. Specifically, 2 days prior to the intervention period, patients were instructed to perform 8 repetitions of each upper-limb exercise with varying resistance levels. The appropriate resistance level was then established based on patient feedback and observations by a physical therapist. During the upper limb exercises, the level of fatigue, as measured by the modified Borg dyspnea scale, was between 3 and 5 out of 10[10,26].

Over a two-day period, the patients in the control group received a daily 60-minute session of a combination of pursed-lips breathing, diaphragmatic breathing, and chest mobilization (the usual care protocol). The patients performed pursed-lips breathing with an I:E ratio of 1:3 or 1:4 in a sitting position, 10 times per set, with 10 sets per treatment session; the rest time was at least one minute

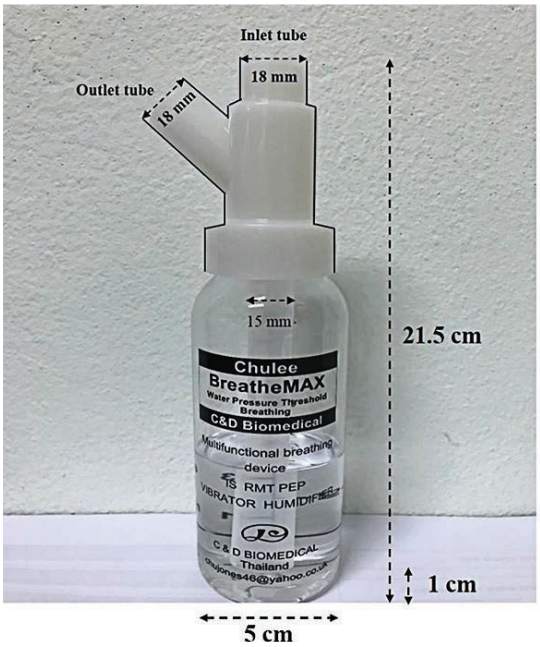


Figure 1 BreatheMAX breathing device

Figure 2 Upper limb exercise A. biceps curls and B. triceps curls

between sets. Concerning diaphragmatic breathing, the patient breathed in through the nose slowly and deeply using the diaphragm; they held their breath for 3 seconds and then exhaled through the mouth for 6 times per set, with a rest period of at least one minute between sets. The entire procedure was performed continuously for a total duration of 10 minutes. Regarding chest mobilization (the active stretch of the anteroposterior chest wall), the patient was asked to place both hands behind their neck, then raise their elbows and move them out as far as possible while deeply and slowly inhaling. Then, they slowly exhaled and moved their elbows forward while keeping their hands behind their neck. This protocol was performed for 8 repetitions per set, 3 sets per day, with a rest time of at least one minute between sets[27].

In both groups, the interventions were administered by a physical therapist with more than 10 years of experience. Moreover, all the patients were allowed to continue receiving their standard medical care.

During all the interventions, heart rate, oxygen saturation, and respiratory rate were monitored[14]. The interventions were interrupted if the patient experienced adverse events, which were characterized as respiratory rate >30 beats/min, heart rate >120 beats/min, oxygen saturation <90%, or paradoxical breathing.

Outcome measures

All the outcomes were evaluated by a research assistant who was blinded to group allocation.

According to the guidelines of the American Thoracic Society (ATS)/European Respiratory Society (ERS) task force[28,29], lung function was measured as SVC in liters via spirometry (Vyntus spiro, Vyaire Medical, Germany) before and after the 2 days of intervention. The rating of perceived exertion (RPE) was also measured before and after the interventions with the modified Borg dyspnea scale[30]. This scale consists of a vertical line with points from 0 to 10; each point has a verbal descriptor, with 0 representing no effort and 10 describing maximal effort.

Statistical analysis

The Shapiro-Wilk test was used to evaluate the normality of the data. All data in the current study were found to be suitable for parametric testing. The characteristics of the CPAU and control groups were analyzed through descriptive statistics. To assess group differences in the patients' characteristics, the unpaired t test was applied to continuous variables, and the chi-square test was used for categorical variables. A paired-sample t test was used to compare pre- and post-variables within each group. To compare changes between the 2 groups,

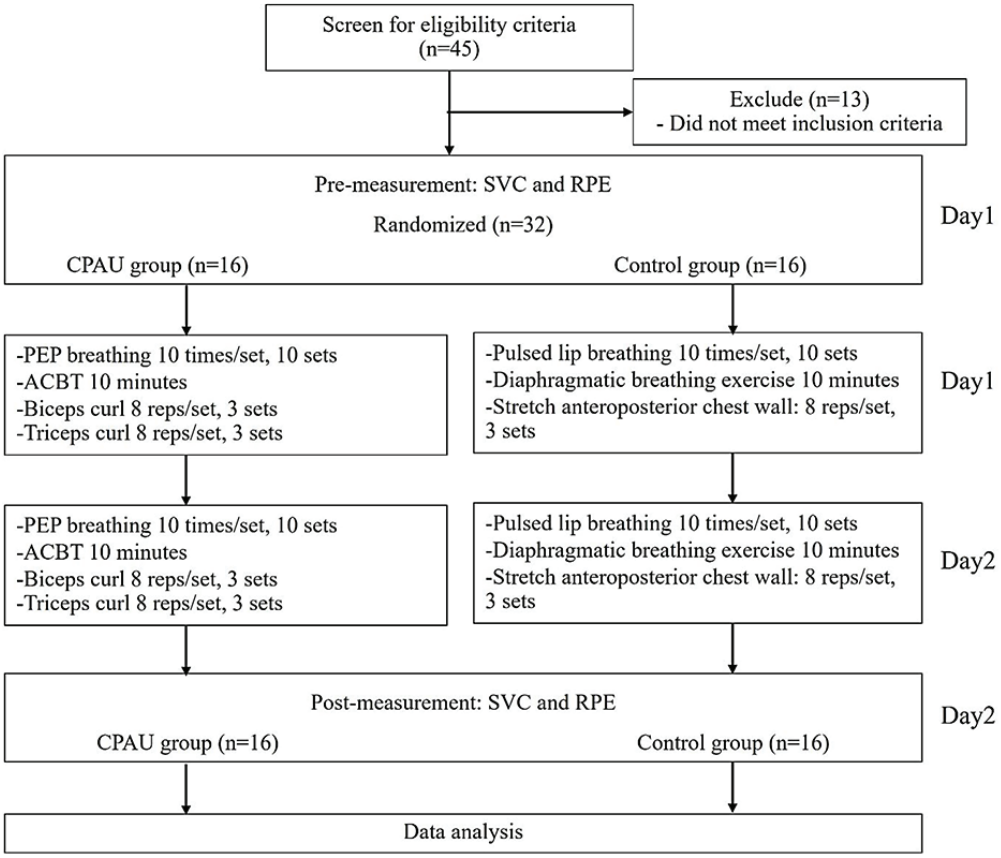
an analysis of covariance (ANCOVA) was performed, with the pretest values of the parameters as covariates. A value of p-value≤0.05 was considered significant.

Results

Forty-five participants were initially screened, but 13 were excluded because they did not meet the inclusion criteria (Figure 3). The participants' demographic data and baseline characteristics are shown in Table 1. All baseline outcome variables were similar, with no statistically significant differences between the 2 groups. In total, 32 AECOPD patients were enrolled (CPAU group n=16; control group n=16) and completed the study requirements. The mean age of the participants was 71.3±7.8 years and 74.2±8.7 years in the CPAU and control groups, respectively. All the participants were ex-smokers. A CONSORT diagram is shown in Figure 3.

Effects of the intervention

There were significant improvements in SVC after the treatment in the CPAU group (p-value<0.05). No statistically significant differences were found after treatment in the control group. Furthermore, no significant improvements in RPE (p-value>0.05) were observed in the CPAU and control groups before and after testing (Paired-sample t-test) (Table 2).



SVC=slow vital capacity, RPE=rating perceive exertion, CPAU=the Combination of PEP breathing, ACBT, and Upper-limb exercises, PEP=positive expiratory pressure, ACBT=active cycle breathing technique

Figure 3 Participant flowchart

Table 1 Characteristics of patients

Parameters	CPAU group (n=16)	Control group (n=16)	p-value
Age (years)	71.3±7.8	74.2±8.7	0.802*
Gender	8 males; 8 females	7 males; 9 females	0.723#
Weight (kilogram)	46.13±5.99	44.94±6.09	0.583*
Height (centimeter)	141.75±8.36	146.93±8.74	0.097*
mMRC score	2.25±0.68	2.00±0.73	0.325*
CAT score	19.19±6.56	16.31±6.06	0.208*
SVC (litter)	1.53±0.67	1.32±0.63	0.377*
Borg scale, RPE scale at rest	1.75±1.13	1.88±1.26	0.769*

CPAU=The combination of PEP breathing, ACBT, and upper-limb exercises, SVC=slow vital capacity, mMRC score=modified British Medical Research Council score, CAT=COPD assessment score; RPE=rate perceived exertion, *=Analyzed using unpaired t-test, #=Analyzed using the chi-square test

Table 2 Comparison of the outcome measures between baseline (pre-test) and post-test assessments in the experimental and control groups (Paired sample t-test)

Parameters	CPAU group				Control group			
	Pre-test (Mean±S.D.)	Post-test (Mean±S.D.)	Mean difference (95% CI)	P-value	Pre-test (Mean±S.D.)	Post-test (Mean±S.D.)	Difference (95% CI)	P-value
Slow vital capacity (SVC)	1.53±0.67	2.12±0.51	0.59* (0.04-0.31)	0.001	1.31±0.63	1.42±0.64	0.11 (-0.05-0.27)	0.176
Rate perceived exertion (RPE)	1.75±1.13	1.41±1.08	-0.34 (-0.70-0.02)	0.060	1.88±1.26	1.75±0.86	-0.13 (-0.51-0.26)	0.497

*=Significant improvement from baseline levels (p-value<0.05); S.D.=standard deviation, CI=confidence interval, CAPU=The Combination of PEP breathing, ACBT, and Upper-limb exercises

Regarding the between-group analysis (ANCOVA), it was seen that after adjustment for baseline values, only SVC exhibited a significant difference (p-value<0.05) between the CPAU and control groups (Table 3).

Discussion

Hyperinflation and reduced lung volume are major factors that limit daily activities, especially during acute exacerbation and hospitalization[28]. Hospitalized AECOPD patients continue to experience functional deterioration and poor clinical outcomes because of a lack of rehabilitation. Therefore, an early PR program should be implemented to prevent further clinical deterioration[31]. To our knowledge, this is the first study that investigates the effects on SVC and RPE in hospitalized AECOPD patients of a two-day treatment that combines PEP breathing, ACBT, and upper-limb exercises compared to usual care (pursed-lips breathing, diaphragmatic breathing, and stretching of the posteroanterior chest wall). The results indicate that the two-day CPAU program significantly increased SVC in patients with AECOPD. Furthermore, concerning the between-group results, CPAU was better than usual care for SVC.

Table 3 Comparison of mean post-test measures between experimental and control groups after adjustment for differences in baseline values (Analysis of Covariance: ANCOVA)

Parameter	CPAU group# (Mean±S.D.)	Control group# (Mean±S.D.)	Difference (95% CI)	p-value
Slow vital capacity (SVC)	2.05 (0.41)	1.49 (0.41)	0.56* (0.26 to 0.86)	0.001
Rate perceived exertion (RPE)	1.45 (0.58)	1.71 (0.58)	−0.26 (− 0.68 to 0.16)	0.215

*=Significant difference between groups (p-value<0.05), #=Experimental and control data are the mean values after adjustment for differences in pre-intervention values by ANCOVA, therefore, the SDs of these mean values provided from ANCOVA analysis are equal across the 2 groups, S.D.=standard deviation, CI=confidence interval

These findings confirm those of previous studies. Nicolini et al.[32] examined the effects of temporary PEP (TPEP), classified as oscillation PEP (1 centimeter of water pressure and an oscillation frequency of 42 Hz), on the level of breathlessness and pulmonary function in patients with COPD. Their results showed that the TPEP group had a statistically significant improvement in breathlessness and pulmonary function compared to the control group. Bellone et al.[33] found that PEP mask therapy was effective for enhanced sputum expectoration and improved weaning time in patients with AECOPD. Cheng et al.[34] reported that the high-frequency chest wall oscillatory expectoration system (HFCWO) increased FVC and forced expiratory volume at 1 s (EFV1) in cases of severe AECOPD.

In the present study, PEP breathing was included in the treatment program so that COPD patients could have a better chance of pushing the expiratory airflow out of their lungs. The PEP effect works because breathing out through a PEP device prevents airway closure, improves mucus clearance, and increases functional residual capacity[19]. In this study, the BreatheMAX breathing device was used during exhalation as part of the PEP breathing exercise. If the patient's exhalation overcame the resistance of 5 cm of water, auditory feedback (a spurting sound) was given, which allowed the patient to prolong the expiratory time (Te). This resulted in a greater retention of airway pressure during exhalation; hence, the expiratory airflow had a better chance of moving out into the atmosphere[20]. This might have been the mechanism that helped improve SVC in our study.

ACBT was chosen to improve participants' secretion clearance. Breathing control, which is the first step of ACBT, was found to relax the patient's airways. In the second step, a thoracic expansion exercise helped loosen the secretion. In the last step, the FET moved the secretions downstream toward the mouth[35,36], which improved the patients' secretion clearance. This may have led to the improvement in SVC found among the participants in this study. To maintain patients' muscle strength, upper-limb exercises were also included in the PR program.

In the control group, patients were given a combination of pursed-lips breathing, diaphragmatic breathing, and chest mobilization. However, none of these techniques were specifically aimed at improving secretion clearance. Moreover, although pursed-lips breathing offers a positive expiratory pressure (PEP) effect, it does not include the auditory feedback that the BreatheMAX device provides. The absence of such feedback and the limited focus on secretion clearance may have contributed to the control group's lower effectiveness in enhancing SVC compared to the CPAU group.

No significant decrease in RPE was observed after treatment compared to the baseline. This result differs from other studies. Milan et al.[15] found that, during a five-day hospitalization, PEP breathing and oscillation PEP breathing

with FET increased sputum discharge and decreased levels of breathlessness in AECOPD patients. Torres-Sanchez et al.[37] showed that a nine-day PR program of 15 minutes of breathing exercises and 20–30 minutes of limb exercises significantly improved muscle strength and exercise capacity in patients with AECOPD. He et al.[38] found that a nine-day PR program that combined endurance and strength exercises with breathing exercises improved the six-minute walk distance test score and the Borg dyspnea score in AECOPD patients. To explain the lack of change in RPE levels observed in this study, Varga[39] noted that dyspnea and RPE can be affected by multiple factors, including inspiratory muscle weakness and fatigue. Hill et al.[40] recommend an eight-week PR program, with sessions held 3 times per week, to effectively address inspiratory muscle weakness. Given this recommendation, the two-day program used in this study may have been inadequate for significantly improving inspiratory muscle strength, which might explain the absence of notable changes in RPE levels. Nevertheless, it is important to highlight that RPE scores in the CPAU group demonstrated a decreasing trend (Table 2), indicating some degree of improvement.

Our study has several limitations. First, the CPAU program lasted only 2 days, which might be inadequate to elicit statistically significant changes in RPE. Thus, similar studies should be conducted with longer periods of intervention. Second, the lack of patient blinding may be considered a limitation, as this may affect the validity of the results. Hence, patient blinding should be considered for future research. Third, the long-term effects of the CPAU program were not evaluated in this study. In the future, scholars should focus on such long-term effects in order to evaluate the program's lasting benefits.

Conclusion

The results of this study show that a two-day program combining PEP breathing, ACBT, and upper-limb exercises was effective in increasing SVC in AECOPD patients during hospitalization.

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Conflict of interest

The authors have no competing interests to declare.

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