ORIGINAL ARTICLE

Arch AHS

Archives of Allied Health Sciences 2023; 35(1): 23-34.

Thai physiotherapists' performance of manual chest wall percussion on an artificial lung: frequency, force, and fatigue perception

Buranat Audsavachulamanee[1,2], Sahachat Aueyingsak[2,3], Chulee Ubolsaka-Jones[1,2], Nimit Kosura[1,2], Jinnipa Chanapon[2,4], Naruemon Yubonpan[2,5], Chatchai Phimphasak[1,2*]

[1] School of Physical Therapy, Faculty of Associated medical science, Khon Kaen University, Khon Kaen, Thailand.

[2] Innovation to Improve Cardiopulmonary & Physical Performances Research Group (IICP), Khon Kaen University, Khon Kaen, Thailand.

[3] Department of Physical Therapy, Faculty of Health Science, Christian University, Nakhon Pathom, Thailand.

[4] Department of Physical Therapy, Ratchaphruek Hospital, Khon Kaen, Thailand.

[5] Department of Physical Therapy, Kalasin-Thonburi Hospital, Kalasin, Thailand.

KEYWORDS
Manual chest percussion;
Physiotherapy;
Chest percussion;
Chest clapping.

ABSTRACT

Manual chest wall percussion (MP) is a conventional chest physical therapy that aims to assist airway clearance. Various frequencies and forces of MP are widely used in current practice. However, MP low frequency, highest frequency, and repeatability have not been explored. Moreover, the relationship between MP force and flow oscillation amplitude (FOA) has not been reported. Our objective is to explore the performance of physiotherapists in performing MP at three frequencies (routine, low, and highest) and repeatability of MP in the artificial lung and explore the relationship between MP force and FOA. Physiotherapists with cardiopulmonary practice experience performed MP at three frequencies: routine, low, and highest. Each physiotherapist performed MP on the artificial lung at each frequency for five minutes, on two different days. We measured the frequency and force of MP, the physiotherapist's fatigue, and the flow and pressure from the artificial lung during percussion. Forty-four participants were recruited for this study. The routine, low, and highest frequencies were 5.4 ± 0.6 Hz, 3.9 ± 0.9 Hz, and 6.5 ± 0.8 Hz, respectively. The force in the dominant hand at the routine, low, and highest frequencies was 5.2 ± 1.2 kg, 4.4 ± 1.4 kg, and 5.9 ± 1.8 kg, respectively. The force in the non-dominant hand at the routine, low, and highest frequencies was 3.8 ± 1.1 kg, 3.3 ± 1.1 kg, and 4.3 ± 1.4 kg, respectively. The average 5-minute upper body fatigue scores for the routine, low, and highest frequencies were 2.5 (range 0.0–5.5), 1.6 (range 0.0–5.6), and 4.1 (range 0.2–8.5), respectively Additionally, the highest and low frequencies show great repeatability (r = 0.90, *p*-value < 0.001, r = 0.86, *p*-value < 0.001, respectively), although the routine frequency only showed moderate repeatability (r = 0.69, *p*-value < 0.001). The positive relationship between dominance and non-dominance in MP force and FOA were met (r = 0.85, *p*-value < 0.001 for the dominant hand and r = 0.76, *p*-value < 0.001 for the non-dominant hand). In conclusion, the possible MP frequency in clinical practices was 3.9 to 6.5 Hz with force 3.3 to 5.2 kg. MP force direct effect on FOA. Based on fatigue perception and repeatability results, we recommend using MP for 3–5 minutes per session.

***Corresponding author:** Chatchai Phimphasak, PT, PhD. School of Physical Therapy, Faculty of Associated Medical Sciences, Khon Kaen University, Khon Kaen, 40002 Thailand. Email address: chatphi@kku.ac.th

Received: 24 October 2022/ Revised: 12 November 2022/ Accepted: 24 November 2022

Introduction

Manual chest wall percussion (MP), manual chest wall vibration, shaking, and postural drainage are conventional chest physiotherapist techniques (CPT) that aim to clear secretion, promote ventilation, and prevent lung complications(1). MP generates mechanical force through the chest wall to manipulate intrathoracic pressure and fluctuate airflow in the bronchial tree(2).

Various chest wall oscillation devices have been developed to replace MP, vibration, and shaking techniques, such as the mechanical vibrator(3), the high-frequency chest wall oscillation machine(4), and the Frequencer®(5). These instruments can adjust the oscillation frequency, oscillation force, and duration of treatment, thereby reducing the therapist's effort. However, in many places, these tools are not available, and in some cases, therapist's help is required to apply CPT.

MP has three essential components that affect the technique efficacy: oscillation frequency, force, and treatment duration. We found only three studies that have investigated routine MP force and frequency from physiotherapists(2,6,7). Previous studies have used MP as a treatment intervention with various parameters, such as 3.0–4.5 Hz for 2 minutes(8), 8.3 Hz(9), and 1.6–2.0 Hz for 10 minutes(10). The textbook recommends an MP frequency of 3.0–6.0 Hz and approximately 2–5 minutes in each position(11-14). Some studies have used MP as a treatment without reporting the frequency and duration(15,16).

According to various MP parameters, it is possible to cause a mixed result of clearance ability(17-20) and difficulty developing a clear indication of MP. MP is less popular than alternative methods due to the labour involved and the lack of evidence regarding its efficacy(21). However, MP is still taught in all Thai physiotherapy curricula and is used in many countries, such as Australia, India, and Turkey(22-24). This technique is easy and has low cost because no equipment is required – nor is the patient's cooperation required, which is especially significant when the patient is a child or an individual in intensive care(22,24).

Reportedly, an oscillation frequency of around 12-13 Hz in mechanical instruments can improve viscoelasticity(25). If the physiotherapist can do MP, a frequency near this range may improve mucus viscosity. Although the higher frequency is possibly more beneficial, the low frequency was used for children(6). Some study showed clearance benefits on low frequency chest percussion(20). Moreover, the therapist's fatigue may be correlated with oscillation frequency, force, treatment duration, and willingness to perform MP.

We still do not know the nature of the current MP techniques, including routine and low frequency, force, and repeatability. Furthermore, the highest frequency at which a physiotherapist can perform MP has not been established. This study investigated physiotherapists' oscillation frequency, force, and fatigue levels when performing MP at three different frequencies (routine, low, and highest) and the repeatability of MP in the artificial lung. Additionally, we aimed to explore the relationship between MP force and flow oscillation amplitude (FOA). We hope that this study would provide essential information for developing standard MP techniques and clear indications under the limits of physiotherapist performance.

Materials and methods

Participants

We recruited Thai physiotherapists who had a current Thai physical therapy license and one year of experience in the cardiopulmonary field. We excluded individuals who could not perform PM due to musculoskeletal problems, such as wrist, shoulder, or neck pain. This study was approved by the Khon Kaen University Ethics Committee for Human Research (HE632208). All subjects signed an informed consent form prior to the study.

Artificial lung

In this study, we built an artificial lung with an acrylic box (13 × 37 × 10 cm) composed of four layers: (1) artificial fat (icepack gel-filled with sac) in which the sac was fixed with an acrylic board via rope to prevent shifting from the artificial lung, (2) 1-litre capacity artificial lung (Ventiplus™, Maxtech, Utah, USA), (3) acrylic board, and (4) force sensor (Model SS25LB, Biopac system Inc., California, USA) (Figure 1). Additionally, we used an air compressor (PP-1, PUMA, Bangkok, Thailand) to connect Bird's respirator mark 7 to the artificial lung for continuous air inflation and flow regulation (0.13 ± 0.10 L/sec) via a corrugated tube (22 mm). We set the Bird's respirator at the highest pressure cycle and at the highest inspiratory flow rate for continuous inflation of air in the artificial lung. Before each MP trial, the artificial lung was fully inflated with 25 ± 2 cm H_2O pressure. The artificial fat bag was lifted off the edge of the box.

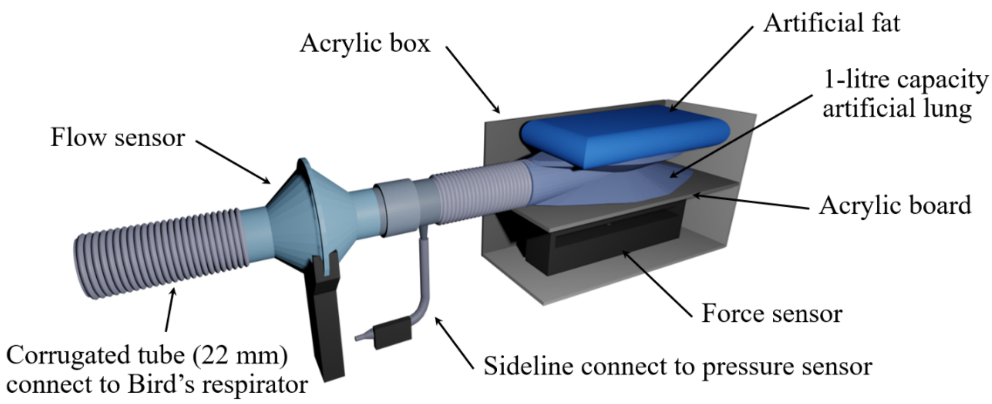

Figure 1 The artificial lung model component and circuit.

Manual percussion (MP)

We directed the physiotherapist to perform percussion at different frequencies for five minutes each: (1) routine frequency ('percuss at a routine frequency that used in daily work'), (2) low frequency ('percuss at a frequency lower than routine frequency'), and (3) highest frequency ('percuss as fast as you can'). This study was conducted for two days: on the first day, the physiotherapists performed percussion at three frequencies; on the second day, they repeated this process. Each subject was directed to start percussion on the artificial lung at routine frequency, followed by low frequency, and then followed by the highest frequency, with 10-minute inter-frequency rests. If the subject could not complete the five minutes of percussion at a given frequency due to fatigue or pain, they could stop.

Outcome measures

Subject characteristics were collected using a questionnaire. Airflow, pressure, and force were continuously measured by a flow transducer (Model SS11LA), a pressure transducer (Model SS13L), and a hand dynamometer (Model SS25LB), respectively, that integrated with BIOPAC MP 36 (BIOPAC Systems, Inc., California, USA). The sample rate was set at 500 Hz. We used the last five seconds in every minute for analysis. The flow and pressure were analysed to FOA and pressure oscillation amplitude (POA). Airflow and pressure data were plotted against time, and the flow-time plot was measured to determine the frequency. A numeric rating scale from 0 to 10 was used to evaluate upper body fatigue perception every minute: 0 indicated 'no fatigue', 5 'moderate fatigue', and 10 'extreme fatigue'.

Statistical analysis

The sample size was calculated from the estimation mean of the infinite population equation[26]. We set the alpha error at 0.05, the margin of error (d) at 0.297 Hz, and the standard deviation based on the previous study[7], and the total sample size was 44.

All analyses were conducted using STATA 10 software (StataCorp LLC, Texas, USA). This study used descriptive statistics for the analysis. After tracking all data from BIOPAC, the data from the first and second MP at each frequency and each time point (each trial n = 44) were individual averaged. Below, data is presented as mean and standard deviation for normal distribution continuous data, as median and range for non-parametric continuous data, and as number and percentage for categorical data. The correlation between the first and second trial of frequency and force in each condition were analyzed by Pearson correlation to explore the repeatability of the physiotherapist. The relationship of MP force and FOA were analyzed by Pearson correlation from average first and second trial data.

Results

Forty-four participants (10 males and 34 females) were recruited for this study. Their characteristics are presented in table 1. All physiotherapists were right-handed.

Table 1 Characteristics of participants

Characteristics	Value
Gender: n(%)	
Male	10 (22.7)
female	34 (77.3)
Age (year)	37 (26-59)
BMI (kg/m^2)	22.2 (17.1-38.9)
Experience in the cardiopulmonary field (year)	12.5 (1-32)
Number of cardiopulmonary patients per week (person/week)	20 (1-75)
Frequency of using the percussion per week (time/week)	10 (1-50)

Note: Data presented in median (min-max) for continuous data and n (%) in categorical data

The distribution of the mean MP frequency (pool data from both trials, n = 88) is illustrated in figure 2. The results showed that MP's average routine and low frequencies were 5.4 ± 0.6 Hz and 3.9 ± 0.9 Hz, respectively. However, the average highest frequency was 6.5 ± 0.8 Hz. The MP frequency range of human performance was 1.9–9.3 Hz or 114–558 times per minute. The highest frequency attained was 9.3 Hz, which occurred during the 3rd minute of the highest frequency MP. The number of physiotherapists who completed MP for five minutes was 42 (95.5%) for routine frequency, 43 (97.7%) for low frequency, and 36 (81.8%) for the highest frequency. The physiotherapists had an average MP force of approximately five kg for the dominant hand and four kg for the non-dominant hand. The frequency and force of percussion were consistent for five minutes (Table 2).

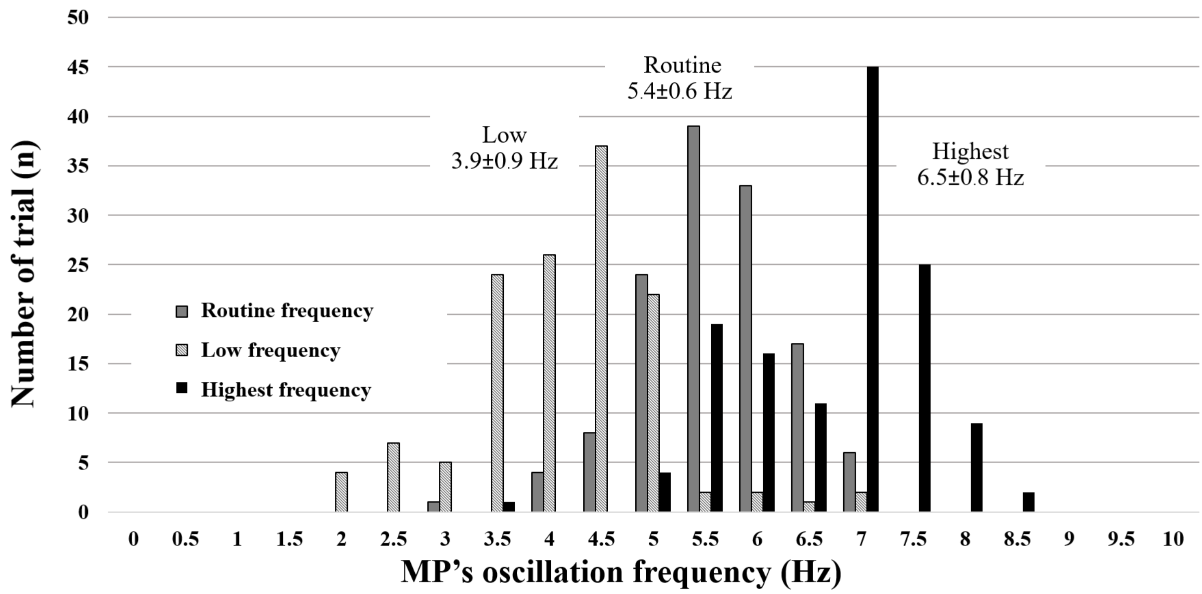

Figure 2 The distribution of MP frequency (pool data from both trials n = 88). The area of each color represents the number of physiotherapist who performed MP under different conditions.

Table 2 Frequency, force, and upper limb fatigue of manual percussion on artificial lung model

Parameters		Time (min)										Average 5 min	
		1		2		3		4		5			
Number of PT n (%)	R	44 (100.0)		44 (100.0)		43 (97.7)		42 (95.5)		42 (95.5)			
	L	44 (100.0)		44 (100.0)		44 (100.0)		43 (97.7)		43(97.7)			
	H	44 (100.0)		43 (97.7)		40 (90.9)		36 (81.8)		36 (81.8)			
Frequency (Hz)	R	5.5 ± 0.6	(3.9 - 6.6)	5.4 ± 0.6	(3.8 - 6.5)	5.4 ± 0.6	(3.9 - 6.5)	5.3 ± 0.6	(4.0 - 6.5)	5.3 ± 0.6	(4.0 - 6.5)	5.4 ± 0.6	(3.9 - 6.5)
	L	3.8 ± 0.9	(2.0 - 6.7)	3.9 ± 0.9	(1.9 - 6.5)	3.9 ± 0.9	(1.9 - 6.6)	3.9 ± 0.7	(1.9 - 5.4)	3.8 ± 1.3	(1.9 - 5.6)	3.9 ± 0.9	(1.9 - 6.6)
	H	6.6 ± 0.8	(5.1 - 8.0)	6.5 ± 0.8	(5.0 - 7.9)	6.4 ± 0.8	(2.8 - 9.3)	6.3 ± 0.9	(4.8 - 7.9)	6.4 ± 0.9	(4.8 - 8.0)	6.5 ± 0.8	(5.0 - 7.9)
Force D (kg)	R	5.0 ± 1.2	(1.6 - 7.2)	5.1 ± 1.2	(2.8 - 7.6)	5.0 ± 1.2	(2.8 - 7.3)	5.1 ± 1.3	(2.8 - 7.9)	5.1 ± 1.2	(2.8 - 7.6)	5.2 ± 1.2	(2.9 - 7.3)
	L	4.5 ± 1.4	(2.0 - 8.5)	4.4 ± 1.4	(2.4 - 8.2)	4.4 ± 1.4	(2.3 - 8.0)	4.4 ± 1.4	(2.3 - 7.7)	4.4 ± 1.3	(2.3 - 7.9)	4.4 ± 1.4	(2.5 - 8.1)
	H	6.0 ± 1.8	(2.8 - 9.6)	5.8 ± 1.3	(3.0 - 9.3)	5.8 ± 1.7	(2.8 - 9.3)	5.7 ± 1.7	(2.5 - 9.6)	5.8 ± 1.9	(2.6 - 10.2)	5.9 ± 1.8	(2.7 - 9.6)
Force nD (kg)	R	3.9 ± 1.2	(1.3 - 7.1)	3.8 ± 1.1	(2.1 - 6.1)	3.8 ± 1.0	(2.1 - 6.2)	3.9 ± 1.1	(2.0 - 6.8)	3.8 ± 1.2	(1.9 - 6.8)	3.8 ± 1.1	(2.1 - 6.6)
	L	3.5 ± 1.2	(1.6 - 6.5)	3.3 ± 1.2	(1.6 - 6.3)	3.2 ± 1.1	(1.7 - 6.3)	3.3 ± 1.1	(1.7 - 6.4)	3.3 ± 1.1	(1.6 - 6.3)	3.3 ± 1.1	(1.7 - 6.3)
	H	4.5 ± 1.4	(2.5 - 7.8)	4.2 ± 1.3	(2.2 - 7.4)	4.2 ± 1.3	(2.1 - 7.1)	4.1 ± 1.4	(1.9 - 7.2)	4.2 ± 1.4	(1.9 - 7.4)	4.3 ± 1.4	(2.0 - 7.8)
Fatigue score Median (min-max)	R	0.8	(0.0 - 3.5)	1.8	(0.0 - 6.0)	3.0	(0.0 - 7.0)	3.0	(0.0 - 6.5)	3.8	(0.0 - 8.0)	2.5	(0.0 - 5.5)
	L	0.3	(0.0 - 3.0)	0.5	(0.0 - 6.0)	1.5	(0.0 - 8.0)	1.5	(0.0 - 7.0)	2.0	(0.0 - 7.5)	1.6	(0.0 - 5.6)
	H	2.0	(0.0 - 8.5)	3.0	(0.0 - 10.0)	4.3	(0.0 - 9.5)	5.0	(0.5 - 9.0)	6.0	(0.5 - 10.0)	4.1	(0.2 - 8.5)

Note: Data presented in mean ± SD and (min - max). PT, physiotherapist; R, routine frequency; L, low frequency; H, Highest frequency; D, Dominant hand; nD, non-dominant hand.

The average 5-minute upper body fatigue scores for the routine, low, and highest frequencies were 2.5 (range 0.0 – 5.5), 1.6 (range 0.0 – 5.6), and 4.1 (range 0.2 – 8.5), respectively. Table 2 shows that fatigue scores increased over time. There was very strong repeatability in both low and highest frequency MP (r = 0.86, *p*-value < 0.001, r = 0.90, *p*-value < 0.001, respectively), and moderate repeatability in routine frequency MP (r = 0.69, *p*-value < 0.001). The dominant hand MP force of highest and low frequency was very strong and strong repeatability (r = 0.80, *p*-value < 0.001, r = 0.73, *p*-value < 0.001, respectively), and routine frequency MP showed moderate repeatability (r = 0.57, *p*-value < 0.001). In the same way, the repeatability of non-dominance hand MP force in highest frequency was strong (r = 0.76, *p*-value < 0.001), and the routine and low frequency were moderate (r = 0.57, *p*-value < 0.001, r = 0.61, *p*-value < 0.001, respectively).

The dominant hand's POA values produced by the routine, low, and highest frequencies were 23.8 ± 6.9, 20.4 ± 2.1, and 29.8 ± 10.8 cm H_2O, respectively. The non-dominant hand's POA values produced by the routine, low, and highest frequencies were 15.4 ± 5.7, 12.9 ± 5.7, and 18.8 ± 8.0 cm H_2O, respectively (Table 3). The FOA values produced by the dominant hand in the routine, low, and highest frequencies were 8.7, 6.9, and 11.7 litres per second, respectively. The FOA values produced by the non-dominant hand in the routine, low, and highest frequencies were 5.1, 4.2, and 6.8 litres per second, respectively. FOA is strongly correlated with MP force of dominance (r = 0.92, *p*-value < 0.001) and non-dominant hand (r = 0.87, *p*-value < 0.001).

Table 3 Flow and pressure oscillation amplitude of manual percussion on artificial lung model

Parameters		Time (min)										Average 5 min	
		1		2		3		4		5			
Number of PT	R	44 (100.0)		44 (100.0)		43 (97.7)		42 (95.5)		42 (95.5)			
n (%)	L	44 (100.0)		44 (100.0)		44 (100.0)		43 (97.7)		43(97.7)			
	H	44 (100.0)		43 (97.7)		40 (90.9)		36 (81.8)		36 (81.8)			
FOA D	R	8.5 ± 3.2	(2.4 - 15.3)	8.6 ± 3.3	(3.1 - 19.2)	8.7 ± 3.4	(3.6 - 18.2)	8.8 ± 7.7	(13.2 - 17.6)	8.9 ± 3.8	(3.4 - 19.9)	8.7 ± 3.4	(3.4 - 18.6)
(l/sec)	L	7.1 ± 3.6	(2.4 - 17.0)	6.9 ± 3.3	(2.5 - 16.4)	6.9 ± 3.2	(2.3 - 16.3)	6.9 ± 3.2	(2.4 - 14.6)	7.0 ± 3.0	(2.1 - 15.0)	6.9 ± 3.2	(2.4 - 15.9)
	H	11.6 ± 5.2	(4.4 - 24.5)	11.3 ± 4.9	(4.0 - 23.9)	11.7 ± 5.2	(4.1 - 24.0)	11.6 ± 5.6	(4.1 - 23.4)	11.8 ± 5.9	(4.3 - 23.8)	11.7 ± 5.2	(4.4 - 23.7)
FOA nD	R	5.3 ± 6.4	(11.6 - 40.4)	5.1 ± 2.4	(1.9 - 14.2)	5.1 ± 2.4	(2.1 - 13.9)	5.1 ± 2.4	(2.2 - 13.0)	5.2 ± 2.6	(2.1 - 15.0)	5.1 ± 2.3	(2.1 - 13.5)
(l/sec)	L	4.5 ± 2.4	(1.3 - 11.8)	4.2 ± 2.2	(1.3 - 11.0)	4.0 ±2.1	(1.3 - 10.6)	4.2 ± 2.2	(1.3 - 11.6)	4.1 ± 2.2	(1.1 - 11.4)	4.2 ± 2.1	(1.3 - 11.1)
	H	7.0 ± 3.5	(2.9 - 18.0)	6.4 ± 2.9	(13.8 - 52.3)	6.6 ± 3.4	(2.5 - 17.2)	6.3 ± 3.0	(2.2 - 12.1)	6.5 ± 3.6	(2.2 - 17.5)	6.8 ± 3.4	(2.5 - 15.5)
POA D	R	23.8 ± 6.4	(11.6 - 40.4)	23.9 ± 7.4	(11.7 - 46.3)	23.8 ± 7.0	(13.8 - 41.5)	23.5 ± 7.7	(13.2 - 47.6)	24.0 ± 8.0	(12.2 - 46.6)	23.8 ± 6.9	(14.0 - 43.6)
(cm H_2O)	L	20.7 ± 8.9	(6.7 - 46.7)	20.3 ± 8.6	(7.8 - 45.1)	20.6 ± 8.5	(8.0 - 46.3)	20.1 ± 7.9	(7.9 - 39.4)	20.5 ± 7.8	(7.4 - 40.6)	20.4 ± 2.1	(1.3 - 11.1)
	H	29.9 ± 10.7	(14.0 - 48.8)	28.8 ± 10.1	(13.2 - 52.3)	29.1 ± 10.3	(13.8 - 49.8)	29.0 ± 11.1	(12.6 - 53.0)	29.3 ± 12.6	(12.9 - 60.9)	29.8 ± 10.8	(14.3 - 52.9)
POA nD	R	16.2 ± 5.9	(8.3 - 37.9)	15.2 ± 5.8	(1.9 - 14.2)	15.2 ± 5.8	(5.4 - 32.9)	15.4 ± 6.0	(7.7 - 36.3)	15.3 ± 6.3	(7.6 - 36.0)	15.3 ± 5.7	(7.8 - 34.5)
(cm H_2O)	L	13.8 ± 6.0	(4.7 - 30.7)	13.0 ± 5.8	(4.6 - 28.9)	12.5 ± 5.7	(4.4 - 26.6)	12.9 ± 5.8	(4.7 - 27.4)	12.8 ± 6.1	(3.9 - 30.4)	12.9 ± 5.7	(4.5 - 27.8)
	H	19.7 ± 8.4	(9.5 - 46.3)	17.9 ± 7.1	(7.9 - 40.3)	17.7 ± 7.9	(8.7 - 49.4)	17.7 ± 6.8	(7.7 - 36.5)	17.7 ± 7.6	(6.2 - 34.1)	18.8 ± 8.0	(8.3 - 41.2)

Note: Data presented in mean ± SD and (min - max). PT, physiotherapist; R, routine frequency; L, low frequency; H, Highest frequency; D, Dominant hand; nD, non-dominant hand; FOA, Flow oscillation amplitude; POA, Pressure oscillation amplitude

Discussion

Our study investigated the frequency and force of the current routine MP in clinical practice. We expanded the survey in low-frequency MP, which is found in clinical use, and extended measurements to the highest frequencies, which the physiotherapist can achieve. Moreover, this study is the first to report the possible treatment duration based on the fatigue score, the repeatability of frequency and force of MP from two trials, and the association between MP force and FOA.

In this study, we found that Thai physiotherapists' routine frequency and force of MP were 5.4 ± 0.6 Hz and 5.2 ± 1.2 kg, respectively. These results differed from those of Blazey et al[7]. They found that Australian physiotherapists' average MP frequency was 6.60 ± 1.00 Hz[7]. In contrast, our results regarding force of MP are close to 58.1 ± 15.3 Newton (5.93 ± 1.56 kg) from Blezey's study[7]. Wong et al[2] found that physiotherapists used a frequency of 6.2 ± 0.9Hz; however, their study used esophagus pressure to represent the percussion force and, therefore, cannot be compared to the present study. A survey by Flower et al[6] reported that physiotherapist MP was around 250 – 480 beats per minute (4.2 – 8.0 Hz); furthermore, they measured the percussion force around 58 – 65 Newtons (5.92 – 6.63 kg) which is similar to the measurement in this study.

In this study, the average highest MP frequency was around 6.5 ± 0.8 Hz (range 1.9 – 9.3 Hz or 114 – 558 times per minute) for maximum performance. The results showed the highest frequency at 9.3 Hz, which occurred during the 3rd minute of the highest frequency MP (Table 2); this was similar to the highest frequency MP in previous studies, 8.0 Hz[6] and 8.47 Hz[7]. However, the maximum MP frequency (9.3 Hz) from this study is beyond the range in which mucus viscosity is improved (12–13 Hz)[25]. Consequently, FOA, characterized as an expiratory flow bias, may be a possible primary clearance mechanism of MP.

In theory, high frequency should provide more benefits, such as changing viscoelasticity or assisting cilia function. Tomkiewicz et al[25] used mucus gel stimulation in an artificial tube. They applied oscillation airflow using high-frequency chest wall oscillation devices (12–13, 22-23 Hz), and they reported that airflow oscillation could decrease the viscosity and spinnability of mucus[25]. Although the MP frequency in our survey did not reach the theoretical model's viscoelasticity effect, greater frequency of MP appeared to have a better benefit for mucus clearing. King and colleagues[27] showed that 5, 8, and 13 Hz of high-frequency chest wall oscillation could improve tracheal mucus clearance (peak improvement at 13 Hz). However, some physiotherapists performing MP at a higher frequency might provide more forceful percussion. Therefore, if the physiotherapist performed high frequency of MP, we advised that the patient should be constantly monitored and that extra towels should be used to avoid complications from unintentional excessive force of MP.

In clinical practice, physiotherapists perform MP for various durations, depending on each patient's clinical status and each physiotherapist's performance characteristics. Some textbooks recommend using MP for 3 – 5 minutes per area[13,14]. This study found that the upper body fatigue scores increased over time. Physiotherapists applying low or routine frequencies were under moderate fatigue after five minutes, whereas physiotherapists applying the highest frequency sometimes experienced fatigue beyond the moderate level. Our results showed that the physiotherapist could percuss consistently in frequency and force for five minutes (Table 2). Based on the above information, we suggest an MP duration of 3 – 5 minutes per area in the routine, low, and highest frequencies for the comfort of the physiotherapist. Our recommendation concurs with the textbook recommendation[11-14]; however, more evidence is needed to confirm the effectiveness of this duration.

This study demonstrates that low and highest conditions have superior repeatability in frequency and force than the routine condition, which has moderate repeatability at both. This result represents that each physiotherapist routinely performed MP with a variety of frequencies and forces. Physiotherapists perform more consistently when given a certain condition, such as performing low or highest frequency. It could be referring to the absence of MP protocol standards in current usage.

Oscillation amplitude represents the magnitude of changing a variable (highest peak to lowest peak) in each oscillation during the oscillation system[28]. Our results prove that force of MP is directly related to FOA. In this article, we demonstrate that the dominant hand is able to generate a greater MP force than the non-dominant hand because the dominant hand had a marginally higher muscle strength[29]. Therefore, the dominating hand with more force can provide a larger rate of expiratory flow. However, this result should be interpreted with caution because our artificial lung may lack some force-absorbing factor, such as the musculoskeleton, the distance between the chest wall and lung, or pleura.

The recruitment of participants in our study was limited to Thai physiotherapists. We used MP on an artificial lung that could have a deviation in airflow and pressure from the human subjects. The artificial lung constituted a limitation as it could not replicate a natural breathing pattern (i.e., inhalation and exhalation) because the changing pressure would automatically cycle the inspiration and the lung would rapidly deflate.

Conclusion

The routine, low, and highest frequencies were 5.40 ± 0.62 Hz, 3.91 ± 0.86 Hz, and 6.49 ± 0.81 Hz, respectively. The force in the dominant hand at the routine, low, and highest frequencies was 5.23 ± 1.18 kg, 4.40 ± 1.35 kg, and 5.88 ± 1.78 kg, respectively. Based on the fatigue scores, we recommend an MP duration of 3 – 5 minutes in the routine, low, and highest frequencies. The physiotherapist routinely applied frequency and force of MP with moderate repeatability, but when they changed to the highest frequency, the repeatability for frequency and force was strong to very strong.

Take home messages

We report a current routine frequency of 5 – 6 Hz with a percussion force of 3 – 5 kg of manual chest wall percussion. The highest frequency is around 6 – 7 Hz. Based on upper body fatigue scores, it is possible to apply 3 – 5 minutes per session in clinical practice.

Conflicts of interest

The authors declared no conflict of interest.

Acknowledgments

This research is funded by The New Researcher Development Project Khon Kaen University 2021, Khon Kaen University, Thailand. We would like to thank IICP research group for providing equipment and location for this research, and all physiotherapists who joined this research.

References

1. Van der Schans CP. Conventional chest physical therapy for obstructive lung disease. Respir Care 2007; 52(9): 1198-206.
2. Wong WP, Paratz JD, Wilson K, Burns YR. Hemodynamic and ventilatory effects of manual respiratory physiotherapy techniques of chest clapping, vibration, and shaking in an animal model. J Appl Physiol 2003; 95(3): 991-8.
3. Gwag HB, Joh HS, Kim JS, Park KM, On YK, Park SJ. Safety of mechanical lung vibrator and high-frequency chest wall oscillation in patients with cardiac implantable electronic device. Clin Cardiol 2021; 44(4): 531-6.
4. Clinkscale D, Spihlman K, Watts P, Rosenbluth D, Kollef MH. A randomized trial of conventional chest physical therapy versus high frequency chest wall compressions in intubated and non-intubated adults. Respir Care 2012; 57(2): 221-8.

5. Schieppati D, Germon R, Galli F, Rigamonti MG, Stucchi M, Boffito DC. Influence of frequency and amplitude on the mucus viscoelasticity of the novel mechano-acoustic Frequencer™. Respir Med 2019; 153: 52-9.
6. Flower KA, Eden RI, Lomax L, Mann NM, Burgess J. New mechanical aid to physiotherapy in cystic fibrosis. Br Med J 1979; 2(6191): 630-1.
7. Blazey S, Jenkins S, Smith R. Rate and force of application of manual chest percussion by physiotherapists. Aust J Physiother 1998; 44(4): 257-64.
8. Hammon WE, McCaffree DR, Cucchiara AJ. A comparison of manual to mechanical chest percussion for clearance of alveolar material in patients with pulmonary alveolar proteinosis (phospholipidosis). Chest 1993;103(5): 1409-12.
9. Ramos EM, Ramos D, Moreira GL, Macchione M, Guimaraes ET, Rodrigues FMM, et al. Viscoelastic properties of bronchial mucus after respiratory physiotherapy in subjects with bronchiectasis. Respir Care 2015; 60(5): 724-30.
10. Tomar GS, Singh GP, Bithal P, Upadhyay AD, Chaturvedi A. Comparison of effects of manual and mechanical airway clearance techniques on intracranial pressure in patients with severe traumatic brain injury on a ventilator: randomized, crossover trial. Phys Ther 2019; 99(4): 388-95.
11. Downs A. Physiological basis of airway clearance techniques. In: Frownfelter D and Dean E, editor. Principles and practice of cardiopulmonary physical therapy. 3rd ed. Missouri: Mosby-Year Book Publishers; 1996. p. 321-38
12. Olseni L, Lannefors L, van der Schans CP. Airway-clearance techniques individually tailored to each patient. In: Rubin BK and van der Schans CP, editor. Therapy for mucus-clearance disorders. New York: Marcel Dekker Publishers; 1996. p. 413-31.
13. Vines D, Gardner D. Airway clearance therapy (ACT). In: Kacmarek RM, Stoller JK and Heuer AJ, editor. Egan's fundamental of respiratory care. 11th ed. Missouri: Elsevier Publisher; 2017. p. 951-70.
14. Rodrigues J, Watchie J. Cardiovascular and pulmonary physical therapy treatment. In: Watchie J, editor. Cardiovascular and pulmonary physical therapy: a clinical manual. 2nd ed. Missouri: Elsevier Publisher; 2010. p. 298-425
15. van der Schans CP, Piers DA, Postma DS. Effect of manual percussion on tracheobronchial clearance in patients with chronic airflow obstruction and excessive tracheobronchial secretion. Thorax 1986; 41(6): 448-52.
16. Bauer ML, McDougal J, Schoumacher RA. Comparison of manual and mechanical chest percussion in hospitalized patients with cystic fibrosis. J Pediatr 1994; 124(2): 250-4.
17. May DB, Munt PW. Physiologic effects of chest percussion and postural drainage in patients with stable chronic bronchitis. CHEST 1979; 75(1): 29-32.
18. Mazzocco MC, Owens GR, Gonzales-Camid F, Warda M, Kirilloff LH, Rogers RM. Chest percussion and postural drainage in patients with bronchiectasis. Chest 1985; 88(3): 360-3.
19. Sutton PP, Lopez-Vidriero MT, Pavia D, Newman SP, Clay MM, Webber B, et al. Assessment of percussion, vibratory-shaking and breathing exercises in chest physiotherapy. Eur J Respir Dis 1985; 66(2): 147-52.
20. Gallon A. Evaluation of chest percussion in the treatment of patients with copious sputum production. Respir Med 1991; 85(1): 45-51.
21. Belli S, Prince I, Savio G, Paracchini E, Cattaneo D, Bianchi M, et al. Airway clearance techniques: the right choice for the right patient. Front Med [online] 2021 [cited 2022 Apr 29]. Available from: https://www.frontiersin.org/article/10.3389/fmed.2021.544826
22. Jingar A, Alaparthi G, Vaishali K, Krishnan S, Zulfeequer, Unnikrishnan B. Clinical management practices adopted by physiotherapists in India for chronic obstructive pulmonary disease: a national survey. Lung India 2013; 30(2): 131.
23. Osadnik CR, McDonald CF, Holland AE. Airway clearance techniques in acute exacerbations of COPD: a survey of Australian physiotherapy practice. Physiotherapy 2013; 99(2): 101-6.

24. Cakmak A, İnce Dİ, Sağlam M, Savcı S, Yağlı NV, Kütükcü EÇ, et al. Physiotherapy and rehabilitation implementation in intensive care units: a survey study. Turk Thorac J 2019; 20(2): 114-9.
25. Tomkiewicz RP, Biviji A, King M. Effects of oscillating air flow on the rheological properties and clearability of mucous gel simulants. Biorheology 1994; 31(5): 511-20.
26. Sharma SK, Mudgal SK, Thakur K, Gaur R. How to calculate sample size for observational and experimental nursing research studies? Natl J Physiol Pharm Pharmacol 2020; 10(01): 8.
27. King M, Phillips DM, Gross D, Vartian V, Chang HK, Zidulka A. Enhanced tracheal mucus clearance with high frequency chest wall compression. Am Rev Respir Dis 1983; 128(3): 511-5.
28. Zhou T. Oscillation Amplitude. In: Dubitzky W, Wolkenhauer O, Cho KH, Yokota H, editors. Encyclopedia of Systems Biology [online] 2013 [cited 2021 Apr 22]. p. 1616–1616. Available from: https://doi.org/10.1007/978-1-4419-9863-7_523
29. Armstrong CA, Oldham JA. A comparison of dominant and non-dominant hand strengths. J Hand Surg Br Eur Vol 1999; 24(4): 421-5.