J. Phys. Ther. Sci.
**18:** 5–10, 2006

# Effectiveness of Cough Exercise and Expiratory Muscle Training: A Meta-analysis

KOJIMA HAJIME[1, 2], YAMADA TAKUMI[1], TAKEDA MADOKA[1], ITOU YAYOI[1], YOSHIDA MIO[1], KIMURA MASAHIKO[1]

[1]*Tokyo Metropolitan University of Health Sciences*
[2]*Rehabilitation Department, St.Luke's International Hospital: 9–1 Akashi-cho, Chuo-ku, Tokyo 104-8560, Japan. e-mail: kojiha@luke.or.jp*

**Abstract.** Coughing is a defensive reflex action of the airway that removes foreign objects and mucus. Here, meta-analysis was performed to review the results of previous studies regarding the effects of coughing exercise and expiratory muscle training (EMT), and to examine the effectiveness of EMT in enhancing cough functions. A systematic literature search was performed using the EBMR, CINAHL, PEDro, MEDLINE, and Ichushi Web (NPO Japan Medical Abstracts Society) databases. Based on a methodological framework, a critical review was performed and summary effect sizes were calculated by applying the random effects model. Both the forced expiration technique (FET) and coughing alone significantly increased mucus clearance. EMT significantly increased expiratory muscle strength, suggesting that it is possible to improve cough effectiveness by EMT. Further studies with larger and more diverse sample groups are necessary to determine the effects of enhancing expiratory muscle strength on cough effectiveness.
**Key words:** Coughing exercise, Expiratory muscle training, Meta-analysis

*(The article was submitted Jul. 29, 2005, and was accepted Oct. 11, 2005 )*

## INTRODUCTION

Coughing is a defensive reflex of the airway. The glottis closes after inspiration, and when the expiratory muscles contract, the pleural, alveolar, and subglottic pressures increase to as much as 200 $cmH_2O$, after which the glottis reopens suddenly. Within 0.02s, expiratory flow (peak cough flow, PCF) may reach 6–16 L/s, resulting in removal of mucus and foreign bodies that have invaded the airway[1].

Coughing exercise is an airway clearance technique consisting of postural drainage, percussion, vibration, bagging, and airway suction, used in chest physiotherapy[2]. These methods include coughing alone, the forced expiration technique (FET), and the assisted coughing method.

In tetraplegic patients, coughing is thought to be insufficient because of severe impairment of expiratory muscle function. Van der Schans et al. reported a statistically significant increase in bronchial mucus transport in such patients due to voluntary coughing[3]. Moreover, Smina et al. reported that patients with PCF≤60 L/min were five times as likely to have unsuccessful extubation and 19 times as likely to die during their hospital stay. These observations suggest that PCF is a predictor of extubation outcome, morbidity, and mortality[4]. However, the effectiveness of chest physiotherapy for airway clearance in patients with acute or chronic respiratory failure has not yet been established[5], and its preventive effect against

aspiration pneumonia in patients with deglutition is still uncertain.

Based on the results of meta-analysis, Smith et al. reported that there was little evidence of benefit of clinical importance of inspiratory muscle training (IMT) in patients with chronic obstructive pulmonary disease (COPD)[6]. However, Lotters et al. re-examined the meta-analysis eight years later, and reported that controlled IMT was effective for these patients, especially those with inspiratory muscle weakness[7]. On the other hand, there have been no previous reports of meta-analysis of expiratory muscle training (EMT). Takahashi et al. reported the effects of respiratory physiotherapy on expiratory muscle confirmed by meta-analysis[8]. However, this study only included data from a Japanese study, which was not performed as a randomized controlled trial (RCT).

The present study was performed to clarify the effectiveness of coughing exercise and EMT by meta-analysis, and to determine whether EMT can enhance the effectiveness of cough.

## METHODS

The databases used for the literature selection were the Evidence-based Medicine Review (EBMR), including the Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, Database of Abstracts of Reviews of Effects, and ACP Journal Club provided by OVID Co., CINAHL (1990 to October 2004), PEDro, MEDLINE (1966 to October 2004), and Ichushi Web (NPO Japan Medical Abstracts Society; 1983 to October 2004). The keywords used in the literature search were as follows: cough, exercise or training, coughing exercise, expiratory muscle training, and human. Publication languages were English or Japanese, and the research design was a randomized controlled trial. Outcomes were described in terms of weight of sputum expectorated, radioactive aerosol clearance, PCF on coughing exercise, maximal expiratory pressure (PEmax), maximal inspiratory pressure (PImax), and PCF on EMT.

We retrieved each database, and obtained the literature that fulfilled the selection criterion based on the title and abstract. In addition, we reconfirmed whether these studies actually fulfilled the selection criteria. Relevant studies were selected for meta-analysis based on the references in the literature.

The methodological quality of each of the included studies was evaluated by two independent reviewers (Kojima, H. and one other) using a modification of the framework for methodological quality used by Smith et al. (full marks, 40 points; Table 1)[6]. Agreement regarding each criterion was evaluated by weighted Kappa statistic. Disagreements regarding methodological quality were resolved by a third reviewer (Yamada, T.).

The meta-analysis was performed using StatsDirect (StatsDirect Ltd., Sale, UK)[9].

The homogeneity test statistic (Q-statistic) of each set of effect sizes was examined to determine whether studies shared a common effect size, the variance of which could only be explained by sampling error[7]. When the p-value was>0.10, the homogeneity was considered consistent. In addition, effect sizes of each individual study were calculated based on a confidence interval of 95% using the random effect model.

## RESULTS

A total of ten studies (six concerning coughing exercise, and four concerning EMT) were used for meta-analysis in the present study. The study population in the coughing exercise studies consisted of 74 people, including patients with cystic fibrosis and COPD, while that in the EMT studies consisted of 76 subjects, including those with multiple sclerosis, COPD, and healthy individuals.

The weighted Kappa of inter-reviewer agreement for the validity criteria varied from 0.27–1.00, and the methodological quality score varied from 24–38 points. All of the coughing exercise studies were of randomized crossover design. The main qualitative faults of the studies were insufficient blinding procedures: in nine studies, the outcome evaluators were either not blinded or it could not be determined whether they had been blinded to experimental groups. There were no studies in which PCF was noted as an outcome.

The results of the meta-analysis are shown in Table 2. The outcomes that retained homogeneity were radioactive aerosol clearance, which was used to evaluate FET, coughing used to evaluate coughing exercise, and PEmax used to evaluate EMT.

There was no significant difference in radioactive

**Table 1.** Criteria for methodological quality[#]

| Literature | Reviewer: |
|---|---|
| Author: | |
| Title: | |

| | Score |
|---|---|
| Randomization | |
| Randomization procedure described | 5 |
| Randomization procedure not described (or unable to tell) | 0 |
| Similarity of groups | |
| Age,sex, BMI, FEV1, PEF | 0–5 |
| Intention to treat analysis | |
| Yes | 5 |
| No | 0 |
| Blinding | |
| Patient | |
| Therapist | |
| Reseacher | 0–5[¶] |
| Outcome measures | |
| Validity and/or reliability mentioned or referred to | 5 |
| Validity and/or reliability not mentioned or referred to | 0 |
| Exercise regimen | |
| Adequate description of intensity, duration and frequency in both exercise and control group | 5 |
| No adequate description of intensity, duration and frequency | 0 |
| Follow-up | |
| 90–100% follow-up | 5 |
| 80–89% follow-up | 3 |
| <80% subjects accounted for | 1 |
| Cannot tell | 0 |
| Aside from the experimental treatment, did the groups receive any additional treatment? | |
| Yes | 5 |
| No | 0 |

FEV1, forced expiratory volume in one second.[#], total score=40 points; [¶], 5 for 3 of 3, 4 for 2 of 3, 3 for 1 of 3, and 0 for 0 of 3.

aerosol clearance as compared with the control group which was prohibited from coughing, although the coughing group showed a significant increase in weight of sputum expectorated. The FET group showed a significant increase in weight of sputum expectorated as compared with the coughing alone group, but no significant differences were observed in radioactive aerosol clearance.

EMT significantly increased PEmax, but no effect was observed on PImax.

## DISCUSSION

Meta-analysis is a statistical technique for combining or pooling data from several studies within a systematic review[10]. Specifically, the effect size is calculated from the difference between means of the treatment and control groups after

**Table 2.** Overall results of meta-analysis using the random effect model

| Outcome measure | Studies n | Effect-size (95%CI) | Hemogeneity Q-statistic | p |
|---|---|---|---|---|
| Cough exercise: | | | | |
| Weight of sputum expectorated Coughing (n=16) vs Control (n=16) | 2 | 3.07 (0.06 to 6.09) | 6.14 | 0.01 |
| Radioactive aerosol clearance Coughing (n=26) vs Control (n=26) | 2 | 4.15 (–0.67 to 8.98) | 22.52 | 0.0001 |
| Weight of sputum expectorated FET (n=48) vs Coughing alone (n=48) | 4 | 2.01 (1.06 to 2.96) | 9.61 | 0.02 |
| Radioactive aerosol clearance FET (n=26) vs Coughing alone (n=26) | 2 | –0.34 (–0.88 to 0.21) | 0.11 | 0.74 |
| EMT: | | | | |
| PEmax Training (n=38) vs Control (n=38) | 4 | 1.38 (0.74 to 2.02) | 4.03 | 0.26 |
| PImax Training (n=32) vs Control (n=32) | 3 | 0.96 (–0.34 to 2.26) | 9.6 | 0.01 |

treatment, divided by the pooled standard deviation of the post-treatment outcome measure of the treatment and control groups[7]. The calculated effect sizes are weighed for sample size and summarized to obtain a weight summary effect size. Clinicians can then read the meta-analysis rather than large numbers of individual reports, which can save a great deal of time. Meta-analysis researchers should retrieve primary reports that fulfill the selection criterion in a comprehensive manner, and meta-analysis studies should be performed on reports with an RCT design to avoid bias in the primary reports. Moreover, it is necessary to evaluate the validity of the primary reports, and to exclude those of low quality. It is not necessary for the selected primary research to correspond with regard to patients, research design, contents of intervention, or outcome. However, homogeneity in the meta-analysis should be high.

The present meta-analysis had some limitations in selection bias in that we used only limited databases and languages, and that sufficient measures were not taken to control publication bias. Therefore, our meta-analysis contains some bias. With regard to the methodological quality of each of the studies included in the meta-analysis, the weighted Kappa of 0.27–1.00 is conventionally considered "fair to very good." There were some differences in judgment between reviewers as quality was evaluated by two or more reviewers. However, a third reviewer made the final decision to obtain reliability in judgment. The meta-analysis showed some heterogeneity. Most of the selected studies were of crossover design, had small sample size, and included various diseases. The effect size was calculated using the random effect model, which is a strict statistical method.

Meta-analysis indicated that coughing was an effective method for expectoration. Two selected reports showed no significant differences in radioactive aerosol clearance between coughing and control groups. However, one of these was a pilot study (Hasani 1991) of the other. The results of each of the other studies reached statistical significance, and the pilot study should not have been selected for meta-analysis. Therefore, the present meta-analysis confirmed that coughing exercise is effective for voluntary expectoration, although coughing was originally a reflex for airway clearance. FET is an alternative coughing technique advocated by Sesehou[11]. This method is called huffing, and is done without closing the glottis. This reduces transpulmonary pressure as compared with coughing, thereby resulting in less airway compression and closure (Hasani 1994). FET was shown to significantly increase the weight of expectoration as compared with coughing alone, but it was not significantly effective in radioactive aerosol clearance. These observations indicate that FET is as effective as coughing alone. Therefore, coughing training by FET is recommended for patients with COPD.

EMT is expected to improve exercise tolerance in patients with COPD (Weiner 2003), and to

strengthen cough function in patients with multiple sclerosis (Gosselink 2000). The findings of the meta-analysis performed in the present study confirm that EMT strengthens the expiratory muscles. All of the primary studies used threshold devices for training loading, and the results were consistent, yielding homogeneity in the meta-analysis. Lotters et al. concluded in their meta-analysis of the effects of controlled inspiratory muscle training in patients with COPD that when training loading was controlled, inspiratory muscle strength and endurance could be increased. Villafranca et al. reported that threshold loading enhanced the velocity of inspiratory muscle contraction[12]. Thus, threshold loading appears to be a suitable expiratory muscle training method to improve cough effectiveness as coughing is a reflex that requires rapid contraction of expiratory muscles within 0.02s.

In conclusion, this meta-analysis indicates that both FET and coughing alone can significantly increase mucus clearance, and that EMT significantly increases expiratory muscle strength. There were no studies in which PCF was noted as an outcome. Further studies with larger and more diverse sample populations are necessary to determine the effects of increasing expiratory muscle strength on cough effectiveness (Smeltzer 1996). It may be possible to improve cough effectiveness by EMT using threshold loading.

## ACKNOWLEDGEMENTS

The authors would like to thank Hanako Misao, RN., CNM., PHN., MSN., PhD. (St.Luke's Life Science Institute, Tokyo), for her kind advice, and Mr. Takayuki Koyama and Mr. Takayuki Taguchi (Tokyo Metropolitan University of Health Sciences), for their help in the critical review of this manuscript.

## REFERENCES

1) Bach JB: Amyotrophic lateral sclerosis: Predictors for prolongation of life by noninvasive respiratory aids. Arch Phys Med Rehabil, 1995, 76: 828–832.
2) Sciaky A, Stockford J, Nixon E: Treatment of acute cardiopulmonary conditions. In:Essentials of cardiopulmonary physical therapy. Philadelphia: W.B. Saunders Company, 2001, pp647–675.
3) Van der Schans CP, Piers A, Mulder GA: Efficacy of coughing in tetraplegic patients. Spine, 2000, 25: 2200–2203.
4) Smina M, Salam A, Khamiees M, et al.: Cough peak flows and extubation outcomes. Chest, 2003, 124: 262–268.
5) Miyagawa T: Kokyuurigakuryouhou no kagakusei. Jinkoukokyuu, 1998, 15: 91–104 (in Japanese).
6) Smith K, Cook D, Guyatt GH, et al.: Respiratory muscle training in chronic airflow limitation: a meta-analysis. Am Rev Respir Dis, 1992, 145: 533–539.
7) Lotters F, van Tol B, Kwakkel G, et al.: Effects of controlled inspiratory muscle training in patients with COPD: a meta-analysis. Eur Respir J, 2002, 20: 570–576.
8) Takahashi H, Shioya T, Miyagawa T: Meta-analysis of respiratory physiotherapy programs in Japan. J Jpn Soc Respiratory Care, 2002, 11: 399–403.
9) Stats Direct Statistical Software. Available from: http://www.statsdirect.com
10) Seers K: Systematic review. In: Evidence-Based Practice. London: Churchill Livingstone, 2003, pp85–100.
11) Thompson BJ: The physiotherapist's role in the rehabilitation of the asthmatic child. NZ J Physiother, 1973, 4: 11–16.
12) Villafranca C, Borzone G, Leiva A, et al.: Effect of inspiratory muscle training with an intermediate load on inspiratory power output in COPD. Eur Respir J, 1998, 11: 28–33.

## SELECTED STUDIES

*Coughing exercise*

· Bateman JR, Newman SP, Daunt KM, et al.: Is cough as effective as chest physiotherapy in the removal of excessive tracheobronchial secretions? Thorax, 1981, 36: 683–687.
· Sutton PP, Parker RA, Webber BA, et al.: Assessment of the forced expiration technique, postural drainage and directed coughing in chest physiotherapy. Eur J Respir Dis, 1983, 64 :62–68.
· van Hengstum M, Festen J, Beurskens C, et al.: Effect of positive expiratory pressure mask physiotherapy (PEP) versus forced expiration technique (FET/PD) on regional lung clearance in chronic bronchitics. Scand J Gastroenterol, 1988, 23 (suppl. 143): 114–118.
· Hasani A, Pavia D, Agnew JE, et al.: The effect of unproductive coughing/FET on regional mucus movement in the human lungs. Respir Med, 1991, 85 (suppl. A): 23–26.
· Steven MH, Pryor JA, Webber BA, et al.: Physiotherapy versus cough alone in the treatment of cystic fibrosis. NZ J Physiother, 1992, 20: 31–37.
· Hasani A, Pavia D, Agnew JE, et al.: Regional lung clearance during cough and forced expiration technique (FET): effects of flow and viscoelasticity. Thorax, 1994, 49: 557–561.

*Expiratory muscle training*

- Suzuki S, Sato M, Okubo T: Expiratory muscle training and sensation of respiratory effort during exercise in normal subjects. Thorax, 1995, 50: 366-70.
- Smeltzer SC, Lavietes MH, Cook SD: Expiratory training in multiple sclerosis. Arch Phys Med Rehabil, 1996, 77: 909–12.
- Gosselink R, Kovacs L, Ketelaer P, et al.: Respiratory muscle weakness and respiratory muscle training in severely disabled multiple sclerosis patients. Arch Phys Med Rehabil, 2000, 81: 747–51.
- Weiner P, Magadle R, Beckerman M, et al.: Specific expiratory muscle training in COPD. Chest, 2003, 124: 468–73.