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Original article

Adherence to home-based inspiratory muscle training in individuals with chronic obstructive pulmonary disease

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A R T I C L E I N F O

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Borg Category Ratio Scale of Perceived Exertion
Internet-based feedback
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A B S T R A C T

Background: Chronic obstructive pulmonary disease (COPD) is an incurable progressive illness characterized by airflow limitation and respiratory failure. Inspiratory muscle training (IMT) combined with pulmonary rehabilitation increases inspiratory muscle strength and endurance, and it decreases dyspnoea. Little is known about IMT adherence, and in the present study, we aimed to evaluate adherence to home-based IMT used with automatic internet-based feedback, in patients with chronic obstructive pulmonary disease.
Method: The adherence was evaluated at an individual level by completing a before-and-after comparison between two groups. Over a 12-week study period, the participants performed two daily sessions of 30 breaths with a mechanical threshold loading training device. They were randomly assigned to either a group of people who self-reported their perceived exertion during breathing and who received automatic internet-based feedback regarding their next threshold loadings, or a group of people who performed IMT with 30% maximal inspiratory pressure and who received no feedback.
Results: The group of patients who self-reported their perceived exertion showed significantly better training adherence compared with the group of patients who received no feedback.
Conclusion: Adherence was greater among patients who self-reported their perceived breathing exertion and received automatic internet-based feedback on the next threshold loadings compared with patients who self-reported training sessions without feedback.

1. Introduction

Chronic obstructive pulmonary disease (COPD) is an incurable progressive illness characterized by airflow limitation and respiratory failure (Vogelmeier et al., 2017). It is also associated with a negative influence on respiratory muscle strength (Hamilton, Killian, Summers, & Jones, 1995) and contributions to hypercapnia (Bégin & Grassino, 1991), dyspnoea and reduced exercise capacity (Gosselink, Troosters, & Decramer, 1996). During exercise training, the diaphragms of patients with COPD are forced to work harder (Sinderby et al., 2001), and these patients use a larger percentage of the maximal inspiratory pressure (PI,max) compared with healthy people (O'Donnell, Bertley, Chau, & Webb, 1997).

A meta-analysis demonstrated that inspiratory muscle training (IMT) combined with pulmonary rehabilitation increases inspiratory muscle strength and endurance, and it decreases dyspnoea (Gosselink et al., 2011). However, adherence to IMT interventions is poor, possibly due to the requirement of two daily 15-minute sessions. Langer et al. (2015) recently completed a randomised controlled trial of a novel IMT intervention in patients with COPD. The tested intervention involved two daily IMT sessions of 30 breaths each, using a newly developed breathing trainer device that applies electronic variable threshold resistance training (POWERbreathe International Ltd., 2018). This reduced the daily training time to only 5–6 min. Although multiple factors influence training adherence (Blackstock, ZuWallack, Nici, & Lareau, 2016; Blasi, Raddi, & Miravitlles, 2015; Bourbeau & Bartlett, 2008), it is expected that shorter training times positively affect adherence, so a training requiring a daily training time of 5–6 min is a promising alternative to traditional IMT requiring two daily 15-minute sessions (Langer et al., 2015).

Although little is known about IMT adherence, it is also expected that breathing trainer devices using electronic variable threshold resistance training positively impact the adherence to IMT (Charususin et al., 2013). Unfortunately, electronic breathing trainer devices, such

Abbreviations: IMT, inspiratory muscle training; MTL, mechanical threshold loadings

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as the POWERbreathe K series, which automatically adapts to training requirements, are significantly more expensive (250–550 euro) than breathing trainers with mechanical threshold loadings (MTL). MTL is a flow-independent one-way valve (Philips Threshold, 2018; YouTube racheeze22, 2018). It is probably not possible to use such an expensive self-purchased breathing trainer device for home-based IMT in patients with COPD (Grigsby et al., 2016). Breathing trainers with MTL cost about one-tenth of the price of electronic breathing trainer devices and are thus a more realistic option for at-home training based solely on price.

Previous studies mainly focused on the effects of IMT. In the present study, we aimed to prospectively evaluate adherence to home-based MTL IMT used with automatic internet-based feedback (automatic feedback) based on COPD participants' effort scores, as an alternative to more expensive electronic breathing trainer devices. The IMT involved two daily sessions of 30 breaths each.

2. Materials and methods

2.1. Study design

In this study, we prospectively evaluated adherence to 12-week home-based IMT using an MTL breathing trainer device combined with automatic feedback, initiated after the completion of a pulmonary rehabilitation program at a municipal outpatient clinic in Denmark. The mechanical threshold loadings were determined based on the participants' self-reported effort scores as well as automatic feedback. Adherence was evaluated at an individual level by completing a before-and-after comparison between two groups.

The study complied with the guidelines of the Declaration of Helsinki for Human Experimentation and received approval from the Danish Data Protection Agency (Jnr.2014-41-3587). Based on Danish law and on the study design, neither approval from the national ethics committee nor registration at ClinicalTrials.gov was necessary. Questionnaire surveys are only to be notified if the project involves a study of human biological material or is a clinical trial (Region Midt, 2018).

The pulmonary rehabilitation program ran for six weeks. Twelve two-hour sessions were held, including psychological counselling, nutritional counselling, education on COPD management, energy-conserving techniques and breathing strategies. Healthcare professionals hosted these sessions (i.e. physiotherapists, a pulmonologist, an occupational therapist, a dietician and a respiratory nurse). During the pulmonary rehabilitation program, the physiotherapists obtained data for each participant, including his or her gender, age, body mass index, marital and work statuses, six-minute walk test (6MWT) data (Brown & Wise, 2007) and spirometry (forced expired volume in the first second) (Vogelmeier et al., 2017). Moreover, during this programme, all participants were introduced to the Borg Category Ratio Scale of Perceived Exertion (Borg Scale) (Hastrup & Hove, 2008; Mador, Rodis, & Magalang, 1995) (Fig. 2).

Study participants were recruited from three pulmonary rehabilitation courses between January and July of 2015. The target group included patients with mild to moderate COPD to whom their general practitioners had prescribed pulmonary rehabilitation. To participate in the evaluation internet access via a computer, tablet or smartphone, the following were necessary: a PI,max equal to or less than the mean predicted PI,max for the person's gender and age group (Rochester & Arora, 1983), and a willingness to participate. A physiotherapist measured the PI,max (O'Donnell et al., 1997) using a POWERbreathe KH1. Exclusion criteria included cognitive, neurological, neuromuscular or orthopaedic problems, as well as the inability to speak Danish. The physiotherapist distributed eligible participants to two groups, and the participants were blinded to the researchers.

2.2. Home-based IMT with or without feedback

Physiotherapists individually trained all of the participants on how to perform IMT with the MTL breathing trainer device, which involved inspiration against a mechanical threshold and unimpeded expiration. The participants were instructed to train twice each day (morning and evening), performing 30 breaths in each session, for a total of 12 weeks as in the study of Langer (Langer et al., 2015). Thus, each participant performed a maximum of 168 IMT sessions. Participants were instructed to log their IMT sessions depending on the group to which they were randomised. Delivering the individual instructions took about 15 min per participant, and the same physiotherapist delivered them throughout the study. The participants had no contact with the healthcare professionals from the outpatient clinic during the 12-week study period. We pre-specified the criteria for success to be the completion of at least 70% of the total IMT sessions.

In one group, home-based MTL IMT was executed with the highest tolerable PI,max. Participants self-reported their perceived exertion in breathing using the Borg Scale, entering this information on a homepage with a responsive Web design, on which the Borg Scale was illustrated. The software (SurveyXact) used was 100% Web based. After entering their numbers, participants received automatic feedback proposing their next IMT threshold levels. The feedback was intended to encourage a perceived IMT intensity level of 3–7 on the Borg Scale. If the participant's perceived Borg Scale score was < 4, he or she was encouraged to increase his or her threshold loading by 2 cm H_2O. If the perceived Borg Scale score was > 7, feedback was provided to reduce the threshold loading by 2 cm H_2O. Data on Borg Scale was not recorded.

In the other group, home-based IMT was executed using 30% of PI,max without the self-reporting of effort scores on the Borg Scale without feedback. Participants in the second group were not instructed to change their threshold loadings on their breathing trainer devices, and they self-reported their numbers of daily IMT sessions in paper diaries.

2.3. Evaluation

The final data for this evaluation included: adherence to IMT sessions, threshold loadings, PI,max and the 6MWT performed in a 15-meter indoor gym hall and allowing the use of all kinds of walking aids. The physiotherapist and the research team performed all measurements at the municipal outpatient clinic.

To assess the comparability between the groups, we used Fisher's exact probability test to analyse categorical data, and the Kruskal-Wallis equality-of-populations rank test. To test for likelihood, we used the Wilcoxon signed-rank test to compare non-parametric data. We used a paired *t*-test to estimate the difference between pre-evaluation and post-evaluation assessments.

All included participants were invited to participate in a qualitative interview to further explore adherence to home-based MTL IMT. The interviews included questions regarding the participants' actions, experiences, concerns, and attitudes towards the training. We report the detailed findings from these interviews elsewhere (article in progress).

3. Results

We recruited 47 prospective participants, of whom 36 were eligible for participation and 27 completed the evaluation (Fig. 1). The group with feedback (n = 17) and the group with no feedback (n = 19) were comparable with regards to baseline characteristics, including gender, age, marital status, spirometry, body mass index, pre-evaluation PI,max, 6MWT and dropout rates (Table 1, “Baseline Characteristics of Possible Participants”).

Of the 11 excluded participants, two did not wish to participate, and nine had no access to the internet or had mean PI,max's of above the

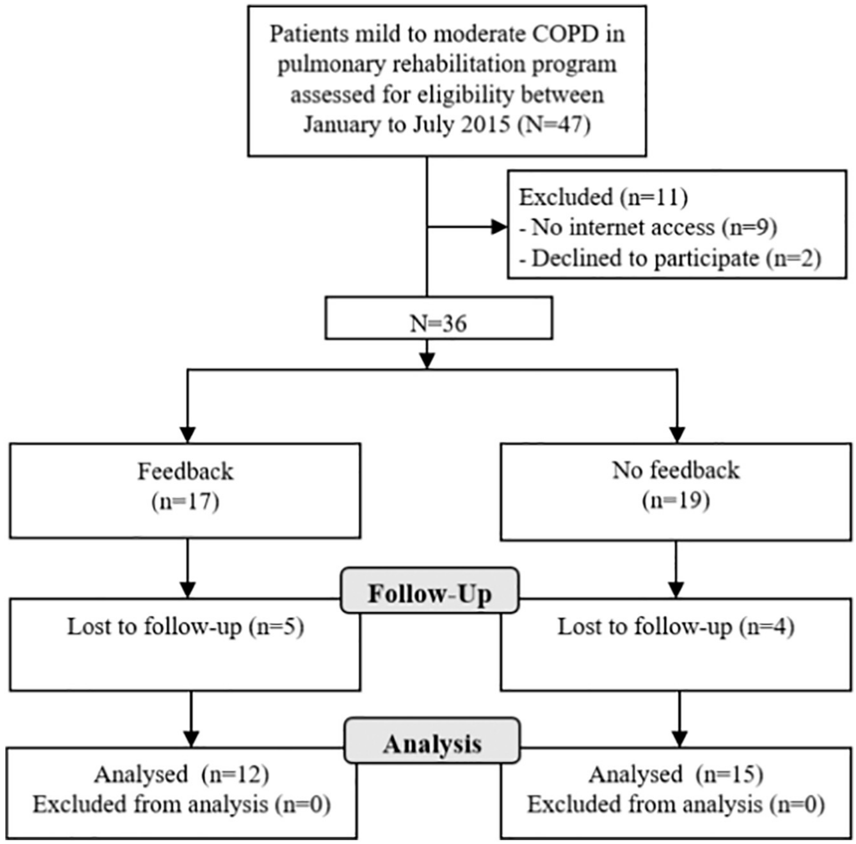

Fig. 1. Flow of the participants in the study.
COPD: chronic obstructive pulmonary disease.
IMT: inspiratory muscle training.
MTL: mechanical threshold loadings.

predicted PI,max. These 11 persons had significantly lower body mass indexes (mean, 23) compared with the included participants (mean, 25; $P = 0.04$), but they were comparable to the included participants with regards to all other variables, including the pre-evaluation PI,max and 6MWT.

3.1. Adherence

The two groups significantly differed in the number of performed IMT sessions: 146 (118–175) in the feedback group versus 113 (84–142) in the no-feedback group ($P = 0.02$). Thus, IMT adherence was 87% in the feedback group and 67% in the no-feedback group (Table 2, "Adherence to IMT and Secondary Outcomes"). Several participants in the feedback group reported problems due to a lack of internet access when they were away from home, which did not interfere with registrations in the no-feedback group.

The nine participants who chose not to return for follow-up reported that they felt that their IMT was too incomplete for follow-up assessments. The primary reason provided was busyness. One participant in the feedback group dropped out of the study after two hospitalisations due to acute exacerbations. One participant in the no-feedback group chose not to proceed because she found the new technical equipment and new instructions to be too complicated. Two participants (one from the feedback and one from the no-feedback group) were unreachable.

Table 1
Baseline characteristics of possible participants.

	Feedback	No-feedback	Non-participant	Test feedback vs. no-feedback
N = 47, n	17	19	11	
Female, n (%)	10 (59)	16 (84)	10 (91)	0.22[a]
Married, n (%)	14 (82)	13 (68)	9 (82)	0.31[a]
In work, n (%)	5 (29)	5 (26)	3 (27)	0.92[a]
Age, year mean (95% CI)	65 (62–68)	64 (60–68)	64 (60–69)	0.96[b]
BMI[c], kg/m^2 mean (95% CI)	26.5 (24–28.9)	24.5 (22.6–26.5)	23.0 (21.5–24.5)	0.10[b]
FEV1[d], % of predicted mean (95% CI)	61.4 (54.6–68.3)	58 (52.4–63.5)	61.6 (52.6–70.6)	0.68[b]
Pre PI,max CM H_2O, mean (95% CI)	66.8 (58–75.6)	57.8 (48.6–67)	58.5 (47.1–70.0)	0.22[b]
Pre 6MWT[e] meter, mean (95% CI)	416 (397–436)	370 (321–420)	350 (286–413)	0.23[b]

[a] Fisher's exact.
[b] Kruskal-Wallis equality of populations rank.
[c] Body mass index.
[d] Forced expired volume in the first second.
[e] 6MWT: six minutes' walk test.

The Borg Category Ratio Scale of Perceived Exertion	
0	Nothing
0.5	Very, very weak (just noticeable)
1	Very weak
2	Weak (light)
3	Moderate
4	Somewhat strong
5	Strong (heavy)
6	
7	Very strong
8	
9	
10	Very, very strong (almost maximum)
•	Maximum

Fig. 2. The Borg Category Ratio Scale of Perceived Exertion (Borg Scale).

Table 2
Adherence to IMT and secondary outcomes.

	n	Feedback	No-feedback
Training sessions, mean (95% CI)	27	146 (118–175)[a]	113 (84–142)
PostPImax-PrePImax, CM H_2O, mean (95% CI)	27	10 (3.9–16)[b]	5 (0.6–11.5)
Post-6MWT[c]–pre-6MWT[c], meter, mean (95% CI)	27	43.1 (18.1–68–1)[b]	15.5 (4.9–35.8)

n = number of participants in the analysis.
[a] Mann-Whitney test = 0.02.
[b] Paired *t*-test $P < 0.05$.
[c] 6MWT = six minutes' walk test.

One participant in the no-feedback group stopped IMT due to a headache, aching muscles and mouth dryness. Two other participants also described these side effects, but they chose to continue with the study and participated in the follow-up assessments. No other side effects were reported.

3.1.1. Secondary outcomes

Walking distance on the 6MWT was significantly increased by 43 m in the feedback group ($P = 0.003$) versus a non-significant increase of 15 m in the no-feedback group ($P = 0.126$). However, some participants in both groups revealed decreased walking distance. The feedback group also showed a significant change of 10 cm H_2O between the pre-evaluation PI,max and the post-evaluation PI,max ($P = 0.004$), whereas the no-feedback group revealed an insignificant increase of 5 cm H_2O ($P = 0.07$). All participants in the feedback group increased their inspiratory threshold loadings based on their effort scores, with a mean increase of 10.1 cm H_2O (95% CI, 6.6–13.6).

4. Discussion

We evaluated adherence to home-based MTL IMT executed using the highest tolerable PI,max intensity based on participants' Borg Scale scores. The participants self-reported their Borg Scale scores and received automatic feedback, including suggestions for their next inspiratory threshold loadings.

Only two of the invited participants declined participating in the evaluation, indicating that the home-based MTL IMT sounded clear and manageable to most invited persons. Although patients with COPD tend to demonstrate low adherence to advice from healthcare professionals (Blackstock et al., 2016), our results depicted reasonably high adherence to home-based MTL IMT during the evaluation period. Similarly, Langer et al. (2015) reported high training adherence with the recommendation of relatively short daily training times. Our criteria for success was 70% adherence, which the feedback group exceeded (87%), and to which the no-feedback group came close (67%). Overall, it seems that the home-based MTL IMT based on effort scores with automatic feedback was highly acceptable.

Adherence is reportedly improved by self-reporting IMT sessions, with simpler tools yielding better results (George, Kong, & Stewart, 2007). In the present evaluation, the no-feedback group participants used pen and paper as their self-reporting tools, but they reported fewer IMT sessions compared with the feedback group. This result may indicate that the internet-based reporting tool was considered acceptable and uncomplicated. We did not include any reminder systems. We perhaps could have achieved even greater adherence in the feedback group by adding a reminder system to the internet-based reporting tool (Guy et al., 2012). Blasi et al. (2015) discovered that these types of interactive technologies can enhance patient compliance and persistence.

Based on the available data, we cannot determine whether the significantly greater adherence in the feedback group compared with the no-feedback group stemmed from the difference in self-reporting tools, the automatic feedback or the perceived benefit of increasing the threshold loadings. Furthermore, the feedback group both reported a higher number of IMT sessions and increased their threshold loadings based on effort scores. Thus, we cannot conclude whether one, both or a combination of these evaluation parameters contributed to the improvements of the 6MWT results and PI,max.

Although the improvement of the 6MWT results was not the primary outcome in the evaluation, it is notable that walking distance increased in both groups, and by nearly threefold more in the feedback group compared with the no-feedback group (Table 2, adherence to IMT and secondary outcomes). This difference was expected based on the belief that higher threshold loadings lead to greater improvement of inspiratory muscle strength (Langer et al., 2015) and thus to better breathing techniques that can improve walking distance (Vogelmeier et al., 2017).

In each group, several participants had 6MWT results that almost matched that of healthy persons (about 500 m). For these participants, the average increase of 43 m was about 10%. On the other hand, for participants who were initially more limited in their 6MWT performance, a 43-meter increase corresponded to 20%. Five participants exhibited a decrease of > 10 m in 6MWT performance, and three of these persons reported completion of > 120 IMT sessions, indicating that more IMT sessions did not necessarily lead to better 6MWT results. We cannot assess the clinical relevance of this finding, as we did not ask participants about health-related life or take other relevant measurements. Likewise, we did not determine whether the significant increase of PI,max in the feedback group had a positive effect on their subjective breathing technique experiences.

About 25% of the participants chose not to return for follow-up in both groups, which is acceptable compared with other studies (Geddes, O'Brien, Reid, Brooks, & Crowe, 2008). The reasons for their failure to return for follow-up were similar to those described in the review of Geddes (Geddes et al., 2008), and they included side effects, illness and busyness for those whom we were able to contact. We do not know the reasons for the withdrawal of those whom we could not contact. However, from the SurveyXact data, we can see that the five participants in the feedback group who did not return for follow-up reported significantly fewer IMT sessions (Table 2, adherence to IMT). Because we could not estimate the performed IMT sessions for the participants in the no-feedback group who did not return for follow-up, we excluded all dropouts from the final estimations.

When implementing IMT in clinical practice, one must weigh the cost and effectiveness of the available approaches (Langer et al., 2015). COPD is associated with a lower socioeconomic status (Grigsby et al., 2016), highlighting the need for relatively inexpensive breathing trainer devices, such as the one we used in this study. The present findings support adherence to 12-week home-based IMT in people with COPD, with automatic feedback on threshold loadings. MTL IMT requires less time and financial investment compared with older studies, which may improve patients' adherence to IMT long term.

4.1. Strengths and limitations

This study was the first to evaluate adherence to home-based MTL IMT executed using the highest tolerable PI,max and with automatic feedback according to self-reported effort scores. We found significant between-group differences in the number of completed IMT sessions, the improvement in PI,max and the improvement in 6MWT distance. However, the study groups were too small to provide any recommendations regarding whether or how IMT should ideally be performed.

Participants and non-participants only significantly differed in body mass index, which may indicate that participants were less ill from their COPD. Notably, no significant baseline differences were found between the two participating groups.

Some participants in the feedback group reported problems reporting their sessions due to a lack of internet access when they were away from home, whereas the no-feedback group participants could write in their paper logs whenever they had pens. Thus, it is possible that the between-group difference in adherence, seen as the difference in the number of reported IMT sessions, could be even higher than estimated.

Overall, it seems practicable to implement home-based IMT based on the present results, the low cost and the limited time required per IMT session. One limitation of the application is that the automatic feedback received via the feedback group has not yet been fully developed.

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Declaration of interest

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