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Original Research

Limitation of the effectiveness of inhalation training in patients with asthma and COPD

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ABSTRACT

Introduction: Knowledge of factors impacting the effectiveness of training of correct inhalation technique could increase the effectiveness of inhalation technique.
Objectives: The aim of the study was to assess the effectiveness of inhalation technique training and to identify factors impacting the effectiveness of training.
Patients and methods: This single centre, interventional, non-randomized study involved 180 adult patients with asthma or COPD. Inhalation technique was evaluated using a checklist of common errors and peak inspiratory flow (PIF). Patients who made any mistakes during inhalation were trained. We searched for factors which may have impacted the effectiveness of inhalation training.
Results: A total of 115 asthma and 65 COPD patients were analyzed. In 140 patients using either metered-dose inhalers (MDI) or soft mist inhalers (SMI; SMI users were grouped with MDI users for analysis), only 9 patients (6.4 %) used inhalers correctly, for dry-powder inhalers (DPI) only 31 (28.2 %). The training of inhalation technique was successful in 112/131 MDI users (85.5 %) and 67/79 DPI users (84.8 %).
Among MDI users, patients who achieved short term improvement in inhalation technique were more likely to have asthma (68.8 % vs. 42.1 %, $p = 0.047$), be non-smokers (33 % vs 5.3 %, $p = 0.039$) and younger (64 vs. 66 years, $p = 0.028$) vs. patients without improvement; respectively among DPI users: cognitive disorders were less often found (0 % vs. 16.7 %, $p = 0.018$), patients more often read drug leaflets (80.6 % vs 50 %, $p = 0.022$) and had good self-esteem of inhalation skills (97 % vs. 75 %, $p = 0.025$).
Conclusions: Training in inhalation leads to short term improvement of inhalation technique for most trainees. As different factors are important for efficacy of training in inhalation skills for MDI and DPI, an individual approach for training is important.

1. Introduction

Asthma and chronic obstructive pulmonary disease (COPD) are a major health problem worldwide. Both diseases are well described, widely investigated and are treated in accordance with dedicated recommendations which are updated annually [1,2]. Nevertheless, despite a proper diagnosis and treatment based on current management guidelines, treatment efficacy may be hindered by a seemingly simple technical issue, i.e. improper inhaled medication intake as a result of inhaler incompetence [3,4]. The rate of inhaler mishandling in patients with obstructive lung diseases remains relatively high despite the increasing awareness of this problem and a considerable development both in drug formulations and in the field of inhaler devices [3–6]. Regular monitoring and repeated training of correct inhalation technique are key elements necessary to improve patients' inhalation skills [7–9], as the effect of single inhalation technique training is short-lasting [4,10]. Knowledge of the factors that affect the effectiveness of inhalation technique training could have a positive impact on inhalation technique and thereby on treatment efficacy. Earlier studies proved that physical demonstration with the use of inhalers containing placebo is essential to improve inhalation technique [1,11–13]. There is also growing use of purpose-designed devices that support inhalation technique, such as In-Check Dial G16 for peak inspiratory flow (PIF) assessment or Aerosol Inhalation Monitor (AIM) for inhalation

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technique training in conditions corresponding to inhaled medication intake via pressurised metered dose inhalers (MDI) or dry powder inhalers (DPI) [14,15].

Poor initial inhalation technique, outpatient setting and short follow up after inhalation technique training have an impact on effectiveness of the training, while the type of the disease (asthma vs. COPD), education group size (individual vs. group training) and type of the inhaler (DPI vs. MDI) do not seem to play a significant role [16].

The aim of this study was to assess the effectiveness of a single individual training with the use of own inhaler and the support of PIF measurement and to search for factors that may lead to failure of such training.

2. Methods

2.1. General study design

This single centre, interventional, non-randomized study (NCT04203446) was performed between January 2021 and December 2023. Patients with asthma or COPD, who had used inhaled medications on regular basis were invited to participate. Patients who used inhalers with any mistakes were trained in inhalation skills. Training was individual, led by a physician with experience in inhalation technique training, with the support of PIF measurement. The effectiveness of training was assessed by an independent observer with use of a checklist of inhalation steps specific for the type of inhaler used immediately after the intervention. Next, the technique of inhaled medication intake was re-evaluated 30 min after completion of the training.

Among the analyzed factors that could potentially affect the effectiveness of inhalation training were patients' demographic data, data on the duration and course of obstructive disease, level of education, motivation for treatment, spirometry results, comorbidities with emphasis on concomitant visual, hearing, neurological and small joint disorders.

The study was approved by the Institutional Review Board (KB/68/2019) and all patients signed an informed consent to participate.

2.2. Patients

The patients were recruited among adults with asthma or COPD treated at the Department of Internal Medicine, Pulmonary Diseases and Allergy, Medical University of Warsaw or at the local respiratory outpatient clinic.

Study inclusion criteria were as follows: 1. Age 18–85 years; 2. Asthma or COPD diagnosed for at least 3 months before the study onset; 3. recommendations of regular daily intake of at least one inhaled medication via: metered dose inhaler (MDI), dry powder inhaler (DPI) or soft mist inhaler (SMI). Exclusion criteria comprised: 1. irregular or only emergency use of inhaled medications; 2. symptoms of acute respiratory infection (up to day 5 from the onset of infection). If hospitalization or a visit to the outpatient clinic was associated with an exacerbation of asthma or COPD, inhalation technique was assessed at the end of hospitalization or during an additional follow up visit, after the patient's condition stabilized and the symptoms of exacerbation resolved.

2.3. Methods

The evaluation of inhalation technique was performed with the use of a checklist of the most common inhalation errors for MDI and DPI (Table 1, Supplementary Materials) by one of the observers (ID or MM) [17,18] with PIF measurement by In-Check Dial G16 [14]. Correct inhalation technique was defined as absence of any mistake during inhalation and adequate PIF (30–60 l/min for MDI and higher than 60 l/min for DPI I/min) [19]. For patients who used SMI, the list of inhalation errors for MDI and a PIF value of 15–30 l/min were applied.

Patients who made any mistakes during inhalation were trained in inhalation skills by a physician with an at least 5-year experience in inhalation technique training (ID). A single, individualized training with the use of placebo containing inhalers and In-Check Dial G16 was conducted. The training lasted from 2 to 15 min depending on patient's need and abilities. The training was defined as effective when the patient could inhale his/her inhaler without any mistakes (according to a checklist of the most common inhalation errors) as assessed by the observer and achieved an appropriate PIF on In-Check Dial G16.

Patient evaluation also included demographic, clinical and spirometric data, quality of life using the St. George's Questionnaire for COPD (SGRQ) and using the Quality of Life Questionnaire for Asthma (AQLQ) respectively [20,21]. A self-constructed 8-item questionnaire (Table 2, Supplementary Materials) was applied to assess motivation for treatment. Cognitive status was evaluated using the Short Mental Status Assessment Scale (MMSE) and Clock Drawing Test (CDT) in the Polish population, a threshold of <27 points constitutes a suspicion of cognitive dysfunction [22]. Additionally, evaluation of visual and hearing disorders using both questionnaires and assessment by investigators with ophthalmological Snellen charts and authoritative subjective assessment of hearing was performed.

Table 1
Patients' characteristics.

	All N = 180	Asthma N = 115	COPD N = 65	P value
Age (years)	63.5 (52–71)	60 (44–66.5)	70 (64–76)	p < 0.001
Sex F/M	104/76	76(66.1 %)/39 (33.9 %)	28(43.1 %)/37 (56.9 %)	p = 0.004
Disease duration (years)	10 (6–20)	15 (7–26.5)	10 (5–15)	p < 0.001
Smoking history (NS/S/EX)	61/104/15	54/7/54	3/8/54	p < 0.001
Education (primary/secondary/higher)	13/95/72	6/59/50	7/36/22	0.238
Asthma Control Test (points)	X	20 (16–23.5)	X	–
COPD Assessment Test (points)	X	X	22 (16–26)	–
Number of comorbidities	1 (1–2)	1(1–2)	2(0–3)	0.264
Number of used inhalers	2 (1–2)	2 (1–2)	2 (2–2)	0.652
Any earlier TI training	76 (42.2 %)	61 (53.5 %)	15 (23.1 %)	p < 0.001
FEV1 %N	69 % (45–88)	81 % (61–95.5)	44.5 % (37–65)	p < 0.001

Data are presented as median and IQR or numbers and proportion of patients. P-value refers to comparison between patients with asthma and COPD.
F-female, M-male, NS-never smoker, S- smoker, EX-ex-smoker, TI- inhalation technique, FEV_1%N – forced expiratory volume in 1st second expressed as percentage of predicted value.

2.4. Statistical analysis

The descriptive analysis of the survey questions was performed in the "Microsoft Excel" software. The statistical analysis was performed using the "r" programming language (Version 3, 2007; https://www.R-project.org/Licenses/). The differences between patients who improved inhalation technique after training and those who failed to improve inhalation technique were assessed by student t-tests for quantitative variables with a normal distribution or Mann-Whitney *U* test for quantitative variables with a distribution other than normal, or chi square test for nominal data. Value of $p < 0.05$ was noted as the significance limit. Single-variate logistic regression models were performed, on the basis of which variables included in multivariate logistic regression models were extracted.

Based on the results of our previous studies, we assumed that only 20

Table 2
Comparison of patients with successful and ineffective training of inhalation technique.

	MDI N = 131			DPI N = 79		
	Successful training N = 112	Training failure N = 19	P value	Successful training N = 67	Training failure N = 12	P value
Age (years)	64 (53.5–70.3)	66 (62–80)	0.028	65 (56–70.5)	65 (62.8–73.5)	0.521
Asthma/COPD	77 (68.8 %)/35 (31.2 %)	8 (42.1 %)/11 (57.9 %)	0.047	39 (58.2 %)/28 (41.8 %)	6 (50 %)/6 (50 %)	0.832
Disease duration (years)	10 (6.5–20.5)	15 (5.5–20)	0.921	10 (6–20)	13 (4.8–20)	0.790
Gender (F/M)	62 (55.4 %)/50 (44.6 %)	12 (63.2 %)/7 (36.8 %)	0.701	41 (61.2 %)/26 (38.8 %)	5 (41.7 %)/7 (58.3 %)	0.344
Smoking history (S/ExS/NS)	9 (8 %)/66 (59 %)/37 (33 %)	3 (15.8 %)/15 (78.9 %)/1 (5.3 %)	0.039	5 (7.5 %)/39 (58.2 %)/23 (34.3 %)	2 (16.7 %)/6 (50 %)/4 (33.3 %)	0.578
Education (primary/ secondary/higher)	7 (6.3 %)/65 (58.1 %)/40 (35.7 %)	3 (15.8 %)/8 (42.1 %)/8 (42.1 %)	0.240	5 (7.5 %)/41 (61.2 %)/21 (31.3 %)	0/8 (67.7 %)/4 (33.3 %)	0.628
Motivation (points)	10 (9–10)	10 (10–10)	0.302	10 (8–10)	10 (6.3–10)	0.587
Number of inhalers	2 (1–2)	2 (1–2)	0.537	2 (2–2)	2 (1–2)	0.678
FEV1 z- score	−1,9 (−2,4; −0,6)	−2,4 (−2,4; −0.7)	0.357	−2.3 (−2,4; −1.4)	−1.6 (−2.4; −0.4)	0.449
Significant visual disorders	35 (31.3 %)	7 (36.8 %)	0.828	20 (29.9 %)	3 (25 %)	0.923
Significant hearing disorders	7 (6.25 %)	2 (10.5 %)	0.621	7 (10.5 %)	0	0.503
Hand muscle/joint disorders	4 (3.6 %)	1 (5.3 %)	0.721	2 (3 %)	1 (8.3 %)	0.372
Any cognitive impairment (MMSE)	23 (20.5 %)	3 (15.8 %)	0.095	20 (29.8 %)	2 (16.7 %)	0.348
Any cognitive disorder (CTD)	2 (2 %)	0	0.988	0	2 (16.7 %)	0.018
Any TI training before	47 (42.3 %)	6 (31.6 %)	0.529	22 (32.8 %)	2 (16.7 %)	0.435
Reading the drug leaflet	90 (81.1 %)	14 (73.7 %)	0.664	54 (80.6 %)	6 (50 %)	0.022
Good self-esteem of TI	105 (93.8 %)	16 (84.2 %)	0.327	65 (97 %)	9 (75 %)	0.025
Taking medications regularly	91 (81.3 %)	14 (73.7 %)	0.650	54 (80.6 %)	8 (66.7 %)	0.484

Data are given as median and interquartile range or number and percentages.
F- female, M – male, TI- inhalation technique, S- smokers, ExS- Ex-smoker, NS- Never smoker, FEV1-forced expiratory volume in first second, MMSE – minimental state examination, CTD -Clock Drawing Test.

% of subjects could initially use their inhalers correctly and training will be successful in 80 % of them [12]. We designed the current study assuming identification of 3 predictor variables with small to medium expected effect size (beta = 0.1). Power analysis and sample size calculations indicated that a sample size of 145 subjects would provide 90 % statistical power to detect significant differences between the two groups (p value = 0.05, beta = 0.10).

3. Results

The investigated group comprised 180 patients (104/57.8 % women and 76/42.2 % men, median age 63,5 years; IQR (52–71)). Asthma was diagnosed in 115 patients while COPD in 65 subjects. Fifty-nine patients (32.8 %) were treated with only 1 inhaler, 67 patients (37.2 %) used 2 inhalers, while 54 patients (30 %) used 3 or more inhalers. Most patients used at least one MDI (n = 135; 75 %), 5 people used SMI, and 110 patients used DPI. Detailed characteristics of patients are presented in Table 1.

Among the 140 patients using either MDI or SMI, only 9 (6.4 %) patients inhaled their medication without any errors, while in 110 patients treated with DPI a correct inhalation technique was noted in 31 (28.2 %) subjects. The remaining patients were qualified for inhalation technique training; thus inhalation technique training was carried out in 131 patients using MDI and 79 patients using DPI. The training of inhalation technique was equally successful in 112/131 MDI users (85.5 %) and 67/79 DPI users (84.8 %), respectively (p = 0.892).

3.1. Factors limiting the effect of inhalation skills training in patients using MDI

Among MDI users, patients who achieved improvement in inhalation technique were more likely to have asthma (68.8 % vs. 42.1 %, p = 0.047), more likely to be non-smokers (33 % vs 5.3 %, p = 0.039) and younger (64 vs. 66 years, p = 0.028) compared to patients who had no improvement after training (Table 2).

Univariate regression models showed that the improvement in inhalation from MDI was influenced by the type of disease and age of patients (Table 2). Based on these results, a multivariate model was created, which showed that only older age significantly reduced the chance of successful training in inhalation skills (Tables 3 and 4).

3.2. Factors limiting the effect of inhalation skills training in patients using DPI

Among patients who improved their DPI inhalation technique after training, cognitive disorders were less often found in the neurological assessment of clock drawing test (0 % vs. 16.7 %, p = 0.018), more often read drug leaflets (80.6 % vs 50 %, p = 0.022) and more often had good self-reported inhalation skills (97 vs. 75 %, p = 0.025) in comparison to patients in whom inhalation training failed (Table 2).

In one-way regression analysis reading the drug leaflet and good self–reported inhalation skills proved to increase the chance of successful training among DPI users (Table 5). In the multivariate logistic regression model, the impact of both variables was preserved (Table 6).

4. Discussion

The results of this study confirm that training in inhalation leads to a short-term improvement of inhalation technique for most trainees and that there are differences in the factors affecting the result of such training between types of inhalers (MDI vs DPI). Older age of the patient may hinder the effect of inhalation technique training in MDI users, while not reading the drug leaflet and low patient self-reported inhalation skills may be predictors of training failure in DPI users. We did not find other factors limiting the effectiveness of inhalation training in the short-term evaluation in our investigated group.

Systematic reviews and meta-analyses of the studies in the field emphasize that any intervention aimed at inhalation technique training

Table 3
One-way logistic regression models assessing the effect of the studied variables on the effect of training of inhalation skills in MDI users.

Factor	Odds Ratio	Standard error	P value	95 %CI
Type of disease: COPD	0.331	0.507	0.029	0.118–0.887
Age (years)	0.935	0.025	0.008	0.886–0.979

Table 4
A multivariate logistic regression model assessing the effect of the studied variables on the effect of training of inhalation skills in MDI users.

Factor	Odds Ratio	Standard error	P value	95 %CI
Type of disease: COPD	0.487	0.527	0.173	0.169–1.365
Age (years)	0.941	0.027	0.023	0.89–0.988

Table 5
One-way logistic regression model assessing the effect of the studied variables on the effect of training of inhalation skills in DPI users.

Factor	Odds ratio	Standard error	P value	95 %CI
Reading the drug leaflet	4.15	0.66	0.03	1.134–15.444
Good self-reported inhalation skills	10.83	0.98	0.015	1.597–91.385

Table 6
A multivariate logistic regression model assessing the effect of the studied variables on the effect of training of inhalation skills in DPI users.

Factor	Odds ratio	Standard error	P value	95 %CI
Reading the drug leaflet	4.04	0.69	0.04	1.019–16.411
Good self-reported inhalation skills	10.42	1.03	0.02	1.394–96.034

leads to an improvement in inhalation skills among patients [4,16]. However, this does not mean that the training will lead to ideal inhalation technique for all trainees even in short-term assessment, what was also documented in this study as only approximately 85 % of trainees managed to achieve optimal inhalation technique. In this context, knowledge about factors hindering effective inhalation technique training could help improve its effectiveness.

It is important to distinguish groups of patients who require personalized training in inhalation skills. The effectiveness of inhalation technique training decreases with age, what was also confirmed in our study. This may probably be a result of an increased incidence of motor coordination disorders and degenerative joint lesions affecting dexterity [23]. Furthermore, advanced age may also affect lung function and reduce ability to generate an adequate PIF [19,24]. Studies have also documented that cognitive impairment is an independent predictor of incorrect inhalation technique [23,25–28]. Although in our investigated group, there was a lower incidence of cognitive disorders among patients with a positive effect of inhalation technique training, this finding applied only to DPI users and was not supported by univariate analysis due to low numbers of cognitive disorders in our group of subjects. In study by Luley et al., patients with severe cognitive deficits were unable to reduce the number of inhalation mistakes despite inhalation training [26]. Thus, it may be postulated that such patients require a special, personalized, simplified training which should be repeated many times [29].

Interestingly, in a univariate logistic regression model, we found that COPD may hinder the efficacy of inhalation training in MDI users, but it was not validated in a multivariate regression model. In a systemic review by Klijn et al., the type of obstructive lung disease (asthma vs COPD) was not associated with inhalation technique effectiveness [16]. Neither obstructive disease had been identified as risk factor for failure in inhalation technique so far [13], although some differences in non-adherence patterns such as sociodemographic characteristics were identified between asthmatics and patients with COPD [30].

Inhalation technique training was shown to be beneficial both for patients using MDI and DPI [4,16,31,32]. However, a meta-analysis by Marko and Pawliczak [4] showed that the effect of education in patients using MDI depended on the type of educational approach - face-to-face vs. demonstration/training – with better response after the latter. This finding had not been demonstrated for DPI. Other differences between MDI an DPI in the effects of inhalation technique training were also documented. Melani et al. showed that the time necessary to achieve correct inhaler technique was shorter for DPI than MDI [33]. Improvement in inhalation technique in patients using MDI proved to be more difficult to achieve than in DPI users [31,34]. Our study also showed differences between MDI and DPI in the factors affecting the result of inhalation technique training although the efficacy of training was similar in MDI and DPI users. Older age and diagnosis of COPD were found as predictors of ineffective inhalation education in MDI users, but not in DPI users. Moreover, we found that not reading the drug leaflet and low self-reported inhalation skill might indicate training failure in patients using DPI, but not in patients treated via MDI.

Inhalation training by one educator only in our study may be viewed as a limitation. It must be emphasized that this educator had an at least 5-year experience in inhalation technique training and demonstrated a good interobserver agreement in assessment of inhalation skills (Miszczuk-Cieśla et al., in press). Moreover, this reflects a real-life setting, as the availability of inhalation technique education still seems to be limited [4,16]. Nevertheless, not only patients, but also healthcare providers staff make inhalation mistakes and require training of inhalation technique [35–37]. Medical staff often overestimate their own inhalation skills what indicates the need for standardization in inhalation technique education and calls for prior assessment of the competence of staff involved in inhalation technique training. Inhalation training may be provided by pharmacists, physiotherapists, nurses or physicians. Studies emphasize the role of pharmacists, who see patients more often and therefore may provide repeated training which allows to maintain inhalation technique improvement [38–42]. Another study showed an improvement in inhalation technique among patients trained by pulmonary nurses [31]. However, no significant differences in the effectiveness of treatment were found between different groups of educators [16].

Besides the issue discussed above, other limitations of the study need to be considered in the analysis of our results. First, this was a single centre study with a limited number of patients. Second, the assessment of the effect of training was performed only once, immediately after the training, so the long-term efficacy of this intervention cannot be assessed. However, this was beyond the scope of this study, as our aim was focused on the short-term effects of a single inhalation technique training and the factors that influence the effects of such a training. Our earlier study showed that inhalation skills after a single inhalation technique training decrease with time [13]. Despite these limitations, we believe that the results of this study add value to the discussion on optimal training of inhalation skills.

In conclusion, training in inhalation skills leads to improvement in inhaler competence in most trainees, but even short-term effect of training in inhalation skills is limited. As different factors are important for efficacy of training in inhalation skills for MDI and DPI, an individual approach in inhalation technique training may improve its effect.

CRediT authorship contribution statement

Izabela Domagala-Manczyk: Writing – original draft, Visualization, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Marta Miszczuk-Ciesla:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation. **Marta Maskey-Warzechowska:** Writing – review & editing, Supervision, Methodology, Formal analysis, Data curation. **Michal Zielecki:** Writing – review & editing, Investigation, Formal analysis. **Piotr Szczudlik:** Writing – review & editing, Formal analysis. **Marta Dabrowska:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Medical Warsaw University (KB/68/2019).

Data availability statement

The datasets analyzed during the current study contain sensitive patient information and are therefore not publicly available. Anonymized data are available from the corresponding author on request and subject to institutional and ethical approvals.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Abbreviations

MDI	Metered Dose Inhaler
DPI Dry	Powder Inhaler
COPD	Chronic Obstructive Pulmonary Disease
PIF	Peak inspiratory flow

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rmed.2025.108603.

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