Journal of Asthma, Early Online, 1–9, 2011

ISSN: 0277-0903 print / 1532-4303 online
DOI: 10.3109/02770903.2011.587583

informa
healthcare

The Effect of Physiotherapy-Based Breathing Retraining on Asthma Control

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Background. The mechanism of the breathing retraining effect on asthma control is not adequately based on evidence. *Objective.* The present study was designed to evaluate the effect of physiotherapy-based breathing retraining on asthma control and on asthma physiological indices across time. *Study design.* A 6-month controlled study was conducted. Adult patients with stable, mild to moderate asthma ($n = 40$), under the same specialist's care, were randomized either to be trained as one group receiving 12 individual breathing retraining sessions ($n = 20$), or to have usual asthma care ($n = 20$). The main outcome was the Asthma Control Test score, with secondary outcomes the end-tidal carbon dioxide, respiratory rate, spirometry, and the scores of Nijmegen Hyperventilation Questionnaire, Medical Research Council scale, and SF-36v2 quality-of-life questionnaire. *Results.* The 2 × 4 ANOVA showed significant interaction between intervention and time in asthma control ($F = 9.03$, $p < .001$, $\eta^2 = 0.19$), end-tidal carbon dioxide ($p < .001$), respiratory rate ($p < .001$), symptoms of hypocapnia ($p = .001$), FEV1% predicted ($p = .022$), and breathlessness disability ($p = .023$). The 2 × 4 MANOVA showed significant interaction between intervention and time, with respect to the two components of the SF-36v2 ($p < .001$). *Conclusion.* Breathing retraining resulted in improvement not only in asthma control but in physiological indices across time as well. Further studies are needed to confirm the benefits of this training in order to help patients with stable asthma achieve the control of their disease.

Keywords asthma control, breathing retraining, $ETCO_2$, hyperventilation, physiotherapy

INTRODUCTION

The main goal in asthma treatment is to achieve and maintain asthma control for prolonged periods (1). Although the Global Initiative for Asthma (GINA) guidelines are available to European doctors for over 10 years, the prevalence of uncontrolled asthma is high (2). Specifically in Greece, among patients under a specialist's care, 65% of them had uncontrolled asthma (3).

Nowadays, adequate attention has been given to the "hyperventilation syndrome" in asthma, its clinical effectiveness and the mechanism that mediates its effect (4). Patients with mild asthma compared to healthy people showed significantly lower end-tidal carbon dioxide ($ETCO_2$) and arterial carbon dioxide (5, 6) even in acute or stable asthma (7, 8). A significant proportion of asthma patients reported hyperventilation symptoms assessed by $ETCO_2$ and the Nijmegen Questionnaire (NQ) (9). A reduction in $ETCO_2$ resulted in an increase in airway resistance in asthma patients, while the same reduction had no effect on healthy people (6). In contrary, an increase in $ETCO_2$ caused a significant reduction in airway resistance in people with and without asthma (6). Although possible mechanisms for hypocapnia inducing bronchoconstriction are reported, the mechanism of bronchoconstriction still remains unclarified and may correlate to the degree of hypocapnia (5).

Complementary interventions, such as Buteyko, physiotherapy, and yoga are of considerable interest in asthma management lately (5). All these therapies teach breathing patterns with slow respiratory rate and breath hold (10). Breathing retraining is used by many patients with asthma worldwide as an adjunctive treatment to their regular medical care and depends on the nature of the therapy, therapist, and cultural background (11, 12). It directly targets decreasing the respiratory rate and increasing the resting pCO_2 to normal levels (13, 14).

So far, only one pilot study has revealed an initial evidence of improvement in asthma control and $ETCO_2$ as a result of breathing retraining across time (14). Previous relative studies showed significant increase in quality of life (12, 15, 16) as well as significant reduction in respiratory rate (14, 15) and hyperventilation symptoms (12, 15, 16). However, no effect on the pulmonary function has been found to provide evidence for successful manipulation of this specific breathing behavior (12, 14, 15).

Social-cognitive models have been developed in order to determine and predict behaviors in chronic health problems such as asthma (17). Among these models, the transtheoretical model explains how individuals can make behavior change in a time-frame of 6 months (17). Five stages have been described (pre-contemplation, contemplation, preparation, action, and maintenance)

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(17, 18), eventually leading to the adoption of a new behavior. In the present study, the transtheoretical model was used to describe the effect of the physiotherapy-based breathing retraining on asthma control.

Based on the above, the present study was designed to examine the effect of physiotherapy-based breathing retraining on asthma control and on physiological indices for Greek patients with stable asthma (1) under a specialist's care.

METHOD

Participants

Invitations to participate in a study of breathing retraining were sent to 283 outpatients who attended the asthma department of "Amalia Fleming" General Hospital in Athens, Greece, from January to June 2009. A total of 86 volunteers responded positively. Forty-six participants were excluded (18 were ≥60 years, 12 smokers, 9 used oral corticosteroids in the previous 3 months, 5 suffered from heart failure, and 2 participated in a prior asthma education program) (19). Finally, 40 (20 per group) adults with diagnosed stable asthma (1) underwent baseline assessment (June 2009). The study protocol was approved by the Research Ethics Committee of the "Amalia Fleming" General Hospital while the informed consent form was signed by all participants.

Sample Size and Power Calculation

The sample size determination was based on the following criteria: (1) effect size = 1.01 for the Asthma Control Test (ACT) found in the pilot study of Meuret et al. (14), (2) power $(1-\beta) = 0.80$, (3) $\alpha = 0.05$, (4) two groups (experimental and control), and (5) four repeated measures. The analysis showed that the minimum sample for the specific study was 26 patients (13 per group) (20).

Research Tools

Participants were assessed by the same trained assessor, blinded to the patients' treatment allocation, in four time points (0, 1, 3, 6 months) with the following measures in a random order:

- a questionnaire regarding the demographic information,
- the ACT (21),
- the NQ (22),
- The SF-36v2 Health Survey (23),
- The Medical Research Council (MRC) breathlessness scale (24),
- The oxi-capnography comdek MD-660P (Comdek Industrial Corp., Taipei, Taiwan), and
- The Spiro sense spirometry system (Burdick, Inc., Deerfield, WI, USA).

The *ACT* (21) evaluates asthma control during the previous 4 weeks and consists of five items. The total ACT score ranges from 5 (poorly controlled) to 25 (completely controlled). The validity and reliability of the ACT measurements were tested in many populations (25–27) just as in Greek asthma patients (3).

The *NQ* (22) was developed to screen the "hyperventilation syndrome" through 16 symptoms of hypocapnia. The NQ is positive when its score is ≥23 with 91% sensitivity and 95% specificity (4).

The *SF-36v2* (23) is a generic quality-of-life questionnaire which has shown validity and reliability evidence in different populations as well as in the Greek general population (28). It consists of 36 items under 2 major components: the physical (PC) and the mental component (MC) (24).

A *portable capnograph* (oxi-capnography comdek MD-660P) was used for the $ETCO_2$ and breathing rate at rest over a 10-minute period (15).

Pulmonary Function Testing tests FEV1% predicted values for the assessment of bronchoconstriction (1). The participants indicated no use of bronchodilators, at least 4 hours before the spirometry test (1). Both FEV1% predicted and $ETCO_2$ were always measured at the end of each measurement's procedure.

The *MRC scale* (24) measures the disability associated with dyspnea and ranges from 1 to 5; the higher the score, the higher the disability level (24). The MRC score has shown validity and reliability evidence (correlation with other breathlessness scales, lung function and asthma control, and 98% agreement between raters) (3, 29).

Severity classification was based on GINA criteria (1).

Treatment Procedures

Study Design. This was an experimental study. Random allocation and allocation concealment was undertaken by sealed envelops (30). Although blinding was impossible for patients and the physiotherapist, this was possible for the assessor. Both groups were under the same specialist's care, with regular follow-up visits and suggested to continue receiving regular asthma medication. The control group did not receive any additional treatment. In case of asthma medicine modification, decided by the specialist, participants of both groups were withdrawn from the study.

The study lasted 6 months (from July to December 2009) according to the transtheoretical model (31) and consisted of two phases: the intervention program completed in the first phase (during July 2009), and the written asthma action plan performed in the second phase (during the remaining 5 months).

First phase: The physiotherapy intervention included

- A 60-minute, small group session (five patients/group) structured according to the health belief model (32). During this session, patients were educated in: (1) the "normal" breathing pattern as well as for the pattern during exacerbations, (2) recognizing asthma symptoms, and (3) the comprehension of their ability to modify their breathing pattern targeting the self-management of the symptoms (13) and expressed

their perceived severity of asthma and the benefits and barriers of adapting a modified breathing pattern for a 6-month period (32).

- Twelve individual sessions (three/week) of nearly 1 hour duration each (13, 15), comprised education and practice of: (1) diaphragmatic breathing, (2) nasal breathing, (3) short hold of breath (2–3 seconds), and (4) adaptation of the speech pattern (speaking, singing), in any position, during physical activity, and in asthma exacerbation (13). The physiotherapist who supervised the intervention was adequately treated.

Second phase: Written asthma action plan

The specific action plan included instructions regarding the duration (20 minutes at least) and frequency (2–3 times/day) of training at home for the remaining 5 months, as well as for the adaptation of the breathing behavior in leisure-time physical activities (e.g., at home, when climbing stairs, carrying weights, at their respective free time, when walking, swimming, etc., throughout the day).

Data Analysis. Preliminary tests of multi- and univariate repeated measures analyses assumptions were done (33, 34). The Statistical Package for the Social Sciences (SPSS, version 13.0) was used for the data analyses. The reliability of repeated measures for the study variables was determined through the Intraclass Correlation Coefficient (IR).

A 2 × 4 repeated measures ANOVA with Bonferroni adjustment (34) was conducted for the interaction between intervention (experimental and control group) and time (0, 1, 3, 6 months) for every depended variable separately: $ETCO_2$, respiratory rate, asthma control, symptoms of hypocapnia, FEV1% predicted, and breathlessness disability. A 2 × 4 repeated measures MANOVA design was conducted for the interaction between intervention and time for the two factors of the SF-36v2 (34).

The *t*-parameter estimates with a difference contrast were used as a simple, main effect test to examine differences between the two groups, across time (34). Eta-squared (η^2) was used for the expression of the total variance explained from the respective interaction effects (between time and group with respect to the dependent variables measured) (34). Finally, orthogonal polynomial analysis (34) was conducted to evaluate the trend for the repeated measurements conducted (e.g., linear, quadratic, cubic order, etc.) for each dependent variable separately.

Differences between groups for asthma control (controlled–not controlled) were examined with 2 × 2 cross-tabulation in each one of the four time points. In this analysis, the Pearson chi-square (χ^2) indices, with the respective *p*-values were calculated (33).

Finally, a discriminant function analysis (34) was used for the determination of the variables which discriminated patients with and without asthma control (ACT score ≤19) (3) across time. The canonical correlation coefficient (CCC), the percentage of explained variability, the prediction equation, and the percent of correct classifications were further examined for that purpose (34).

RESULTS

A total sample of 40 participants (aged 18–60 years) was randomized in experimental group (7 females and 13 males) and control group (10 females and 10 males). No significant differences were found between the groups at baseline (Tables 1 and 2). Nonsignificant interaction was noted regarding the gender [ACT ($F = 1.181$, $p > .05$), $ETCO_2$ ($F = 0.319$, $p > .05$), respiratory rate ($F = 0.544$, $p > .05$), NQ ($F = 1.186$, $p > .05$), FEV1% predicted ($F = 1.593$, $p > .05$), MRC ($F = 0.896$, $p > .05$), SF36v2 PC ($F = 1.593$, $p > .05$), SF36v2 MC ($F = 0.896$, $p > .05$)]. Among participants, 27/40 (67.5%) patients had not controlled asthma (ACT score ≤19), while 19/40 (52.5%) participants had the "hyperventilation syndrome" (NQ score ≥23). As for the experimental group: (1) in the baseline measurement, 15/20 (75%) patients had not controlled asthma, while 11/20 (55%) participants had the "hyperventilation syndrome," and (2) in the final measurement, 3/20 (15%) patients had "not controlled" asthma, while 3/20 (15%) participants had the "hyperventilation syndrome." Table 1 shows sociodemographics by intervention category (experimental and control groups). The two groups did not differ significantly in the baseline measurement ($p > .05$) (Table 2).

Test-retest reliability for the study variables, determined through the IR between the four measurements, was high (35) for the total sample. Specifically, IR was found to be 0.93 for ETCO2, 0.84 for respiratory rate, 0.85 for ACT, 0.91 for NQ, 0.99 for FEV1%, 0.93 for MRC, 0.92 for SF-36v2PC, and 0.85 for SF-36v2MC.

Interaction Effect between Intervention and Time

The factorial 2 × 4 ANOVA analysis showed significant interaction between intervention and time regarding: (1) $ETCO_2$ ($F = 27.18$, $p < .001$, $\eta^2 = 0.69$) (Figure 1), (2) respiratory rate ($F = 22.00$, $p < .001$, $\eta^2 = 0.65$) (Figure 2), (3) ACT ($F = 16.10$, $p < .001$, $\eta^2 = 0.57$) (Figure 3), (4) NQ ($F = 6.99$, $p = .001$, $\eta^2 = 0.37$)

TABLE 1.—Distribution of 40 study participants with asthma by sociodemographic according to intervention category.

Variables	Experimental group ($n = 20$)	Control group ($n = 20$)	*P*-value
Gender	—	—	.337
Female	7 (35.0%)	10 (50.0%)	—
Male	13 (65.0%)	10 (50.0%)	—
Age (years)	48.15 ± 14.63	45.45 ± 12.67	.536
Asthma severity	—	—	.752
Mild	11 (55.0%)	10 (50.0%)	—
Moderate	9 (45.0%)	10 (50.0%)	—
Follow-up	—	—	.527
Regular	9 (45.0%)	11 (55.0%)	—
In emergency	11 (55.0%)	9 (45.0%)	—

TABLE 2.—Participants' performance assessment across time.

Variables	Experimental group ($n = 20$)	Control group ($n = 20$)	P-value
$ETCO_2$ (mmHg)			
1st measurement	34.30 ± 2.58	34.60 ± 2.98	.735
2nd measurement	37.95 ± 2.70	34.90 ± 2.91	.002
3rd measurement	38.50 ± 1.88	35.15 ± 2.58	<.0001
4th measurement	37.90 ± 3.54	34.60 ± 2.91	.003
Respiratory rate, breaths/min			
1st measurement	20.05 ± 2.89	18.75 ± 2.77	.155
2nd measurement	14.05 ± 2.58	18.55 ± 3.10	<.0001
3rd measurement	13.50 ± 1.39	18.45 ± 3.50	<.0001
4th measurement	12.90 ± 2.53	18.20 ± 3.20	<.0001
ACT score			
1st measurement	18.10 ± 2.59	19.00 ± 3.52	.364
2nd measurement	22.20 ± 2.14	19.70 ± 3.28	.007
3rd measurement	22.90 ± 1.89	19.90 ± 3.19	.001
4th measurement	22.00 ± 3.37	20.30 ± 2.99	.100
NQ score			
1st measurement	21.90 ± 9.40	18.60 ± 8.74	.258
2nd measurement	13.85 ± 6.88	18.05 ± 8.16	.087
3rd measurement	11.45 ± 5.73	15.80 ± 7.92	.055
4th measurement	14.00 ± 6.80	16.40 ± 7.44	.294
FEV1% predicted			
1st measurement	83.50 ± 7.74	83.90 ± 10.14	.889
2nd measurement	85.35 ± 7.97	84.50 ± 10.84	.779
3rd measurement	86.65 ± 8.23	84.65 ± 10.64	.510
4th measurement	86.25 ± 8.21	84.55 ± 10.66	.576
MRC			
1st measurement	1.45 ± 0.60	1.25 ± 0.64	.316
2nd measurement	1.15 ± 0.37	1.25 ± 0.64	.548
3rd measurement	1.00 ± 0.00	1.25 ± 0.64	.096
4th measurement	1.05 ± 0.22	1.25 ± 0.64	.199
SF-36v2 PC			
1st measurement	48.47 ± 5.29	48.15 ± 6.75	.867
2nd measurement	53.94 ± 4.02	48.32 ± 6.76	.003
3rd measurement	54.82 ± 3.17	48.00 ± 6.50	.0002
4th measurement	52.30 ± 5.40	48.79 ± 6.31	.066
SF-36v2 MC			
1st measurement	47.66 ± 6.65	45.55 ± 6.31	.319
2nd measurement	49.17 ± 7.62	47.22 ± 6.48	.389
3rd measurement	49.44 ± 7.28	48.46 ± 6.73	.663
4th measurement	46.52 ± 12.24	48.04 ± 6.25	.623

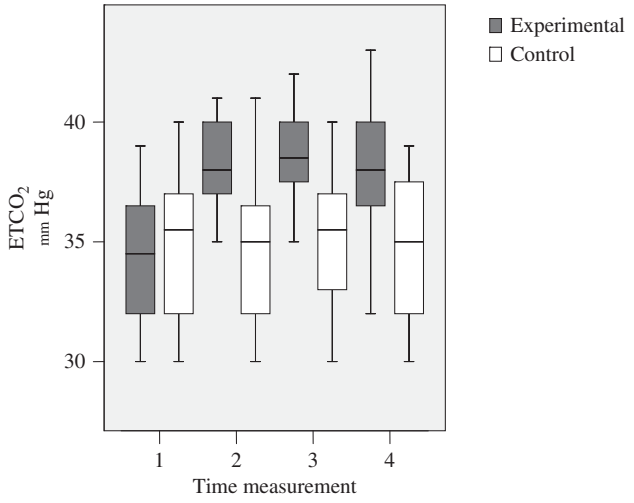

FIGURE 1.—Mean values of $ETCO_2$ for each group (experimental and control) in four time points (1st, 2nd, 3rd, and 4th measurement).

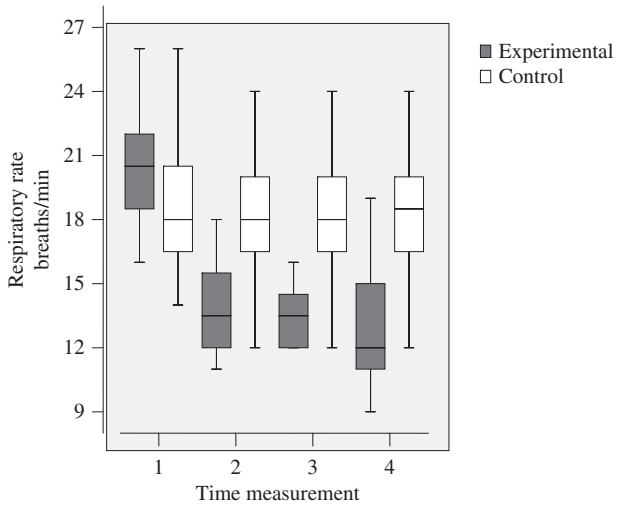

FIGURE 2.—Mean values of respiratory rate for each group (experimental and control) in four time points (1st, 2nd, 3rd, and 4th measurement).

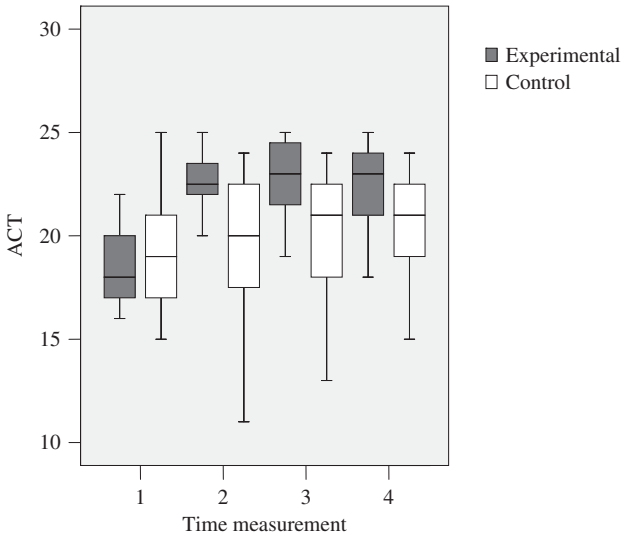

FIGURE 3.—Mean values of ACT for each group (experimental and control) in four time points (1st, 2nd, 3rd, and 4th measurement).

(Figure 4), (5) FEV1% predicted ($F = 3.64$, $p = .022$, $\eta^2 = 0.23$) (Figure 5), and (6) MRC ($F = 3.60$, $p = .023$, $\eta^2 = 0.23$) (Figure 6).

The factorial 2 × 4 MANOVA analysis showed significant interaction between intervention and time regarding the two factors of SF-36v2 ($\Lambda = 0.46$, $F = 6.53$, $p < .001$, $\eta^2 = 0.54$). Post hoc univariate analysis with Bonferroni adjustment ($p = .05/2 = .025$) showed significant interaction for the SF-36v2PC ($F = 10.26$, $p < .001$, $\eta^2 = 0.21$) (Figure 7) but not for the SF-36v2MC ($F = 1.52$, $p = .225$, $\eta^2 = 0.04$) (Figure 8).

Differences between Experimental and Control Groups

Table 2 presents means and standard deviations of the study variables in both experimental and control groups across time.

The t-parameter estimates were used to examine the study variable differences between experimental and

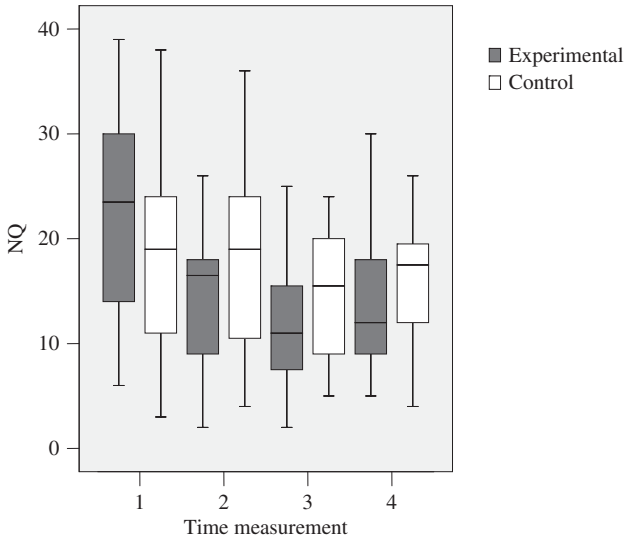

FIGURE 4.—Mean values of NQ for each group (experimental and control) in four time points (1st, 2nd, 3rd, and 4th measurement).

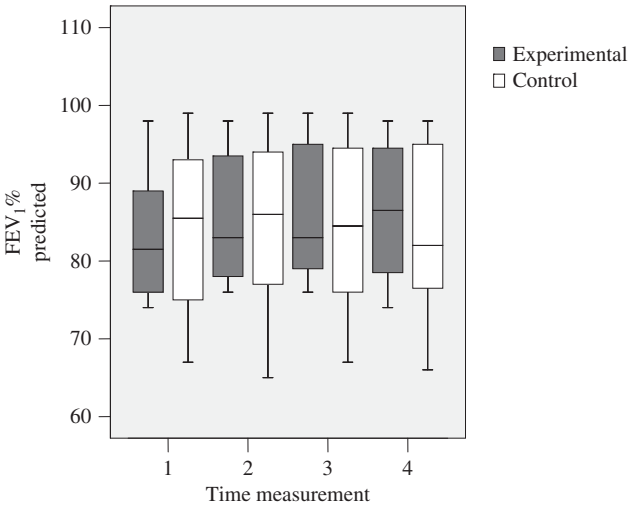

FIGURE 5.—Mean values of FEV1% for each group (experimental and control) in four time points (1st, 2nd, 3rd, and 4th measurement).

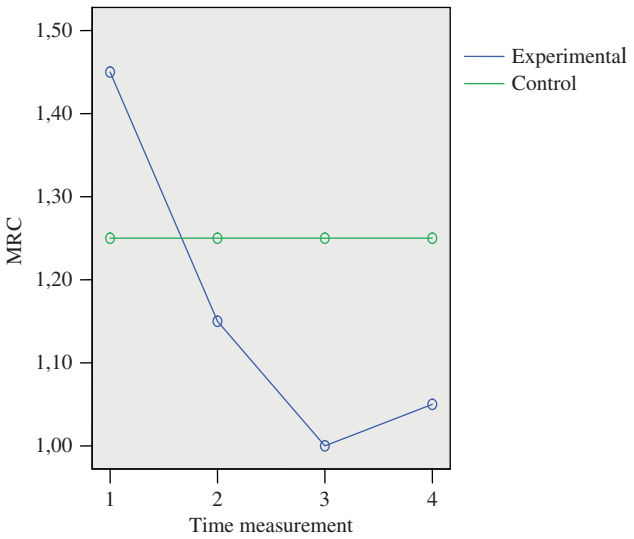

FIGURE 6.—Mean values of MRC for each group (experimental and control) in four time points (1st, 2nd, 3rd, and 4th measurement).

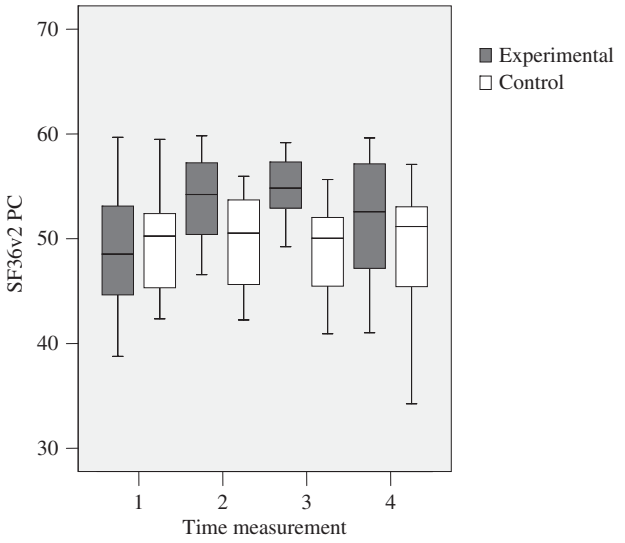

FIGURE 7.—Mean values of SF-36v2 PC for each group (experimental and control) in four time points (1st, 2nd, 3rd, and 4th measurement).

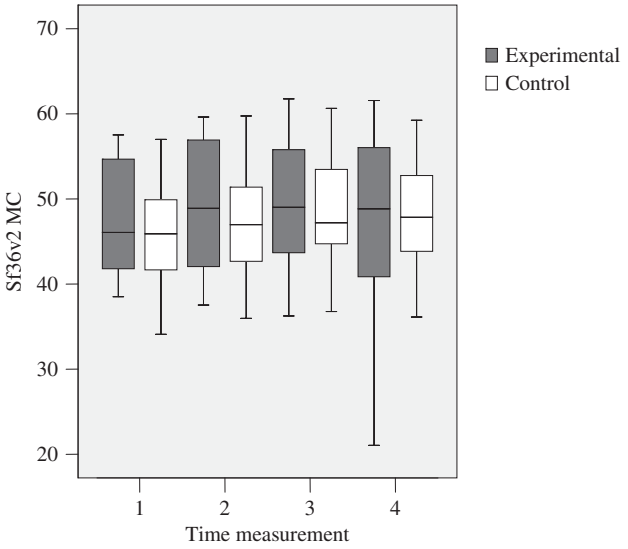

FIGURE 8.—Mean values of SF-36v2 MC for each group (experimental and control) in four time points (1st, 2nd, 3rd, and 4th measurement).

control groups, across time. Results are presented in Table 3.

Time Effect

Time effect on the study variables for the experimental group was significant between 1st and 2nd measurement as regards: $ETCO_2$ ($F = 61.33$, $p < .001$, $\eta^2 = 0.76$), respiratory rate ($F = 67.72$, $p < .001$, $\eta^2 = 0.78$), ACT ($F = 100.12$, $p < .001$, $\eta^2 = 0.84$), NQ ($F = 26.91$, $p < .001$, $\eta^2 = 0.59$), FEV1% predicted ($F = 17.93$, $p < .001$, $\eta^2 = 0.48$), MRC ($F = 5.52$, $p = .030$, $\eta^2 = 0.22$), SF-36v2 PC ($F = 41.73$, $p < .001$, $\eta^2 = 0.69$), and SF-36v2 MC ($F = 4.85$, $p = .040$, $\eta^2 = 0.20$). Specifically, in the 2nd measurement, the mean $ETCO_2$, ACT, FEV1% predicted, SF-36v2 PC, and SF-36v2 MC values were significantly higher, while the mean respiratory rate, NQ and MRC values were lower compared to the 1st measurement.

TABLE 3.—Differences between experimental and control group across time.

Variable measurement	Group	*t*-parameter estimates	*P*-value	η^2
$ETCO_2$ 1st	Experimental control	−0.340	.735	<0.01
$ETCO_2$ 2nd	Experimental control	3.428	.001	0.24
$ETCO_2$ 3rd	Experimental control	4.964	<.001	0.37
$ETCO_2$ 4th	Experimental control	3.222	.003	0.21
Respiratory rate 1st	Experimental control	1.452	.155	0.05
Respiratory rate 2nd	Experimental control	−4.983	<.001	0.39
Respiratory rate 3rd	Experimental control	−5.873	<.001	0.48
Respiratory rate 4th	Experimental control	−5.803	<.001	0.47
ACT 1st	Experimental control	−0.920	.363	0.02
ACT 2nd	Experimental control	2.850	.007	0.12
ACT 3rd	Experimental control	3.620	.001	0.26
ACT 4th	Experimental control	1.686	.100	0.07
NQ 1st	Experimental control	1.149	.258	0.03
NQ 2nd	Experimental control	−1.759	.087	0.07
NQ 3rd	Experimental control	−1.989	.054	0.09
NQ 4th	Experimental control	−1.064	.294	0.03
FEV1% 1st	Experimental control	−0.140	.889	<0.01
FEV1% 2nd	Experimental control	0.283	.779	<0.01
FEV1% 3rd	Experimental control	0.665	.510	0.01
FEV1% 4th	Experimental control	0.565	.576	<0.01
MRC 1st	Experimental control	0.102	.580	0.03
MRC 2nd	Experimental control	−0.605	.547	0.01
MRC 3rd	Experimental control	−1.751	.088	0.07
MRC 4th	Experimental control	−1.322	.194	0.04
ySF-36v2 PC 1st	Experimental control	0.169	.867	0.00
SF-36v2 PC 2nd	Experimental control	3.193	.003	0.21
ySF-36v2 PC 3rd	Experimental control	4.217	<.001	0.32
SF-36v2 PC 4th	Experimental control	1.891	.066	0.09
ySF-36v2 MC 1st	Experimental control	1.009	.319	0.03
SF-36v2 MC 2nd	Experimental control	0.871	.389	0.02
SF-36v2 MC 3rd	Experimental control	0.439	.663	<0.01
SF-36v2 MC 4th	Experimental control	−0.497	.622	0.01

Further, significant differences were found between the 2nd and 3rd measurement for NQ ($F = 7.18$, $p = .015$, $\eta^2 = 0.27$) and FEV1% predicted ($F = 7.28$, $p = .014$, $\eta^2 = 0.28$). In the 3rd measurement, the FEV1% predicted mean value was higher, while the NQ mean was lower compared to the 2nd measurement. In the 4th measurement, SF-36v2 PC was significantly lower compared to the 3rd measurement ($F = 5.21$, $p = .03$, $\eta^2 = 0.21$).

Regarding the control group, a significantly higher ACT mean score was found in the 2nd measurement compared to the 1st measurement solely ($F = 6.16$, $p = .023$, $\eta^2 = 0.24$).

Orthogonal Polynomial Analysis

The orthogonal polynomial analysis revealed significance for quadratic power with respect to all study variables: $ETCO_2$ ($F = 39.054$, $p < .001$), respiratory rate ($F = 46.40$, $p < .001$), ACT ($F = 29.69$, $p < .001$), NQ ($F = 25.73$, $p < .001$), FEV1% predicted ($F = 8.52$, $p = .009$), MRC ($F = 7.11$, $p = .015$), SF-36v2 PC ($F = 40.48$, $p < .001$), and SF-36v2 MC ($F = 22.25$, $p < .001$). In turn, for the control group, significance for the linear trend was found with respect to ACT ($F = 16.22$, $p = .001$), while quadratic significance was evident with respect to $ETCO_2$ scores ($F = 9.62$, $p = .006$).

2 × 2 (Asthma Control × Group) Cross-Tabulation Analysis

The 2 × 2 (asthma control × group) cross-tabulation in each of the four time points revealed significant differences between experimental and control groups regarding asthma control in the 2nd ($\chi^2 = 7.62$, *df* 1, $p = .006$) and 3rd ($\chi^2 = 8.533$, *df* 1, $p = .003$) measurements. There was no significant difference in the 1st ($\chi^2 = 1.026$, *df* 1, $p = .311$) and 4th measurements ($\chi^2 = 3.13$, *df* 1, $p = .077$). The results of the specific analysis are presented in Table 4.

Discriminant Analysis

According to discriminant analysis, the prediction equation for asthma control (ACT) was (1) in the 1st measurement: $Y_{ACT} = -6.65 + 0.08X_{NQ} + 0.22X_{RESPIRATORY\ RATE}$ with CCC = 0.67, 44.62% of explained variability, and 85% prediction accuracy; (2) in the 2nd measurement: $Y_{ACT} = -5.55 + 0.34X_{RESPIRATORY\ RATE}$ with CCC = 0.74, 36.12% of explained variability, and 80% prediction accuracy; (3) in the 3rd measurement: $Y = -5.92 + 0.37X_{RESPIRATORY\ RATE}$ with CCC = 0.68, 44.26% of explained variability, and 85% prediction accuracy; and (4) in the 4th measurement: $Y = -9.41 + 0.30X_{ETCO2} - 0.09X_{NQ}$ with CCC = 0.74, 54.61% of explained variability, and 87.5% prediction accuracy.

DISCUSSION

The present study showed that the physiotherapy-based breathing retraining improved both asthma control and

TABLE 4.—Number of patients with and without controlled asthma in experimental and control groups as regards every measurement.

	Experimental	Control group	Total
1st measurement			
"Not controlled" asthma	15	12	27
"Controlled" asthma	5	8	13
Total	20	20	40
$\chi^2 = 1.026$, df 1, $p = .311$			
2nd measurement			
"Not controlled" asthma	2	10	12
"Controlled" asthma	18	10	28
Total	20	20	40
$\chi^2 = 7.619$, df 1, $p = .006$			
3rd measurement			
"Not controlled" asthma	1	9	10
"Controlled" asthma	19	11	30
Total	20	20	40
$\chi^2 = 8.533$, df 1, $p = .003$			
4th measurement			
"Not controlled" asthma	3	8	11
"Controlled" asthma	17	12	29
Total	20	20	40
$\chi^2 = 3.135$, df 1, $p = .077$			

physiological indices across time. The attempt was to validate the assumption that breathing retraining may reduce hyperventilation, raise $ETCO_2$ levels of asthma patients, and eventually decrease bronchoconstriction (5). The present study is in agreement with Meuret et al. (14) and has extended their respective findings. Specifically, in the present study, breathing retraining decreased hyperventilation through a process sequence of decreasing respiratory rate and symptoms of hypocapnia, raised ETCO2 levels and thus reversed airway bronchoconstriction. To that extent, asthma control was predicted by variables related to hyperventilation such as respiratory rate, symptoms of hypocapnia, and $ETCO_2$.

Most specifically, in the first month of the study as well as 3 months after intervention, the experimental group compared to the control group increased asthma control, $ETCO_2$, the physical component of quality of life, while it decreased the respiratory rate. Six months after intervention, the experimental group, compared to the control group, continued to improve $ETCO_2$ and reduction in respiratory rate. What is more, the experimental group: (1) improved all dependent variables 1 month after intervention, (2) reduced hyperventilation and increased FEV1% predicted 3 months after intervention, and (3) increased solely the physical component of quality of life 6 months after intervention. Finally, a sharp change was observed for all variables for the experimental group with the greater change being observed during the first month of the study.

This is the first study that demonstrated a continuous improvement in asthma control and $ETCO_2$ for the experimental group compared to the control group, over a period of 3 months as a result of physiotherapy-based breathing retraining. In the pilot study of Meuret et al. (14), the experimental group compared with the control group significantly improved asthma control and raised $ETCO_2$ for 8 weeks (total duration of the study).

Another originality of the present study is that the specific physiotherapy-based breathing retraining intervention provoked a significant increase in FEV1% predicted, a physiological index of asthma, in the experimental group. No effect on the pulmonary function was found as a result of breathing retraining (12, 14, 15) in previous studies except for the study by Thomas et al. (12) where both experimental and control groups improved their respective FEV_1 values after a month (within groups' significant differences). Factors such as participants' age (<60 years), their familiarity with the spirometry test, their long-term training and guidance for the major effort (36), and the specialist's recommendation to continue regular asthma medication during the study might have contributed to their best spirometry performance and increment in FEV1% predicted values (14). However, the large effect found on FEV1% predicted does not seem to be simply explained by the aforementioned factors in the present study (14).

Finally, this is the first study in which the written action plan included the adaptation of breathing behavior in leisure-time physical activities, which may have contributed complementarily to the reduction of breathlessness disability and improvement of the physical component of quality of life for the experimental group.

The strength of the present study lies in the methodological differences with previous breathing retraining interventions. In particular, internal validity for the present study was assured with randomization, blinding for the assessor, null withdrawn, use of valid and reliable tools, random administration of the questionnaires used and $ETCO_2$ and FEV1% performance carried out always at the end of each measurement (30). The seasonal effect on the outcomes of the study was assured by (1) choosing summer (in July), wherein seasonal variation of asthma is eliminated (37, 38), as the intervention period; and (2) excluding any participant in case he/she needed modification of the regular asthma medication. At this point, it is worth mentioning that for all participants asthma remained "stable" till the end of the study. The external validity of the present study was ensured by randomization and by conducting the study in a real setting (30).

A combination of group and individual physiotherapy sessions used in the present study was based on the common practice in asthma management (39). Individual physiotherapy sessions are often preferable in asthma, which in turn usually complement group sessions (39). During the group session, patients shared experiences

with others and realized they were not the only ones suffering from asthma (40). This in itself was a therapeutic procedure for the patient's compliance to the intervention protocol used in the present study (40). Individual sessions gave to the participants the opportunity to develop perceptiveness and a good partnership with the physiotherapist (1). Moreover, both individual and group sessions were conducted by an adequately trained physiotherapist (41). Finally, the construction of the group educational session in the present study was based on the health belief model (32) that explains the modification of breathing behavior according to the beliefs and attitudes of the participants.

The duration of the present study was 6 months, longer than 12 weeks, which is the optimal period for asthma intervention assessment according to GINA, and in line with the transtheoretical model (17), which suggests that a participant of an intervention program will develop behavioral adaptation in 6 months' time. According to the transtheoretical model, participants adopted the new breathing behavior which appeared as a finding of significant merit although it was not the primary focus of the present study.

The fact that all participants were volunteers and none of them withdrew from the study suggests they may have been at the contemplation change (second stage). This is in line with Cassidy (17) who stated that the majority of patients under health professional care are included in the first and second stage. Further, for the experimental group, the sharp effect of breathing retraining on all study variables during the intervention phase is likely to imply change in the behavior stage (third stage—contemplation, or fourth stage—action). According to the transtheoretical model (17, 30), an intervention program might double the participants' possibilities to act alone in the near future in case the intervention has helped them change behavior stage in the first month (17, 31). The hypothesis that experimental-group participants changed their breathing behavior may also be supported by the decrease in the number of participants with not controlled asthma across time. However, it is impossible to determine which participants proceeded to the action stage or regressed between the stages of the transtheoretical model, which constitutes a certain limitation.

The interpretation of the findings in an experimental study cannot exclude the effect of other factors, such as awareness of participation in the study and sensation of increased care and cure (Hawthorn effect) (30), specialists' recommendations to continue regular asthma medication, expectancy of improvement (12, 14), asthma beliefs, motivation as well as expectation related to the participants' capability to cope with difficulties, and to achieve the target result (42). The above factors should explain the improvement in asthma control mainly for the control group in the present study as opposed to the experimental group where the large effect of the intervention on the study variables should not be imputed solely to the aforementioned factors.

The clinical implication of the present study refers to the magnitude of the breathing retraining effect on asthma control. The experimental group seems to have changed its breathing behavior thus accomplishing better asthma control. We suggest that patients with stable asthma under a specialist's care should be trained with physiotherapy-based breathing retraining in order to adopt the new breathing behavior and achieve self-management of their symptoms. What is more, the findings of the present study may support the inclusion of physiotherapy in asthma self-management education.

The present study, however, has some potential limitations. The total sample comprised only patients with mild to moderate asthma as it consisted solely of outpatients. Another limitation of the present study is the absence of validity evidence for the NQ. A pilot validation study for the NQ was conducted but has not been published yet. Finally, there are no data for the breathing behavior-changing stages for the experimental group, due to the absence of a relative measure validated in Greece.

Future researchers should (1) examine the effect of physiotherapy-based breathing retraining on severe asthma, (2) compare the protocol used in the present study with other kind of breathing exercises, (3) repeat this study and define behavior-change stages across time, and (d) conduct financial studies regarding the cost of health services in case of breathing retraining standardization in asthma self-management.

Conclusion

This study gave a rationale of the mechanism of breathing retraining effectiveness on asthma control and pulmonary function in patients with stable asthma. The present study strengthened the theory that breathing retraining increases $ETCO_2$ and thus can reverse the airway bronchoconstriction in patients with stable asthma. Future researchers are needed to strengthen the findings of the present study so that patients with stable asthma can achieve the control of their disease.

Acknowledgments

The authors wish to thank GlaxoSmithKline and Dr. Folgering for the no charge permission given to use the Greek version of Asthma Control Test and the Nijmegen Questionnaire as well as Aikaterini Haniotou, M.D., Director of the Respiratory Medicine Clinic of "Amalia Fleming" General Hospital in Athens, Greece, and the participants of the study.

Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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