Internet-Based Self-management Plus Education Compared With Usual Care in Asthma

A Randomized Trial

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Background: The Internet may support patient self-management of chronic conditions, such as asthma.

Objective: To evaluate the effectiveness of Internet-based asthma self-management.

Design: Randomized, controlled trial.

Setting: 37 general practices and 1 academic outpatient department in the Netherlands.

Patients: 200 adults with asthma who were treated with inhaled corticosteroids for 3 months or more during the previous year and had access to the Internet.

Measurements: Asthma-related quality of life at 12 months (minimal clinically significant difference of 0.5 on the 7-point scale), asthma control, symptom-free days, lung function, and exacerbations.

Intervention: Participants were randomly assigned by using a computer-generated permuted block scheme to Internet-based self-management ($n = 101$) or usual care ($n = 99$). The Internet-based self-management program included weekly asthma control monitoring and treatment advice, online and group education, and remote Web communications.

Results: Asthma-related quality of life improved by 0.56 and 0.18 points in the Internet and usual care groups, respectively (adjusted between-group difference, 0.38 [95% CI, 0.20 to 0.56]). An improvement of 0.5 point or more occurred in 54% and 27% of Internet and usual care patients, respectively (adjusted relative risk, 2.00 [CI, 1.38 to 3.04]). Asthma control improved more in the Internet group than in the usual care group (adjusted difference, -0.47 [CI, -0.64 to -0.30]). At 12 months, 63% of Internet patients and 52% of usual care patients reported symptom-free days in the previous 2 weeks (adjusted absolute difference, 10.9% [CI, 0.05% to 21.3%]). Prebronchodilator FEV_1 changed with 0.24 L and -0.01 L for Internet and usual care patients, respectively (adjusted difference, 0.25 L [CI, 0.03 to 0.46 L]). Exacerbations did not differ between groups.

Limitation: The study was unblinded and lasted only 12 months.

Conclusion: Internet-based self-management resulted in improvements in asthma control and lung function but did not reduce exacerbations, and improvement in asthma-related quality of life was slightly less than clinically significant.

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Asthma is a chronic disorder of the airways that is characterized by recurring respiratory symptoms, variable airflow obstruction, airway hyperresponsiveness, and underlying inflammation (1, 2). Recent clinical guidelines for the management of asthma distinguish 4 essential components of asthma care: assessment and monitoring, patient education, control of environmental and comorbid factors that affect asthma, and drug treatment. With appropriate medical care, well-informed and empowered patients can control their asthma and live full, active lives (1, 2). However,

despite the availability of monitoring tools and effective therapy, asthma control is suboptimal in many patients worldwide, and long-term management falls far short of the goals set in the guidelines (3).

Self-monitoring, education, and specific medical care are important aspects in improving the lives of patients with asthma (1, 2). However, many patients with mild or moderate persistent asthma do not attend checkups regularly or visit their physician with symptoms of the disease (4). In addition, in practice, both patients and their health care providers are reluctant to use written self-management plans (5).

Internet technology is increasingly seen as an appealing tool to support self-management for patients with chronic disease in remote and underserved populations (6–8). However, to date, studies on Internet-based asthma self-management show only short-term improvements in asthma control, lung function, and quality of life (9–11). Long-term studies on the effect of Internet-based self-management, including all its essential features, are not available.

Therefore, we developed a guided self-management tool for adult patients with asthma that included Internet-based home monitoring and treatment advice (action plan), online education, and remote Web communication with a specialized asthma nurse. The goal of our study was to assess the long-term clinical effectiveness of Internet-based self-management education compared with usual physician-provided care alone.

METHODS

Design Overview

We conducted a 12-month, multicenter, nonblinded, randomized, controlled trial. We randomly assigned patients to Internet-based self-management (Internet group) as an adjunct to usual care or to usual physician-provided care alone (usual care group). The Internet-based self-management program included weekly asthma control monitoring and treatment advice, online and group education, and remote Web communications with a specialized asthma nurse. The intervention continued for 12 months after enrollment. The Medical Ethics Committee of the Leiden University Medical Center, Leiden, the Netherlands, approved the study.

Setting and Participants

We recruited patients from 37 general practices (69 general practitioners) in the Leiden and The Hague area and the Outpatient Clinic of the Department of Pulmonology at the Leiden University Medical Center from September 2005 to September 2006. Inclusion criteria were physician-diagnosed asthma coded according to the International Classification of Primary Care in the electronic medical record (12), age 18 to 50 years, prescription of inhaled corticosteroids for at least 3 months in the previous year, no serious comorbid conditions that interfered with asthma treatment, access to the Internet at home, and mastery of the Dutch language. We excluded patients who were receiving maintenance oral glucocorticosteroid treatment. On the basis of diagnosis, age, prescribed asthma medication, and comorbid conditions, we sent eligible patients an invitation letter followed by 1 reminder letter after 2 to 4 weeks if they did not respond to the first. We continued this process until a total of 200 patients had entered the study (September 2006). All participants gave written consent.

Randomization and Intervention

In a 2-week baseline period before randomization, we collected data on patient demographic characteristics, asthma-related quality of life, symptom control, lung function, and medication level. We provided basic education about core information on asthma, action of medications, and inhaler technique instructions to all patients. We trained all participants to measure FEV_1 daily with a handheld electronic spirometer (PiKo-1, Ferraris Respiratory, Hertford, United Kingdom) and to report the highest

Context

Patient self-management is an essential component of asthma care, and the Internet is a medium to potentially support patients in self-management.

Contribution

This randomized trial compared Internet-based asthma self-management with usual care and found modest improvements in asthma control and lung function with the Internet intervention, but found no reduction in exacerbations and changes in asthma-related quality of life that were less than clinically significant at 12 months.

Implication

Although Internet-based self management can improve some asthma outcomes, the improvements were small and the program did not reduce the number of exacerbations.

—The Editors

value of 3 measurements in the morning before taking medication (2, 13). They were shown how to report these values on a personal page on a secure Web application by using a login password (or how to report by mobile telephone text message). Patients were also asked to report their nighttime and daytime asthma symptom scores on this Internet page or by text message. We asked all participants to complete the Asthma Control Questionnaire on their personal Internet page each week (14). We did not give any patients feedback about lung function or asthma control.

After the 2-week baseline period, we randomly assigned participants to either the Internet group or the usual care group. We stratified according to care provider (primary vs. subspecialty care) and asthma control at baseline (15). We randomly assigned patients to the 2 groups (1:1 ratio) by using a computer-generated, permuted-block scheme. Allocation took place by computer after collection of the baseline data, ensuring concealment of allocation.

The Internet-based self-management program consisted of the 4 principal components of asthma self-management and was accessed through the specially designed Web site, which allowed monitoring through the Web site (or text message on a mobile telephone), use of an Internet-based treatment plan, online education, and Web communications with a specialized asthma nurse (16). Patients monitored their asthma weekly by completing an electronic version of the Asthma Control Questionnaire on the Web site and instantly received feedback on the current state of their asthma control along with advice on how to adjust their treatment according to a predefined algorithm and treatment plan (**Table 1** and **Appendix Figures 1** to **5**, available at www.annals.org). Depending on the scores submitted, patients received 4 types of self-treatment advice. When 4 consecutive Asthma Control Questionnaire

Table 1. Treatment Plan

Step*	Medication
1	Rapid-acting β_2-agonist, as needed†
2	Low-dose inhaled glucocorticosteroids
3a	Low-dose inhaled glucocorticosteroids plus long-acting β_2-agonist
3b	Medium-dose inhaled glucocorticosteroids
3c	High-dose inhaled glucocorticosteroids
4a	Medium-dose inhaled glucocorticosteroids plus long-acting β_2-agonist
4b	High-dose inhaled glucocorticosteroids plus long-acting β_2-agonist
4c	Contact asthma nurse‡; consider addition of leukotriene modifier
5	Contact asthma nurse‡; consider addition of oral glucocorticosteroid

* Step numbers correspond with recommended steps in the Global Initiative for Asthma guidelines (1).
† Applies to all treatment steps.
‡ Or other health care provider.

scores were 0.5 or less, patients were advised to decrease treatment according to treatment plan. When 2 consecutive scores were greater than 0.5 but less than 1.0, patients were advised to increase treatment according to treatment plan. When 1 score was 1.0 or more but less than 1.5, patients were advised to immediately increase treatment according to treatment plan. Finally, when 1 score was 1.5 or more, patients were advised to immediately increase treatment and contact the asthma nurse.

We advised no medication changes during the 4 weeks after treatment was stepped up (evaluation period). In addition to weekly assessments, patients could optionally report daily symptoms and lung function and were able to contact our asthma nurse though the Web or by telephone. Thus, any acute deterioration warranting a visit to the general practitioner or hospital could be detected (**Appendix Figures 2** and **3**, available at www.annals.org).

We aimed to empower patients to use the Internet-based self-management tool and to develop a patient–provider partnership in asthma care (2). Self-management education consisted of both Web-based and face-to-face, group-based education. Web-based education included asthma information, news, frequently asked questions, and interactive communication with a respiratory nurse specialist. We scheduled 2 group-based education sessions, which lasted 45 to 60 minutes, for patients in the Internet-based self-management group within 6 weeks after entering the trial. Both sessions included exploration of a patient's interests and previous knowledge (negotiating an agenda and patient-centered education), personalized feedback, and empowerment of self-management (self-efficacy and implementing a plan for change) (2, 17). The first educational session also included pathophysiology of asthma, information on the Web-based action plan, and information and review of inhalation technique. The second educational

Table 2. Baseline Characteristics

Characteristic	Usual Care Group (n = 99)	Internet Group (n = 101)
Men, %	29	32
Mean age (range), y	37 (18–50)	36 (19–50)
Mean asthma duration (range), y	18 (0–47)	15 (1–47)
Education level, %		
Low	14	11
Middle	33	37
High	53	52
Smoking status, %		
Never	53	58
Former	33	30
Current	14	12
Care provider, %		
General practitioner	80	79
Chest physician	20	21
Mean FEV_1 (prebronchodilator) (range), L	3.13 (1.56–5.23)	3.08 (1.14–5.19)
Mean predicted FEV_1 (prebronchodilator) (range), %	90 (53–118)	88 (34–133)
Mean daily inhaled corticosteroid dose (range), μg	517 (0–2000)	497 (0–1000)
Inhaled long-acting β_2-agonist use, %	60	59
Leukotriene modifier use, %	2	3
Mean educational outcomes (range)*		
Asthma knowledge†	8.32 (3–12)	8.74 (2–12)
Inhaler technique‡	4.11 (1–5)	4.34 (3–5)
Self-reported medication adherence§	6.19 (0–7)	6.46 (0–7)
Clinical outcomes		
Mean Asthma Quality of Life Questionnaire score (range)	5.79 (3.03–7.00)	5.73 (3.66–6.94)
Mean Asthma Control Questionnaire score (range)	1.11 (0–3.86)	1.12 (0.07–3.22)
Symptom-free days (range), %	44.5 (0–100)	44.9 (0–100)

* Baseline data for asthma knowledge and self-reported medication adherence were available for 91 and 99 patients in the usual care and Internet groups, respectively.
† Consumer Asthma Knowledge Questionnaire score range (worst–best), 0–12.
‡ Checklist of Dutch Asthma Foundation score range (worst–best), 0–5.
§ Range, 0–7 d/wk.

session gave information about the mechanisms and side effects of medication and explained trigger avoidance.

Patients in the usual care group received asthma care according to the Dutch general practice guidelines on asthma management in adults, which recommend a medical review and treatment adjustment every 2 to 4 weeks in unstable asthma and medical review once or twice yearly for patients whose asthma is under control (18). These national guidelines are based on international guidelines, such as the Global Initiative for Asthma guidelines (1, 18).

Outcomes, Measurements, and Follow-up Procedures
Process Evaluation

The process evaluation included educational outcomes (asthma knowledge, inhaler technique, and self-reported medication adherence), health care provider contacts for asthma, use of the Internet-based monitoring tool, and medication changes. We assessed asthma knowledge with the 12-item Consumer Asthma Knowledge Questionnaire (19, 20) and inhalation technique with the standardized checklist of the Dutch Asthma Foundation (21). We assessed knowledge, inhaler technique, and medication adherence at baseline and 12 months.

Health care provider contacts included physician visits, telephone contacts (quarterly questionnaire), and remote Web communications with a specialized asthma nurse. We extracted the frequency of Internet-based monitoring from Web site log files and included optional daily lung function and symptom monitoring and weekly Asthma Control Questionnaire monitoring.

Medication use was reported at baseline, 3 months, and 12 months. For each patient, we measured the number of medication changes (or steps) by comparing treatment step at 3 months with treatment step at baseline (number of medication changes in first 3 months) and treatment step at 12 months with treatment step at 3 months (number of medication changes in the next 9 months). We totaled the numbers of medication changes in the first 3 months and next 9 months and reported averages per patient.

Clinical Outcomes

The primary clinical outcome measure was asthma-related quality of life, as measured by the 32-item Asthma Quality of Life Questionnaire (22). The minimal important difference is 0.5 on a 7-point scale. We assessed 5 secondary clinical outcomes: asthma control (minimal important difference is 0.5 on the 7-point Asthma Control Questionnaire scale), symptom-free days, prebronchodilator FEV_1, daily inhaled corticosteroid dose, and exacerbations. We assessed all outcomes except for exacerbations over 2 weeks, at 3 months, after the baseline period, and again at 12 months. During these assessments, all patients kept Internet-based daily diaries as they had during the baseline period. We restricted Web site access for usual care patients to this diary page. We defined symptom-free

days as a night and day without asthma symptoms or being awakened by asthma symptoms, as measured by the TRUST (The Regular Use of Salbutamol Trial) diary card (23). We measured prebronchodilator FEV_1 during each 2-week assessment period (the end value used for analysis). We calculated daily inhaled corticosteroid dose as fluticasone equivalents. We defined exacerbations as deterioration in asthma that required emergency treatment or hospitalization (collected by quarterly questionnaire) or the need for oral steroids for 3 days or more (collected by pharmacy records), as judged by the attending physician, and assessed them over the whole year (24). We collected all outcome data similarly in both groups. Participants provided the Asthma Control Questionnaires, symptom-free days, and prebronchodilator FEV_1 through the Internet (the usual care group had limited access to the Web site for 2 weeks at baseline, 3 months, and 12 months). We collected the other outcomes by written questionnaires.

Statistical Analysis

Our primary objective was to determine whether changes in asthma-related quality of life (Asthma Quality of Life Questionnaire score) differed between the Internet group and the usual care group. With a total of 100 patients per group, an SD of 0.75 (17), and a correlation coefficient of 0.5, our repeated-measures analysis had a statistical power of 80% (at the 2-tailed 5% significance level) to detect a 0.26-point difference in Asthma Quality of Life Questionnaire score.

We analyzed the differences in the demographic characteristics between participants and nonparticipants and differences in baseline characteristics between the 2 randomization groups by using Fisher exact tests and unpaired Student t tests for proportions and continuous data, respectively. We analyzed within- and between-group differences in the process outcomes with paired and unpaired Student t tests, respectively.

We analyzed changes in the Asthma Quality of Life Questionnaire scores, Asthma Control Questionnaire scores, percentage of symptom-free days, and lung function by using linear mixed-effects models. We added a random intercept at the patient level to adjust for repeated measurements over time (25). We added 6 covariates (sex, age, education level, smoking status, type of care provider, and number of control problems in the previous year) to the models. We entered time to the models as a categorical covariate. We aimed the primary analysis at treatment effects after 12 months. In addition, we analyzed differences in treatment effects between 3 and 12 months. We compared exacerbations between the 2 groups with a Cox proportional hazards model, including the same 6 covariates as added to the linear mixed-effects model.

To estimate the number of patients who gained a clinically important benefit from treatment, we used logistic regression analysis with "clinical improvement at 12 months" as a dichotomized outcome and the same 6 co-

variates, as previously described (26). We analyzed complete cases and did not impute missing values. Clinical improvements in Asthma Quality of Life Questionnaire and Asthma Control Questionnaire scores were changes from baseline of 0.5 or more and changes from baseline of −0.5 or less, respectively (27, 28). As the outcomes of interest were common, odds ratios were inappropriate to estimate relative risks (RRs); therefore, we recalculated them into RRs with CIs on the basis of marginal standardization by using a bootstrap method (29).

We did all analyses on an intention-to-treat basis. We did not impute missing values. We used Stata, version 9.0 (StataCorp, College Station, Texas), for all analyses.

Role of the Funding Source

The Netherlands Organization for Health Research and Development, ZonMw, and Netherlands Asthma Foundation supported the study. The funding sources had no role in the study design or conduct; collection, analysis, or interpretation of the data; or in the decision to submit the article for publication.

RESULTS

We invited the 930 patients who met the selection criteria to participate in the study. Patients who consented to participate ($n = 200$ [21.5%]) did not differ from nonparticipants in age (mean age, 36.6 years vs. 35.8 years; $P = 0.27$) or socioeconomic status (living in an underprivileged area, 5.0% vs. 7.1%; $P = 0.29$), but they did differ in sex (women, 69.5% vs. 59.7%; $P = 0.012$). Baseline characteristics of the randomization groups were similar (**Table 2**).

Process Evaluation

Asthma knowledge improved in the Internet group (0.42 [95% CI, 0.05 to 0.79]) and the usual care group (0.86 [CI, 0.35 to 1.36]), but the improvements did not differ between the groups ($P = 0.70$) (**Table 3**). Similarly, inhalation technique improved in the Internet group (0.21 [CI, 0.04 to 0.38]) and the usual care group (0.32 [CI, 0.15 to 0.50]), but the improvements did not differ between the groups ($P = 0.143$) (**Table 3**). There were no within- or between-group differences in self-reported medication adherence.

Patients in the Internet group had 5.9 (CI, 4.8 to 7.1) online contacts with the asthma nurse during the 1-year follow-up. The Internet group had slightly fewer physician visits than the usual care group (−0.74 physician visits [CI, −1.55 to 0.06 physician visits]). Patients in the Internet group reported optional daily lung function and symptom scores at 108 days (CI, 98 to 126 days) and Asthma Control Questionnaire scores at 35 weeks (CI, 31 to 38 weeks). Treatment increases (step-up) and decreases (step-down) both occurred more often in the Internet group than in the usual care group (**Table 3**).

Clinical Outcomes

Participants did not deviate from the study protocol. We obtained 90% and 91.5% of primary outcome data during the assessment periods at 3 and 12 months, respectively (**Figure 1**). The analysis set included all randomly assigned patients who provided any data during the study.

Table 4 summarizes the results of the primary and secondary clinical outcomes. Asthma-related quality of life (Asthma Quality of Life Questionnaire) improved more in

Table 3. **Process Outcomes After 12 Months**

Variable	Usual Care Group (n = 92)	Internet Group (n = 91)	Difference (95% CI)	P Value
Educational outcomes				
Asthma knowledge*	9.10	9.21	0.11 (−0.44 to 0.66)	0.70
Inhaler technique†	4.49	4.63	0.15 (−0.05 to 0.34)	0.143
Self-reported medication adherence‡	6.37	6.32	−0.05 (−0.59 to 0.49)	0.86
Health care provider contacts for asthma, average number per patient				
Physician visits	1.86	1.11	−0.74 (−1.55 to 0.06)	0.071
Telephone contacts with health care provider	2.35	2.39	0.04 (−0.75 to 0.84)	0.91
Online contacts with asthma nurse§	NA	5.93	–	–
Use of Internet-based monitoring tool§				
Optional daily lung function scores, average days per patient	NA	107.8	–	–
Asthma Control Questionnaire monitoring, average weeks per patient	NA	34.8	–	–
Medication changes, average number per patient				
Step-up treatment	0.39	0.90	0.51 (0.30 to 0.72)	<0.001
Step-down treatment	0.44	0.75	0.31 (0.09 to 0.53)	0.006

NA = not applicable.
* Consumer Asthma Knowledge Questionnaire score range (worst–best), 0–12.
† Checklist of the Dutch Asthma Foundation score range (worst–best), 0–5.
‡ Range, 0–7 d/wk.
§ Obtained from Web site log files available for all patients in the Internet group ($n = 101$).

the Internet group than in the usual care group (change from baseline, 0.56 vs. 0.18; adjusted difference, 0.38 [CI, 0.20 to 0.56]) (**Figure 2***A*). This treatment effect was not statistically different between 3 and 12 months. Patients assigned to the Internet group more often had a clinically relevant improvement (≥0.5) in asthma-related quality of life than did those in the usual care group (54% vs. 27%; adjusted RR, 2.00 [CI, 1.38 to 3.04]) (**Figure 3**, *top*).

The Internet group showed greater improvement of asthma control (Asthma Control Questionnaire) than did the usual care group (change from baseline, −0.54 vs. −0.06; adjusted difference, −0.47 [CI, −0.64 to −0.30]) (**Figure 2***B*, and **Table 4**). This treatment effect was not statistically different between 3 and 12 months. Patients assigned to the Internet group had a clinically relevant improvement (−0.5 or less) in asthma control more often than those in the usual care group (48% vs. 17%; adjusted RR, 2.87 [CI, 1.86 to 5.14]) (**Figure 3**, *bottom*). After 12 months, the proportion of symptom-free days reported for the previous 2 weeks increased by an absolute 18.2% and 7.3% (adjusted difference, 10.9% [CI, 0.05% to 21.3%]) in the Internet and usual care groups, respectively. Pre-bronchodilator FEV_1 changed by 0.24 L and −0.01 L (adjusted difference, 0.25 L [CI, 0.03 to 0.47 L]) for the Internet and usual care groups, respectively (**Figure 2***C*). Daily inhaled corticosteroid dose did not statistically significantly differ after 12 months (difference, 57 μg [CI, −38 to 152 μg]) (**Figure 2***D*). However, a statistically significant time-by-intervention effect occurred during the first 3 months when the daily inhaled corticosteroid dose increased by 164 μg ($P < 0.001$) in the Internet group followed by a change of −107 μg (CI, −202 to −12 μg; $P = 0.027$) in the next 9 months in the Internet group compared with the usual care group. During follow-up, 17 exacerbations occurred in 11 patients in the Internet group compared with 20 exacerbations in 10 patients in the usual care group (hazard ratio, 1.18 [CI, 0.51 to 2.74]).

DISCUSSION

We compared the clinical effectiveness of Internet-based self-management (as an adjunct to physician care) with usual physician-provided care alone. We offered all the components for optimal self-management (monitoring, education, medical review, and an action plan) through the Internet: electronic Internet-based symptom and lung function monitoring, access to an online personalized action plan, online education, and professional review using e-mail and private messaging. Our results suggest that Internet-based self-management of asthma improves quality of life, asthma control, and lung function and increases the number of symptom-free days compared with usual physician-provided care.

To our knowledge, this is the first randomized, controlled evaluation of Internet-based asthma self-management that shows sustained improvement in asthma-related quality of

Figure 1. Study flow diagram.
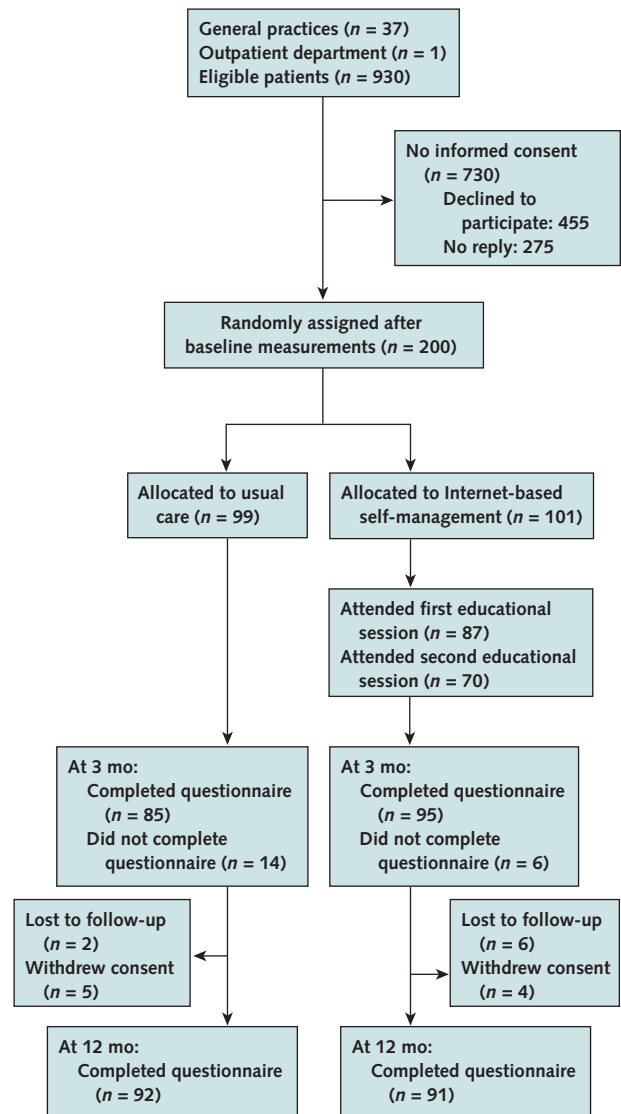
life. The improvement achieved in the Internet group was as large as the minimal important difference with patients who reached optimal scores for asthma-related quality of life during 1-year follow-up (27). Two previous trials on Internet-based asthma management in adults and children, respectively, reported only short-term improvements on asthma-related quality of life (10, 11), whereas a 1-year, randomized, controlled trial that compared Internet-based and office-based asthma care in children did not show any changes in quality of life (9). Previous trials of paper-and-pencil self-management programs showed only moderate and inconsistent improvements on asthma-related quality of life (16, 17).

For secondary end points, we consistently demonstrated clinically relevant improvements in asthma control, lung function, and the percentage of symptom-free days.

Table 4. Primary and Secondary Clinical Outcomes*

Variable	Usual Care Group (n = 99)				Internet Group (n = 101)			
	Baseline	3 Months	12 Months	Change From Baseline to 12 Months (95% CI)	Baseline	3 Months	12 Months	Change From Baseline to 12 Months (95% CI)
Primary outcome								
Asthma Quality of Life Questionnaire†	5.79	5.96	5.97	0.18 (0.05 to 0.31)	5.73	6.15	6.29	0.56 (0.43 to 0.68)
Secondary outcomes								
Asthma Control Questionnaire‡	1.11	1.05	1.04	−0.06 (−0.18 to 0.05)	1.12	0.67	0.59	−0.54 (−0.65 to −0.42)
Symptom-free days, %	44.5	47.5	51.8	7.3 (0.0 to 14.6)	44.9	63.4	63.1	18.2 (10.8 to 25.6)
FEV_1, L	3.13	3.10	3.12	−0.01 (−0.16 to 0.14)	3.08	3.20	3.32	0.24 (0.08 to 0.39)
Daily inhaled corticosteroid dose, μg	517	494	470	−48 (−115 to 20)	497	638	506	9 (−58 to 76)

* Values are model estimates of linear mixed-effects models with a random intercept, adjusted for sex, age, education level, smoking status, type of care provider, and number of control problems in the previous year.
† Score range (worst–best), 1–7.
‡ Score range (worst–best), 6–0.

The beneficial clinical effects were reached without an increase in inhaled corticosteroid dose at 12 months. In the first 3 months, many patients had uncontrolled asthma and were advised to increase their inhaled corticosteroid doses. The improvement in asthma control seen after 3 months allowed a decrease in inhaled corticosteroid medication over the next 9 months without loss of asthma control. This pattern suggests tailoring medication to patients' needs rather than increasing medication for the whole study sample.

The process evaluation included outcomes on the principal components of asthma self-management. We showed improvements in asthma knowledge and inhalation technique in both groups for asthma education but without between-group differences. The improvements in the usual care group may be explained by the baseline meeting and measurements, which triggered patients to improve their asthma knowledge and inhalation skills. Other studies that assessed the behavioral effect of self-management programs found a similar result (9, 30). Basic education only, therefore, did not seem to be the key component explaining the positive effects of the Internet-based self-management intervention. The Internet group tended to have fewer annual physician visits. This was due to either increased asthma control in this group and therefore fewer requirements for medical review or physician visits may have been substituted by online contacts with our asthma nurse. By protocol, Internet-based monitoring only occurred in the intervention group. Patients reported symptoms and lung function once in 3 days and reported weekly asthma control in 35 of 52 weeks. The difference in the number of treatment changes between the groups may be explained by this frequency of monitoring and subsequent treatment advice.

Differences in the baseline characteristics, patient selection, participation rate, or underperformance of usual care do not seem to influence the results of this study. First, we found no statistically significant differences in the baseline characteristics between the 2 groups. Second, we selected patients from primary care practices and an outpatient subspecialty practice on the basis of a physician's diagnosis of asthma. We cannot exclude the possibility that some patients did not meet the lung function or airway responsiveness criteria for a diagnosis of asthma, according to recent guidelines. However, in our study, as in a realistic routine care setting, we identified patients who were eligible for an asthma Internet-based self-management intervention through a physician's diagnosis of asthma. Consequently, this might have diluted the effect of the Internet-based self-management intervention but enhanced the external validity of our study (31). Third, the participation rate was 21.5%, which is similar to rates in other asthma education and management studies (17, 32, 33). Age and socioeconomic status of nonparticipants were similar to those of participants, and women were only slightly overrepresented in the study sample. Demographic characteristics would suggest broad applicability in the general population; however, other important determinants of the nonparticipants were unknown. Patients with previously uncontrolled asthma are more likely to participate in a self-management program than are patients with well-controlled asthma (7). Structural barriers, such as lack of time; living too far; and social behavioral factors, such as self-efficacy, belief in personal benefits, and social influence, also predict participation in a self-management program (34). These clinical and psychological factors could have differed in participants and nonparticipants and might therefore have bearing on generalizability. In addition, about 20% of the population in the Netherlands does not have access to the Internet, which is an obvious reason for nonparticipation in our study. However, because Internet access is increasing worldwide, this barrier might dis-

Table 4—Continued

Between-Group Comparisons

Difference in Changes (95% CI)	P Value
0.38 (0.20 to 0.56)	<0.001
−0.47 (−0.64 to −0.30)	<0.001
10.9 (0.05 to 21.3)	0.039
0.25 (0.03 to 0.46)	0.025
57 (−38 to 152)	0.24

appear. Fourth, because we also saw improvements in asthma-related quality of life and control in the usual care group, although these did not reach statistical significance, it seems unlikely that our results can be explained by underperformance of physician-provided care during the study compared with prestudy standards.

A potential limitation of our study was that the patients and physicians were aware of the allocation group. Because asthma-related quality of life, asthma control, and symptom-free days were self-reported, the improvements may have resulted from increased awareness rather than the Internet-based intervention. Furthermore, because the Asthma Control Questionnaire score was the target measurement that drove the treatment algorithm, we expected improvements. In addition, the absence of a difference in an objective outcome, such as exacerbations, does not sup-

Figure 2. Changes in mean Asthma Quality of Life Questionnaire score (*A*), Asthma Control Questionnaire score (*B*), FEV$_1$ (*C*), and daily inhaled corticosteroid dose (*D*) during 1-year follow-up for the Internet and usual care groups.
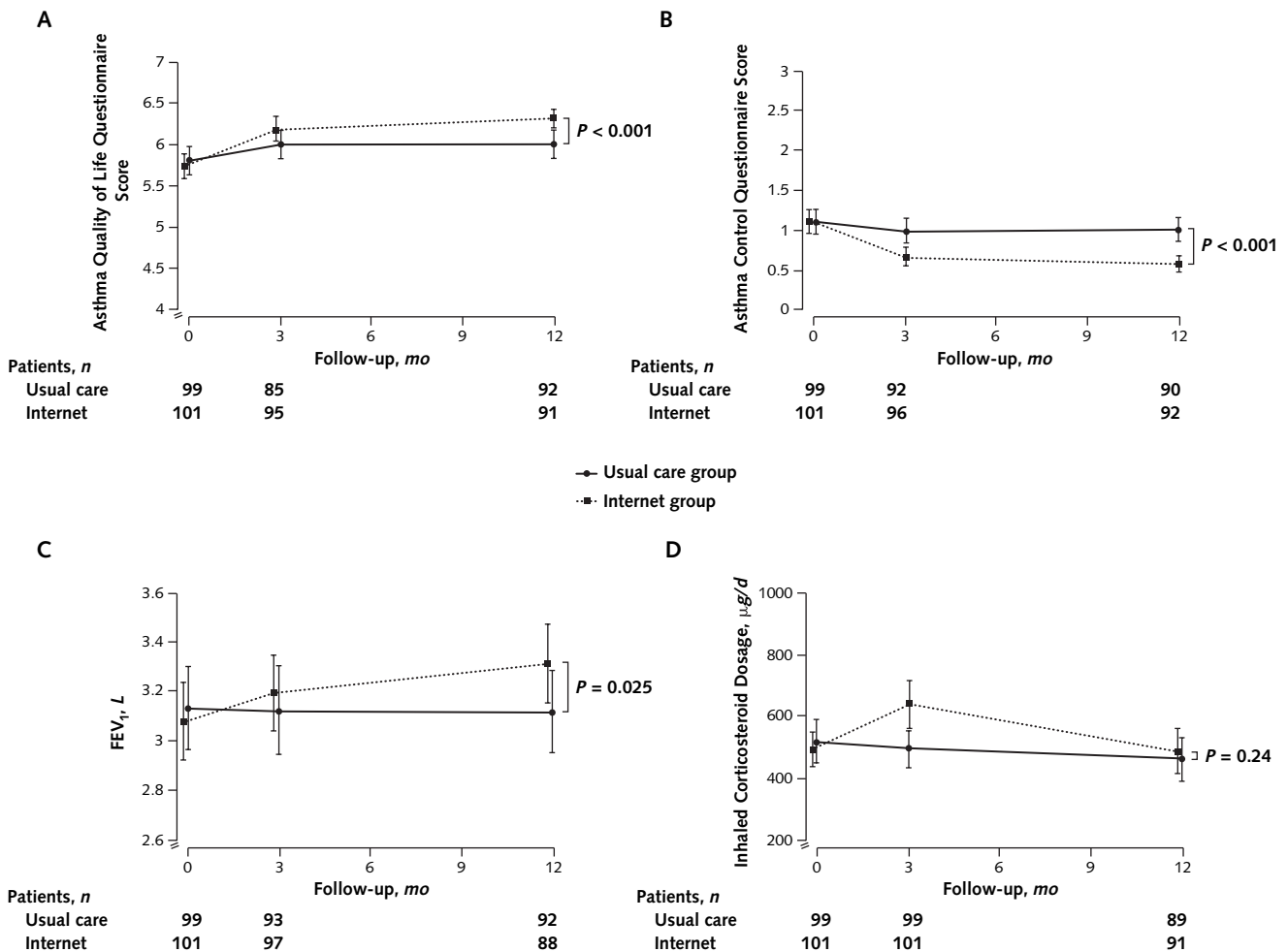
The minimal important difference for the Asthma Quality of Life Questionnaire is 0.5, with higher scores indicating better quality of life. The minimal important difference for the Asthma Control Questionnaire is 0.5, with lower scores indicating better asthma control. Plotted values are based on complete cases. Error bars indicate 95% CIs. *P* values are shown for between-group differences in change in scores at 12 months and are from linear mixed-effects models.

Figure 3. Distribution of change in scores for Asthma Quality of Life Questionnaire (*top*) and Asthma Control Questionnaire (*bottom*).
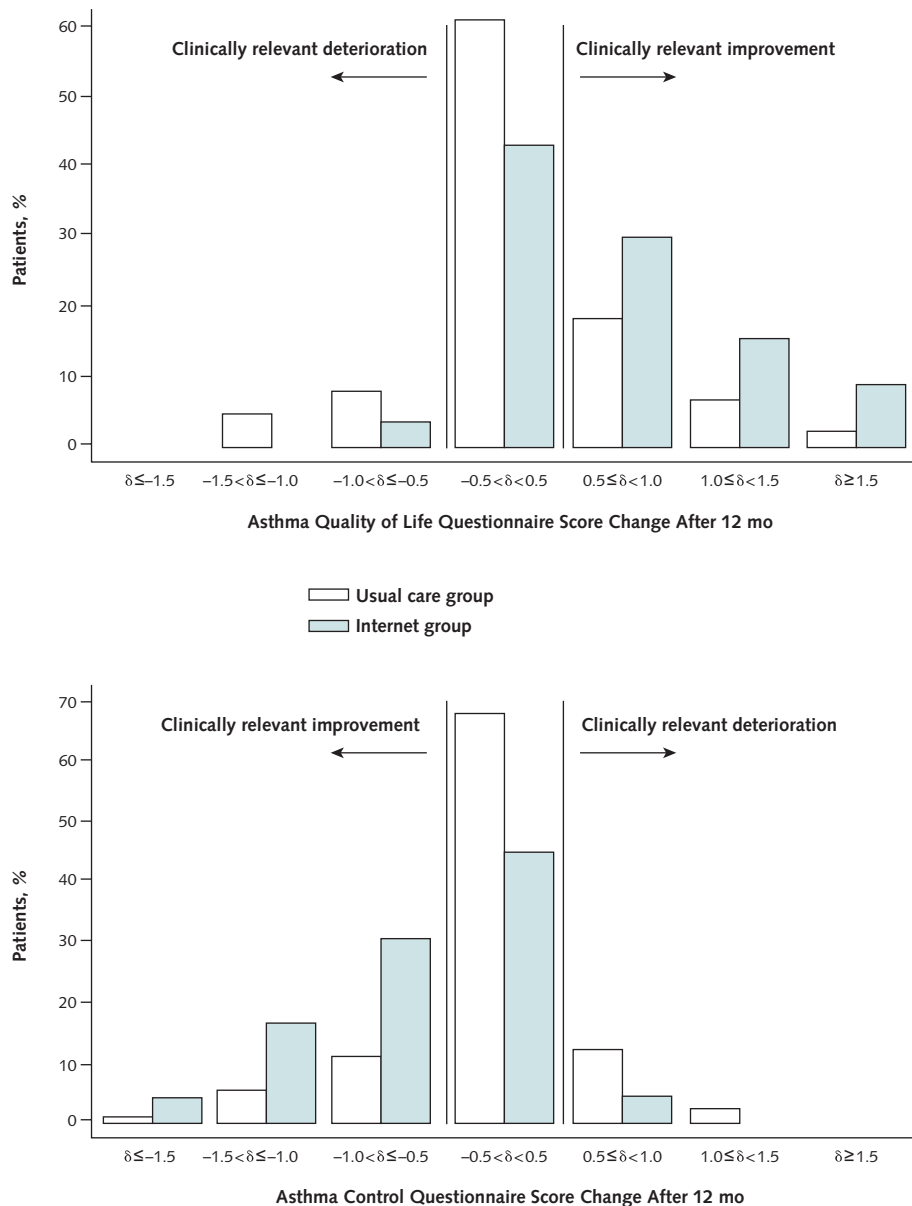
δ = 12-month score minus baseline score. The minimal important difference for the Asthma Quality of Life Questionnaire is 0.5, with higher scores indicating better quality of life. The minimal important difference for the Asthma Control Questionnaire is 0.5, with lower scores indicating better asthma control.

port our positive findings in patient-reported outcomes. However, this study was not designed or powered to detect a difference in exacerbation rate in patients with mild-to-moderate persistent asthma (24). Moreover, the improvement in lung function, as an objective measurement, provides a fair basis for our findings in quality of life, asthma control, and symptom-free days.

The implications of our findings show that self-management of asthma guided by a validated, short questionnaire on asthma control, as recommended by recent guidelines, is feasible and improves quality of life. In addition, we demonstrate that the Internet is an effective way to disseminate knowledge to patients with asthma and a successful tool that can empower patients to achieve and maintain control of their asthma by adjusting treatment with effective medication. Our study further supports the emphasis that recent guidelines have placed on monitoring asthma control and illustrates that a relatively simple validated instrument, such as the Asthma Control Questionnaire, can be used to operationalize asthma control in

guided self-management (1, 2, 14). Taken together, Internet-based self-management provides new ways to tailor monitoring and education continuously to patients' needs, which empowers patients to control their asthma and to live full, normal, and active lives, even potentially in remote and underserved populations in developed and developing countries (35).

In conclusion, Internet-based self-management improves asthma-related quality of life, asthma control, and lung function and increases the number of symptom-free days. The challenge is implementing Internet-based self-management on a wider scale within routine asthma care.

References

1. **Global Initiative for Asthma.** Global Strategy for Asthma Management and Prevention. Bethesda, MD: National Institutes of Health; 1995. NIH publication no 02-3659.
2. **National Asthma Education and Prevention Program.** Guidelines for the diagnosis and management of asthma: expert panel report 3. Bethesda, MD: National Institutes of Health; 2007.
3. **Rabe KF, Adachi M, Lai CK, Soriano JB, Vermeire PA, Weiss KB, et al.** Worldwide severity and control of asthma in children and adults: the global asthma insights and reality surveys. J Allergy Clin Immunol. 2004;114:40-7. [PMID: 15241342]
4. **O'Byrne PM, Parameswaran K.** Pharmacological management of mild or moderate persistent asthma. Lancet. 2006;368:794-803. [PMID: 16935690]
5. **Jones A, Pill R, Adams S.** Qualitative study of views of health professionals and patients on guided self management plans for asthma. BMJ. 2000; 321:1507-10. [PMID: 11118179]
6. **Newman S, Steed L, Mulligan K.** Self-management interventions for chronic illness. Lancet. 2004;364:1523-37. [PMID: 15500899]
7. **van der Meer V, van Stel HF, Detmar SB, Otten W, Sterk PJ, Sont JK.** Internet-based self-management offers an opportunity to achieve better asthma control in adolescents. Chest. 2007;132:112-9. [PMID: 17400674]
8. **Green BB, Cook AJ, Ralston JD, Fishman PA, Catz SL, Carlson J, et al.** Effectiveness of home blood pressure monitoring, Web communication, and pharmacist care on hypertension control: a randomized controlled trial. JAMA. 2008;299:2857-67. [PMID: 18577730]
9. **Chan DS, Callahan CW, Hatch-Pigott VB, Lawless A, Proffitt HL, Manning NE, et al.** Internet-based home monitoring and education of children with asthma is comparable to ideal office-based care: results of a 1-year asthma in-home monitoring trial. Pediatrics. 2007;119:569-78. [PMID: 17332210]
10. **Rasmussen LM, Phanareth K, Nolte H, Backer V.** Internet-based monitoring of asthma: a long-term, randomized clinical study of 300 asthmatic subjects. J Allergy Clin Immunol. 2005;115:1137-42. [PMID: 15940125]
11. **Jan RL, Wang JY, Huang MC, Tseng SM, Su HJ, Liu LF.** An internet-based interactive telemonitoring system for improving childhood asthma outcomes in Taiwan. Telemed J E Health. 2007;13:257-68. [PMID: 17603828]
12. **Lamberts H, Wood M, eds.** International Classification of Primary Care. Oxford: Oxford Univ Pr; 1987.
13. **Fonseca JA, Costa-Pereira A, Delgado L, Silva LN, Magalhães M, Castel-Branco MG, et al.** Pulmonary function electronic monitoring devices: a randomized agreement study. Chest. 2005;128:1258-65. [PMID: 16162716]
14. **Juniper EF, O'Byrne PM, Guyatt GH, Ferrie PJ, King DR.** Development and validation of a questionnaire to measure asthma control. Eur Respir J. 1999; 14:902-7. [PMID: 10573240]
15. **Vollmer WM, Markson LE, O'Connor E, Frazier EA, Berger M, Buist AS.** Association of asthma control with health care utilization: a prospective evaluation. Am J Respir Crit Care Med. 2002;165:195-9. [PMID: 11790654]
16. **Gibson PG, Powell H, Coughlan J, Wilson AJ, Abramson M, Haywood P, et al.** Self-management education and regular practitioner review for adults with asthma. Cochrane Database Syst Rev. 2003:CD001117. [PMID: 12535399]
17. **Thoonen BP, Schermer TR, Van Den Boom G, Molema J, Folgering H, Akkermans RP, et al.** Self-management of asthma in general practice, asthma control and quality of life: a randomised controlled trial. Thorax. 2003;58:30-6. [PMID: 12511716]
18. **Geijer RM, Smeele IJ, Goudswaard AN.** [Summary of the practice guideline 'Asthma in adults' (second revision) from the Dutch College of General Practitioners]. Ned Tijdschr Geneeskd. 2008;152:1146-50. [PMID: 18549139]
19. **Kritikos V, Krass I, Chan HS, Bosnic-Anticevich SZ.** The validity and reliability of two asthma knowledge questionnaires. J Asthma. 2005;42:795-801. [PMID: 16316877]
20. **Armour C, Bosnic-Anticevich S, Brillant M, Burton D, Emmerton L, Krass I, et al.** Pharmacy Asthma Care Program (PACP) improves outcomes for patients in the community. Thorax. 2007;62:496-502. [PMID: 17251316]
21. **Kamps AW, van Ewijk B, Roorda RJ, Brand PL.** Poor inhalation technique, even after inhalation instructions, in children with asthma. Pediatr Pulmonol. 2000;29:39-42. [PMID: 10613785]
22. **Juniper EF, Guyatt GH, Ferrie PJ, Griffith LE.** Measuring quality of life in asthma. Am Rev Respir Dis. 1993;147:832-8. [PMID: 8466117]
23. **Dennis SM, Sharp SJ, Vickers MR, Frost CD, Crompton GK, Barnes PJ, et al.** Regular inhaled salbutamol and asthma control: the TRUST randomised trial. Therapy Working Group of the National Asthma Task Force and the MRC General Practice Research Framework. Lancet. 2000;355:1675-9. [PMID: 10905242]
24. **Rabe KF, Atienza T, Magyar P, Larsson P, Jorup C, Lalloo UG.** Effect of budesonide in combination with formoterol for reliever therapy in asthma exacerbations: a randomised controlled, double-blind study. Lancet. 2006;368:744-53. [PMID: 16935685]
25. **Twisk J.** Applied Longitudinal Data Analysis for Epidemiology—A Practical Guide. New York: Cambridge Univ Pr; 2003.
26. **Guyatt GH, Juniper EF, Walter SD, Griffith LE, Goldstein RS.** Interpret-

ing treatment effects in randomised trials. BMJ. 1998;316:690-3. [PMID: 9522799]

27. **Juniper EF, Guyatt GH, Willan A, Griffith LE.** Determining a minimal important change in a disease-specific Quality of Life Questionnaire. J Clin Epidemiol. 1994;47:81-7. [PMID: 8283197]

28. **Juniper EF, Svensson K, Mörk AC, Ståhl E.** Measurement properties and interpretation of three shortened versions of the asthma control questionnaire. Respir Med. 2005;99:553-8. [PMID: 15823451]

29. **Localio AR, Margolis DJ, Berlin JA.** Relative risks and confidence intervals were easily computed indirectly from multivariable logistic regression. J Clin Epidemiol. 2007;60:874-82. [PMID: 17689803]

30. **van der Palen J, Klein JJ, Zielhuis GA, van Herwaarden CL, Seydel ER.** Behavioural effect of self-treatment guidelines in a self-management program for adults with asthma. Patient Educ Couns. 2001;43:161-9. [PMID: 11369149]

31. **Travers J, Marsh S, Williams M, Weatherall M, Caldwell B, Shirtcliffe P, et al.** External validity of randomised controlled trials in asthma: to whom do the results of the trials apply? Thorax. 2007;62:219-23. [PMID: 17105779]

32. **Asthma in Adolescents Research Team.** A web-based, tailored asthma management program for urban African-American high school students. Am J Respir Crit Care Med. 2007;175:888-95. [PMID: 17290041]

33. **Pinnock H, Bawden R, Proctor S, Wolfe S, Scullion J, Price D, et al.** Accessibility, acceptability, and effectiveness in primary care of routine telephone review of asthma: pragmatic, randomised controlled trial. BMJ. 2003;326:477-9. [PMID: 12609944]

34. **Lemaigre V, Van den Bergh O, Van Hasselt K, De Peuter S, Victoir A, Verleden G.** Understanding participation in an asthma self-management program. Chest. 2005;128:3133-9. [PMID: 16304253]

35. **Solberg KE.** Telemedicine set to grow in India over the next 5 years. Lancet. 2008;371:17-8. [PMID:18183655]

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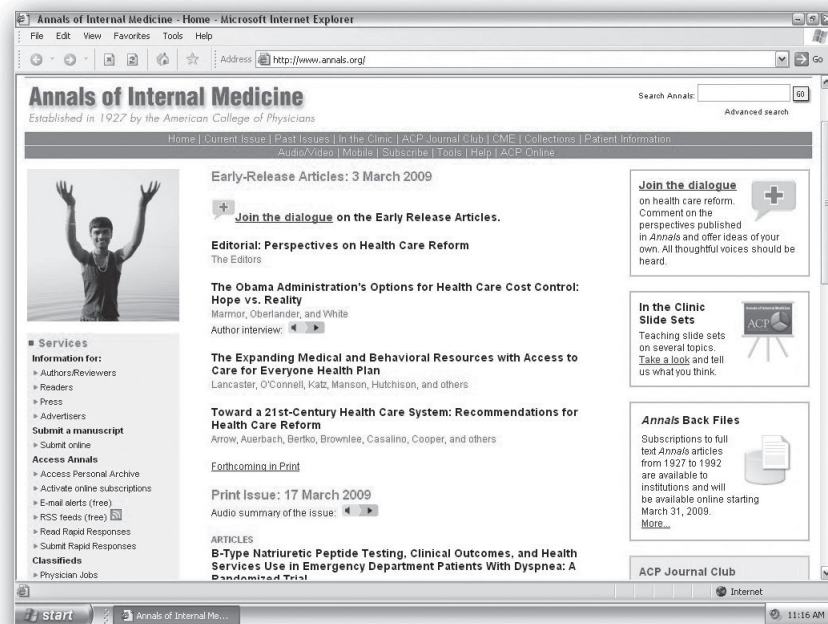
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Collection and assembly of data: V. van der Meer, M.J. Bakker, W.J.J. Assendelft, J.K. Sont.

Appendix Figure 1. **Algorithm based on consecutive ACQ scores to adjust medical treatment.**
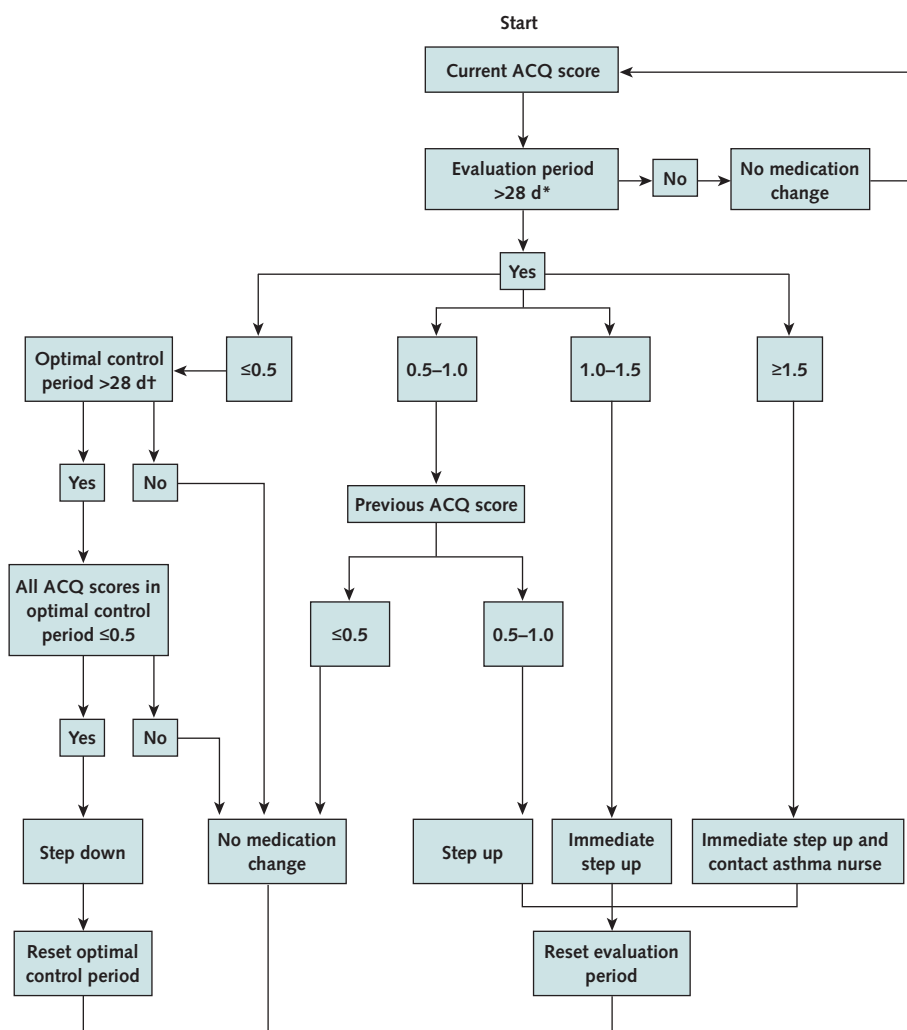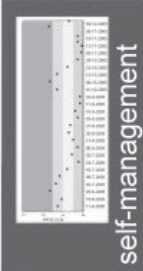
* ACQ = Asthma Control Questionnaire. At entry of the algorithm, the evaluation period is bypassed. The evaluation period starts after treatment was stepped up.
† The optimal control period starts after 1 ACQ score ≤0.5 and ends after 1 ACQ score >0.5.

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  - □ monitoring
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    - □ self-management
  - □ presentations
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  - □ useful links

ICT

self-management

asthma

Start

Measurements and questionnaires

| Enter lung function | Enter ACQ | Show results | Print |

Week: 46

Last FEV1: 13-11-2007, 08h03

FEV1
2.78

Night time symptom score
Symptoms are chest tightness, wheezing, breathlessness and cough.
- ○ No symptoms during the night.
- ○ Symptoms on waking but not causing you to wake early.
- ○ Symptoms causing you to wake once or to wake early.
- ○ Symptoms causing you to wake twice or more (including waking early).
- ◉ Symptoms causing you to be awake most of the night.
- ○ Symptoms so severe that you did not sleep at all.

Daytime symptom score
Symptoms are chest tightness, wheezing, breathlessness and cough.
- ○ No symptoms
- ○ Symptoms for one short period during the day.
- ◉ Symptoms for two ore more short periods during the day.
- ○ Symptoms for most of the day, which did not interfere with usual daytime activities.
- ○ Symptoms for most of the day, which did interfere wiht usual daytime activities.
- ○ Symptoms so severe that you could not perform your usual daytime activities.

Add comments

| Restore | Save |

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| Search |

News
- □ 11/04 New York marathon
- □ 10/31 getting the flu
- □ 10/10 asthma in Japan
- □ 09/25 expensive health care
- □ 08/28 fatter and fatter
- □ 07/19 sun tanning
- □ 07/01 smog
- □ 06/07 smoking prohibited
- □ 05/29 apples and fish
- □ 05/01 World Asthma Day
- □ 04/19 asthma in New York
- □ 04/10 hay fever
- □ 03/15 grandma smokes
- □ 02/20 Spider Award
- □ 01/01 happy new year

Poll

Flu vaccination protects me against asthma attack

true — 43%

false — 57%

Number of votes: 34

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  ☐ presentations
  ☐ video instruction about inhaler technique
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Start

Measurements and questionnaires

| Enter lung function | Enter ACQ | Show results | Print |

Entered on: 15-11-2007, 08h29
Your values have been received.

FEV1 value: 2.78 L
FEV1 is 70.7% of predicted value

You have entered a low FEV1 value and/or severe symptoms.
Please consult our asthma nurse via private messaging or telephone.

Change

Search

Search

News

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☐ 10/10 asthma in Japan
☐ 09/25 expensive health care
☐ 08/28 fatter and fatter
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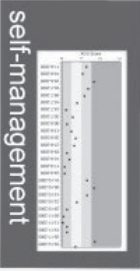
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false 57%

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Measurements and questionnaires

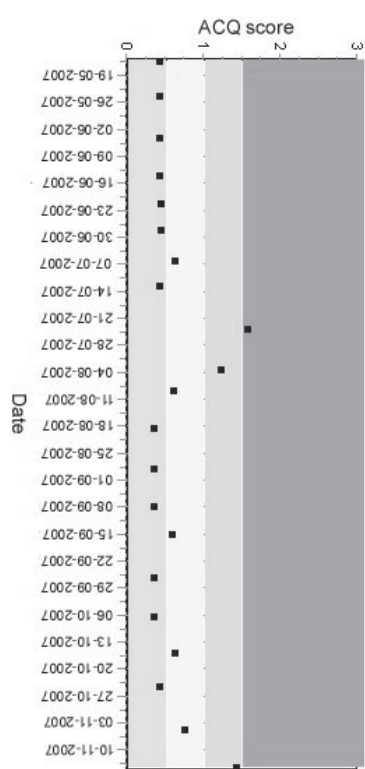| Enter lung function | Enter ACQ | Show results | Print |

Week: 46
Last entered ACQ: 06-11-2007

| Restore | Save |

1. On average, during the past week, how often were you **woken by your asthma** during the night?
   ○ Never
   ○ Hardly ever
   ◉ A few times
   ○ Several times
   ○ Many times
   ○ A great many times
   ○ Unable to sleep because of asthma

2. On average, during the past week, how **bad were your asthma symptoms when you woke up** in the morning?
   ○ No symptoms
   ○ Very mild symptoms
   ◉ Mild symptoms
   ○ Moderate symptoms
   ○ Quite severe symptoms
   ○ Severe symptoms
   ○ Very severe symptoms

3. In general, during the past week, how **limited were you in your activities** because of your asthma?
   ◉ Not limited at all
   ○ Very slightly limited
   ○ Slightly limited
   ○ Moderately limited
   ○ Very limited
   ○ Extremely limited
   ○ Totally limited

Search

| Search |

News
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