Patient Preference and Adherence

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ORIGINAL RESEARCH

Investigating Adherence to Asthma Management with an Electronic Monitoring System

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Background: Adherence to prescribed inhaler use is critical for effective asthma management and to prevent exacerbations. However, overall adherence to inhaler use among asthma patients is low and the most frequent measures of adherence are considered not sufficiently reliable. The aim of this study was to investigate adherence rates and their impact on asthma management via an electronic monitoring system.

Methods: This was a prospective observational study of adults diagnosed with asthma who were equipped with electronic monitoring sensors whose data were recorded from August 2019 to June 2020. The study participants were also divided into two groups: allergic and nonallergic. The study lasted 90 days, and participants' demographic information, inhaled corticosteroid (ICS) dosage, lung function and asthma control test scores, blood samples, exhaled nitric oxide concentrations, and inhaler usage records from the electronic monitoring system were collected.

Results: In total, 39 asthma patients completed the follow-up period. The study results revealed a significant difference in the adherence rates between the allergy and nonallergy groups at 30 days, with respective adherence rates of 49.9% and 22.8%, and at 90 days, the rates were 37.3% in the allergy group and 19.3% in the nonallergy group. The study results also revealed a significant positive correlation between medication adherence and the allergy group, and adherence was negatively correlated with the ICS dosage.

Conclusion: In this study, the average medication adherence rates among asthma patients were low and even lower in the nonallergy group than in the allergy group. Electronic monitoring can provide a clearer understanding of patients' medication patterns and could serve as a valuable tool for improving asthma management in the future.

Keywords: asthma, adherence, asthma management, asthma control, electronic monitoring system

Introduction

Approximately 300 million people worldwide suffer from asthma which is also a leading cause of disability, economic stress, and death. The average prevalence rate is 10%~12% in adults and 15% in children.[1] Asthma affects 10%~11% of the population in Taiwan.[2]

Effective asthma management is crucial for controlling symptoms and preventing acute exacerbation. However, the literature indicates that adherence rates in asthma has been shown to vary widely from 22% to 78% which is poor medication adherence (often defined as ≤80% adherence) and is partially related to the morbidity[3,4] and mortality[5] of asthma.

Adherence can be assessed in a number of ways.[6,7] It can be obtained via questionnaires,[8,9] checking the patient's remaining medication or calculating the medication possession ratio or the proportion of days covered, neither of which are considered sufficiently reliable. These questionnaires could be affected by the relationships of the patient and physician. Similarly, a patient could also intentionally empty their medication if they do not comply with the doctor's prescription.[10] Technological advancements in the development of electronic monitoring of inhaler devices allow for monitoring of use which provide an objective and personalized asthma assessment method for medical staff and patients.

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There is limited research on adherence to inhaler use among asthma patients via electronic monitoring system. In addition, asthma affects mainly people with allergies. Therefore, to investigate the actual medication performance of patients, this study had three purposes:

1. The use of an electronic monitoring device (AsthmaHelps+ app with Flores sensor) to measure the real-world medication adherence rate of asthma patients with inhaler use;
2. Evaluate the adherence rate of asthma patients with inhaler use and its impact on symptom control; and
3. Correlations of the adherence rate to inhaler use with allergies, symptom control, lung function, and inflammation indicators were explored.

When the AsthmaHelps+ App was connected to the Flores sensor via Bluetooth and patient inhaled medication through the sensor, it precisely recorded the time at which the medication was taken.

Methods and Materials

Study Design and Patients

This was a prospective observational, single-center study designed to assess and analyze medication adherence in patients with allergic asthma and those with nonallergic asthma. Adherence to inhaled medication was analyzed over a 90-day period and was measured via electronic data capture devices, which saved the date and time of each inhalation device actuation and transferred these data daily via wireless connection to a web-based database. The study was approved by the Taipei Medical University-Joint Institutional Review Board (TMU-JIRB no. N201905051) and was conducted in compliance with the Declaration of Helsinki (2000). Written informed consent was obtained from all participants.

The inclusion criteria were as follows: (1) aged ≥20 years and ≤80 years; (2) confirmed diagnosis of asthma according to the Global Initiative for Asthma criteria and bronchodilator reversibility test; (3) treatment with budesonide/formoterol (a pressurized metered-dose inhaler (MDI)) as maintenance therapy; (4) smartphone use; and (5) signed an informed consent form. The exclusion criteria were as follows: (1) not suitable for an MDI device; (2) not suitable for taking budesonide/formoterol as treatment medication; and (3) not having a smartphone or unable to use the AsthmaHelps+ (Asthma Patient Care Management System) application (App).

The study participants were divided into two groups: allergic and nonallergic. We defined the elevation of immunoglobulin E (IgE) above 100 kU/L or the use of Xolair as indicative of the allergic group.[11–13]

Study Procedures

In total, 39 asthma patients completed the follow-up period from August 2019 to June 2020 (Figure 1). All the participants downloaded the AsthmaHelps+ app (https://asthmahelps.com/login.php) and matched the individual sensors at the baseline visit. The goal of the baseline visit was to ensure that all participants were correctly using their medication and operating the app with the sensor. There was a 30-day clinical visit and a 90-day clinical visit. Assessment and education were performed during every clinical visit.

Measurements

The following sociodemographic variables were registered: sex, age, body mass index (BMI), smoking status, and occupational status. The clinical variables assessed at the baseline visit were years since onset, asthma severity, biomarkers (IgE and eosinophil (EOS) count), comorbidities, allergens, and AE in the past year, which led to an emergency room visit or hospitalization. Pulmonary function test (PFT), fraction exhaled nitric oxide (FeNO), disease control, and medication treatment status were assessed at each visit.

Disease severity was assessed by the Global Initiative for Asthma 2019 criteria,[14] and disease control was assessed by the Asthma Control Test (ACT). The ACT is a validated five-item, self-completed questionnaire that assesses whether a patient's asthma symptoms are well controlled. Each question has five response options scored from 5 to 1. The total

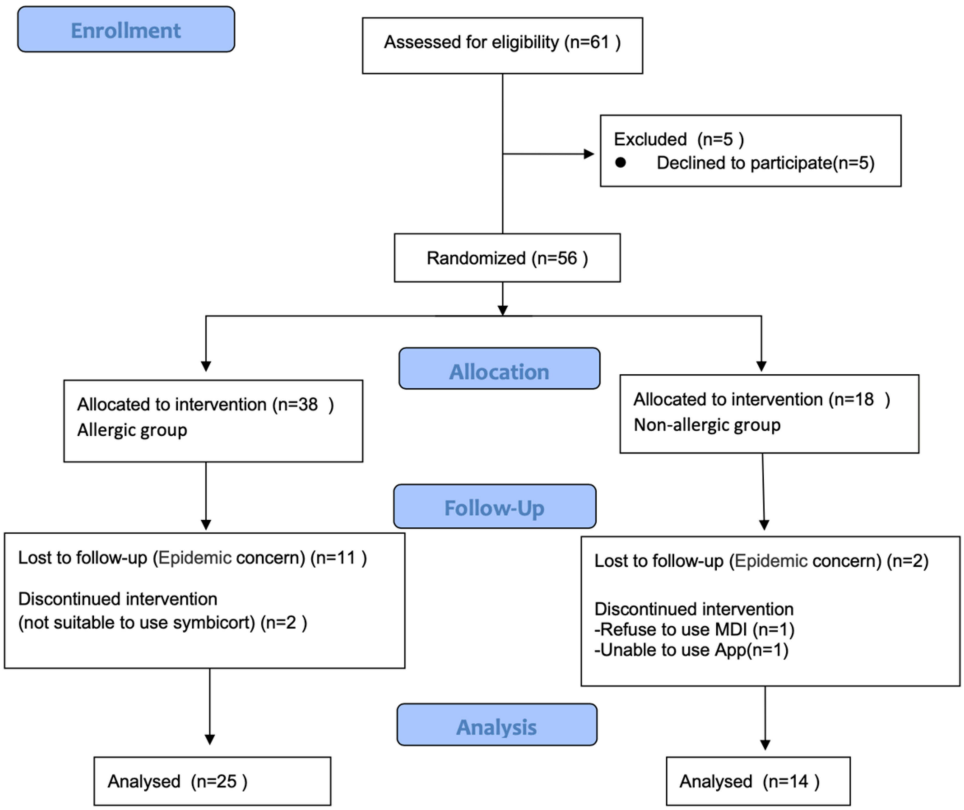

Figure 1 Study enrollment flowchart.

scores range from 5 to 25 points, with 25 points indicating full control, 20 to 24 points indicating partial control, and less than 20 points indicating poor control.

An IgE level of 1.5–114 kU/L is considered within the normal range,[15] with a level >100 kU/L being elevated. An EOS count in the peripheral blood of <500 cells/μL is typically considered normal.[16] FeNO was analyzed with a portable analyzer, the Niox Mino® (Aerocrine AB, Solna, Sweden). FeNO levels of <25 ppb are considered normal, those of 25~50 ppb are considered intermediate, and those of >50 ppb are considered high.[17]

PFTs were performed with a Vitalograph model 6800, which monitors forced expiratory vital capacity (FVC), forced expiratory volume in 1 s (FEV1), the FEV1/FVC ratio (FEV1/FCV), and other values. During the process, the patient was asked to take a few steady breaths, then take a deep breath and blow hard for 6 s.

Adherence to inhaled medication was measured by the AsthmaHelps+ app with Flores sensor (average adherence rate = [complete days/study period days] × 100%). After the AsthmaHelps+ App was connected to the Flores sensor, patient inhaled medication through the sensor, it precisely recorded inhaler actuation time, frequency, and technique (including flow rate and orientation) using an integrated flow sensor and microprocessor. Data are automatically transmitted via Bluetooth to a secure cloud-based platform for analysis, ensuring objective and continuous monitoring of inhaler use behavior (Figure 2).

Statistical Analysis

The data were analyzed via the SPSS software package (vers. 23, IBM, Armonk, NY, USA). Statistical significance was set at the 5% level. A descriptive analysis of the sociodemographic and baseline clinical characteristics of the study population was performed. The data are presented as the means ± standard deviations (SDs) or numbers and percentages (%). To check if the data were normally distributed, the Shapiro–Wilk test was used. Spearman correlation was used for correlation analysis between factors. The Mann–Whitney *U*-test was used for continuous variables, and the Pearson chi–square test or Fisher's test (when the frequencies of some categories were below 5) was used for categorical variables in comparisons between two groups. The Wilcoxon signed rank test and Friedman test were used for continuous variables in

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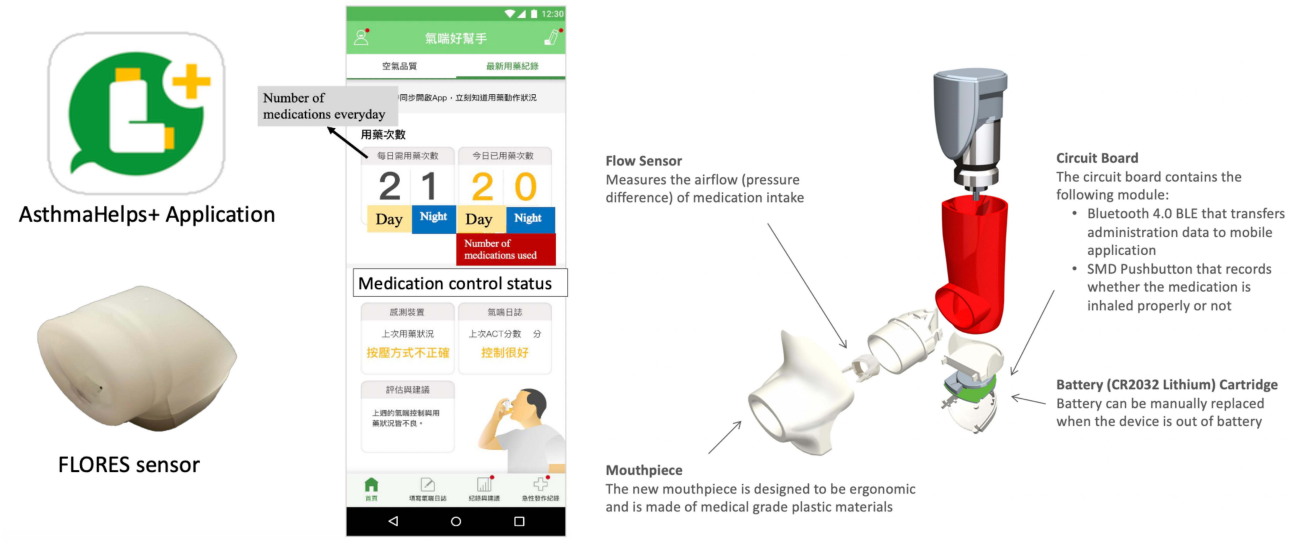

Figure 2 AsthmaHelps+ Application and FLORES sensor.

comparisons within a group. Linear regression analyses were conducted to examine the associations between adherence rates and various potential influencing factors. All assumptions of multiple linear regression were evaluated and met, including linearity, independence of errors, homoscedasticity, normality of residuals, and absence of multicollinearity.

Results

Sociodemographic and Patient Characteristics

Table 1 shows the sociodemographic and clinical characteristics of the enrolled patients. There were no significant differences in several study variables between the groups. The mean age was 51.3 years in the allergic group and 50.3 years in the nonallergic group (p=0.884). Disease severity was mainly moderate (60% in the allergic group and 85.7% in the

Table 1 Characteristics of the Subjects and Comparison of Allergy and Nonallergy Patients (N=39)

Variable	All Patients N=39	Allergic N=25	Nonallergic N=14	*p* value
Age (years)	50.9±14.4	51.3±14.9	50.3±14	0.884
Gender				0.757
Male, n (%)	18 (46)	12 (48)	6 (42.9)	
Female, n (%)	21 (54)	13 (52)	8 (57.1)	
BMI (kg/m2)	25.4±4.5	24.1±3.5	27.8±5.3	**0.017**
Smoking history				0.866
Never, n (%)	25 (64.1)	17 (68)	8 (57.1)	
Ex-smoking, n (%)	12 (30.8)	7 (28)	5 (35.7)	
Smoking, n (%)	2 (5.1)	1 (4)	1 (7.1)	
Age of onset (years)	32.1±20.7	34.2±19	28±24	0.389
Asthma severity				0.302
Mild, n (%)	4 (10.3)	3 (12)	1 (7.1)	
Moderate, n (%)	27 (69.2)	15 (60)	12 (85.7)	
Severe, n (%)	8 (20.5)	7 (28)	1 (7.1)	
ACT score	22.5±3.0	22.8±3.3	22.1±2.2	**0.026**
ICS dosage (μg)	602.1±176.2	595.2±187.7	615.4±157.9	0.765
AE, n (%)	7 (17.9)	6 (24)	1 (7.1)	0.391

(*Continued*)

Table 1 (Continued).

Variable	All Patients N=39	Allergic N=25	Nonallergic N=14	*p* value
Pulmonary function test				
FEV1 (L)	2.46±0.7	2.55±0.7	2.31±0.7	0.272
FEV1 (%)	86.3±14.3	87.6±12.6	84.1±17.3	0.482
FVC (L)	3.07±0.8	3.2±0.8	2.84±0.7	0.224
FVC (%)	88.9±14.6	90.8±15	85.5±14	0.291
FEV1/FVC	80.5±10.4	80.1±10.3	81.1±11.1	0.758
IgE (kU/L)	514.1±970.2	774.3±1137.2	49.3±34.8	**0.000**
EOS (/μL)	292.3±253.8	356±263.1	178.6±196.8	**0.005**
FeNO at enrollment (ppb)	23.8±21.2	27.7±24.3	16.9±11.9	**0.025**
Comorbidities				
GERD, n (%)	28(71.8)	17(68)	11(78.6)	0.713
Rhinitis, n (%)	18(46.2)	13(52)	5(35.7)	0.328
Sinusitis, n (%)	15(38.5)	12(48)	3(21.4)	0.171
OSA, n (%)	7(17.9)	2(8)	5(35.7)	0.075
Allergen				
Dust, n (%)	21(53.8)	15(60)	6(42.9)	0.303
Seafood, n (%)	8(20.5)	6(24)	2(14.3)	0.686
Fur, n (%)	7(17.9)	7(28)	0(0)	**0.036**
Pollen, n (%)	2(5.1)	2(8)	0(0)	0.528
Vegetable, n (%)	3(7.7)	3(12)	0(0)	0.540
Mold, n (%)	1(2.6)	1(4)	0(0)	1.000

Notes: Data are presented as the percentage or mean±standard deviation. Bold values indicate $p < 0.05$.
Abbreviations: BMI, body mass index; ACT score, asthma control test score; ICS, inhaled corticosteroids; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; IgE, immunoglobulin E; EOS, eosinophils; FeNO, fractional exhaled nitric oxide; GERD, gastroesophageal reflux disease; OSA, obstructive sleep apnea.

nonallergic group; p=0.333). The smoking status in both groups was mainly nonsmokers (68% vs 57.1%, respectively; p=0.488). The results of the PFTs were normal in both groups. There were also no significant differences in comorbidities (gastroesophageal reflux disease (GERD), rhinitis, sinusitis, or obstructive sleep apnea (OSA)) between the two groups.

Significant differences in several study variables between groups were observed. Patients in the allergic group had a lower BMI than did those in the nonallergic group (24.1 vs 27.8 kg/m^2). Patients in the allergic group had higher ACT scores (22.8 vs 22.1), IgE (774.3 vs 49.3 kU/L), EOS counts (356/μL vs 178.6/μL), FeNO (27.7 vs 16.9 ppb), and fur as the main allergen (28% vs 0%) than did those in the nonallergic group at enrollment.

Adherence Rates for the Inhaler

Figure 3 shows the adherence rates for the inhaler. The 90- and 30-day adherence rates in the allergic group were 37.3% ±23.3% and 49.9%±28.9%, respectively. In addition, the 90- and 30-day adherence rates in the nonallergic group were 19.3%±18.8% and 22.8%±19.3%, respectively. Figure 3a and b also show that the 30- and 90-day adherence rates significantly differed between the groups. Furthermore, the adherence rates in the allergic group were higher than those in the nonallergic group during all the study periods (Figure 3c).

Changes in ACT, FeNO, Pulmonary Function, and the Dosage of Inhaled Corticosteroids (ICS)

ACT, FeNO, pulmonary function, and the ICS dosage were tracked on days 1, 30, and 90 (Table 2). There were no significant changes in pulmonary function or ACT in the allergic group, while the FVC on the 30th day in the nonallergic group significantly improved compared with that on the first day, and the ACT on the 90th day was also significantly

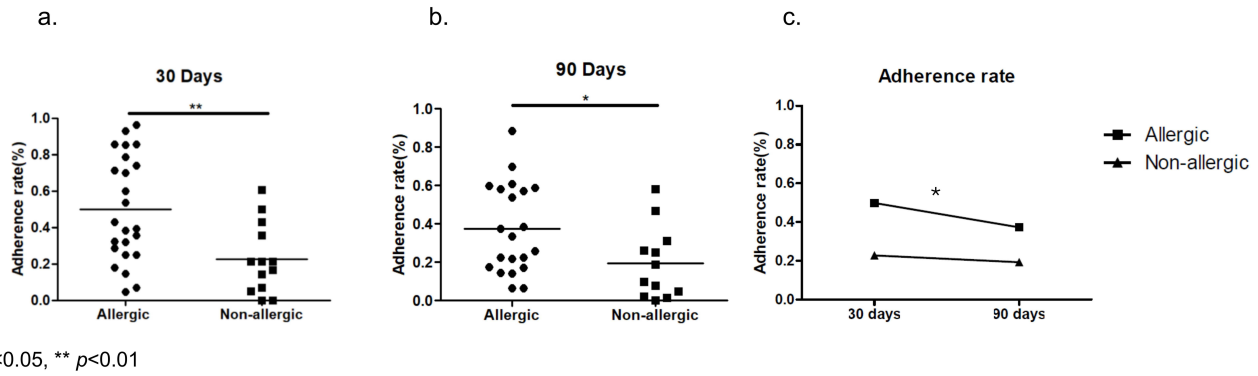

Figure 3 Adherence rate in allergic group and non-allergic group. (**a**) Adherence rate in 30 days (**b**) Adherence rate in 90 days (**c**) Trend of adherence rate within group in 90 days.

better than that on the first and 30th days. The allergy group showed significant improvement in the frequency of AEs by the 30th and 90th days.

In comparisons between the two groups, only the FeNO measured on the 90th day was significantly greater in the allergic group than in the nonallergic group, and there were no significant changes in other factors.

Correlation Analysis Between Adherence Rates and Other Factors

Spearman correlation analysis was performed between the medication adherence rates and patient age, sex, BMI, pulmonary function, ACT, AE, IgE, EOS count, FeNO, etc. The results revealed that the 30- and 90-day adherence rates were significantly positively correlated with the allergy group and significantly negatively correlated with the ICS dosage and that there were no significant changes in the other factors (Table 3).

According to the results of the correlation analysis, a linear regression analysis was performed to analyze the influence of the allergy group, ICS dosage, and other factors on the 30- and 90-day adherence rates. The ICS dosage significantly affected the 30- and 90-day adherence rates (Table 4). In particular, the allergy group significantly affected the 30- and 90-day adherence rates. Other influencing factors, such as age, sex, ACT, and FeNO, had no statistically significant effects on the 30- or 90-day adherence rates.

Table 2 Differences in Pulmonary Function Test Results, Asthma Control Test (ACT) Scores, Fractional Expired Nitric Oxide (FeNO) Levels, and Inhaled Corticosteroid (ICS) Dosages Between the Two Groups at Baseline, 30 days, and 90 days

	Allergy (*n*=25)			**Nonallergy (*n*=14)**			**Between-Group Test**	
	Baseline	**30 Days**	**90 Days**	**Baseline**	**30 days**	**90 days**	**30 Days**	**90 Days**
							***p* value**	
PFT								
FEV1 (L)	2.55±0.7	2.55±0.8	2.45±0.9	2.31±0.7	2.54±0.8	2.45±0.9	0.3147	0.6420
FEV_1 (%)	87.6±12.6	87.0±14.5	84.7±15.6	84.1±17.3	92.7±13.2	88.4±19.2	0.4678	0.7718
FVC (L)	3.2±0.8	3.25±0.9	3.09±0.9	2.84±0.7	**3.09±0.86** [a]**	3.0±0.9	0.1742	0.4558
FVC (%)	90.8±15.0	90.6±13.5	87.3±12.8	85.5±14.0	94.1±11.2	89.8±12.7	0.2843	>0.9999
ACT	22.8±3.3	23.3±3.0	22.7±4.9	22.1±2.2	22.5±2.3	**23.9±1.2**[a]*	0.4445	0.4569
ICS dosage (μg)	595.2±187.7	606.7±205.5	611.8±197.9	615.4±157.9	617.1±151.9	608.0±181.6	0.8693	0.8238
AE history, *n* (%)	**0.24±0.44**[a]*	0.00±0.00	0.00±0.00	0.14±0.53	0.07±0.27	0.14±0.36	0.1850	0.0542
FeNO (ppb)	27.7±24.3	38.1±33.9	38.1±31.4	16.9±11.9	18.9±10.6	**17.7±6.5**[b]*	0.1268	**0.0403**

Notes: The values are the means ± standard deviations. a Baseline vs 30 days and 90 days; b 30 days vs 90 days; * p<0.05, ** p<0.01; Bold values indicate p < 0.05.
Abbreviations: FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity.

Table 3 Spearman Correlation Analysis Between Adherence Rates and Other Factors

Variables	30 Days	90 Days
Age (years)	0.130	0.051
BMI (kg/m2)	–0.016	0.077
Gender	0.010	0.010
Severity	–0.161	–0.156
Allergy G	**0.459****	**0.387***
ACT	0.176	0.002
ICS Dosage	**–0.0425***	**–0.399***
AE history	-0.041	-0.044
FEV1 (L)	0.003	0.014
FEV1 (%)	0.082	0.031
FVC (L)	–0.027	0.009
FVC (%)	-0.010	0.033
IgE (kU/L)	–0.157	0.144
EOS (/μL)	0.239	0.314
FeNO (ppb)	0.092	0.290

Notes: * p<0.05;** p<0.01; Bold values indicate p < 0.05.
Abbreviations: BMI, body mass index; ACT, asthma control test; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; EOS, eosinophils; FeNO, fractional exhaled nitric oxide; ICS, inhaled corticosteroids; AE, acute exacerbation.

Table 4 Linear Regression Analysis Between 30- and 90-Day Adherence Rates and Other Factors

Independent Variables	30 Days Adjusted R2=0.292					90 Days Adjusted R2=0.218				
	B	**SE**	**β**	**t**	**p value**	**B**	**SE**	**β**	**t**	**p value**
Age	0.002	0.003	0.106	0.674	0.506	0.003	0.002	0.003	0.146	0.835
Gender	0.060	0.087	0.105	0.698	0.491	0.035	0.029	0.079	0.063	0.362
Allergy G	0.281	0.092	0.462	3.073	**0.005**	0.224	0.080	0.468	2.783	**0.010**
ACT	−0.011	0.015	−0.116	−0.726	0.474	−0.006	0.014	−0.073	−0.402	0.691
FeNO	0.000	0.002	−0.013	−0.082	0.935	−0.001	0.002	−0.085	−0.468	0.664
ICS Dosage	−0.001	0.000	−0.424	−2.912	**0.007**	0.000	0.000	−0.379	−2.349	**0.027**

Note: Bold values indicate p < 0.05.
Abbreviations: ACT, asthma control test; FeNO, fractional exhaled nitric oxide; ICS, inhaled corticosteroid; SE, standard error.

Discussion

The medication adherence rate of asthma patients has always been an important factor in assessing treatment effectiveness. Currently, poor medication adherence is associated with inadequate symptom control, and increasing the dosage of inhaled corticosteroids might not be helpful. Increasing research has explored how to improve patients' medication adherence.[18–23] However, the medication adherence of asthma patients has never been objectively measured. Therefore, this is the first study in our country to use an electronic monitoring system to assess the actual medication adherence of patients. In this study, the actual medication adherence of asthma patients was significantly correlated with a reduction in the dosage of inhaled corticosteroids, indicating that medication adherence rates gradually decreased over time.

According to past research, the medication adherence rate of patients with chronic diseases tends to gradually decrease over time.[24] Asthma patients, whether inhaled bronchodilators or steroids, have lower medication adherence rates than patients with other diseases do.[25] Additionally, adherence rates are influenced by the frequency of prescribed medication. As the daily dosage frequency increases, the medication adherence rate tends to decrease.[7,26] In our study, we found the same results, as both the allergic and nonallergic groups showed gradual decreases in adherence rates over time. The rate of decline was even greater in the allergic group (Figure 3c).

The medication adherence rates of the two groups were significantly greater in the allergic group than in the control group at both 30 and 90 days. However, in the nonallergic group, there was no significant decrease in asthma control, as assessed by the ACT, and no significant increase in FeNO, an indicator of airway inflammation. Additionally, there were no cases of AE events in patients. One possible reason for these findings could be the relatively short duration of the observational period, which was only 3 months. If continuous follow-up had been conducted, it might have revealed whether a decrease in adherence rates would lead to an increase in the frequency of asthma symptoms and whether it resulted in subsequent adverse events. Furthermore, a detailed analysis of the ACT questionnaires indicated that the primary difference in scores between the two groups was attributable to the presence of nighttime symptoms in the allergic group, whereas variations in the nonallergic group were mainly related to subjective perceptions of asthma control. The presence of perceivable symptoms may play a critical role in influencing medication adherence by motivating patients to seek medical consultation, obtain prescriptions, and maintain regular use of medication.[27] This may account for the observed differences in adherence rates between the two groups.

There was no significant correlation between medication adherence rates and lung function indicators or inflammatory indicators (FeNO), but there was a significant correlation with the ICS dosage. A further regression analysis indicated that the medication adherence rate at 30 and 90 days did indeed have an effect on the ICS dosage. However, in the treatment strategy, ICS dosage adjustments were primarily based on symptom control, and there was no significant correlation between the asthma control level and the medication adherence rate. This lack of correlation between adherence rates and symptom control in this study may be attributed to the insufficient duration of follow-up.

Generally, good medication adherence is usually defined as a rate greater than 80%. In this study, the adherence rates for most patients were relatively low. However, factors influencing adherence include not only symptoms but also socioeconomic factors (such as medication costs and lack of social support), healthcare system issues (poor communication or relationships between patients and clinical staff, spending too much time waiting for outpatient appointments), treatment-related factors (lengthy treatment durations, frequent medication changes, medication side effects), and patient-related factors (lack of disease awareness, lack of confidence and motivation, cognitive barriers). All the factors mentioned above can affect patients' adherence.[28] In this study, relevant information to further analyze the reasons for low adherence was not gathered. In the future, the collection of more relevant data will provide a greater understanding of the comprehensive factors that influence asthma patient adherence.

In this study, the basic characteristics of patients in the allergic and nonallergic groups, such as age, sex, disease severity, and lung function, were not significantly different. However, there were significant differences in BMI values and ACT scores between the two groups. According to the literature, asthma patients with obesity may experience impacts on asthma control or a decline in lung function,[29–31] but the correlation analysis in this study did not reveal a significant relationship between BMI values and ACT scores, and there were also no significant correlations with ACT scores in the follow-up period. This difference could have been due to the definition of obesity as a BMI value of $\geq$30 kg/m^2. In contrast, the average BMI in the allergic group was 24.1±3.5 kg/m^2, and in the nonallergic group, it was 27.8±5.3 kg/m^2. In addition, according to standards of the health department in Taiwan, a BMI exceeding 27 kg/m^2 is considered obese but is considered overweight only by the international definition. Therefore, in this study, no significant correlation was found between obesity and its impact on asthma control. This may have occurred because the tracking period was only 90 days. Tracking over a longer period of time would allow a better understanding of the impact of obesity on asthma control. With regard to the ACT scores, although a statistically significant difference was observed between the two groups, it is essential to consider the clinical relevance of this finding. According to the Asthma Control Test (ACT), scores ranging from 20 to 24 indicate partially controlled asthma. Both groups fell within this range, suggesting that their asthma was similarly categorized as partially controlled. Consequently, while the

difference reached statistical significance, it may have been affected by the short follow-up period, which could have limited the ability to observe clinical changes.

The electronic monitoring device used in this study, which was equipped with an app, could record the frequency of medication usage by patients, thereby allowing us to understand patient adherence to medication. Related devices in the past have been used to monitor the time and frequency of patient usage and even to record the sounds of patients using inhalers to determine if inhalation techniques are correct.[32,33] This can subsequently assist clinical personnel in evaluating patients' medication techniques and adherence to further improve medication issues. However, this device can only be used with a salmeterol/fluticasone Diskus inhaler and cannot be used with other medications. The smartinhaler sensor device produced by Hailie has corresponding sensors for MDI inhalers such as budesonide/formoterol, Salbutamol, and Fluticasone/salmeterol. When paired with its app, it can also record the frequency of patient usage, and reminders can be set within the app to improve patient adherence to medication. However, the purpose of this study was to observe the original medication adherence rate of asthma patients with no intervention on the sensor or app to avoid affecting the observed values. If we solely consider the functionality of the app, suggestions for adjustments can be given to patients on the basis of their completion of the ACT, improving asthma management. These studies provide promising solutions for future improvements in asthma management quality for asthma patients.[34]

Study Limitations

The current study has several limitations: this study was limited to a single hospital, and the number of cases was relatively small. Since the COVID-19 pandemic emerged during that time, patients were concerned about the risk of infection and were therefore less willing to visit the hospital, which resulted in a lower number of enrolled cases. This also led to difficulties in follow-up, with some patients being lost to follow-up and potentially underpowered due to the small number of patients. Furthermore, the observation period for assessing medication adherence rates among patients was only 90 days, which did not provide insights into the impacts of reduced adherence on symptoms, asthma severity, frequency of acute exacerbations, or hospitalizations. Moreover, the participation of asthma patients using only budesonide and formoterol as maintenance therapy in the trial may have resulted in an incomplete observation of medication adherence rates among asthma patients. Finally, data collection could have been more integrated. Lack of socioeconomic and behavioral data, which may influence adherence[20,22,35,36] and potentially impact patients' quality of life.

Conclusions

This study utilized electronic monitoring system devices to record the actual medication adherence rates of asthma patients, monitoring the medication adherence rates for a period of 90 days and observing their changes. Our study involving 39 asthma patients revealed that medication adherence rates among asthma patients were relatively low and that there were significant differences in medication adherence rates between those with allergic asthma and those without. Patients in the allergic group exhibited higher adherence levels at both 30 and 90 days than did those in the nonallergic group. It is important to note that during the 90-day follow-up period, low medication adherence was not associated with significant clinical deterioration, which may be attributable to the relatively short duration of observation and small sample size. Our study highlights the necessity of tailored interventions to improve medication adherence, particularly among nonallergic asthma patients and those requiring higher ICS doses. However, medication adherence is influenced by various factors. Although our study did not analyze individual behaviors and social factors, effective asthma management is fundamentally based on patients correctly following medical instructions for the use of therapeutic medications and methods. Therefore, improving patient medication adherence has always been the goal. With technological developments, it is possible to understand patient adherence rates more accurately and even analyze the reasons for low adherence and the correctness of medication techniques. These comprehensive insights can aid asthma patients in optimizing the effectiveness of their care strategies.

Data Sharing Statement

All data generated or analyzed during this study are included in this published article.

Ethics Approval and Consent to Participate

The study was approved by the TMU-Joint Institutional Review Board (TMU-JIRB No. N201905051) and was conducted in compliance with the Declaration of Helsinki (2000). Written informed consent was obtained from all participants.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests. The abstract of this paper was presented at the European Respiratory Society (ERS) International Congress 2024 as a poster presentation with interim findings. The poster's abstract was published in European Respiratory Journal, 2024; 64(Suppl 68): PA2513. https://publications.ersnet.org/content/erj/64/suppl68/pa2513

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