

Ambulatory Management of Childhood Asthma Using a Novel Self-management Application

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abstract

BACKGROUND AND OBJECTIVES: Pediatric ambulatory asthma control is suboptimal, reducing quality of life (QoL) and causing emergency department (ED) and hospital admissions. We assessed the impact of the electronic-AsthmaTracker (e-AT), a self-monitoring application for children with asthma.

METHODS: Prospective cohort study with matched controls. Participants were enrolled January 2014 to December 2015 in 11 pediatric clinics for weekly e-AT use for 1 year. Analyses included: (1) longitudinal changes for the child (QoL, asthma control, and interrupted and missed school days) and parents (interrupted and missed work days and satisfaction), (2) comparing ED and hospital admissions and oral corticosteroid (OCS) use pre- and postintervention, and (3) comparing ED and hospital admissions and OCS use between e-AT users and matched controls.

RESULTS: A total of 327 children and parents enrolled; e-AT adherence at 12 months was 65%. Compared with baseline, participants had significantly ($P < .001$) increased QoL, asthma control, and reduced interrupted and missed school and work days at all assessment times. Compared with 1 year preintervention, they had reduced ED and hospital admissions (rate ratio [RR]: 0.68; 95% confidence interval [CI]: 0.49–0.95) and OCS use (RR: 0.74; 95% CI: 0.61–0.91). Parent satisfaction remained high. Compared with matched controls, participants had reduced ED and hospital admissions (RR: 0.41; 95% CI: 0.22–0.75) and OCS use (RR: 0.65; 95% CI: 0.46–0.93).

CONCLUSIONS: e-AT use led to high and sustained participation in self-monitoring and improved asthma outcomes. Dissemination of this care model has potential to broadly improve pediatric ambulatory asthma care.



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Dr Nkoy conceptualized and designed the study, drafted the initial manuscript, and oversaw the analysis; Dr Fassl, Dr Wilkins, Dr Johnson, Ms Koopmeiners, Ms Jensen, Ms Frazier, Ms Gaddis, Ms Malmgren, Ms Williams, Ms Oldroyd, Mr Greene, Mr Sheng, Mr Uchida, Dr Maloney, and Dr Stone participated in the concept and design, interpretation of data, and revision of the manuscript; Ms Unsicker coordinated and supervised data collection and critically reviewed the manuscript; and all authors approved the final manuscript as submitted.

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WHAT'S KNOWN ON THIS SUBJECT: Despite recommendations and potential benefits, asthma self-management interventions for children are rare, and uptake by patients is poor. Little data exist about their effectiveness on outcomes of children with asthma.

WHAT THIS STUDY ADDS: In this study, we report participants' adherence and the impact on multiple outcomes of implementing a novel self-management tool for children with asthma at 11 clinics.

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Poorly controlled childhood asthma is associated with frequent exacerbations and a significant impact on child and family quality of life (QoL) and health care use.¹ In 2016, about 8.3 million children <18 years had asthma, and 53.7% experienced an exacerbation.² Asthma is one of the most common causes of school absenteeism and missed work for parents.^{2,3} In 2008, children aged 5 to 17 years with at least 1 asthma exacerbation in the previous year missed 10.5 million school days, and their parents missed 14.2 million work days,¹ a productivity loss of \$3.8 billion per year.⁴ The annual cost of pediatric asthma in the United States is estimated at \$20.7 billion.⁵

Despite broad distribution of guidelines, >50% of children with asthma still have poorly controlled disease,^{6,7} leading to poor QoL, increased exacerbation risk, and frequent acute health care use.⁸ Multiple factors are associated with poor control, including^{9–13} (1) insufficient education and support for self-management, (2) limited self-management skills, (3) failure to recognize and act on early changes in asthma control,^{14,15} (4) nonadherence with therapy,¹⁶ and (5) inadequate therapy prescribing by physicians.^{8,17–19}

To reduce the risk of exacerbations and acute health care use, guidelines recommend control assessments and preventive measures at clinical encounters, including initiating self-management support to help patients achieve and maintain optimal control.^{18,20–22} However, self-management support interventions are rarely implemented in general pediatric ambulatory clinics.¹⁸

With input from parents, we developed a Web and mobile-Web application (<https://asthmatracker.utah.edu/public/index.php>), the electronic-AsthmaTracker (e-AT).²³

The e-AT was designed to support the self-monitoring and management of children with asthma by using the asthma control test (ACT)²⁴ (modified and validated for weekly assessment) coupled with decision support for proactive care.^{25,26} Our objective in this study was to assess the impact of implementing the e-AT in general pediatric ambulatory clinics.

METHODS

Setting

We contacted and enrolled 11 general pediatric ambulatory clinics (no clinic refused participation) on the basis of their proximity to our team, and/or readiness to implement the e-AT, with (1) a physician champion to facilitate clinic e-AT use, (2) a clinic

care coordinator with 15% full-time equivalent dedicated to using the e-AT in patient care, and (3) capacity to accommodate enrollment and e-AT training (eg, private room). We involved 11 clinics to achieve our targeted sample size of 30 patients per clinic for a total of 330 patients.

Overall, 9 of the 11 clinics are owned by Intermountain Healthcare (IH), whereas 2 are non-IH clinics. IH, a regional not-for-profit integrated health care delivery system, has 22 hospitals and 185 clinics and urgent care facilities in Utah and southeastern Idaho,²⁷ providing care to about 1 680 000 patients and serving about 60% of Utah's residents and 85% of Utah's children.²⁸ The University of Utah Institutional Review Board approved the study.

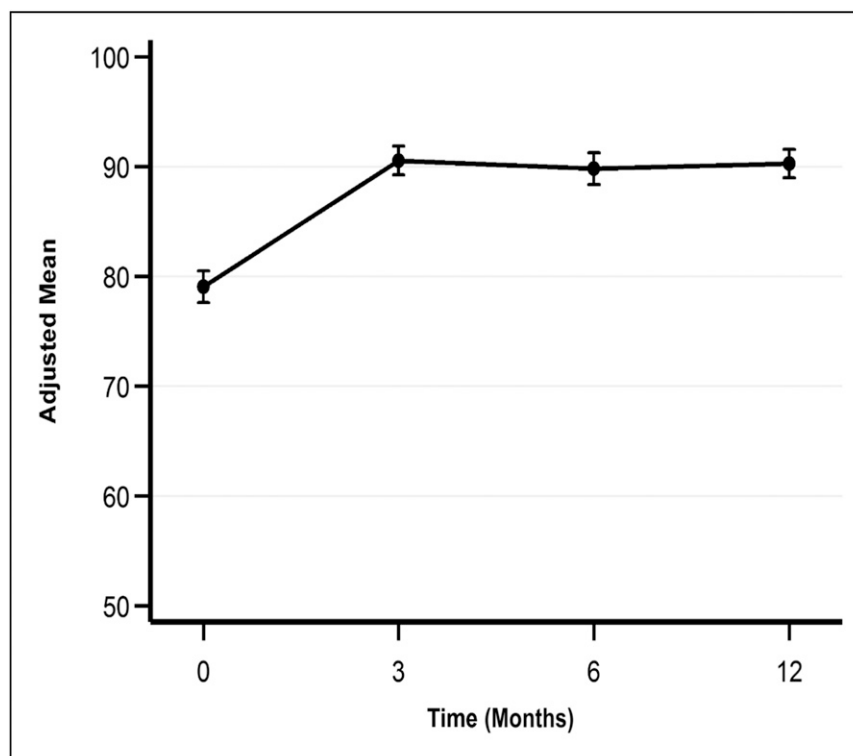


FIGURE 1

Adjusted mean in QoL scores at baseline and 3, 6, and 12 months. Overall adjusted mean QoL scores with SEs at baseline (0 months) and 3, 6, and 12 months. There was a significant increase (from baseline) of about 12 points in QoL scores, starting early at 3 months and remaining high through the end of the study follow-up period. Y-axis units show only QoL score ranges between 50 and 100 (rather than 0–100) for easy reading.

Parent and Stakeholder Engagement

The AsthmaTracker was developed and tested in a paper version,^{25,29} translated into the electronic version (e-AT),²³ and implemented in participating clinics with the assistance of 6 parents and 7 community stakeholders who provided input on study design and implementation. Community stakeholders included 2 primary care providers (PCPs), 2 insurance company representatives, 2 representatives for the Asthma Program of the Utah Department of Health, and the IH Pediatric and Primary Care Clinical Program Directors.

Study Population and Study Design

Inclusion criteria consisted of the following: (1) children 2 to 17 years with persistent asthma (determined by the PCP based on National Institutes of Health criteria of ongoing need for a controller medication) who received asthma care in the previous year at participating clinics (and their parents), (2) English speakers, and (3) having Internet access. Exclusion criteria included children who previously used the AsthmaTracker (paper version) because this may influence results.^{25,29} We conducted a prospective cohort study, comparing e-AT participants to their own baselines and to a concurrent matched-control population.

Participant Identification, Enrollment, and Follow-up

The research team provided training to clinical staff at each clinic, addressing gaps in asthma care and opportunities to improve care with the e-AT. Eligible patients were identified electronically at each clinic and invited to enroll in the study by clinic care coordinators from January 2014 to December 2015. Families who consented received education about the e-AT using a standardized

teaching flipchart, were given e-AT access, and were asked to use it weekly for 1 year.

e-AT Description

The e-AT features include the following: (1) automated reminders to sustain use, (2) real-time results graphing, (3) alerts for patients and parents (via e-mail or text) and PCP's office (via e-mail or clinic dashboard) for early signs of asthma control deterioration, and (4) real-time recommendations using the colors green, yellow, and red. Scores (range 5–25) had 3 categories: 20 to 25 (well controlled or green), 15 to 19 (not well controlled or

yellow), and ≤ 15 (poorly controlled or red).

The e-AT Web-based clinic dashboard facilitates patient management in the clinic and provides real-time data on patient's asthma control status with longitudinal graphs, adherence to e-AT use, and adherence to medications. After an alert, the clinic proactively contacts patients and parents to identify and address care issues and adjust treatment using step therapy.³⁰ Additional features to support participant adherence include the following: (1) a progress bar, adding 25 points per completion of an assessment and, at 100 points (every 4 completions), generating

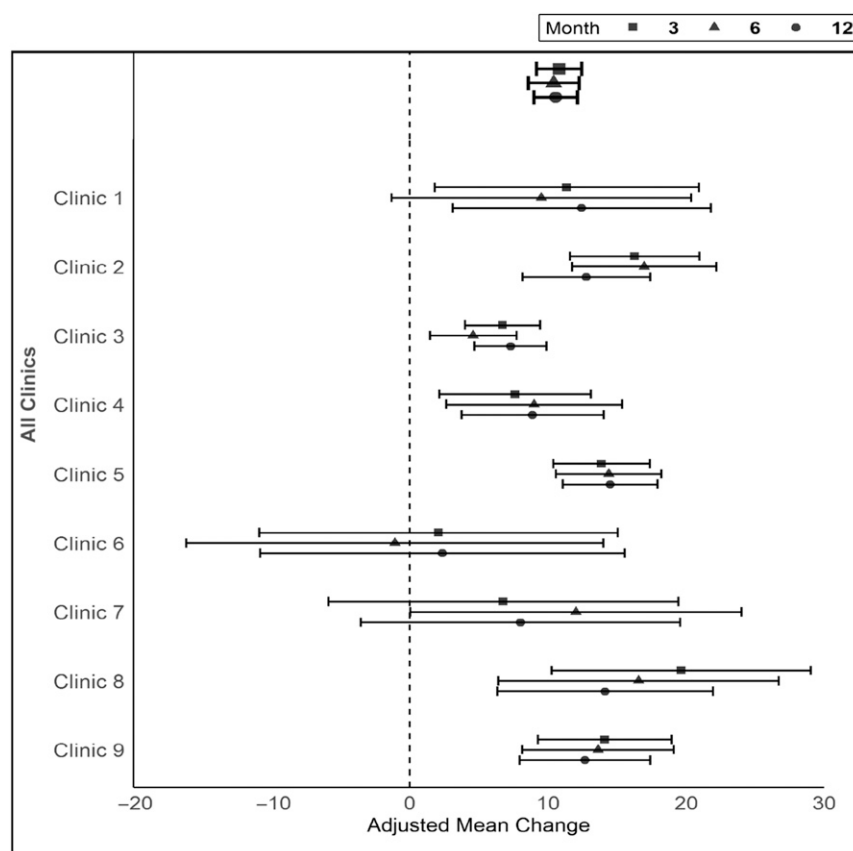


FIGURE 2

Adjusted mean change in QoL scores at 3, 6, and 12 months. Adjusted mean change (from baseline) in QoL scores (x-axis), overall (top) and by individual clinics, at months 3, 6, and 12, with SE bars of the adjusted means. The vertical line at 0 is a reference, and each bar crossing this line indicates no change (from baseline) at a specified follow-up time. For instance, clinic 6 did not change at any follow-up time period, as the 3 SE bars are crossing the vertical line. SE bars on the right, not crossing the vertical line, indicate significant improvement from baseline. For instance, there was an improvement of ~10 points at 3-, 6-, and 12-month follow-up times overall.

a congratulatory message with fireworks and a notice of an incentive (\$10 gift certificate); and (2) a leader board, allowing users to see weekly adherence of the top 5 deidentified users.

Outcomes Measures, Data Collection, and Sources

The child's QoL (primary outcome) was measured at baseline, 3, 6, and 12 months by using the Integrated Therapeutics Group Child Asthma Short Form.^{31,32} Asthma control was collected weekly using the e-AT, which was also used to collect data on the number of child interrupted or missed school days and parent interrupted or missed work days. Parent satisfaction with overall asthma care was measured at baseline and 12 months by using the client satisfaction survey.³³ Collection of the above outcomes was restricted to e-AT users.

We used the IH enterprise data warehouse³⁴ to identify a concurrent matched-control group and collected patient demographics (age, sex, race, and insurance) and usage outcomes data for the whole study population, including the number of oral corticosteroid (OCS) prescriptions and number of emergency department (ED) and hospital admissions during 1 year before and 1 year after e-AT initiation. The enterprise data warehouse is an integrated database, linking administrative and clinical data from IH hospitals and clinics, and captures about 95% of pediatric ED and hospital admissions in Utah. Controls with persistent asthma were matched two to one to cases by age, sex, clinic visit dates within ± 2 months of enrollment of cases, and clinic visit types (asthma versus nonasthma). Controls were drawn from 42 IH ambulatory clinics not contacted to participate in the study in the same geographical regions as participating clinics. Control

patients were identified by using *International Classification of Diseases, Ninth Revision* and *International Classification of Diseases, Tenth Revision* codes, and persistent asthma was assumed on the basis of having at least 2 controller prescriptions in the previous year.

Statistical Analysis

Descriptive analyses were used to summarize the study population baseline characteristics, by using means and SDs for continuous variables, and frequencies for categorical and ordinal variables. Three sets of analyses were used to assess the e-AT impact, including (1) longitudinal changes in outcomes (QoL, asthma control, interrupted or missed school and work days, and

satisfaction) within subjects (e-AT users), comparing baseline (before e-AT initiation) to follow-up values (while using the e-AT); (2) comparisons of ED or hospital admission and OCS use rates within subjects, during 1 year before versus 1 year after e-AT initiation; and (3) comparisons of ED or hospital admission and OCS use rates between subjects in clinics that received the e-AT versus matched controls from clinics that did not receive it.

Longitudinal Analysis

Outcome measurements obtained at enrollment (before e-AT exposure) were used as baseline values, reflecting patient outcomes under usual care. For QoL, we fitted a linear fixed effect repeated measures model to estimate the adjusted mean QoL

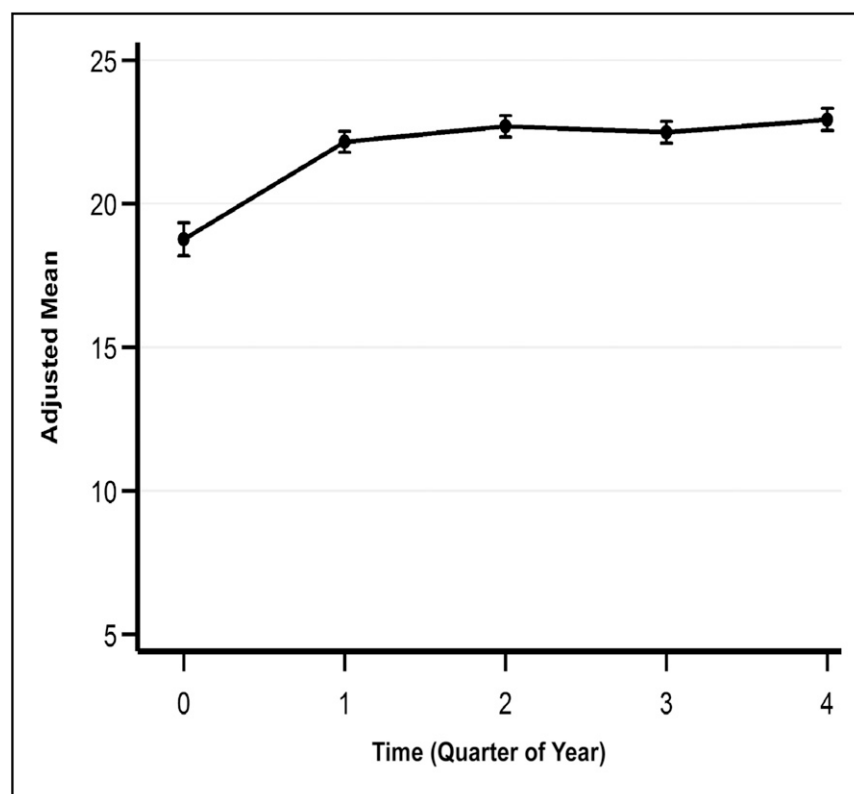


FIGURE 3

Adjusted mean in asthma control at baseline and quarters 1, 2, 3, and 4. Overall adjusted mean asthma control scores with SEs at baseline (0) and at quarters 1, 2, 3, and 4. The overall mean asthma control score shows a significant increase (from baseline) of close to 4 points early after initiation of the e-AT at quarter 1, with scores remaining high through the end of the study follow-up period.

score change between baseline and each follow-up (3, 6, 12 months), with clinic, time (month), and clinic-by-time interaction terms used as fixed effects, using a common unstructured covariance matrix to account for correlations in QoL measurements in the same patient.

For asthma control, we used random patient effects models with weekly ACT scores as a continuous variable, assessing mean changes from baseline to first, second, third, and fourth quarter. Models included patient's adherence (cumulative proportion of weeks of e-AT use) as an additional covariate. For parent satisfaction, we used linear fixed effects like in QoL. For interrupted or missed school and work days, we used generalized estimating equations with robust SEs and a compound symmetry working covariance model under negative binomial model. The model estimated rate ratios (RRs) for the outcomes between baselines and follow-up periods. All models were controlled for sine and cosine transformations of calendar months to account for seasonality.

Comparisons of ED or Hospital Admission and OCS Use Rates (Within Subjects)

We used clustered negative binomial regression to compare 1 year before (used as baseline) to 1 year after e-AT initiation periods, accounting for nesting of the pre- and postperiod within each subject.

Comparisons of ED or Hospital Admission and OCS Use Rates Between Subjects and Matched Controls

We used intention-to-treat analysis, comparing ED or hospital admission and OCS use rates over a 1-year follow-up period between cases and controls, using a generalized linear model with a negative binomial outcome, logarithmic link and random site effects, and matching variables and ED or hospital admission and OCS use rates in the preceding 1 year as covariates.

RESULTS

General Summary

We enrolled 327 children (and 327 parents or primary caregivers) from the 11 clinics. Two clinics had only 1 patient enrolled and were excluded, leaving 325 children from 9 clinics for analyses, of which 318 (97.2%) completed baseline assessments and were included in the longitudinal analysis. Overall, enrollment included 40% female patients and 76% white patients, with a mean age of 7.9 years (4.0 SD). Adherence with weekly e-AT use at 12 months was 65%.

Longitudinal Analyses

Overall, the average child QoL score (Fig 1) significantly ($P < .001$) increased from 79.1 at baseline to 90.9, 90.0, and 90.6 at 3, 6, and 12 months, respectively. This ~12-point increase occurred early at 3 months and remained high thereafter. Increases ($P < .001$) in QoL occurred in 8 of 9 clinics, with Fig 2 showing SEs of changes (from baseline) at 3, 6, and 12 months overall and at individual clinics, with 0 representing no change. We also found improvement ($P < .001$) in the overall average asthma control score (Fig 3) from 18.8 at

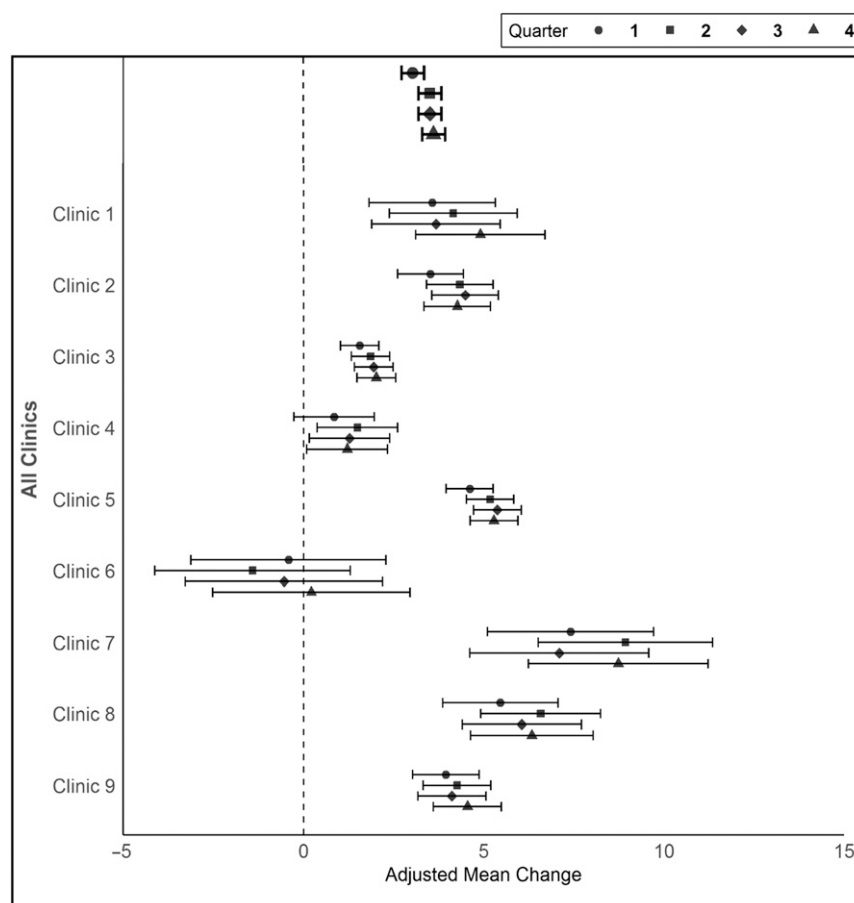


FIGURE 4

Adjusted mean change in asthma control at quarters 1, 2, 3, and 4. Adjusted mean change (from baseline) in asthma control scores (x-axis), overall (top) and by individual clinics, at quarters 1, 2, 3, and 4, with SE bars of the adjusted means. The vertical line at 0 is a reference, and each bar crossing this line indicates no change (from baseline) at a specified follow-up time. For instance, clinic 6 did not change at any follow-up time period, as the 3 SE bars are crossing the vertical line. SE bars on the right, not crossing the vertical line, indicate significant improvement from baseline. For instance, there was an improvement of ~4 points at quarters 1, 2, 3, and 4 overall (all clinics).

baseline to 22.3, 22.8, 22.8, and 22.9 at quarters 1, 2, 3, and 4, respectively. The increase occurred early (quarter 1) after e-AT initiation, stayed high thereafter, and was seen in 8 clinics. In Fig 4, we show SE of changes (from baseline) at quarters 1, 2, 3, and 4 overall and at individual clinics. Supplemental Figs 9 and 10 are QoL and asthma control changes overall and across clinics.

The overall average number of interrupted or missed school days significantly decreased ($P < .001$) from 1.91 at baseline to 0.79, 0.52, and 0.79 at 3, 6, and 12 months, respectively. Significant reductions occurred at all follow-up time

periods, overall and at most clinics (Fig 5). The overall average number of interrupted or missed work days significantly decreased ($P < .001$) from 0.72 at baseline to 0.27, 0.25, and 0.20 at 3, 6, and 12 months, respectively. Significant reductions occurred at all follow-up time periods, overall and at most clinics (Fig 6). The parent satisfaction score was high at baseline (4.7) and slightly reduced ($P < .001$) but remained high (4.5) at 12 months.

Comparisons of ED or Hospital Admissions and OCS Use (Within Subjects)

The average ED and hospital admission rates (per year) were 0.15

overall and 0.22 pre- and 0.09 postintervention, with an adjusted RR between pre- and postintervention of 0.68 (95% confidence interval [CI]: 0.49–0.95). The average OCS use was 0.63 days overall and 0.74 days pre- and 0.51 days post-e-AT, with an adjusted RR between pre- and postintervention of 0.74 (95% CI: 0.61–0.91). Overall and individual clinic outcomes are provided in Figs 7 and 8.

Comparisons of ED or Hospital Admissions and OCS Use Between Subjects and Matched Controls

Using intention-to-treat analysis, we compared 325 cases to 603 matched controls, with patient characteristics described in Table 1.

ED and Hospital Admissions

The overall average ED and hospital admission rates (per 1000 days) were 0.42 for cases and 0.23 for controls. Among cases, average ED and hospital admission rates were 0.59 over 1 year pre- and 0.24 over 1 year post-e-AT implementation. Among controls, ED and hospital admission rates were 0.23 over 1 year pre- and 0.24 over 1 year post-e-AT initiation. In analysis, it was shown that ED and hospital admissions were significantly reduced (RR: 0.43; 95% CI: 0.27–0.67) among cases but not among controls (RR: 1.04; 95% CI: 0.69–1.58), with an intervention effect RR of 0.41 (95% CI: 0.22–0.75) or 59% reduction among cases.

OCS Use

The overall average OCS use rates (per 1000 days) were 1.71 for cases and 1.93 for controls. Among cases, OCS use was 2.02 over 1 year pre- and 1.41 over 1 year post-e-AT initiation. Among controls, OCS use was 1.87 pre- and 1.99 post-e-AT initiation. The fixed effect model showed that OCS use was significantly reduced (RR: 0.69; 95% CI: 0.52–0.93) among cases but not

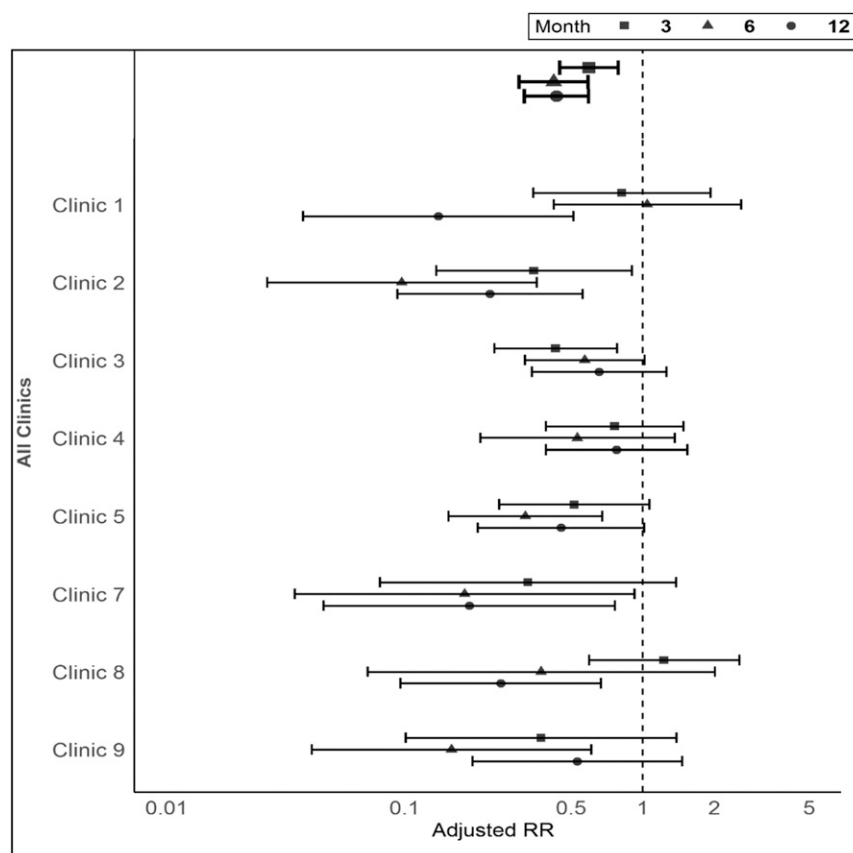


FIGURE 5

Adjusted RR interrupted or missed school days at 3, 6, and 12 months. Adjusted RRs with their SE bars for interrupted or missed school days (x-axis) overall (all clinics) and by individual clinics at 3, 6, and 12 months. SE bars on the left of the line (not crossing 1) indicate significant reductions from baseline. SE bars crossing this line indicate no change at a specified follow-up. Overall (all clinics), a significant reduction occurred at 3, 6, and 12 months. RRs are displayed on the log scale.

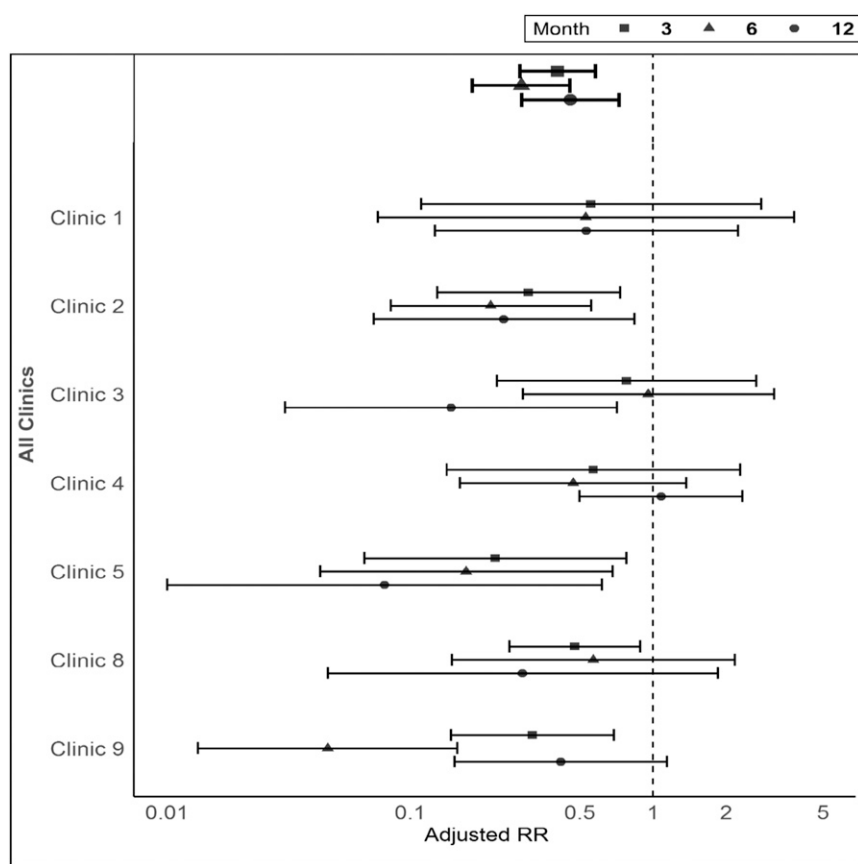


FIGURE 6

Adjusted RR of interrupted or missed work days at 3, 6, and 12 months. Adjusted RRs with their SE bars for interrupted or missed work days (x-axis) overall (all clinics) and by individual clinics at 3, 6, and 12 months. SE bars on the left of the line (not crossing 1) indicate significant reduction from baseline. SE bars crossing this line indicate no change at a specified follow-up. Overall (all clinics), a significant reduction occurred at 3, 6, and 12 months. RRs are displayed on the log scale.

among controls (RR: 1.06; 95% CI: 0.87–1.31), with an intervention effect RR of 0.65 (95% CI: 0.46–0.93) or 35% reduction in cases.

DISCUSSION

When assessing longitudinal changes in outcomes, we found significant improvements from baseline in a child's QoL and asthma control and reductions in a child's interrupted or missed school days, parent's interrupted or missed work days, OCS use, and ED and hospital admissions, with persisting high parent satisfaction. Compared with controls, e-AT users experienced

significant reductions in ED and hospital admissions and OCS use during 1 year postintervention, whereas controls did not change, supporting a significant intervention effect.

Previous self-monitoring and management support interventions have focused mostly on adults^{35–41} and have shown improved QoL, disease control, and less activity limitation.^{38,42–45} Studies of self-monitoring support interventions for children with asthma remain rare.¹⁸ In our results, it is demonstrated that multiple outcomes for the child and parent can be improved with integration of an effective technology that

promotes parent and PCP engagement in asthma self-monitoring and identification of early signs of deterioration. With the e-AT, improvements in QoL and asthma control were sustained over the 12-month study duration, whereas Rijkers-Mutsaerts et al,⁴⁶ using an Internet-based asthma self-management program, reported only short-term QoL improvement (at 3 but not 12 months) among adolescents recruited from general ambulatory practices. Also, asthma control scores increased about 4 points, twice the minimal clinically important difference of a 2-point change, reported with use of a Web-based asthma control monitoring diary in children.⁴⁷

Asthma guidelines recommend regular assessment of chronic asthma control to prompt timely adjustment of therapy.²⁰ However, physicians in general do not regularly assess asthma control during clinical encounters.⁴⁸ Lack of assessment leads to failure to initiate new or adjust asthma therapy, resulting in suboptimal treatment.^{14,15} Failure to regularly assess asthma control is attributed to busy schedules, lack of resources, and lack of an effective process for monitoring patients between clinic visits.^{14,15} The e-AT provides an effective way to regularly and remotely assess a patient's asthma control and identify worsening control early, enabling proactive care.

The few studies of self-monitoring and management interventions for patients with asthma in general ambulatory practices have suffered from high attrition, with poor patient adherence over time.^{49,50} A study in adults with asthma after 6 months of follow-up achieved an adherence of only 55% with weekly Asthma Control Questionnaire use for self-monitoring.⁵¹ Van der Meer et al,⁴¹ also in a study of adults with

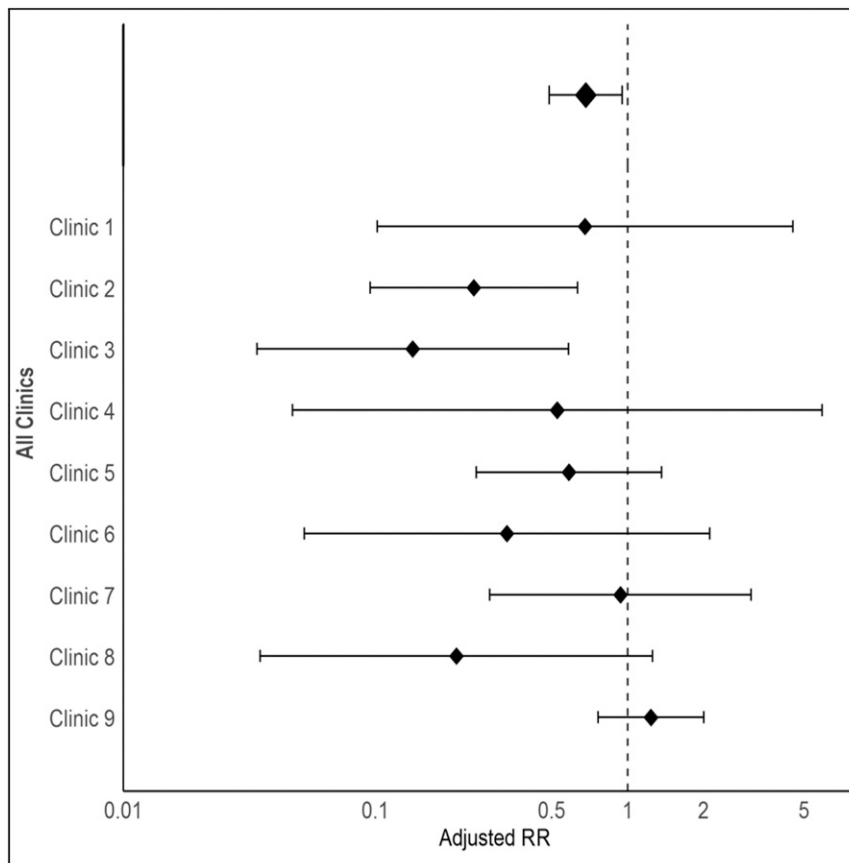


FIGURE 7

Adjusted RR (pre- versus postintervention) of ED and hospital admissions. Adjusted RRs between 1 year pre- versus 1 year post-e-AT intervention, with SE bands, for ED and hospital admissions at each clinic and overall (all clinics). SE bars on the left of the line (not crossing 1) indicate significant reduction from baseline. SE bars crossing this line indicate no change. Overall (all clinics), a significant reduction occurred between 1 year pre- and 1 year postintervention. RRs are displayed on the log scale.

asthma, reported low adherence (53% at 12 months) with weekly use of Internet-based Asthma Control Questionnaire for self-monitoring. In our study, adherence with weekly use of e-AT decreased over time but remained high at 65% after 12 months; one of the highest 1-year adherence levels reported. Our high adherence may be intrinsic to the e-AT model or due to user motivation to comply with weekly e-AT use knowing that their PCP would review their data and by a small financial incentive (\$10 per 4 weeks of adherence).

Our primary limitation is the study design recommended by our parent partners and community stakeholders who opposed withholding the e-AT from a control group, as would have occurred in the cluster randomized trial initially planned, and the subsequent lack of QoL data from the control group. These may have introduced unrecognized biases, yet the magnitude and sustainability of improvements observed in multiple outcomes among e-AT users (an ambulatory asthma population for whom enrollment was not driven by exacerbations) and the differences in outcomes when the study

population was compared with a concurrent control group (which experienced no improvement over the study period despite matching on multiple characteristics) support the validity of our findings and the generalizability of our results. We excluded 2 clinics with only 1 patient enrolled in each from analyses because clinic was a variable used in the fixed effects model, which requires within-clinic variation analysis. The impact of this is negligible. We used controller prescriptions to define persistent asthma in matched controls but could not differentiate the level of severity (eg, mild, moderate, or severe persistent asthma). Having these data could have led to improved matching and different results. Baseline ED and hospital admission rate was lower for matched controls, suggesting a less-ill population; however, the 2 groups were equivalent in baseline OCS use, and controls did not change in either ED and hospital admissions or OCS use over the course of the study, whereas e-AT users improved, supporting a lack of extrinsic factors contributing to improvement among e-AT users. In addition, study participants were drawn from general pediatric ambulatory clinics and had a mean baseline asthma control, measured by ACT, of 18.8 (a score below 19 or not well controlled), not atypical in ambulatory care settings.⁵²⁻⁵⁴ The significant improvements in asthma control and other outcomes among e-AT users only bolsters the need for self-monitoring and management interventions in typical ambulatory settings. Lastly, we provided monetary incentive to support participant adherence with weekly use of the e-AT and do not know the impact this may have had on adherence or outcomes. However, if monetary incentive is needed to support a high level of adherence,

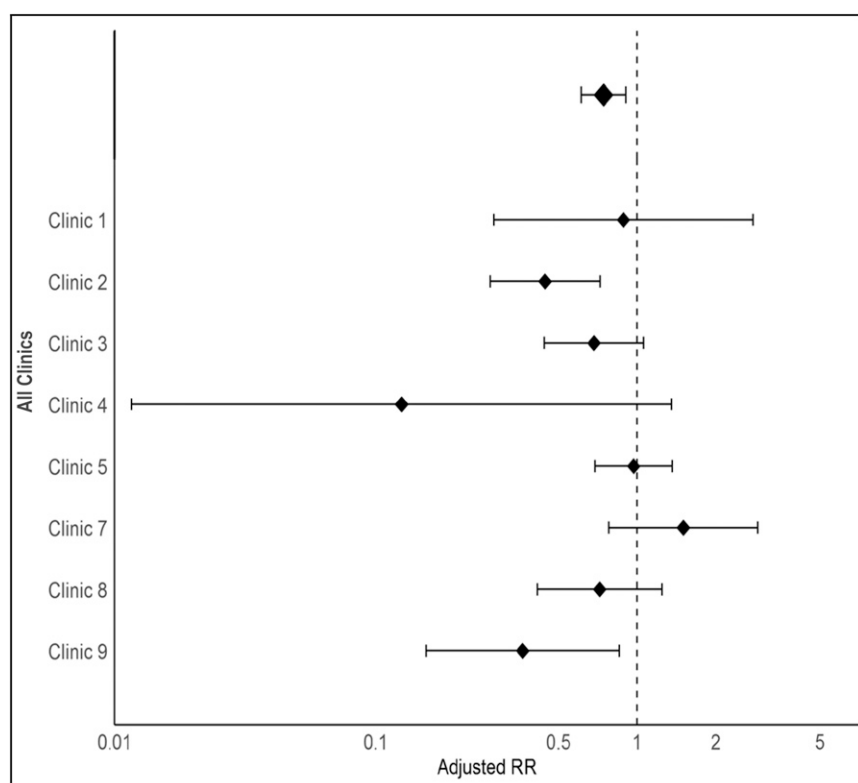


FIGURE 8

Adjusted RR (pre- versus postintervention) of OCS use. Adjusted RRs between 1 year pre- versus 1 year post-e-AT intervention, with SE bars, for OCS use at each clinic and overall (all clinics). SE bars on the left of the line (not crossing 1) indicate significant reduction from baseline. SE bars crossing this line indicate no change. Overall (all clinics), a significant reduction occurred between 1 year pre- and 1 year postintervention. RRs are displayed on the log scale.

a model involving payers sharing back a portion of their savings from reduced resource use may be appropriate for the e-AT care model.

CONCLUSIONS

The e-AT was effective in engaging parents in asthma self-management and in achieving sustained improvement in asthma outcomes for

children and parents. Dissemination of this proactive care model can lead to major improvements in asthma care and outcomes, with potential for significant reductions in asthma-related health care costs.

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ABBREVIATIONS

ACT: asthma control test
CI: confidence interval
e-AT: electronic-AsthmaTracker
ED: emergency department
IH: Intermountain Healthcare
OCS: oral corticosteroid
PCP: primary care provider
QoL: quality of life
RR: rate ratio

TABLE 1 Baseline Characteristics of Cases and Matched Controls

Baseline Characteristics	Cases	Controls
Total N	325	603
Patient demographics		
Age in y, mean (SD)	7.9 (4.0)	8.0 (3.9)
Sex, n (%)		
Female	129 (39.7)	230 (38)
Male	196 (60.3)	373 (62)
Insurance, n (%)		
Medicaid or self-pay	75 (23.1)	159 (26.4)
Private	237 (72.9)	441 (73.1)
Unknown	13 (4.0)	3 (0.5)
Race or ethnicity, n (%)		
Hispanic	42 (12.9)	72 (12.0)
Other ^a	25 (7.7)	47 (7.7)
Unknown	15 (4.6)	4 (0.7)
White	243 (74.8)	480 (79.6)

Similar baseline characteristics are shown between cases and matched controls.

^a Includes American Indian, Asian American, African American, and Native Hawaiian.

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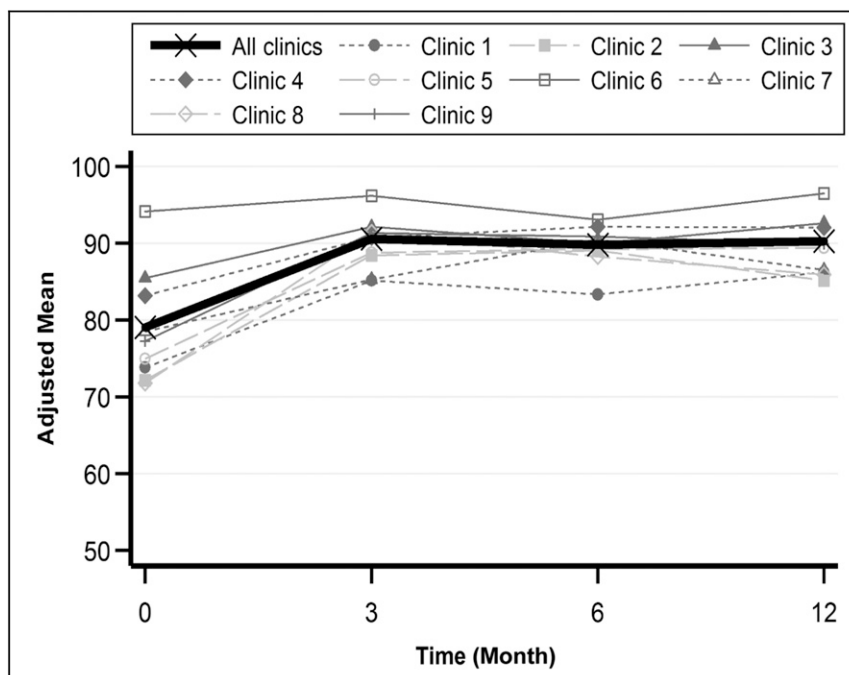
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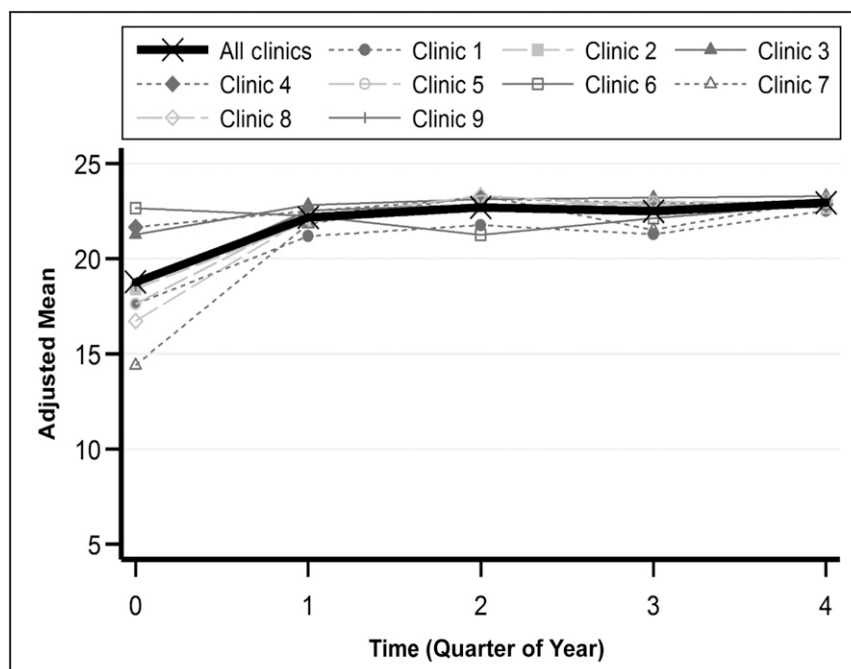


Supplemental Information



SUPPLEMENTAL FIGURE 9

Adjusted mean QoL scores (overall and by clinics) at baseline and 3, 6, and 12 months. Adjusted mean QoL scores, by clinic and overall (all clinics), increasing from baselines (0 months) to months 3, 6, and 12, with the greatest increase seen by month 3. Thereafter, QoL scores remained higher through the end of the study. Clinic 6's mean score was already high at baseline and did not change over time, whereas other clinics improved by month 3 and stayed high through the end of the study. Y-axis units show only QoL scores between 50 and 100 (rather than 0–100) for easy reading.



SUPPLEMENTAL FIGURE 10

Adjusted mean asthma control (overall and by clinics) at quarters baseline and quarters 1, 2, 3, and 4. Adjusted mean asthma control scores, by clinic and overall (all clinics), increasing from baseline to quarters 1, 2, 3, and 4, with the greatest increase occurring by quarter 1. Thereafter, asthma control scores remained higher through the end of the study. Mean scores for clinics 3 and 4 were high at baseline and had a slight but not significant increase over time. Clinic 6's mean score was high at baseline and did not change over time. The remaining clinics had baseline scores <19 (not well-controlled asthma) and improved to well-controlled asthma scores overtime. Y-axis units show only asthma control scores between 13 and 25 (rather than 5–25) for easy reading.