

Supplementary Material

Table E1. Current Digital Strategies to Improve Adherence in Asthma and COPD

Electronic Monitoring Devices			
Study Description	Features	Effect on Adherence	Other Outcomes
<i>Charles et al. 2007</i> [1] <ul style="list-style-type: none"> • 24-week RCT • 110 patients (aged 12 to 65 years) with asthma 	<ul style="list-style-type: none"> • EMD recorded date/time and number of actuations • Intervention group also utilized an audiovisual reminder function 	<ul style="list-style-type: none"> • Significantly higher adherence in patients who received an audiovisual reminder compared with the control group (93% vs 74% median percentage taken in last 12 weeks of trial, $P < .001$) 	<ul style="list-style-type: none"> • No significant differences occurred in clinical outcomes between the 2 groups
<i>Burgess et al. 2010</i> [2] <ul style="list-style-type: none"> • 4-month RCT • 26 patients (aged 6 to 14 years) with suboptimal asthma control 	<ul style="list-style-type: none"> • EMD recorded date and time of actuation • Intervention group also received feedback based on EMD measured adherence 	<ul style="list-style-type: none"> • Significantly higher adherence in patients who received feedback compared with the control group (79% vs 58%, $P < .01$) • Adherence in the control group declined slightly over the study, whereas in the intervention group mean adherence was maintained ($P < .01$) 	<ul style="list-style-type: none"> • Change in forced FEV was greater in the intervention group (13.8%) than in the control group (9.8%), but did not reach statistical significance
<i>Foster et al. 2014</i> [3] <ul style="list-style-type: none"> • 6-month RCT • 143 patients (aged 14 to 65 years) with suboptimal asthma control 	<ul style="list-style-type: none"> • EMD recorded date/time of all actuations and uploaded data monthly to a secure Web site • Intervention group also received IRF and/or personalized adherence discussions 	<ul style="list-style-type: none"> • Significantly higher adherence in the IRF groups than in the non-IRF groups (73% vs 46% of prescribed daily doses; $P < .0001$) • Adherence decreased over time in all groups, but remained twice as high in the IRF groups vs the non-IRF groups ($60\% \pm 38\%$ vs $29\% \pm 33\%$) 	<ul style="list-style-type: none"> • 11% of patients in the IRF groups had exacerbations compared with 28% in the non-IRF groups ($P = .013$); this difference was not significant ($P = .06$) after adjustment for clustering and past self-reported prednisone use
<i>Chan et al. 2015</i> [4] <ul style="list-style-type: none"> • 6-month RCT • 220 children (aged 6 to 15 years) with prior history of asthma exacerbation 	<ul style="list-style-type: none"> • EMD recorded date/time and number of actuations • Intervention group also utilized an audiovisual reminder function 	<ul style="list-style-type: none"> • Significantly higher adherence in the intervention group compared with the control group (median 84% vs 30%, $P < .001$) • Overall adherence fell in both groups over time, with no difference in the rate of decline ($P = .10$) 	<ul style="list-style-type: none"> • Reduction in asthma morbidity score from baseline to 6 months was significantly greater ($P = .008$) in the intervention group (9.30 to 7.3) than in the control group (9.20 to 8.0)

<i>Vasbinder et al. 2016</i> [5]	<ul style="list-style-type: none"> • EMD recorded date and time of actuation • Intervention group also received tailored SMS reminders when a dose was at risk of omission 	<ul style="list-style-type: none"> • Higher mean adherence in the intervention group compared with the control group (69.3% vs 57.3%; difference 12.0%, 95% CI 6.7%–17.7%) 	<ul style="list-style-type: none"> • No differences were found between groups for asthma control, quality of life, or asthma exacerbations
<i>Merchant et al. 2016</i> [6]	<ul style="list-style-type: none"> • 12-month parallel arm study • 495 patients (aged >5 years) with asthma • Intervention included a sensor to monitor inhaler use, an education component, reminders and alerts, data visualization and trends, and predictive analytics and feedback • Control group utilized sensors to monitor inhaler use along with usual care 	<ul style="list-style-type: none"> • Greater decrease in mean daily SABA uses per person in the intervention group (-0.41) vs routine care (-0.31), $P < .001$ • Greater increase in the proportion of SABA-free days increased in the intervention group (21% vs routine care (17%), $P < .01$ 	<ul style="list-style-type: none"> • Improved ACT scores among adults initially lacking asthma control
<i>Morton et al. 2017</i> [7]	<ul style="list-style-type: none"> • 1-year RCT • 90 children with asthma (aged 6 to 16 years) • EMD recorded date and time of actuation • Adherence data also reviewed by patient and caregiver every 3 months and reminders utilized in the intervention group 	<ul style="list-style-type: none"> • Significantly higher adherence in the intervention group compared with the control group (70% vs 49%; $P \leq .001$) was maintained in the intervention group, but declined in the control group over 1 year 	<ul style="list-style-type: none"> • Significant decrease in exacerbations requiring oral steroids or hospitalization in the intervention group • Decrease in ACQ in both groups (1.0 in control group and 0.9 in intervention group) but no significant difference between groups
Text messaging			
Study Description	Features	Effect on Adherence	Other Outcomes
<i>Strandbygaard et al. 2010</i> [8]	<ul style="list-style-type: none"> • 12-week RCT • 26 patients (aged 18 to 45 years) with asthma • Intervention group received daily SMS reminder to take asthma medication 	<ul style="list-style-type: none"> • Mean medication adherence increased in the SMS group (77.9% to 81.5%) and decreased in the control group (84.2% to 70.1%) • The absolute difference in mean medication adherence between the 2 groups was 17.8%, $P = .019$ 	<ul style="list-style-type: none"> • No between-group differences in change in exhaled nitric oxide levels, FEV1 (% of predicted), ACQ, or mini AQLQ
<i>Prabhakaran et al. 2010</i> [9]	<ul style="list-style-type: none"> • 12-week RCT • 120 patients (aged >21 years) hospitalized for asthma • All patients received inpatient individualized asthma education at the beginning of the study • Intervention group received SMS messages to assist with asthma management, including medication use, according to a structured workflow 	<ul style="list-style-type: none"> • Not measured 	<ul style="list-style-type: none"> • No significant difference in ACT scores, number of nebulizations, or ED visits between groups
<i>Lv et al. 2012</i> [10]	<ul style="list-style-type: none"> • 12-week RCT • Verbal asthma education (all groups) • Individualized asthma action plan with peak 	<ul style="list-style-type: none"> • Medication adherence was higher in the SMS (80.0%) and traditional (74.1%) groups than in the control 	<ul style="list-style-type: none"> • Significant increase in perceived asthma control and AQLQ in the SMS and

<ul style="list-style-type: none"> 150 patients (aged >18 years) with asthma 	<p>expiratory flow monitoring and asthma diary (traditional and SMS groups)</p> <ul style="list-style-type: none"> Daily SMS reminders on how to manage asthma and option to ask questions via text message (SMS group) 	<p>group (50.0%), but changes were not significant.</p> <ul style="list-style-type: none"> Follow-up appointment rates were significantly higher in the SMS (60%) and traditional (54%) groups compared with the control group (28%) 	<p>traditional groups relative to control</p> <ul style="list-style-type: none"> Improved FEV1 (% predicted) in all groups, but no significant between-groups difference.
<p><i>Petrie et al. 2012</i> [11]</p> <ul style="list-style-type: none"> 9-month RCT 147 patients (aged 16 to 45 years) with asthma 	<ul style="list-style-type: none"> Treatment group received individually tailored text messages for 18 weeks based on their illness and medication beliefs 	<ul style="list-style-type: none"> Average self-reported adherence was higher (57.8%) in the intervention group than the control group (43.2%) ($P < .05$) Percentage taking over 80% of prescribed inhaler doses was 25.9% in the intervention group and 10.6% in the control group ($P < .05$) 	<ul style="list-style-type: none"> At 18 weeks, the text-message group was significantly higher than control on perceived necessity of preventer medication, belief in the long-term nature of their asthma, and perceived control over their asthma
<p><i>Kolmodin MacDonell et al. 2016</i> [12]</p> <ul style="list-style-type: none"> 3-month RCT 48 African American adults (aged 18 to 29 years) with asthma 	<ul style="list-style-type: none"> Intervention group received 2 computer-delivered motivational interviewing (MI) sessions with text reminders between sessions Control group completed asthma education matched for length, location, and method of delivery of the intervention MI sessions 	<ul style="list-style-type: none"> Both groups missed fewer doses of controller medication at 3 months than at baseline The magnitude of the trend was greater for the intervention group for total doses missed, average doses missed per day, and number of days medication was missed, but did not reach statistical significance 	<ul style="list-style-type: none"> There was a larger magnitude decrease in symptoms in the intervention vs control group in total symptoms, $P < .05$ and average symptoms per day, $P < .05$ Intervention group improved in FEV-1 percent predicted (+4.41%) and control group decreased (-4.14%), $P \leq .01$
<p><i>Britto et al. 2017</i> [13]</p> <ul style="list-style-type: none"> 6-month RCT 64 patients (aged 12 to 22 years) with asthma 	<ul style="list-style-type: none"> Intervention group received text message reminders personalized by the patient Ability to change, add, or delete reminders as desired Participants divided into intervention from baseline to month 3 or intervention from month 3 to month 6 	<ul style="list-style-type: none"> Increased adherence to ICSs by 2.75% per month with the intervention vs without ($P < .01$). For the group that received text messages first, adherence subsequently declined, suggesting no long-term effect 	<ul style="list-style-type: none"> Improved ACT score after 1 month that was maintained for the 6-month duration of the study in both groups Asthma symptoms improved and asthma worry decreased in both groups
<p><i>Akrom et al. 2015</i> [14]</p> <ul style="list-style-type: none"> Controlled pre- and post-intervention study 66 patients (aged 18 to 80 years) with COPD 	<ul style="list-style-type: none"> Intervention group received daily text messages with motivational messages and reminders to take medication, and brief counseling Control group received hospital standard of care 	<ul style="list-style-type: none"> Intervention group experienced significant improvement in MMAS score (from 46% to 88% high compliance) from pretest to posttest; control group did not (55% to 61% high compliance). 	<ul style="list-style-type: none"> Not measured

Web-based and Mobile Applications			
Study Description	Features	Effect on Adherence	Other Outcomes
<i>Van der Meer et al. 2009</i> [15] <ul style="list-style-type: none"> • 12-month RCT • 200 patients (aged 18 to 50 years) with asthma 	<ul style="list-style-type: none"> • Internet-based self-management program included weekly asthma control monitoring, treatment advice, online and group education, and remote communication with an asthma nurse • Control group received usual care 	<ul style="list-style-type: none"> • Inhalation technique improved in both groups but improvements did not differ between groups ($P = .143$) • Self-reported medication adherence did not differ between groups 	<ul style="list-style-type: none"> • Internet-based self-management was associated with improved asthma control and lung function • Asthma-related quality of life improved, but was not statistically significant in the intervention group vs control and exacerbations did not differ between groups
<i>Liu et al. 2011</i> [16] <ul style="list-style-type: none"> • 6-month prospective, controlled study • 120 patients with asthma 	<ul style="list-style-type: none"> • Mobile phone-based interactive asthma self-care system including electronic symptoms diary and record of reliever use and PEFR • Control group received a written symptoms booklet and asked to record PEFR regularly 	<ul style="list-style-type: none"> • Significant increase in mean daily dose of either systemic or ICSs in intervention group compared with control group 	<ul style="list-style-type: none"> • Significant increase in PEFR in intervention group compared with control group at 4 and 6 months • Improved quality of life and fewer exacerbations in the intervention group
<i>Ryan et al. 2012</i> [17] <ul style="list-style-type: none"> • 6-month RCT (aged >12 years) • 288 patients with asthma 	<ul style="list-style-type: none"> • Mobile phone-based system with twice-daily recording and transmission of symptoms, drug use, and peak flow, with immediate feedback • Control group recorded the same data using a paper diary 	<ul style="list-style-type: none"> • Not measured 	<ul style="list-style-type: none"> • No significant difference in change in asthma control or self-efficacy between groups • No significant difference in number of acute exacerbations, prescribed steroid courses, and unscheduled HCP consultations or ED visits between groups
<i>Farooqui et al. (2015)</i> [18] <ul style="list-style-type: none"> • 30-day single-arm study • 24 patients (aged 9 to 16 years) with asthma 	Intervention included: <ul style="list-style-type: none"> • Daily reminders for medication use • Personalized trigger avoidance measures • Algorithm-based, interactive asthma treatment plan • Gamification features and reward points based on medication use and interaction with the app 	<ul style="list-style-type: none"> • Increased adherence to controller medication in 18 of 21 subjects (85%) during the intervention period compared with the 30 days immediately preceding enrollment 	<ul style="list-style-type: none"> • Increase in measures to avoid asthma triggers after intervention period
<i>Mosnaim et al. (2015)</i> [19] <ul style="list-style-type: none"> • 8-week single-arm study • 12 African American patients (aged 11 	Intervention included: <ul style="list-style-type: none"> • Daily visual reminders to take their ICS • Positive reinforcement (texts and gaming) for taking ICS 	<ul style="list-style-type: none"> • Median ICS adherence increased from 19% at baseline to 67% at 8 weeks • At baseline 8% of patients met target ICS adherence (>50%); at week 8, 58% of 	<ul style="list-style-type: none"> • ACT scores increased from baseline to week 8 (18 vs 23) with 58% of participants achieving the minimal clinically important difference (3 points) in ACT score

to 16 years) with persistent asthma	<ul style="list-style-type: none"> • Immediate (ability to customize avatar) and long-term (\$1.00/dose-to purchase music, movies, applications, and games) rewards 	patients met target ICS adherence	<ul style="list-style-type: none"> • SABA use decreased from a median of 3 puffs per week at baseline to 0 puffs per week at 8 weeks
<i>Cingi et al. (2015) [20]</i> <ul style="list-style-type: none"> • 3-month RCT • 136 patients with asthma (aged 25 to 41 years) 	<ul style="list-style-type: none"> • Intervention included physician/patient communication; health status and medication compliance tracking; sharing of motivational and educational content; and medication reminders • Control group received standard care 	<ul style="list-style-type: none"> • Not measured 	<ul style="list-style-type: none"> • In the intervention group, more patients (49%) achieved a well-controlled asthma score (ACT >19) compared with the control group (27%, ($P < .05$))
<i>Johnson et al. 2016 [21]</i> <ul style="list-style-type: none"> • 3-week RCT • 98 patients with asthma (aged 12 to 17 years) 	<ul style="list-style-type: none"> • Personalized health application (MyMediHealth) to help patients manage medications and receive dosing reminders • Control group received action lists as part of usual care 	<ul style="list-style-type: none"> • Significant improvement in self-reported 7-day adherence ($P = .011$) in the intervention group vs control group 	<ul style="list-style-type: none"> • Increased quality of life ($P = .037$) and perception of self-efficacy ($P = .016$) in the intervention group compared with the control group
<i>Ahmed et al. 2016 [22]</i> <ul style="list-style-type: none"> • 6-month, RCT • 100 patients (aged 18 to 69 years) with asthma 	<ul style="list-style-type: none"> • My Asthma Portal mobile application, which allowed participants to view personal health information, receive information tailored to identified knowledge gaps, and monitor and receive feedback on current self-management practices • Control group received usual care 	<ul style="list-style-type: none"> • Not measured 	<ul style="list-style-type: none"> • No significant between-group effects on asthma-related quality of life • No significant effect on asthma control
<i>Cook et al. 2016 [23]</i> <ul style="list-style-type: none"> • Prospective single-arm, treatment-only, 4-month study • 60 adults (aged 17 to 82 years) with asthma 	Intervention included: <ul style="list-style-type: none"> • Continuous patient data collection including self-assessment of asthma control and assessment of patient knowledge regarding asthma control • Individualized alerts, coaching, and educational materials 	<ul style="list-style-type: none"> • Not measured 	<ul style="list-style-type: none"> • Statistically significant improvement in ACT scores and FEV₁ (in subset of patients with available before-and-after spirometry data) • Nonsignificant decrease in total number of systemic corticosteroids prescribed
<i>Koufopoulos et al. 2016 [24]</i> <ul style="list-style-type: none"> • 9-week RCT • 216 patients (aged 18 to 64 	<ul style="list-style-type: none"> • Intervention group included access to “AsthmaVillage,” an online community for patients with asthma 	<ul style="list-style-type: none"> • No difference in self-reported medication adherence in the intervention group vs control 	<ul style="list-style-type: none"> • Not measured

years) with asthma	<ul style="list-style-type: none"> Control group did not have access to the online community, but utilized the “AsthmaDiary,” an online diary for recording ICS preventer use 		
<i>Kim et al. (2016)</i> [25] <ul style="list-style-type: none"> 8-week study 44 patients (aged >19 years) with asthma 	<ul style="list-style-type: none"> Intervention group utilized an application that included: <ul style="list-style-type: none"> Asthma monitoring application and peak flow meter Questionnaires and daily patient symptom score Daily alerts and action plans based on asthma control status The control group did not use the application 	<ul style="list-style-type: none"> Adherence improved in the intervention group ($P = .017$) but not in the control group ($P = .674$) 	<ul style="list-style-type: none"> Lung function parameters did not significantly differ between visits or between the intervention and control groups at each visit
<i>Morrison et al. (2016)</i> [26] <ul style="list-style-type: none"> 12-week RCT 51 patients (aged ≥ 16 years) with asthma 	<ul style="list-style-type: none"> “Living Well with Asthma” Web site designed to assess current level of asthma control and support optimal medication management; challenge attitudes and concerns around medication; and prompt use of personal action plan Control group received usual care 	<ul style="list-style-type: none"> No significant between-group difference in the percentage of recommended ICS doses self-reportedly taken, nor the equivalent beclometasone doses prescribed 	<ul style="list-style-type: none"> No significant difference in ACQ scores and mini-AQLQ scores Significant improvement in PAM scores in the intervention group compared with the control group
<i>Pool et al. (2017)</i> [27] <ul style="list-style-type: none"> 12-month RCT 408 adults (aged 21 to 60 years) with asthma 	<ul style="list-style-type: none"> Tailored feedback and reminders based on answers to questions (at least once per month) related to asthma symptoms, medications, provider care, and asthma management plan Control group received similar questions and feedback, but focused on preventive services unrelated to asthma control (eg, cancer screening) 	<ul style="list-style-type: none"> No differences were observed in medication adherence between the intervention group and control 	<ul style="list-style-type: none"> Greater mean improvement in ACT score in the intervention group (2.3 vs 1.2; $P = .02$) No differences in asthma-related health care utilization
<i>Pinnock et al. 2013</i> [28] <ul style="list-style-type: none"> 12-month RCT 256 adults with COPD 	<ul style="list-style-type: none"> Intervention group recorded symptoms and medication use and monitored oxygen saturation daily 	<ul style="list-style-type: none"> Not measured 	<ul style="list-style-type: none"> Number and mean duration of hospital admissions for COPD did not differ significantly between groups

	<ul style="list-style-type: none"> • Intervention included algorithm-generated alerts to clinical team based on patient input • Control group utilized standard self-monitoring 		<ul style="list-style-type: none"> • No significant effect on health-related quality of life between groups
<i>Farmer et al. 2017</i> [29] <ul style="list-style-type: none"> • 12-month RCT • 166 patients (aged ≥ 40 years) with COPD 	<ul style="list-style-type: none"> • Intervention included daily symptom diary including medication use; Bluetooth-enabled pulse oximeter with finger probe; monthly mood screening questionnaires; and tailored videos and education based on patient entries • Control group received usual care 	<ul style="list-style-type: none"> • No difference on MARS in self-reported medication adherence 	<ul style="list-style-type: none"> • No significant difference in number of exacerbations, relative risk of hospital admission, quality of life, self-reported smoking cessation, depression, or anxiety • Better overall health status (measured with 5-Level EuroQol 5-Dimension Questionnaire) in the intervention group ($P = .03$)

ACQ, Asthma Control Questionnaire; ACT, Asthma Control Test; AQLQ, Asthma Quality of Life Questionnaire; CI, confidence interval; COPD, chronic obstructive pulmonary disease; ED, emergency department; EMD, electronic monitoring device; FEV1, forced expiratory volume in one second; HCP, health care provider; ICS, inhaled corticosteroid; IRF, inhaler reminders and feedback; MARS, Medication Adherence Report Scale; MI, motivational interviewing; MMAS, Morisky Medication Adherence Scale; PAM, patient activation measure; PEF, peak expiratory flow rate; RCT, randomized controlled trial; SABA, short-acting beta agonist; SMS, short message service.

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