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Key drivers of implementation during a practice facilitation intervention in primary care: a longitudinal analysis of the STop UNhealthy alcohol use now (STUN) trial

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Abstract

Background

Practice facilitation (PF) is widely used to support implementation of evidence-based interventions in primary care, yet how PF improves implementation remains poorly specified. PF's influence may operate in part through changes in clinical practice and office systems, such as workflows, leadership support, and information systems, which shape the extent to which use of an evidence-based practice is expected, supported, and rewarded. Within the broader context of the STop UNhealthy Alcohol Use Now (STUN) trial, this analysis examined whether PF was associated with progress in implementing clinical and organizational change supporting alcohol screening and brief intervention.

Methods

Twenty-one small to medium primary care practices in North Carolina received 12 months of PF, including quality improvement coaching, electronic health record support, and structured implementation guidance, followed by 6 months of sustainment follow-up. Clinical practice and office systems changes were measured monthly with the Key Driver Implementation Scale (KDIS; range 0–45). Repeated-measures analysis of variance (RM-ANOVA) provided an overall test of change in KDIS over the facilitation phase, with paired-t contrasts comparing early intervention (Q1, months 1–3) to intervention midpoint (Q2) and to the end of facilitation (Q4). Mixed-effects growth models with quadratic time characterized trajectory shape across all 18 months.

Results

PF was associated with significant increases in KDIS scores across implementation periods (Q1 mean 20.41, Q2 mean 24.49, Q4 mean 25.04; $p<.001$). Growth modeling showed a non-linear pattern with steep early gains that decelerated over time (linear $\beta = 1.52$, $p<.001$; quadratic $\beta=-0.06$, $p<.001$) and predicted KDIS scores increasing by roughly 7 points over 18 months on the 0–45 scale. Higher baseline screening rate was associated with faster early gains that leveled off, whereas greater practice capacity for QI was associated with slower but more sustained gains through month 18.

Conclusions

PF was associated with measurable KDIS improvement that decelerated over the facilitation period and varied with baseline screening performance and operational QI capacity. The pace and durability of change, not endpoint alone, may inform PF dose, timing, and tailoring. Repeated measurement of these drivers may help advance research on PF’s relationship to clinical change.

Trial registration:

ClinicalTrials.gov NCT04317989. March 23, 2020 –registered, https://clinicaltrials.gov/study/NCT04317989

Contributions to the literature

- Practices with stronger baseline screening performance developed clinical practice and office systems changes more rapidly and reached higher predicted levels earlier, suggesting that existing implementation performance may shape responsiveness to facilitation.
- The findings suggest that uniform facilitation protocols may fit practices unevenly and that repeated organizational measurement could help guide when to intensify, sustain, or taper facilitation support.
- By linking longitudinal organizational measurement to the clinical adoption gains reported in the parent trial, this study positions change in the key drivers of implementation, the practice systems through which alcohol screening becomes rewarded, supported, and expected, as a candidate explanation for PF's influence on clinical outcomes that future analyses can test directly.

Background

Unhealthy alcohol use remains substantially under-addressed in U.S. primary care(1, 2). Fewer than one-third of adults seen in primary care are screened using validated tools, and even fewer receive evidence-based interventions following a positive screen, despite long-standing recommendations and robust evidence of benefits (3–6). This persistent implementation gap is attributable to structural constraints within primary care practices, such as limited visit time, competing demands, inadequate electronic health record (EHR) support, and the absence of routinized workflows for systematic screening and follow-up(7–9). These practice-level barriers are compounded by financing constraints, as existing reimbursement models do not consistently support the delivery of screening or treatment of alcohol use disorder in primary care(10). Addressing these barriers requires implementation strategies capable of developing or improving practice-level systems rather than solely targeting individual clinician behavior.

In our STop UNhealthy Alcohol Use Now (STUN) trial(11), we found that adoption of evidence-based screening and interventions for unhealthy alcohol use was improved with practice facilitation (PF), a strategy intended to support implementation by combining quality improvement coaching, audit and feedback, EHR optimization, and iterative testing of change to embed new practices into routine (12–14). Importantly, we found variable effects of PF on the extent and pace of penetration of evidence-based screening and interventions for unhealthy alcohol use across practices (11).

The variation in PF’s influence on screening offers an opportunity to shed light on how PF improves implementation outcomes. Despite its demonstrated effectiveness, PF remains limited by weak specification of the core functions that comprise PF and how it produces change(15, 16). Across clinical domains, PF is typically evaluated as a multicomponent strategy, with effectiveness established more clearly than *how* PF influences implementation. Recent efforts have begun to address this gap by attempting to "open the black box" of PF and examining how specific facilitation activities (17) and relational processes (18) drive implementation outcomes. Despite these developments, study designs are often not well suited to capture how PF influences practice-level changes. PF is still often treated as an intervention package whose internal logic is inferred rather than empirically tested (19). Limited understanding of PF’s influence constrains

optimization, adaptation to new settings, and the ability to tailor support to practices with differing capacities (15, 20). Understanding how PF operates may advance PF from a broadly effective strategy to a more precise and scalable one.

One way PF is theorized to act is by helping practices develop the care-delivery structures and processes needed to integrate evidence-based care into routine workflows (21). In primary care, these include clinical information systems, standardized care processes, optimized team care, patient self-management support, and leadership for quality improvement. These clinical practice and office systems changes have been used in PF trials as 'key drivers' to gauge practices' progress in implementing clinical and organizational changes. Prior work has treated key drivers as practical operationalizations of implementation policies and practices (IPP) (22, 23): the formal and informal plans, practices, structures, and strategies that shape whether innovation use is expected, supported, and rewarded (24, 25). Prior psychometric work has evaluated the KDIS as a PF-facing measure of practice progress on these implementation activities, supporting its use for tracking organizational response to facilitation while also noting the need for continued validation (21). If PF operates by strengthening these key drivers, then changes in clinical practice and office systems should be observable during facilitation and may help explain practice-level variation in adoption of alcohol screening and brief intervention.

Implementation theory suggests that PF's effectiveness will vary across contexts and the interventions whose implementation PF is used to improve (26). Frameworks emphasizing organizational readiness for change(27, 28) and practice capacity for QI (29, 30) suggest that practices differ in their ability to mobilize resources, coordinate roles, absorb disruption, and sustain new routines. Practices therefore enter facilitation under markedly different starting conditions, raising the question of which conditions shape how readily, and how durably, the key drivers of implementation take hold. Prior implementation efforts may represent indicators of established workflows, team roles, and information systems needed to respond quickly to PF. Self-reported capacity for quality improvement and readiness to implement change may capture a practice's preparedness to initiate and sustain that response, distinct from what its prior performance reveals. Structural and contextual characteristics such as Patient-Centered Medical Home (PCMH) recognition, Medically Underserved Area/Population (MUA/P) designation, practice size, and ownership may further shape the resources, constraints, and accountability pressures under which facilitation occurs.

This study examined whether PF is associated with changes in clinical practice and office systems for the implementation of evidence-based screening and counseling in primary care. We characterized the timing and shape of these changes across implementation (months 1–12) and sustainment (months 13–18) periods and assessed whether trajectories differed by practices' baseline screening performance, practice capacity for QI, organizational readiness for change, and other contextual characteristics.

Methods

Study Design and Setting

This study reports a longitudinal analysis of implementation outcomes from the STUN trial (occurring from February 1, 2020 through September 1, 2023), which tested the impact of one to two hours of PF per month

over a 12-month implementation phase and an additional 6-month sustainment phase on screening and counseling for unhealthy alcohol use in primary care. PF was predominately delivered remotely due to the COVID-19 pandemic. COVID-19 was declared a public health emergency in the US in January 2020, meaning that clinic recruitment and training, as well as collection of adoption measures, overlapped with the peak and aftermath of the pandemic. All 21 practices that entered the implementation phase comprise the analytic sample for this evaluation. The study was approved by the University of North Carolina at Chapel Hill Institutional Review Board and prospectively registered at ClinicalTrials.gov (NCT04317989). This report follows the Standards for Reporting Implementation Studies (StaRI) guidelines(31). Complete details of the trial design, recruitment, facilitation activities, and implementation strategy are reported elsewhere(11, 32).

Measures

Table 1 summarizes the primary measures, their scoring, and data availability. Clinic and patient panel characteristics were obtained from baseline participant surveys and EHR documentation, including practice specialty composition (single- versus multi-specialty), number of clinicians, and patient panel demographics and payer mix (age, sex, race and ethnicity, and insurance coverage).

Primary outcome

To measure the clinical practice and office systems changes, we used the Key Driver Implementation Scale (KDIS), a practice-level instrument developed by the North Carolina Area Health Education Center (NC AHEC) Practice Support Program, a statewide practice-facilitation program that provides quality-improvement coaching to primary care practices across the state's nine regional AHECs (21). Each of the 9 items assesses a key driver of quality improvement (quality monitoring, QI team composition, leadership support, clinical information systems, evidence-based guidelines, patient empowerment, care team optimization, experience of care, and fiscal health) on a 6-level behaviorally anchored ordinal scale (0 = no activity to 5 = fully integrated). Total scores are computed as the sum of 9 items (range 0–45), with higher scores indicating greater implementation capacity; fractional ratings between anchor points were permitted during data entry. Individual KDIS item means were computed quarterly to characterize which drivers contributed to observed change in the composite score; items were not modeled inferentially, as the pre-specified analytic target was the total score. The KDIS was completed monthly by the assigned practice facilitator, yielding up to 18 observations per practice.

Baseline moderators

Candidate moderators of the KDIS trajectory included baseline screening rate, practice capacity for quality improvement (QI), and organizational readiness for change, and contextual practice characteristics. *Baseline screening rate*, defined as the percentage of adult patients who were screened for unhealthy alcohol use for the three months prior to beginning PF, was derived from EHR data and dichotomized at ≥ 50% (high; n = 9) versus < 50% (low; n = 12). *Practice capacity for QI* was measured with two complementary instruments grounded in change-process-capability framework and the adaptive-reserve framework(29, 30). The 14-item

Strategies subscale of the Change Process Capability Questionnaire (CPCQ)(30), a self-reported measure of QI-strategy use validated against practices' change priorities and care systems, was completed by a single practice manager per clinic and scored as the mean of applicable items (1–5). A 3-item version of the Adaptive Reserve Questionnaire (ARQ)(29), derived through factor analysis in the National Demonstration Project, was completed by practice staff at baseline and aggregated to clinic-level means. The two instruments were analyzed separately. *Organizational readiness for change* was assessed using the 12-item Organizational Readiness for Implementing Change measure (ORIC), which has demonstrated a two-factor structure and supports aggregation to the practice level (28). ORIC yields two subscale means scored 1–5: Change Commitment (5 items) and Change Efficacy (7 items), both of which were completed by practice staff and aggregated to clinic-level means. *Practice characteristics* included several practice-specific measures that were examined as exploratory moderators: PCMH recognition, MUA/P status, the number of providers at a clinic, and the ownership status of the clinic.

Data Analysis

Clinic characteristics were summarized as frequencies for categorical variables and means with standard deviations for continuous variables. Patient panel characteristics (demographics and payer mix) were weighted by adult panel size so that estimates reflect the population of patients served rather than treating each clinic equally, while baseline implementation context measures were summarized unweighted at the clinic level. Three clinics had missing data on ownership status but were retained in descriptive tables with explicit "Unknown" categories; moderation models used listwise-available cases.

Inferential analyses paralleled those of the parent trial(32) and proceeded in three stages. First, we tested whether mean KDIS scores increased across the facilitation phase using repeated measures analysis of variance (ANOVA) with paired t-tests. Second, we characterized the shape of KDIS development over 18 months using mixed-effects growth modeling, allowing examination of the pace and pattern of organizational change across the implementation and sustainment periods. Third, we examined whether KDIS trajectories differed by baseline practice characteristics, addressing whether practice capacity for QI, organizational readiness for change, and various practice characteristics (all measured at baseline) moderate the relationship between PF and KDIS development.

Tests of Change in KDIS

For each practice, monthly KDIS observations were averaged within each quarter to yield one practice-level score per quarter, computed from the months observed within that window. Repeated-measures ANOVA tested overall change across Q1 (months 1–3), Q2 (months 4–6), and Q4 (months 10–12), with the Huynh-Feldt correction for sphericity. Because repeated-measures ANOVA requires complete cases, only practices with a quarterly mean in all three windows contributed to this test. Two a priori contrasts were evaluated using paired t-tests: Q1 to Q2 (the initial six-month protocol phase, mirroring the primary endpoint timing of the parent trial) and Q1 to Q4 (end of facilitation), with Holm correction across the two contrasts. KDIS measurement began at the start of facilitation; Q1 therefore served as the early-implementation reference period in place of a pre-intervention baseline.

Mixed-effects trajectory modeling

To characterize trajectory shape across the full 18-month observation period, monthly clinic-level KDIS scores (level 1) nested within practices (level 2) were modeled using linear mixed-effects regression with random intercepts and random linear slopes of month at the practice level. The functional form of time was selected from nested polynomial specifications (linear, quadratic, cubic) using likelihood-ratio tests refit under maximum likelihood, with Akaike information criterion (AIC) and Bayesian information criterion (BIC) as supporting criteria; a quadratic specification was retained, and final models were re-estimated under restricted maximum likelihood for inference. Missing observations, largely reflecting COVID-19 disruption and management transitions, were assumed missing at random; no imputation was performed. Effect sizes for the primary trajectory were reported as model-predicted change in KDIS from month 1 to month 18 on the natural 0–45 scale.

Moderation of trajectory shape

Moderation was tested in separate mixed-effects models, each including the moderator, its interaction with linear time, and its interaction with quadratic time. Following bivariate tests, moderators with significant associations with linear or quadratic time ($p < .05$) were combined in a joint model to evaluate their relative contributions. Predicted values were estimated at months 1, 9, and 18. Because the trial is single arm, these analyses describe differential trajectories by baseline characteristics rather than moderation of a randomized intervention effect. Analyses were conducted in Stata/BE 19(33).

Results

Thirty-two practices were enrolled in STUN. Of these, 11 withdrew before the implementation phase, leaving 21 practices in the sample for this analysis; 1 practice withdrew during the 12-month implementation phase, and 1 additional practice withdrew during the 6-month sustainment phase. Table 2 summarizes clinic and patient characteristics for the 21 participating practices. Practices were generally small, with 66.7% having 2 to 5 clinicians, 85.7% being single-specialty, and 52.4% classified as clinic-owned. Patient demographic and payer characteristics, weighted by adult patient population, indicated that panels were predominantly middle-aged and older adult, with the largest age groups being 40 to 59 years (27.5%) and 60 to 75 years (26.9%); 51.7% of patients were female, and 40.1% were Black or African American. Weighted payer mix showed that 38.0% of patients were covered by private insurance, 34.2% by Medicare, 16.2% by Medicaid, and 7.6% were uninsured. Overall, 38.1% of practices were located in medically underserved areas. Across the 21 practices, 257 clinic-month KDIS observations were available over 18 months (mean 12.2, range 2-18) while baseline moderator data was available for 18 practices for CPCQ and for 15 practices for ORIC and ARQ. Throughout the intervention, there were 280 PF encounters (mean 15.5, range 5–28) with 49.6% delivered by video conference.

Change in KDIS over time

Across the 21 practices, KDIS scores increased significantly across the prespecified implementation intervals ($F(2, 36) = 25.33$, $p < .001$, Huynh–Feldt corrected). Planned paired contrasts showed a mean gain of 3.47

KDIS points by the midpoint of the facilitation phase relative to early implementation (95% CI 1.55 to 5.39, p=.001, n=20) and a mean gain of 7.13 points by the end of facilitation (95% CI 4.97 to 9.29, p<.001, n=18). Both planned contrasts remained significant after Holm correction. Observed quarterly KDIS means are reported in Table 3.

The mixed-effects model characterized the shape of this change across the full 18-month observation window with predicted **KDIS scores rising from 19.08 (95% CI 14.91 to 23.25) at month 1 to 27.18 (95% CI 21.55 to 32.81) at month 18, a gain of roughly 8 points on the 0–45 scale (Figure 1A; Table 3). A quadratic specification of time was preferred over linear and cubic alternatives based on likelihood ratio tests and AIC/BIC (Supplementary Table 1). In the quadratic model (Table 4), the linear month term was positive (β = 1.52, 95% CI 1.23 to 1.82, p < .001) and the quadratic term negative (β = −0.06, 95% CI −0.07 to −0.04, p < .001), indicating a 1.52-point monthly gain at the start of implementation that decelerated by 0.06 points each subsequent month. Observed quarterly means followed the same overall trajectory as predicted values, rising from 20.41 in quarter 1 to 28.98 in quarter 5 before modest attenuation by quarter 6. Full coefficient estimates and model fit statistics for all models reported below are in Supplementary Table 1.**

Item-level means showed that gains were concentrated in six of the nine drivers, with the largest changes from quarter 1 to quarter 6 in patient empowerment (1.93 to 3.32), clinical information systems (2.65 to 3.73), and leadership for QI (2.13 to 3.14). Three items showed minimal change: fiscal health (1.67 to 1.77), evidence-based guidelines (2.89 to 3.05), and experience of care (1.71 to 1.91); evidence-based guidelines began at a comparatively higher baseline, while fiscal health and experience of care began among the lowest.

Moderation by baseline screening performance

Modeled KDIS trajectories differed by baseline screening rates (Table 4; Figure 1B). Baseline screening interacted with both linear time (β = 0.96, 95% CI 0.35 to 1.56, p = .002**) and quadratic time (β = −0.06, 95% CI −0.08 to −0.03, p < .001). Predicted KDIS for high-baseline practices rose from 21.54 at month 1 to 31.19 at month 9 before declining to 28.21 by month 18 post-intervention; low-baseline practices rose more gradually, from 17.07 to 23.66 to 26.03 across the same time points.**

Moderation by organizational measures

Of the two measures of practice capacity for QI, the CPCQ Strategies scale was associated with differential KDIS trajectories (Table 4; Figure 1C), while the ARQ was not. The CPCQ × month² interaction was statistically significant (β = 0.04, 95% CI 0.02 to 0.07, p = .001); the linear interaction was not (month × CPCQ: β = −0.51, 95% CI −1.02 to 0.002, p = .051). Predicted KDIS for practices at 1 SD above the mean CPCQ score rose from 22.74 at month 1 to 29.79 at month 9 and 33.79 at month 18; practices at 1 SD below the mean rose from 18.27 to 26.46 before declining to 21.92 across the same time points. Predicted trajectories suggested slower early increases but continued later increases among practices with higher CPCQ, whereas lower-CPCQ practices showed earlier increases followed by lower predicted scores by month 18. Baseline ARQ was not associated with differential KDIS change over time (month × ARQ: β = 0.35, 95% CI −0.29 to 0.98, p = .284; month² × ARQ: β = 0.01, 95% CI −0.012 to 0.041, p = .293).

Organizational readiness for change did not moderate KDIS trajectories (Table 4). Neither ORIC Change Commitment (month × commitment: β = 0.10, 95% CI −0.54 to 0.73, p = .769; month² × commitment: β = 0.01, 95% CI −0.02 to 0.04, p = .474) nor ORIC Change Efficacy (month × efficacy: β = 0.12, 95% CI −0.52 to 0.75, p = .718; month² × efficacy: β = 0.01, 95% CI −0.02 to 0.04, p = .422) showed significant interactions with time.

Moderation by practice characteristics

Among contextual characteristics, MUA/P-designated practices showed steeper early increases in KDIS than non-designated practices, followed by stronger deceleration (linear β = 1.48, 95% CI 0.84 to 2.13, p < .001; quadratic β = −0.08, 95% CI −0.11 to −0.05, p < .001; Supplemental Table 1); predicted KDIS was higher among MUA/P practices across the observation window, with the difference widest near mid-facilitation and narrowing by month 18. PCMH-recognized practices did not differ in early slope but showed stronger later deceleration (quadratic β = −0.05, 95% CI −0.08 to −0.02, p = .002; linear interaction nonsignificant). Clinician-owned practices showed the opposite pattern from MUA/P practices, with slower early increases (linear β = −0.94, 95% CI −1.66 to −0.23, p = .010) that attenuated over time (quadratic β = 0.05, 95% CI 0.02 to 0.08, p = .001); solo practices did not differ from practices with two or more clinicians.

Joint model: baseline screening and CPCQ as competing moderators

In a model including both baseline screening performance and the CPCQ Strategies scale, baseline screening interactions remained statistically significant (month × high baseline: β = 0.91, 95% CI 0.08 to 1.74, p = .031; month² × high baseline: β = −0.05, 95% CI −0.08 to −0.02, p = .003), while the CPCQ × month² interaction weakened and no longer reached statistical significance (β = 0.03, 95% CI −0.001 to 0.05, p = .058). Moderator main effects reached significance in the joint model (high baseline: β = 9.15, 95% CI 0.20 to 18.11, p = .045; CPCQ: β = 6.15, 95% CI 0.22 to 12.08, p = .042) (Table 4; Figure 1D).

Discussion

We found that PF, when administered to small and medium-sized primary care practices, was associated with an increase in KDIS scores alongside previously reported gains in alcohol screening and counseling uptake in the parent study(11). This finding is consistent with the hypothesis that PF may support clinical change by strengthening the practice systems captured by KDIS (25, 32). That these associations were observed under conditions of pandemic disruption(34), with staffing shortages, COVID-related attrition, and shift to PF delivery by video conference, suggests that PF's organizational influence is detectable even when implementation conditions are substantially constrained.

By measuring KDIS repeatedly throughout implementation and sustainment, this study characterized the pace, shape, and variability of change in clinical practice and office systems as it unfolded, rather than inferring it from facilitator inputs or downstream clinical outcomes alone(35). Model-estimated KDIS development followed a nonlinear trajectory, with steep early gains across the intervention phase plateauing during the sustainment phase, coinciding with the end of the PF intervention. Item-level patterns specified where this change concentrated: the largest gains occurred in clinical information systems, QI leadership, and patient empowerment, the organizational domains most directly targeted by PF in STUN and most consistently identified as barriers to routine alcohol screening implementation in primary care(7–9). Domains

outside the scope of facilitation (fiscal health, experience of care) showed minimal change, suggesting that observed KDIS gains reflect targeted organizational development rather than a nonspecific facilitation effect.

Practices varied in how they responded to PF, with baseline screening rate providing the clearest signal. Practices already conducting substantial alcohol screening showed more rapid early increases in KDIS and reached higher predicted levels earlier, whereas practices beginning near zero showed slower but more sustained organizational development. CPCQ Strategies scores were also associated with KDIS trajectories in separate models, but this association attenuated after adjustment for baseline screening performance. These findings suggest overlap between self-reported QI capacity and observable prior implementation behavior, with baseline screening providing the stronger indicator of how practices responded to facilitation. In contrast, neither ORIC nor the abbreviated ARQ differentiated KDIS trajectories, suggesting that generalized readiness and adaptive reserve, as measured here, were less informative than indicators tied to existing implementation efforts.

These findings have implications for how PF is designed, monitored, and combined with other implementation strategies. Change concentrated in the drivers PF directly targeted in STUN, the practice-internal systems a clinic can reshape through workflow redesign, team processes, and QI activity, and was minimal in domains PF did not address, such as fiscal health and experience of care. The practical implication is not that these latter domains are immovable, but that PF as delivered here did not engage them (potentially due to their irrelevance to this alcohol screening and treatment in primary care), so improving them would require strategies operating on payment and system-level conditions rather than facilitation alone.(36) Prior PF and EHR implementation research has similarly noted that facilitators can help practices optimize workflows and use existing systems, while broader constraints related to EHR vendor capabilities, interoperability, reimbursement structures, and workforce capacity often remain outside the practice's direct control(37, 38). This points toward a division of labor: PF for the organizational drivers practices control, paired with complementary strategies for the conditions they do not.

Within the scope of PF itself, three practical implications follow. First, the early-period concentration of KDIS gains raises questions about optimal facilitation dose and duration(39); a uniform 12-month protocol may provide diminishing organizational returns for practices that plateau early while remaining insufficient for practices whose development continues beyond the active facilitation period. Trajectory shape, not endpoint performance, could inform decisions about when to intensify, sustain, or taper facilitation. Second, the differential trajectories associated with baseline screening performance and CPCQ scores suggest that baseline assessment of existing implementation performance and operational QI capacity may complement performance-based metrics in tailoring facilitation support(40). Third, repeated measurement offers practices and facilitators a means of monitoring organizational change directly during implementation rather than relying solely on downstream clinical indicators, which may lag or reflect influences beyond the facilitation itself(17).

Limitations

This study has several limitations. First, COVID-19 disruption forced adaptation from the planned adaptive RCT design to a single-arm design and analysis. As a result, observed changes in KDIS might not be causally

attributed to PF. Secular trends, regression to the mean, or other time-varying influences may explain the observed trajectories. Further, the pandemic made recruitment more difficult and contributed to attrition, resulting in a smaller analytic sample than originally planned. Second, PF is a complex multicomponent strategy, and this analysis cannot identify which specific PF activities were most strongly associated with change, limiting our ability to draw generalizable conclusions regarding PF. Third, findings derive from small and medium predominantly clinician-owned primary care practices in North Carolina and may not generalize to other settings or to PF programs of different intensity, duration, or delivery format. Fourth, the primary outcome, KDIS, was rated by the practice facilitator delivering the implementation strategy, creating conditions under which rater drift or metric-gaming could inflate estimated trajectories; however, the observed deceleration in trajectory is inconsistent with monotonic rater drift. Fifth, moderator measurement was constrained in ways that limit inference about practice-level characteristics. ORIC and ARQ were available for 15 practices, with clinic-level scores aggregated across 2–4 respondents and ORIC exhibiting marked ceiling effects, so null moderation findings for these measures cannot be distinguished from insufficient measurement resolution. CPCQ reflected a single practice manager respondent per clinic. Sixth, all 5 FQHCs in the sample were simultaneously high-baseline, MUA-designated, and non-clinician-owned, so MUA and clinician-ownership interactions cannot be interpreted independently of the baseline-screening contrast. PCMH recognition is the only contextual moderator distributed across baseline strata, and contextual findings should be considered hypothesis-generating. Finally, the complexity of the mixed-effects models, with random slopes and multiple interaction terms, relative to the analytic sample raises the possibility of overfitting, particularly in moderator analyses.

Implications for future research

Several lines of work follow directly from these findings. The most immediate is to test whether the clinical and organizational changes measured by KDIS help explain the gains in alcohol screening and counseling reported in the parent trial(11), rather than simply occurring alongside them; a formal mediation analysis would establish whether KDIS change statistically accounts for those clinical improvements. A complementary question is which features of PF, such as the activities used, how often practices were visited, and the working relationship between the facilitator and practice, are associated with the organizational changes observed here (17, 18). Finally, two design extensions would strengthen inference: independent (non-facilitator) measurement to address rater concerns, and stepped-wedge or matched-comparison designs that permit causal inference beyond what single-arm pre-post analysis allows.

Conclusion

In this 18-month longitudinal analysis, PF was associated with significant changes in clinical practice and office systems, with the steepest organizational development in the early months of facilitation and deceleration thereafter. A clinic's existing screening practices and, to a lesser extent, its self-reported capacity for QI were also found to condition how readily organizational change takes hold under PF. Read alongside the gains in screening and counseling reported in the parent trial(11), these results suggest that PF can strengthen the practice systems through which alcohol screening becomes expected, supported, and built into routine care, the organizational groundwork that plausibly underlies clinical change and that future analyses can test directly.

Abbreviations

AHRQ
Agency for Healthcare Research and Quality
AIC
Akaike information criterion
ANOVA
analysis of variance
ARQ
Adaptive Reserve Questionnaire
BIC
Bayesian information criterion
CI
confidence interval
COVID-19
coronavirus disease 2019
CPCQ
Change Process Capability Questionnaire
EHR
electronic health record
FQHC
federally qualified health center
IPP
implementation policies and practices
KDIS
Key Driver Implementation Scale
MUA/P
Medically Underserved Area/Population
NC AHEC
North Carolina Area Health Education Center
ORIC
Organizational Readiness for Implementing Change
PCMH
Patient-Centered Medical Home
PF
practice facilitation
QI
quality improvement
RCT
randomized controlled trial
SD
standard deviation

StaRI
Standards for Reporting Implementation Studies
STUN
STop UNhealthy alcohol use now.

Declarations

Ethics approval and consent to participate:

All procedures performed in studies involving human participants were in accordance with the ethical standards of the University of Chapel Hill Institutional Review Board and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Consent for publication:

Not applicable

Competing interests:

The authors declare that they have no competing interests.

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Author Contribution

DJ, SR CW, and SC conceived and designed the study. All authors contributed to the acquisition, analysis, or interpretation of data. SR drafted the manuscript, and DJ, LB, CB, DG, CW, AZ, SC, and DD critically revised it for important intellectual content. SR performed the statistical analysis. DJ and SC obtained funding. SR, DJ, LB, CB, DG, CW, AZ, SC, and DD provided administrative, technical, or material support. DJ and CW supervised the study. All authors read and approved the final manuscript.

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Data Availability

The data set supporting this analysis is available upon request by contacting the corresponding author.

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Tables

Table 1. Measures and Data Sources

Construct	Instrument	Scale (scoring)	Respondent (n)	n practices	Timepoint(s)
Adult panel size	Practice characteristics survey	Continuous	Practice manager (1)	21	Baseline (month 0)
Implementation policies and practices	KDIS(21)	9 items; 0–5 per item; sum score 0–45	Practice facilitator	21	Monthly (months 1–18)
Baseline screening rate	EHR-derived	Continuous (0–100%); dichotomized at ≥50% vs. <50% for analysis	EHR query	21	Pre-intervention (three months prior to baseline)
Organizational readiness: change commitment and change efficacy	ORIC(28)	12 items; 1–5; subscale means	Practice staff (2–4)	15	Baseline (month 0)
Practice capacity for QI: Change process capabilities	CPCQ(30)	14 items; 1–5; item mean	Practice manager (1)	18	Baseline (month 0)
Practice capacity for QI: Adaptive reserve	ARQ(29)	3 items; 1–5; item mean	Practice staff (2–4)	15	Baseline (month 0)

Abbreviations: ARQ=Adaptive Reserve Questionnaire; CPCQ=Change Process Capability Questionnaire; EHR=Electronic Health Record; KDIS=Key Driver Implementation Scale; ORIC=Organizational Readiness for Implementing Change; QI=quality improvement.

Table 2. Characteristics of Participating Practices (N = 21 Clinics)

Characteristic	Unweighted	Weighted
Clinic characteristics (n = 21 clinics)		
Practice size, n (%)		
Solo practice	3 (14.3)	NA
2–5 clinicians	14 (66.7)	NA
6–10 clinicians	3 (14.3)	NA
11–15 clinicians	1 (4.8)	NA
Ownership type, n (%)		
Clinician-owned	11 (52.4)	NA
Federally qualified health center	5 (23.8)	NA
Hospital-owned	2 (9.5)	NA
Unknown	3 (14.3)	NA
Specialty, n (%)		
Single specialty	18 (85.7)	NA
Multi-specialty	3 (14.3)	NA
Patient-Centered Medical Home, n (%)	12 (57.1)	NA
Medically Underserved Area/Population, n (%)	8 (38.1)	NA
Weekly patient volume, M (SD)	315.0 (432.8)	NA
Total patient volume, M (SD)	3386.2 (3418.0)	NA
Patient panel characteristics (mean clinic-level %)		
Age, %		
0–17 years	6.5 (7.2)	11.5 (7.8)
18–39 years	19.1 (6.4)	21.5 (5.0)
40–59 years	30.8 (9.7)	27.5 (6.7)
60–75 years	30.0 (10.5)	26.9 (8.5)
76+ years	13.7 (8.2)	13.0 (5.4)
Gender, %[a]		
Female	54.3 (4.8)	51.7 (5.1)
Male	39.0 (7.4)	37.7 (8.7)
Not described	10.4 (10.2)	19.0 (11.2)

Characteristic	Unweighted	Weighted
Gender fluid	0.2 (0.4)	0.2 (0.5)
Race, %		
White	54.4 (16.2)	52.0 (14.4)
Black or African American	37.8 (15.3)	40.1 (14.0)
Unknown	6.6 (4.9)	6.0 (3.6)
Other or multiple races	2.4 (3.3)	3.0 (3.5)
Asian	0.5 (0.7)	0.4 (0.5)
American Indian or Alaska Native	0.4 (0.7)	0.1 (0.3)
Native Hawaiian or Pacific Islander	0.3 (0.6)	0.1 (0.2)
Ethnicity, %		
Hispanic or Latino	7.5 (8.0)	7.0 (8.8)
Payer mix, %		
Private insurance	36.9 (14.7)	38.0 (13.8)
Medicare	33.5 (14.9)	34.2 (14.7)
Medicaid	15.7 (12.7)	16.2 (10.6)
Uninsured	7.4 (4.4)	7.6 (3.3)
Dual Medicare/Medicaid	6.4 (6.8)	4.0 (5.3)
Baseline implementation context		
CPCQ Strategies, M (SD)[b]	3.43 (0.77)	NA
ARQ, M (SD)[c]	4.17 (0.60)	NA
ORIC Change Commitment, M (SD)[c]	4.47 (0.57)	NA
ORIC Change Efficacy, M (SD)[c]	4.43 (0.58)	NA

Abbreviations: ARQ = Adaptive Reserve Questionnaire; CPCQ = Change Process Capability Questionnaire; M = mean; ORIC = Organizational Readiness for Implementing Change; SD = standard deviation.

Notes: Three clinics did not complete the baseline practice-characteristics survey and are reported as Unknown for clinic-level structural variables. For clinic-level categorical variables, the unweighted column reports n (%) of clinics; the patient-weighted column reports the percentage of adult patients in the sample served by clinics with each characteristic, weighted by adult panel size. For patient panel characteristics, the unweighted column reports the mean of clinic-level percentages (each clinic counted equally); the patient-weighted column reports the patient-level percentage, weighted by adult panel size. Cell n values for patient

panel characteristics differ from N = 21 because of variable item completion across clinics; see prior version of Table 2 in supplementary materials for cell-level n.

[a] Gender percentages may not sum to 100% because of differential EHR category coding and missingness across clinics.

[b] CPCQ Strategies subscale (14 items, scored 1–5), completed by one practice manager per clinic; n = 18 clinics. Patient-weighted estimate not reported because the instrument measures clinic-level capacity.

[c] ARQ (3-item adaptation, scored 1–5) and ORIC (12 items, two subscales scored 1–5) completed by 2–4 practice staff and aggregated to clinic-level means; n = 15 clinics. Patient-weighted estimates not reported because the instruments measure clinic-level constructs.

Table 3. Observed and Model-Estimated KDIS Scores by Quarter, with Item-Level Means

	Q1	Q2	Q3	Q4	Q5	Q6	Δ Q1→Q2	Δ Q1→Q4	Δ Q1→Q6
Clinic-month observations, n	55	48	55	37	40	22	—	—	—
Clinics contributing, n	21	20	19	18	16	8	—	—	—
KDIS									
Observed, M (SD)	**20.41 (9.28)**	**24.49 (9.89)**	**25.64 (9.38)**	**25.04 (9.63)**	**28.98 (8.59)**	**26.59 (8.72)**	**+4.08**	**+4.63**	**+6.18**
Predicted	**20.40**	**23.82**	**26.24**	**27.67**	**28.11**	**27.55**	**+3.42**	**+7.27**	**+7.15**
Item-level means, M (SD), each item scored 0–5									
Quality monitoring	2.40 (1.16)	2.90 (1.22)	3.02 (1.33)	2.95 (1.45)	3.50 (1.18)	3.18 (1.47)	+0.50	+0.55	+0.78
QI team composition	2.34 (0.86)	2.78 (0.84)	3.18 (0.92)	3.07 (0.93)	3.38 (0.70)	3.09 (0.68)	+0.44	+0.73	+0.75
Leadership for QI	2.13 (1.12)	2.56 (1.15)	2.75 (0.93)	3.03 (1.09)	3.12 (0.97)	3.14 (1.13)	+0.43	+0.90	+1.01
Clinical information systems	2.65 (1.22)	3.12 (1.08)	3.29 (0.94)	3.38 (0.92)	3.77 (0.83)	3.73 (0.94)	+0.47	+0.73	+1.08
Evidence-based guidelines	2.89 (1.49)	3.04 (1.38)	3.20 (1.24)	3.08 (1.23)	3.45 (1.06)	3.05 (1.21)	+0.15	+0.19	+0.16
Patient empowerment	1.93 (1.55)	2.73 (1.67)	2.91 (1.61)	2.73 (1.71)	3.35 (1.35)	3.32 (1.17)	+0.80	+0.80	+1.39
Patient-centered care team	2.69 (1.54)	2.88 (1.51)	3.05 (1.25)	3.22 (1.25)	3.52 (1.04)	3.41 (1.18)	+0.19	+0.53	+0.72
Experience of care	1.71 (1.44)	2.31 (1.55)	2.22 (1.52)	1.81 (1.60)	2.42 (1.72)	1.91 (1.82)	+0.60	+0.10	+0.20
Fiscal health	1.67 (1.39)	2.17 (1.65)	2.02 (1.81)	1.78 (1.75)	2.45 (1.72)	1.77 (1.60)	+0.50	+0.11	+0.10

Abbreviations: CI = confidence interval; KDIS = Key Driver Implementation Scale; M = mean; QI = quality improvement; SD = standard deviation.

Notes: KDIS is scored 0–45 (sum of 9 items, each rated 0–5). Items were completed monthly by the assigned practice facilitator. Quarterly values aggregate clinic-month observations within each three-month window. The Δ Q1→Q6 column reports the unadjusted difference in observed means between Q1 and Q6; sample size attenuates over time and the Q6 estimate is correspondingly less precise.

 Predicted estimates from the linear mixed-effects model with quadratic time and random intercepts and slopes; values shown are model-implied means at the midpoint month of each quarter (months 2, 5, 8, 11, 14, 17). See Supplementary Table 1 for full model coefficients.

Table 4. Multilevel Modeling Results

Model	n clinics	Month	Month²	Moderator main	Month × Moderator	Month² × Moderator
Trajectory (primary)	21	1.52***	−0.06***	—	—	—
Baseline screening (≥50%)	21	1.15***	−0.03***	3.58	0.96**	−0.06***
CPCQ Strategies	18	3.28***	−0.20***	3.37	−0.51	0.04**
ORIC Change Commitment	15	1.33	−0.11	−6.70	0.10	0.01
ORIC Change Efficacy	15	1.24	−0.11	−7.24	0.12	0.01
ARQ (baseline)	15	0.33	−0.13*	−1.97	0.35	0.01
Joint: baseline + CPCQ	18	1.89	−0.12**	screen 9.15*; CPCQ 6.15*	screen 0.91*; CPCQ −0.21	screen −0.05**; CPCQ 0.03

* p < .05 ** p < .01 *** p < .001

Abbreviations: ARQ = Adaptive Reserve Questionnaire; CPCQ = Change Process Capability Questionnaire; ORIC = Organizational Readiness for Implementing Change; screen = baseline screening rate;

Figures

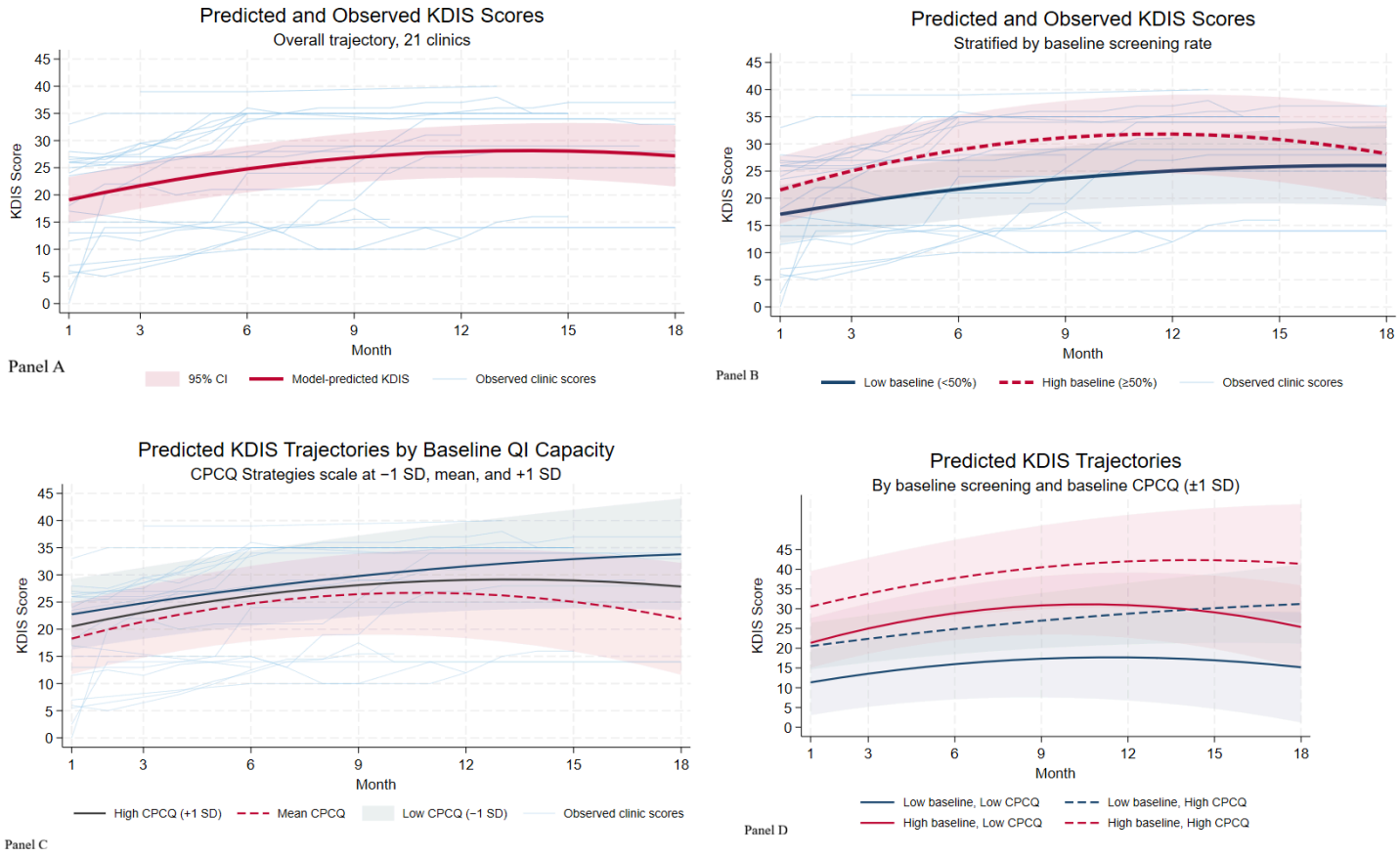


Figure 1

Panel A Predicted and Observed Implementation Policies and Practices

Panel B stratified by baseline screening

Panel C stratified by baseline practice capacity for QI (CPCQ)

Panel D Joint Analysis stratified by combined baseline screening and practice capacity for QI

Supplementary Files

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