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Effect of a Nurse-Led, Technology-Enabled Antenatal Care Programme (e-MACC) on Quality of Life and Maternal-Fetal Outcomes among Primigravid Women: A Randomized Controlled Trial with Mixed-Effects and Multivariable Analysis

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ABSTRACT:

Background: Pregnancy imposes profound physical, psychological, social and environmental demands on first-time mothers, and a substantial proportion of primigravid women report a measurable decline in health-related quality of life (QoL) across gestation. Nurse-led, technology-enabled antenatal programmes have been proposed as a scalable way to sustain engagement with antenatal advice between clinic visits, but rigorously designed trials that track QoL longitudinally alongside maternal and fetal outcomes remain scarce, particularly from India.

Objective: To evaluate the effect of a nurse-led, smartphone-delivered antenatal care programme (e-MACC) on the trajectory of quality of life and on maternal and fetal outcomes among primigravid women, and to identify independent predictors of postpartum quality of life.

Methods: A two-arm, parallel-group randomized controlled trial was conducted at Salem Polyclinic Hospital, Salem, Tamil Nadu, India (CTRI/2022/12/048086). One hundred sixty primigravid women at 12 weeks' gestation were randomized 1:1 to the e-MACC mobile application plus routine antenatal care (n = 80) or routine antenatal care alone (n = 80). Quality of life was assessed with the WHOQOL-BREF at baseline, second trimester, third trimester and one month postpartum. Maternal outcomes (labour pain, duration of labour, mode of delivery, oxytocin augmentation) and fetal outcomes (Apgar score, birth weight, birth injury) were recorded with a structured observation checklist. Data were re-analysed using mixed-design (group × time) analysis of variance, analysis of covariance, multivariable linear and logistic regression, and Pearson/Spearman correlation, with Hedges' g effect sizes and 95% confidence intervals throughout (Python 3.12; pandas, SciPy, statsmodels, pingouin).

Results: The two arms were comparable at baseline on education, occupation, income, source of information, antenatal visit frequency, marital duration and baseline clinical parameters (all $p > 0.13$), although the intervention group was on average younger (23.3 ± 2.6 vs 25.6 ± 4.2 years, $p < 0.001$), which was retained as a covariate in adjusted models. Overall quality of life rose steadily in the intervention arm (baseline 43.9 ± 3.6 to postpartum 68.5 ± 15.3) while remaining flat in the control arm (43.8 ± 4.3 to 44.2 ± 4.5). A mixed-design ANOVA showed a large group × time interaction ($F = 145.4$, $p < 0.001$, partial $\eta^2 = 0.48$), consistent across all four WHOQOL-BREF domains (partial η^2 0.30–0.38). After adjusting for baseline score, the intervention effect on postpartum overall QoL remained large (ANCOVA $F = 197.4$, $p < 0.001$, partial $\eta^2 = 0.56$; Hedges' $g = 2.15$, 95% CI 1.76–2.53). A multivariable model explained 60% of the variance in postpartum QoL ($R^2 = 0.60$), with group assignment ($\beta = 23.9$, $p < 0.001$) and 5–6 antenatal visits ($\beta = 5.3$, $p = 0.002$) as independent predictors. The intervention group reported less labour pain (3.5 ± 0.8 vs 4.6 ± 0.8 on a 0–10 scale, $g = 1.27$), shorter labour (8.0 ± 0.8 vs 9.2 ± 0.9 hours, $g = 1.41$) and higher one-minute Apgar scores (9.0 ± 0.8 vs 8.6 ± 1.0, $g = 0.51$), all $p \leq 0.001$. Birth weight, mode of delivery, oxytocin augmentation and birth injury did not differ significantly between arms. The magnitude of QoL gain correlated with less labour pain ($r = -0.53$), shorter labour ($r = -0.47$) and higher Apgar scores ($r = 0.29$; all $p < 0.001$).

Conclusion: A nurse-led, app-based antenatal care programme was associated with a substantially better quality-of-life trajectory across pregnancy and the early postpartum period, with parallel improvements in labour pain, labour duration and neonatal condition at birth, but no measurable effect on birth weight or mode of delivery. These findings support the integration of structured, nurse-supervised mobile health support into routine antenatal care for first-time mothers, while underlining the need for multicentre trials with stratified randomization to confirm generalisability.

1. INTRODUCTION

Pregnancy is a transitional life stage in which physiological adaptation, role change and anticipatory anxiety about labour and the newborn combine to place first-time (primigravid) mothers at particular risk of reduced health-related quality of life (QoL).[1–3] Cross-sectional work using the World Health Organization Quality of Life-BREF (WHOQOL-BREF) instrument has repeatedly shown that the physical and psychological domains are the most vulnerable during pregnancy, while social and environmental domains are comparatively preserved, and that QoL is patterned by parity, trimester, obstetric morbidity and socio-economic circumstances.[1,2,4] Because WHOQOL-BREF captures a woman's own appraisal of her physical, psychological, social and environmental well-being rather than a single biomedical marker, it is well placed to detect the cumulative benefit of a supportive antenatal intervention that biomedical checklists alone would miss.

Mobile health (mHealth) technologies have moved from a peripheral add-on to a mainstream component of maternal healthcare delivery over the past decade, driven by near-universal smartphone penetration even in low- and middle-income settings.[5,6,14] Systematic and scoping reviews of digital antenatal interventions describe consistent gains in health knowledge, appointment attendance and satisfaction, alongside more heterogeneous effects on hard clinical endpoints, and specifically call for adequately powered trials that combine patient-reported outcomes with maternal and neonatal endpoints rather than reporting either in isolation.[7–9] In India, mHealth evaluations have mostly targeted antenatal-visit uptake and health-worker-mediated messaging in resource-constrained states, with comparatively little trial evidence on nurse-supervised, self-administered applications aimed directly at the pregnant woman herself.[9] Trials of app-based self-management in other obstetric contexts – for example pregnancy-related urinary incontinence – have shown that a well-designed application can simultaneously improve a specific clinical symptom and general quality of life, reinforcing the plausibility of a similar dual benefit for a broader antenatal-support application.[5,6]

Independently of digital-health research, a distinct body of evidence on nurse- and midwife-led continuity of care demonstrates that sustained, personalised professional contact throughout pregnancy and labour reduces labour pain, shortens labour and increases the likelihood of spontaneous vaginal birth, without adverse effects on the neonate.[11–13] The nurse-led, technology-enabled antenatal care model evaluated in this trial (e-MACC) sits at the intersection of these two literatures: a nurse-initiated smartphone application intended to extend antenatal counselling, danger-sign education and reassurance into the interval between clinic visits, monitored centrally by the nursing team and reinforced through a help-desk and reminder system.

Despite the conceptual promise of combining nurse-led continuity with mobile reinforcement, no trial identified in the literature has simultaneously modelled the quality-of-life trajectory across all three trimesters and the early postpartum period using a repeated-measures design and linked this trajectory statistically to maternal labour outcomes and fetal condition at birth within the same cohort. Most published evaluations report either a single post-intervention QoL score or dichotomous obstetric endpoints, but rarely both, and rarely with the multivariable adjustment needed to separate the contribution of the intervention from that of concurrent antenatal attendance, maternal age or educational attainment.

This paper re-analyses data from a randomized controlled trial of the e-MACC programme among primigravid women attending a tertiary obstetric hospital in Salem, Tamil Nadu, with three aims: (1) to characterise the trajectory of overall and domain-specific quality of life across pregnancy and the early postpartum period in the intervention and control arms using a mixed-design (group × time) framework; (2) to quantify the intervention's effect on maternal and fetal outcomes and to test whether quality-of-life gain is statistically associated with these outcomes; and (3) to identify, through multivariable regression, the independent predictors of postpartum quality of life and of spontaneous vaginal delivery. We hypothesised that women receiving the e-MACC intervention would show a significantly steeper improvement in quality of life than controls, that this improvement would be associated with more favourable labour and neonatal outcomes, and that the intervention effect would persist after adjustment for baseline quality of life, maternal age and antenatal-visit frequency.

2. METHODS

2.1 Study design and setting

This was a two-arm, parallel-group, randomized controlled trial with a 1:1 allocation ratio, conducted in the antenatal outpatient department of Salem Polyclinic Hospital, Salem, Tamil Nadu, India, between April 2023 and September 2024, following a pilot phase (April–September 2023) in the same clinic. The trial was prospectively registered with the Clinical Trials Registry – India (CTRI/2022/12/048086) and approved by the Institute Ethics Committee, Salem Polyclinic Hospital (IEC/2022/July/01/01). The trial is reported in line with the CONSORT statement for parallel-group randomized trials.

2.2 Participants

Eligible participants were primigravid women who had completed 12 weeks of gestation, were literate enough to interact with a smartphone application, and provided written informed consent. Women with a known high-risk pregnancy, multiple gestation, pre-existing psychiatric illness, or without access to a compatible smartphone were not enrolled. Recruitment proceeded at a rate of approximately 20 women per day (10 per arm) until the target of 160 participants (80 per arm) was reached, matching the sample originally calculated from the pilot study's effect-size estimate for the primary quality-of-life outcome.

2.3 Randomization and allocation concealment

Allocation used a simple random sampling procedure. Group assignment was concealed in sequentially numbered, opaque envelopes bearing the e-MACC logo only on the intervention allocation; envelopes were opened by the investigator only after a woman had consented and completed baseline assessment, and the logo sticker was then affixed to the intervention group's case sheet as an allocation record. Because the intervention required active use of a smartphone application, participants and the nurse investigator could not be blinded to allocation; outcome assessment of Apgar score, birth weight and mode of delivery, however, was performed by attending obstetric staff who were not informed of the study hypothesis.

2.4 Intervention and comparator

Women allocated to the intervention arm had the e-MACC (electronic Mother and Child Care) mobile application installed on their personal smartphone by the investigator, with registration under their name and e-mail address. The application delivered trimester-specific antenatal education (danger signs, diet, exercise, immunisation, medication safety, travel, clothing and sexual health advice) through pictorial and short-video content, generated automated push reminders for antenatal visits, vaccination and medication, and provided an in-app help-desk for queries; usage was monitored centrally by the nursing team, with weekly WhatsApp-based follow-up to reinforce engagement. Women allocated to the control arm received routine antenatal care only, consisting of standard clinic counselling and follow-up without the application; for beneficence, the app's educational content was made available to control-arm participants after their third-trimester assessment, once outcome data collection for the comparative analysis was complete.

2.5 Outcome measures

The primary outcome was health-related quality of life, measured with the WHOQOL-BREF, a 26-item self-administered instrument yielding four domain scores (physical health, 7 items; psychological, 6 items; social relationships, 3 items; environment, 8 items) plus two general items, each domain transformed to a 0–100 scale following the WHO scoring algorithm; higher scores indicate better quality of life.[4] The instrument's content validity was established by an expert panel (psychiatry, clinical psychology, nursing, physiotherapy, biostatistics and web design) and its internal consistency in this cohort was previously reported as Cronbach's $\alpha = 0.86$. Quality of life was assessed at four time points: baseline (12 weeks' gestation, before intervention), second trimester, third trimester, and one month postpartum. Secondary outcomes – labour pain (0–10 numerical pain rating scale), duration of labour (hours), mode of delivery, oxytocin augmentation, Apgar score at one minute, birth weight and birth injury – were recorded using a structured observation checklist and partograph review by the attending obstetric team at the time of delivery.

2.6 Follow-up and attrition

One participant in the intervention arm and two in the control arm were lost to follow-up after relocating to their parental home for delivery; consistent with the trial's pre-specified protocol for early-stage replacement, these women were replaced with newly enrolled, eligible participants so that the analysed sample retained 80 women per arm (160 in total). Because replacement occurred before any intervention-specific data had accrued for the withdrawn participants, we treat the analysed cohort as the effective per-protocol sample for this re-analysis and note the loss transparently in the participant flow diagram (Figure 1).

2.7 Statistical analysis

Data were re-analysed independently of the original thesis analysis to allow more granular modelling of the repeated-measures structure. Continuous variables are summarised as mean ± standard deviation and compared between arms with independent-samples t-tests; categorical variables are summarised as frequency (%) and compared with Pearson's chi-square test. The trajectory of overall and domain-specific WHOQOL-BREF scores across the four time points was modelled with a mixed-design (2 group × 4 time) analysis of variance, with Greenhouse-Geisser correction reported where sphericity was violated, and partial eta-squared (η^2p) as the effect-size measure. Analysis of covariance (ANCOVA), adjusting postpartum score for the corresponding baseline score, provided a covariate-adjusted estimate of the intervention effect for the overall score and each domain. Between-group differences at each time point were quantified with Hedges' g and its 95% confidence interval, computed with a small-sample correction to the pooled-variance Cohen's d. A multivariable linear regression model estimated independent predictors of postpartum overall quality of life, entering group assignment, baseline quality of life, maternal age, educational attainment and antenatal-visit frequency simultaneously. Pearson and Spearman correlations related the magnitude of quality-of-life change (postpartum minus baseline) to labour pain, labour duration, Apgar score and birth weight. A multivariable logistic regression modelled the odds of spontaneous (versus assisted) vaginal delivery as a function of group assignment, baseline quality of life, maternal age and antenatal-visit frequency; baseline rather than postpartum quality of life was used as the covariate in this model to avoid conditioning on a variable that lies on the causal pathway between the intervention and the delivery outcome. A two-sided p-value below 0.05 was considered statistically significant throughout. All analyses were performed in Python 3.12 using pandas, SciPy, statsmodels and pingouin.

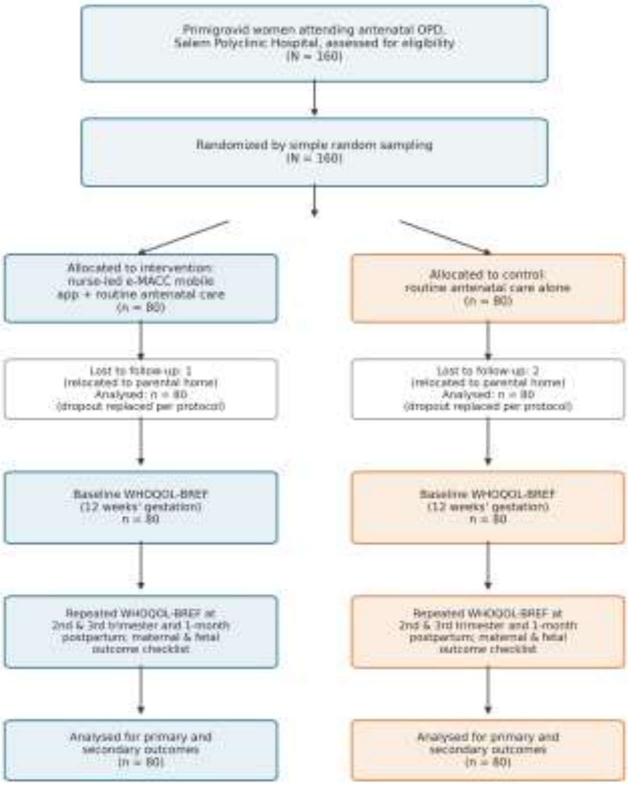

Figure 1. CONSORT participant flow diagram.

3. RESULTS

3.1 Participant flow and baseline comparability

Of 160 women randomized, 80 were allocated to the e-MACC intervention arm and 80 to the routine-care control arm; three women who withdrew after relocation were replaced per protocol, and all 160 women contributed complete data to this analysis (Figure 1). The two arms were statistically comparable on baseline education, occupation, monthly family income, source of antenatal information, number of antenatal visits, duration of marital life and baseline clinical parameters (haemoglobin, systolic and diastolic blood pressure, weight; all $p \geq 0.13$; Table 1). The intervention arm was, however, significantly younger on average than the control arm (23.3 ± 2.6 vs 25.6 ± 4.2 years; $t = -4.23$, $p < 0.001$) and the two arms differed in age-band distribution ($\chi^2 = 22.3$, $p < 0.001$); maternal age was therefore retained as a covariate in all adjusted (ANCOVA, regression) models reported below.

Table 1. Baseline demographic and clinical comparability between study arms (N = 160).

Characteristic	Intervention (n=80)	Control (n=80)	Test statistic	p-value
Age, years (mean ± SD)	23.3 ± 2.6	25.6 ± 4.2	t = -4.23	<0.001**
Age group 18-22 / 23-25 / 26-29 / 30-32 yrs (%)	38.8 / 40.0 / 21.3 / 0	22.5 / 25.0 / 36.3 / 16.3	$\chi^2 = 22.3$	<0.001**
Education: secondary / diploma / undergraduate / postgraduate (%)	25.0 / 7.5 / 53.8 / 13.8	25.0 / 2.5 / 61.3 / 11.3	$\chi^2 = 2.6$	0.459
Occupation: homemaker (%)	95.0	95.0	$\chi^2 = 0.0$	1.000

Characteristic	Intervention (n=80)	Control (n=80)	Test statistic	p-value
Monthly family income <10k / 10-30k / 30-50k INR (%)	21.3 / 32.5 / 46.3	23.8 / 37.5 / 38.8	$\chi^2 = 0.93$	0.629
Source of information: health professional (%)	63.8	56.3	$\chi^2 = 0.65$	0.420
Antenatal visits: 1-2 / 3-4 / 5-6 (%)	22.5 / 36.3 / 41.3	27.5 / 32.5 / 40.0	$\chi^2 = 0.58$	0.749
Duration of marital life 0-1 / 1-2 / >2 yrs (%)	60.0 / 22.5 / 17.5	71.3 / 12.5 / 16.3	$\chi^2 = 3.09$	0.213
Haemoglobin, g/dL (mean ± SD)	10.71 ± 1.10	10.90 ± 1.18	t = -1.04	0.299
Systolic BP, mmHg (mean ± SD)	110.1 ± 5.4	110.9 ± 5.1	t = -0.97	0.335
Diastolic BP, mmHg (mean ± SD)	68.6 ± 4.7	69.7 ± 4.6	t = -1.49	0.136
Weight, kg (mean ± SD)	58.5 ± 12.2	59.4 ± 13.9	t = -0.42	0.674

*Note: ** $p < 0.001$. Age differed significantly between arms and was retained as a covariate in adjusted analyses; all other baseline characteristics were statistically comparable.*

3.2 Trajectory of quality of life

Overall WHOQOL-BREF scores were near-identical between arms at baseline (intervention 43.9 ± 3.6 vs control 43.8 ± 4.3) and diverged progressively thereafter (Table 2, Figure 2). By one month postpartum, the intervention arm's overall score had risen to 68.5 ± 15.3 while the control arm remained essentially unchanged at 44.2 ± 4.5. A mixed-design ANOVA confirmed a very large group × time interaction for overall quality of life ($F(3,474) = 145.4$, $p < 0.001$, $\eta^2p = 0.48$), in addition to significant main effects of group ($F(1,158) = 152.7$, $p < 0.001$, $\eta^2p = 0.49$) and time (Greenhouse-Geisser corrected $p < 0.001$, $\eta^2p = 0.50$). The same pattern of large group × time interactions was observed for every WHOQOL-BREF domain (Table 3, Figure 3): physical health ($F = 96.3$, $p < 0.001$, $\eta^2p = 0.38$), psychological ($F = 75.6$, $p < 0.001$, $\eta^2p = 0.32$), social relationships ($F = 81.8$, $p < 0.001$, $\eta^2p = 0.34$) and environmental ($F = 68.7$, $p < 0.001$, $\eta^2p = 0.30$). The social relationships domain showed the largest absolute gain in the intervention arm (45.3 to 78.2, +32.9 points), while the environmental domain showed the smallest (43.1 to 64.1, +21.0 points).

Table 2. WHOQOL-BREF domain and overall scores (mean ± SD, 0-100 scale) by study arm and time point.

Time point	Arm	Physical	Psychological	Social	Environmental	Overall
Baseline (12 wks)	Intervention	42.70 ± 5.07	44.40 ± 7.10	45.31 ± 8.48	43.12 ± 6.65	43.88 ± 3.60
Baseline (12 wks)	Control	42.54 ± 4.59	43.30 ± 7.47	45.59 ± 10.77	43.64 ± 8.04	43.77 ± 4.29
2nd trimester	Intervention	52.41 ± 9.85	54.41 ± 7.13	59.01 ± 12.32	57.40 ± 12.10	56.32 ± 7.70
2nd trimester	Control	42.69 ± 4.83	43.38 ± 7.45	45.91 ± 10.52	43.79 ± 7.99	43.94 ± 4.35

Time point	Arm	Physical	Psychological	Social	Environmental	Overall
3rd trimester	Intervention	62.39 ± 13.11	61.20 ± 14.52	64.78 ± 19.09	61.06 ± 17.03	62.36 ± 13.80
3rd trimester	Control	42.84 ± 4.96	43.45 ± 7.55	46.22 ± 10.40	43.79 ± 7.99	44.08 ± 4.41
Postpartum (1 mo)	Intervention	65.56 ± 14.38	66.09 ± 15.22	78.19 ± 21.23	64.06 ± 17.59	68.47 ± 15.31
Postpartum (1 mo)	Control	42.99 ± 5.09	43.45 ± 7.48	46.38 ± 10.41	43.86 ± 8.02	44.17 ± 4.45

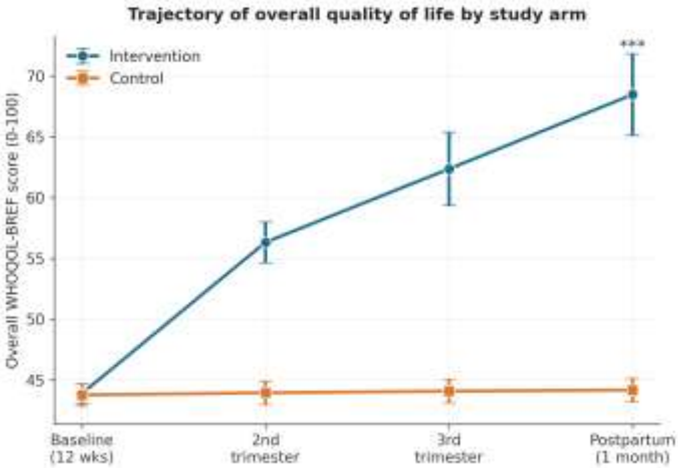

Figure 2. Trajectory of overall WHOQOL-BREF score by study arm across four assessment points, with 95% confidence intervals. *** p < 0.001 (postpartum between-group comparison).

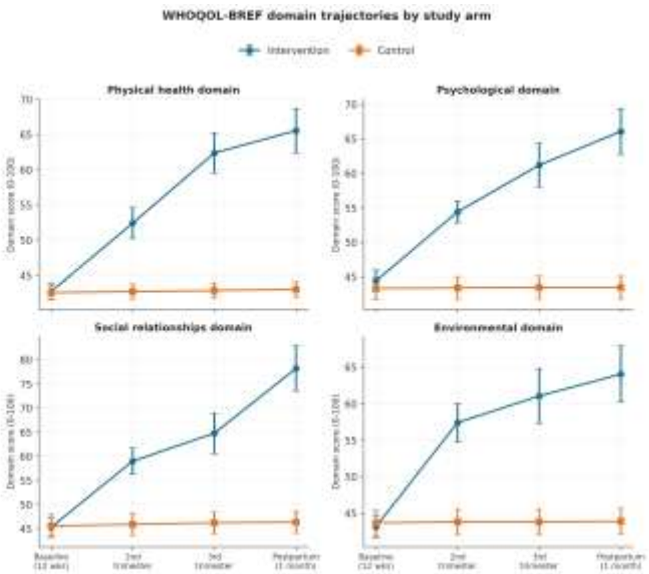

Figure 3. WHOQOL-BREF domain-wise trajectories by study arm.

Table 3. Mixed-design (2 group × 4 time) analysis of variance for overall and domain-specific quality of life.

Outcome	Source	F	p-value	Partial η²
Overall QoL	Group	152.66	<0.001	0.491
	Time (GG-corrected)	155.34	<0.001	0.496
	Group × Time	145.36	<0.001	0.479
Physical health	Group × Time	96.31	<0.001	0.379
Psychological	Group × Time	75.59	<0.001	0.324
Social relationships	Group × Time	81.77	<0.001	0.341
Environmental	Group × Time	68.71	<0.001	0.303

3.3 Adjusted (ANCOVA) and effect-size analysis

At the postpartum assessment, between-group effect sizes were very large for overall quality of life (Hedges' g = 2.15, 95% CI 1.76–2.53) and for every domain (physical g = 2.08, psychological g = 1.88, social g = 1.89, environmental g = 1.47; all $p < 10^{-16}$; Table 4, Figure 4). After covariate adjustment for baseline score, the ANCOVA-estimated intervention effect on postpartum overall quality of life remained large ($F(1,157) = 197.4$, $p < 0.001$, $\eta^2p = 0.56$), with a smaller but still significant contribution of baseline score itself ($F = 11.9$, $p = 0.0007$, $\eta^2p = 0.07$; Table 5). Domain-level ANCOVA results followed the same pattern, confirming that the crude between-group differences were not attributable to chance imbalance in baseline scores.

Table 4. Between-group effect sizes at the postpartum assessment (Hedges' g with 95% CI).

Domain	Intervention (mean ± SD)	Control (mean ± SD)	Hedges' g (95% CI)	p-value
Overall QoL	68.48 ± 15.31	44.17 ± 4.45	2.15 (1.76, 2.53)	<0.001
Physical health	65.56 ± 14.38	42.99 ± 5.09	2.08 (1.70, 2.47)	<0.001
Psychological	66.09 ± 15.22	43.45 ± 7.48	1.88 (1.52, 2.25)	<0.001
Social relationships	78.19 ± 21.23	46.38 ± 10.41	1.89 (1.52, 2.27)	<0.001
Environmental	64.06 ± 17.59	43.86 ± 8.02	1.47 (1.13, 1.82)	<0.001

Table 5. Analysis of covariance (ANCOVA) for postpartum overall quality of life, adjusted for baseline score.

Source	Sum of squares	df	F	p-value	Partial η²
Group	23452.50	1	197.40	<0.001	0.557
Baseline QoL (covariate)	1413.82	1	11.90	0.0007	0.070
Residual	18652.60	157	—	—	—

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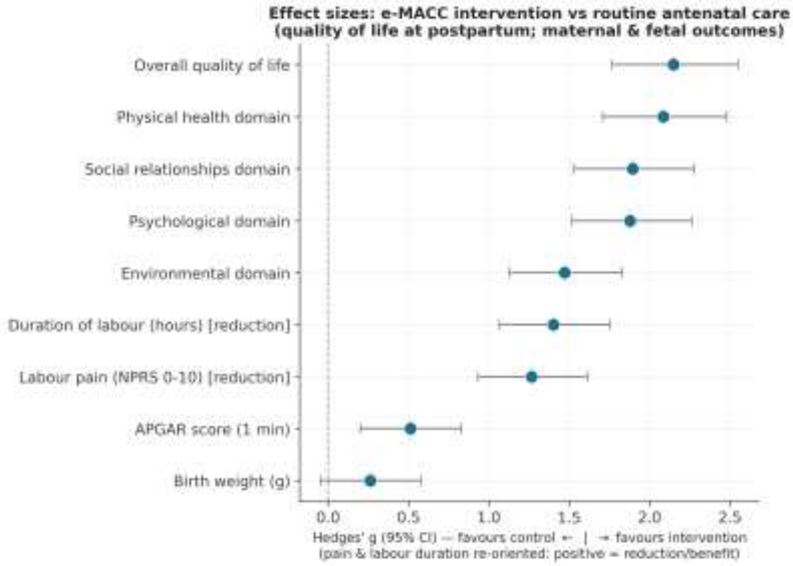

Figure 4. Forest plot of Hedges' g effect sizes (95% CI) for postpartum quality-of-life domains and maternal/fetal outcomes. Labour pain and labour duration are re-oriented so that a positive value denotes benefit (reduction).

3.4 Predictors of postpartum quality of life

In the multivariable linear regression predicting postpartum overall quality of life ($R^2 = 0.600$, adjusted $R^2 = 0.587$; $F(5,154) = 46.1$, $p < 0.001$; Table 6), group assignment to the e-MACC intervention remained the strongest independent predictor ($\beta = 23.9$, 95% CI 20.4–27.4, $p < 0.001$) after adjustment for baseline quality of life ($\beta = 0.77$, $p = 0.001$), maternal age ($\beta = -0.09$, $p = 0.71$, not significant), graduate-or-higher education ($\beta = -0.41$, $p = 0.83$, not significant) and attending 5–6 antenatal visits ($\beta = 5.3$, 95% CI 1.9–8.7, $p = 0.002$). Maternal age and educational attainment therefore did not independently predict postpartum quality of life once group and antenatal-visit frequency were accounted for.

Table 6. Multivariable linear regression predicting postpartum overall quality of life ($R^2 = 0.600$).

Predictor	B (95% CI)	Standard error	t	p-value
Intercept	11.11 (-13.00, 35.21)	12.20	0.91	0.364
Group (intervention vs control)	23.91 (20.40, 27.43)	1.78	13.44	<0.001
Baseline overall QoL	0.77 (0.34, 1.20)	0.22	3.55	0.001
Maternal age (years)	-0.09 (-0.59, 0.40)	0.25	-0.37	0.711
Graduate or higher education	-0.41 (-4.07, 3.25)	1.85	-0.22	0.826
5-6 antenatal visits	5.33 (1.91, 8.75)	1.73	3.08	0.002

3.5 Change in quality-of-life category

The proportion of women classified as having "good" overall quality of life (WHOQOL-BREF ≥ 61 on the transformed 0-100 scale, following the categorisation used in the source study) rose from 0% at baseline to 56.3% at one month postpartum in the intervention arm, while no control-arm participant reached the "good" category at any assessment point (Figure 5); a small minority of control-arm women (1.25%) remained in the "poor" category throughout, whereas no intervention-arm participant was ever categorised as "poor" beyond baseline.

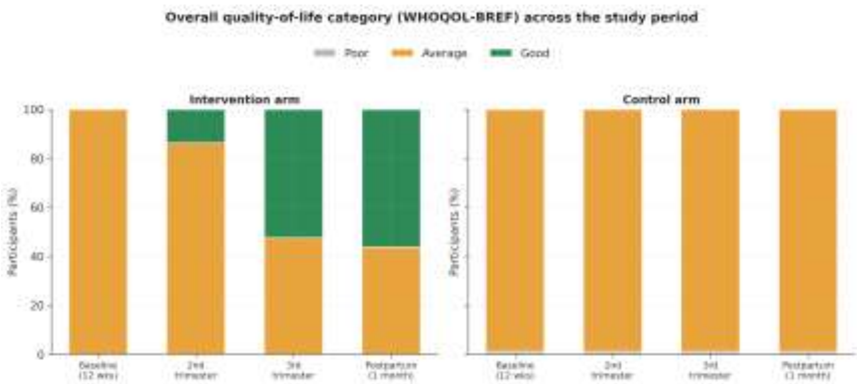

Figure 5. Distribution of overall quality-of-life category (poor / average / good) across the study period, by arm.

3.6 Maternal and fetal outcomes

Maternal outcomes differed substantially by arm (Table 7, Figure 6). Labour pain was lower in the intervention arm (3.5 ± 0.8 vs 4.6 ± 0.8 on a 0–10 scale; $t = -8.04$, $p < 0.001$; Mann-Whitney $p < 0.001$; Hedges' $g = 1.27$ in favour of the intervention), and labour duration was shorter (8.0 ± 0.8 vs 9.2 ± 0.9 hours; $t = -8.90$, $p < 0.001$; $g = 1.41$). Mode of delivery did not differ significantly between arms (spontaneous vaginal delivery in 90.0% of the intervention arm vs 87.5% of the control arm; $\chi^2 = 0.06$, $p = 0.80$), nor did the likelihood of oxytocin augmentation ($\chi^2 = 1.56$, $p = 0.21$). For fetal outcomes, one-minute Apgar scores were higher in the intervention arm (9.0 ± 0.8 vs 8.6 ± 1.0; $t = 3.25$, $p = 0.001$; $g = 0.51$), while birth weight showed a non-significant trend favouring the intervention arm (3013.8 ± 263.0 g vs 2934.9 ± 328.2 g; $t = 1.68$, $p = 0.095$; $g = 0.27$). No birth injury was recorded in either arm (0/80 in each group).

Table 7. Maternal and fetal outcomes by study arm.

Outcome	Intervention (n=80)	Control (n=80)	Test statistic	p-value	Hedges' g / effect
Labour pain, 0-10 NPRS (mean ± SD)	3.50 ± 0.81	4.55 ± 0.84	t = -8.04	<0.001	g = 1.27
Duration of labour, hours (mean ± SD)	8.00 ± 0.78	9.20 ± 0.92	t = -8.90	<0.001	g = 1.41
Apgar score at 1 min (mean ± SD)	9.03 ± 0.83	8.56 ± 0.97	t = 3.26	0.001	g = 0.51
Birth weight, g (mean ± SD)	3013.75 ± 263.0	2934.88 ± 328.2	t = 1.68	0.095	g = 0.27
Spontaneous vaginal delivery, %	90.0	87.5	$\chi^2 = 0.06$	0.802	—
Oxytocin augmentation (more likely), %	7.5	15.0	$\chi^2 = 1.56$	0.211	—
Birth injury, %	0	0	—	—	—

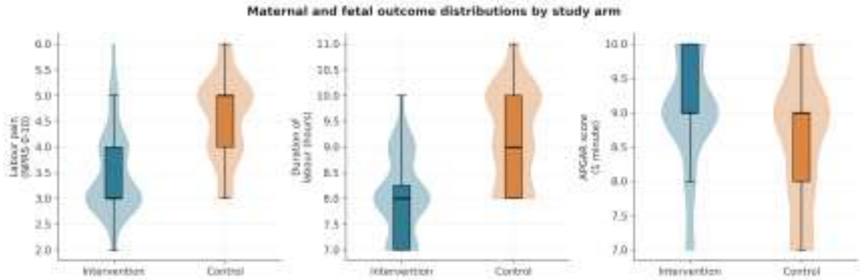

Figure 6. Distribution of labour pain, duration of labour and Apgar score by study arm.

3.7 Correlation between quality-of-life gain and outcomes

The magnitude of quality-of-life gain (postpartum minus baseline overall score) correlated significantly with all four maternal/fetal measures examined (Table 8, Figures 7–8): more negatively with labour pain (Pearson $r = -0.53$, $p < 0.001$; Spearman $\varrho = -0.58$, $p < 0.001$) and labour duration ($r = -0.47$, $p < 0.001$), and positively with Apgar score ($r = 0.29$, $p < 0.001$) and birth weight ($r = 0.22$, $p = 0.005$). These associations held across both arms combined and are consistent with, though not proof of, a mechanistic link between improved antenatal well-being and a more favourable intrapartum course.

Table 8. Correlation between change in overall quality of life (postpartum minus baseline) and maternal/fetal outcomes.

Outcome	Pearson's r	p-value	Spearman's ϱ	p-value
Labour pain	-0.53	<0.001	-0.58	<0.001
Duration of labour	-0.47	<0.001	-0.52	<0.001
Apgar score	0.29	<0.001	0.30	<0.001
Birth weight	0.22	0.005	0.23	0.003

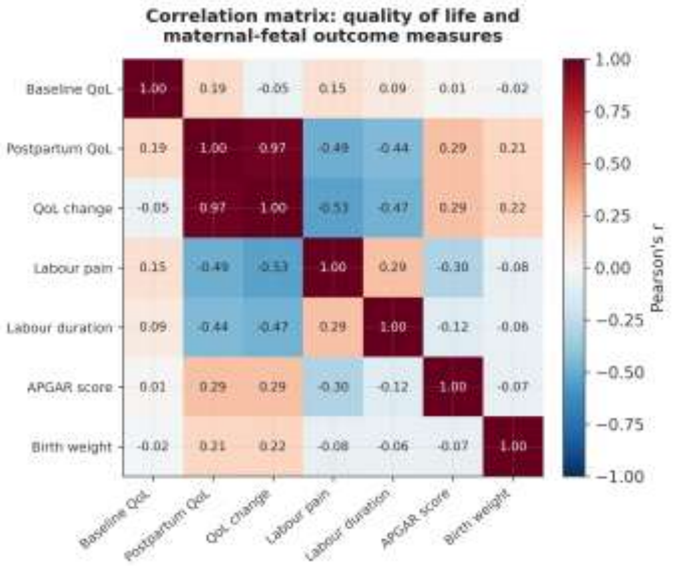

Figure 7. Correlation matrix of quality-of-life measures and maternal/fetal outcome variables (Pearson's r).

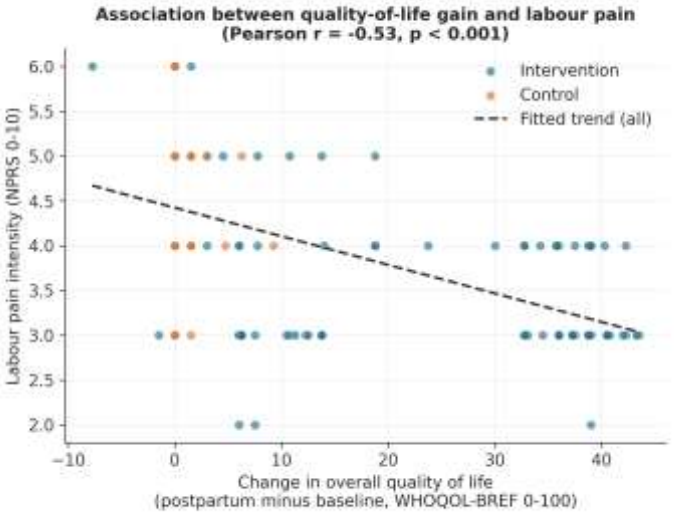

Figure 8. Association between change in overall quality of life and labour pain intensity, by study arm.

3.8 Predictors of spontaneous vaginal delivery

A multivariable logistic regression modelling spontaneous (versus assisted) vaginal delivery as a function of group assignment, baseline quality of life, maternal age and antenatal-visit frequency showed no statistically significant predictor (model $\chi^2 = 2.1$, $p = 0.89$, pseudo-$R^2 = 0.01$; Table 9), corroborating the null univariate finding for mode of delivery and indicating that, in this cohort, the intervention's benefit was concentrated in subjective well-being, labour pain, labour duration and neonatal condition rather than in the likelihood of operative or assisted birth.

Table 9. Multivariable logistic regression predicting spontaneous (vs assisted) vaginal delivery.

Predictor	Odds ratio (95% CI)	p-value
Group (intervention vs control)	1.48 (0.53, 4.13)	0.455
Baseline overall QoL	1.02 (0.90, 1.15)	0.808
Maternal age (years)	1.07 (0.92, 1.24)	0.367
5-6 antenatal visits	1.13 (0.41, 3.12)	0.806

4. DISCUSSION

In this randomized controlled trial, a nurse-led, smartphone-delivered antenatal care programme produced a quality-of-life trajectory that diverged sharply and progressively from routine care across pregnancy and into the early postpartum period, with effect sizes (Hedges' g approximately 1.5–2.2 across domains) that are considerably larger than those typically reported for single-symptom mHealth interventions such as app-based management of pregnancy-related urinary incontinence, where quality-of-life effects, while statistically significant, are more modest.[5,6] A plausible explanation is that e-MACC, unlike a narrowly targeted symptom-management application, addressed the breadth of the WHOQOL-BREF construct directly – checkups, diet, exercise, immunisation, medication, warning signs and reassurance – combined with active nurse monitoring and a responsive help-desk, which together may have supported not only knowledge but also a sense of continuity and psychological security through pregnancy. This interpretation is consistent with reviews of digital antenatal interventions describing the largest and most consistent benefits where the technology functioned as a supplement to, rather than a substitute for, personal nurse or midwife contact.[7–9,14]

The parallel improvement in labour pain, labour duration and one-minute Apgar score in the intervention arm mirrors findings from the nurse- and midwife-led continuity-of-care literature, where sustained professional support through pregnancy and labour has been linked to shorter labour, less pain and better neonatal condition without an increase in operative delivery.[11–13] The absence of a significant effect on mode of delivery or birth weight in the present cohort is therefore biologically plausible rather than a contradictory finding: antenatal education and reassurance would be expected to influence a labouring woman's coping, anxiety and possibly uterine efficiency, but has less obvious mechanistic pathway to altering birth weight, which is determined predominantly by maternal nutrition, placental function and gestational duration over a much longer time frame than a single trimester of app-based support. The moderate positive correlation between quality-of-life gain and Apgar score, and the moderate negative correlations with labour pain and labour duration, are consistent with a model in which improved antenatal psychological and physical well-being contributes incrementally, alongside many other determinants, to a smoother intrapartum course, rather than being its sole cause.

The independent contribution of antenatal-visit frequency (5–6 visits) to postpartum quality of life, over and above group assignment, is a noteworthy secondary finding: it suggests that the benefit of e-MACC and the benefit of more frequent in-person antenatal contact are at least partly additive rather than substitutive, reinforcing the broader digital-health literature's conclusion that mHealth tools perform best as a complement to, not a replacement for, conventional antenatal care.[9,14] Maternal age and educational attainment, by contrast, did not independently predict postpartum quality of life once group and visit frequency were accounted for, suggesting that the intervention's benefit was not confined to any particular demographic subgroup in this cohort – an encouraging signal for equity of impact, though one that should be tested formally with interaction terms in a larger, multicentre sample.

This study has several limitations. First, it was conducted at a single centre with a modest sample size (n = 160), and the observed age imbalance between arms, although adjusted for statistically, indicates that the randomization procedure (simple random sampling with per-day block allocation) may benefit from stratification by age or parity-adjacent variables in future iterations. Second, blinding of participants and the nurse investigator to allocation was not feasible given the nature of a self-administered mobile application, which raises the possibility of performance and social-desirability effects on the self-reported WHOQOL-BREF outcome, even though delivery-related endpoints were assessed by staff not informed of the study hypothesis. Third, the three participants lost to follow-up were replaced per the trial's pre-specified protocol rather than analysed on an intention-to-treat basis with imputation, which is appropriate for an early-stage substitution but means the effective analytic sample is a per-protocol rather than strict intention-to-treat cohort. Fourth, the trial was powered around the original quality-of-life outcome from the pilot phase rather than around the secondary maternal/fetal endpoints, so the non-significant findings for birth weight and mode of delivery should be interpreted as inconclusive rather than as evidence of no effect. Finally, generalisability beyond a semi-urban South Indian tertiary obstetric setting, and beyond women with sufficient literacy and smartphone access to engage with the application, should be tested in more diverse, multicentre samples, ideally with stratified or minimisation-based randomization and a health-economic evaluation of the app's scale-up cost.

Notwithstanding these limitations, the consistency of effect across four repeated quality-of-life assessments, five WHOQOL-BREF-derived scores, and multiple analytic approaches (mixed-design ANOVA, ANCOVA, multivariable regression) strengthens confidence that the observed benefit reflects a genuine intervention effect rather than an artefact of any single statistical test. For nursing practice, the findings support embedding structured, nurse-supervised mobile applications within routine antenatal care for first-time mothers as a low-cost, scalable adjunct capable of sustaining engagement with antenatal advice between clinic visits, provided that nurse oversight and a responsive support channel are maintained rather than relying on the application in isolation.

5. CONCLUSION

A nurse-led, technology-enabled antenatal care programme delivered through a purpose-built smartphone application produced a substantially better quality-of-life trajectory across pregnancy and the early postpartum period among primigravid women than routine antenatal care alone, with parallel reductions in labour pain and labour duration and an improvement in one-minute Apgar score, but no measurable effect on birth weight or mode of delivery. The intervention effect persisted after adjustment for baseline quality of life, maternal age and antenatal-visit frequency, and antenatal-visit frequency itself contributed independently to postpartum quality of life, supporting a complementary rather than substitutive relationship between digital and in-person antenatal support. These findings justify larger, multicentre trials with stratified randomization to confirm generalisability and to establish the intervention's cost-effectiveness before wider policy adoption.

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