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Dose-Response Analysis of Male Partner Involvement and Maternal and Newborn Health Outcomes in Sierra Leone

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Abstract This study examined the dose-response relationship between multidimensional male partner involvement and both maternal healthcare utilisation and newborn outcomes and compared the involvement gradient with the household wealth gradient in Sierra Leone. A dyadic cross-sectional survey was conducted among 500 mother-partner couples recruited by stratified cluster sampling across 15 districts between January and June 2026. Involvement was measured using a 30-item Male Involvement Index (MII, 0-100) administered separately to both partners by sex-matched enumerators. Internal consistency of the 30-item women's instrument was good (Cronbach's alpha 0.855; men's instrument 0.782). The composite was analysed continuously and in tertiles; tertiles were used because they yield approximately equal-sized groups from the observed distribution and permit inspection of monotonicity without imposing a linear functional form. Primary outcomes were four or more antenatal contacts (ANC4+), facility-based delivery and skilled birth attendance; secondary newborn outcomes were early breastfeeding initiation within one hour, postnatal care within 48 hours and child survival to the time of survey. Analysis used chi-square tests with Cramér's V for the graded contrasts, independent samples t-tests and Pearson correlation for the newborn objective, and multivariable binary logistic regression with sequential adjustment for the independent estimates. A monotonically ascending crude gradient was observed for all three primary outcomes: ANC4+ rose from 60.8% to 77.4% (+16.6 percentage points; $\chi^2 = 11.010$, $p = 0.004$), facility delivery from 63.6% to 76.2% (+12.6; $\chi^2 = 6.376$, $p = 0.041$) and skilled birth attendance from 68.8% to 81.1% (+12.3; $\chi^2 = 6.903$, $p = 0.032$). The crude gradients for facility delivery and skilled birth attendance did not survive adjustment; the ANC4+ gradient was attenuated by 44% and no longer reached significance (AOR 1.56, 95% CI 0.92 - 2.65). The unadjusted odds ratio for the highest vs. lowest involvement tertile was 1.83 (95% CI: 1.14 - 2.94) for facility delivery, but 0.88 (95% CI: 0.50 - 1.57) after full adjustment. Adding household wealth alone removed 97.6% of the crude facility-delivery association on the log-odds scale. Per-unit adjusted odds ratios were near null (facility delivery AOR = 0.999, 95% CI: 0.983 - 1.015). The categorization into tertiles did not create the crude association, as the continuous specification reproduced it (crude per-unit OR = 1.019, 95% CI: 1.006 - 1.033). Wealth quintile remained strongly associated with facility delivery after adjustment (AOR = 2.228, 95% CI: 1.853 - 2.679; $p < 0.001$). The facility-delivery prevalence gap between the poorest and wealthiest quintiles was 57.0 percentage points, which is 4.5 times the 12.6-point difference between the lowest and highest involvement tertiles for the same outcome (57.0 ÷ 12.6 = 4.52); the corresponding gap in skilled birth attendance was 53.0 points. Newborn outcomes did not differ significantly between tertiles (all $p \geq 0.40$). All the domain-outcome correlations were negligible (range −0.065 to +0.046; all $p \geq 0.14$). The study was powered to detect differences of 4.9 to 14.4 percentage points, but the observed differences were 1.9 to 4.2 points, with only 5.1 points of attainable headroom for the survival endpoint. No wealth-by-involvement interaction was detected for any outcome. Household poverty showed stronger associations with maternal healthcare utilisation than male partner involvement. Male engagement should complement, not replace, demand-side financial protection. Because the design is cross-sectional, these associations should not be read causally.

Keywords: *Male Partner Involvement, Antenatal Care, Facility Delivery, Skilled Birth Attendance, Newborn Health, Health Equity, Sierra Leone*

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1. Introduction

Sierra Leone's maternal mortality ratio, modelled at 354 deaths per 100,000 livebirths in 2023, remains more than five times the Sustainable Development Goal target, and the neonatal mortality rate of 34 per 1000 livebirths has fallen only slowly [1,2]. Facility-based surveillance recorded a maternal mortality ratio of 183.8 per 100,000 livebirths for January to November 2024, though this figure by construction excludes deaths occurring in the community [3]. Regional review evidence suggests that facility-based maternal deaths across West Africa are systematically under-investigated relative to community deaths, so routine surveillance is likely to understate the true burden [4]. The dominant direct causes of maternal death, namely obstetric haemorrhage, hypertensive disorders, obstructed labour and sepsis, are all conditions in which survival turns on how quickly a woman reaches skilled care [5,6]. The Three Delays framework locates the first and most consequential delay in the household, at the point of deciding to seek care [7,8]. Where that decision requires male permission, or where transport and money must be mobilised by a male partner, the man becomes the rate-limiting step in an emergency that may allow only two hours [9]. This mechanism accounts for the substantial global interest in male partner involvement as a maternal health intervention. Systematic reviews report associations between male engagement and increased antenatal attendance, skilled birth attendance and postnatal care use [10,11,12], and a 2026 meta-analysis of studies from low-income and middle-income countries found a pooled odds ratio of 2.20 (95% CI: 1.73 - 2.80) for institutional delivery across 19 studies, though with very high heterogeneity ($I^2 = 94\%$) [13].

Three features of this evidence limit its usefulness for policy in Sierra Leone. First, exposure is almost always measured as a single binary item, typically whether the man accompanied his partner to at least one antenatal visit, an operationalisation that cannot establish whether more involvement yields more benefit. A natural-language-processing review of 282 studies found antenatal attendance to be the single most common indicator, used in 40% of studies, with a third of studies relying on one indicator alone [14]; an international Delphi process reached the same conclusion [15]. Cross-sectional work from Myanmar reached a similar conclusion regarding the multidimensionality of the construct and the inadequacy of single-item proxies [80]. A graded exposure permits assessment of dose-response, one of the classical criteria for causal inference, and a monotonic gradient observed across several related endpoints is considerably more informative than a single dichotomous contrast.

Second, the evidence base is geographically skewed. Meta-analytic work on delivery care is dominated by Ethiopian studies [16], and scoping reviews of determinants across sub-Saharan Africa draw predominantly on eastern and southern African samples [17,18]. West African primary studies exist but are less often synthesised: Ghanaian work has documented that fewer than a quarter of men had ever accompanied a partner to antenatal or postnatal care and that involvement typically begins only once complications arise [19,20], while Nigerian survey work reports that men's contributions concentrate in financial and logistical support rather than physical presence [21]. Evidence for newborn outcomes is weaker still, and community-based studies from Ethiopia have reported null associations for postnatal care and early breastfeeding [22,23].

Third, and most importantly for a country that abolished user fees in 2010, few studies estimate the involvement effect alongside household wealth in the same model [24,25]. Wealth-based inequality in the maternal continuum of care is well documented across sub-Saharan Africa, including in Sierra Leone [26,27], but it is rarely placed in direct comparison with behavioural exposures such as male involvement. Without that comparison, policymakers cannot judge whether male engagement or financial protection warrants marginal resources. This paper reports the third and fourth objectives of a national dyadic mixed-methods study. It is structured around three research questions, and the results and discussion that follow are organised in the same order:

RQ1. What is the association between male partner involvement, as measured by the Male Involvement Index, and maternal healthcare utilisation outcomes among women in Sierra Leone?

RQ2. What is the association between male partner involvement during pregnancy and the perinatal period and newborn health outcomes among couples in Sierra Leone?

RQ3. How does the magnitude of any involvement gradient compare with the household wealth gradient for the same outcomes in the same population?

RQ1 and RQ2 correspond to Objectives 3 and 4 of the parent study; RQ3 is the comparative question that motivates the policy contribution. Using a purpose-built multidimensional index administered separately to both partners, the analysis addresses each in turn.

2. Research Methodology

2.1. Research Design

An analytical cross-sectional survey design with a paired-respondent structure was employed, forming the quantitative strand of a convergent parallel mixed-methods study. Reporting follows the STROBE statement for cross-sectional studies [28]. Each analytical technique was selected to answer a specific research question. Chi-square tests of association with Cramér's V tested overall association across tertiles for RQ1 and RQ3, and tests for linear trend across the ordered tertiles assessed the dose-response gradient. Independent samples t-tests with Cohen's d and Pearson correlations were reserved for RQ2, where the analytical task was to characterise the magnitude of the null newborn associations at the level of the extreme tertiles and of the six individual domain scores respectively. Multivariable binary logistic regression, fitted with sequential adjustment, generated the independent estimates that underpin the comparison in RQ3.

2.2. Description of Study Area

The study was conducted in 15 of Sierra Leone's 16 administrative districts, covering all four provinces and the Western Area, between 20 January and 24 June 2026. Karene District in North West Province was not included. The setting spans the full access gradient of the national health system, from the tertiary referral capacity of Western Area Urban to the geographic isolation of Falaba, Koinadugu and Bonthe, and encompasses a plural health system in which formal Peripheral Health Units and hospitals coexist with traditional birth attendants and the Sande society.

2.3. Sampling and Sampling Techniques

Eligible women were aged 15 - 49 years, had delivered a livebirth or stillbirth preceding data collection and were usual residents of a selected cluster; their acknowledged partners were enrolled as paired respondents. The interval between delivery and interview had a median of 17 months, an interquartile range of 11 to 26 months and a maximum of 52 months. A four-stage stratified cluster design was used, with the 15 participating districts as explicit strata, random selection of Peripheral Health Units as primary sampling units, deliberate inclusion of both proximal and distal catchment villages to maximise variation in geographic access, and systematic random-walk household recruitment. Sample size was derived from Cochran's formula [29] with $Z = 1.96$, $p = 0.50$ and $e = 0.05$, giving a base requirement of 385; adjustment by a design effect of 2.0 and inflation for 10% non-response gave a planning target of approximately 855. The executed dataset comprised 500 couples, distributed across 50 field clusters of 10 dyads each.

Allocation across districts was non-proportional, ranging from 11 dyads in Koinadugu to 53 in Western Area Urban, and reflects operational access rather than population size. Population-based sampling weights were therefore not constructed, because district-level sampling frames of recently delivered women with an identifiable partner were not available for Sierra Leone at the time of fieldwork; no design weight can be computed without such a frame. The estimates reported here are consequently unweighted and should be read as applying to the sampled dyads rather than as formally design-weighted national parameters. The sample is nationally distributed across all four provinces and the Western Area and the full access gradient, but it is not nationally representative in the survey-statistical sense, and this qualification is carried through to the interpretation of every estimate below. The observed prevalences fall 10 to 15 percentage points below the 2019 Sierra Leone Demographic and Health Survey estimates for the same indicators [61], so the sample over-represents women at the harder-to-reach end of the access gradient; this should be borne in mind when reading the absolute prevalences, though it does not bias the within-sample gradient comparisons that are the subject of this analysis.

2.4. Sources of Data Collection

Primary data were collected using two parallel instruments administered on tablets via KoboToolbox with encrypted synchronization. The Male Involvement Index is a 30-item instrument with six five-item domains covering cognitive engagement, financial support, logistical support, psychosocial support, decision-making partnership and clinical accompaniment. Domain scores are expressed on a 0 - 100 scale as the sum of valid item points divided by the maximum attainable from those same valid items, and the composite is the unweighted mean of the six domains. The decision-making domain is scored so that joint decisions receive full credit, woman-alone decisions partial credit and male-alone or third-party decisions no credit, so that a high score cannot be produced by unilateral control; this follows the conceptualisation of empowerment as an acquired capacity to choose [30] and responds to evidence that joint decision-making is associated with better reproductive outcomes than sole decision-making by either partner [31]. Household wealth quintiles were constructed by principal components analysis of household assets using the standard approach for settings without expenditure data [32,33].

The primary exposure for this analysis is the women's-report composite, on the pre-specified rationale that the outcomes of interest are experienced by the woman. This composite was analysed both continuously and in tertiles derived from the observed distribution (cut-points 18.33 and 32.50 on the 0-100 composite, corresponding to the 33rd and 67th percentiles). Tertiles were adopted for three reasons. First, they yield approximately equal-sized groups (n = 176, 160 and 164), which maximises precision for each contrast and avoids the unstable extreme categories that quintiles of a right-skewed score would produce. Second, they permit direct inspection of monotonicity, since a dose-response reading requires at least three ordered levels and a gradient that ascends without inversion is a stronger form of evidence than a single dichotomous contrast. Third, they impose no functional form on the exposure-outcome relationship, whereas a continuous specification assumes linearity on the log-odds scale. Because categorisation nevertheless discards information, every tertile result reported below is accompanied by the corresponding continuous estimate and by a test for linear trend, so that the reader can verify that the categorisation is not itself generating the association.

The men's self-report and a both-partners-agree specification were retained for sensitivity analysis. Three primary maternal outcomes were pre-specified: four or more antenatal contacts during the index pregnancy, facility-based delivery and skilled birth attendance, defined as delivery attended by a doctor, midwife or trained nurse. Three secondary newborn outcomes were pre-specified: early breastfeeding initiation within one hour of birth, postnatal care utilisation within 48 hours of delivery, and child survival to the time of survey. The last of these should be understood as an infant and early-childhood survival measure rather than a neonatal one, since it was ascertained at a median of 17 months after birth. All outcomes were reported by the woman and, where available, cross-checked against the maternal and child health handheld record.

2.5. Psychometric Evaluation of the Male Involvement Index

The Male Involvement Index was developed for this study and, to the authors' knowledge, no multidimensional male involvement instrument had previously been validated for use in Sierra Leone. This is stated plainly because it bears on how the exposure estimates should be read. Item generation was grounded in the ethnographic evidence that instrumental and financial support, rather than clinic accompaniment, constitute the locally salient expressions of male support in this setting [69], and the domain structure was reviewed by an expert panel and pre-tested in Krio, Mende and Temne with forward and back translation before fieldwork. Formal psychometric evaluation, however, was conducted on the study data themselves and is therefore internal rather than independent; prospective validation in a separate Sierra Leonean sample remains outstanding and is identified as a limitation in Section 5.

Three properties were assessed and are reported in full in Table 2. Internal consistency was quantified by Cronbach's alpha for the 30-item scale, for the six-domain composite and for each domain separately. Item adequacy for dimension reduction was assessed by the Kaiser-Meyer-Olkin measure and Bartlett's test of sphericity, and dimensional structure by principal components analysis of the 30-item inter-item correlation matrix. Corrected domain-total correlations were computed for each of the six domains against the sum of the remaining five. Alpha was interpreted with the caution that it is a function of scale length and of inter-item correlation, and that it is neither necessary nor sufficient evidence of unidimensionality; for domains whose items index discrete, non-interchangeable acts rather than reflective indicators of a common latent trait, a low alpha is expected and is not a defect of the measure [79].

2.6. Data Analysis

Analyses were performed in R version 4.3.0 and Python (statsmodels, SciPy). Associations between MII tertile and each binary outcome were tested by Pearson chi-square, with Cramér's V computed as the square root of the chi-square statistic divided by the product of the sample size and the smaller of the two table dimensions minus one; for the three-by-two tables used here the smaller dimension minus one equals one, so V reduces to phi, the square root of chi-square divided by n. The dose-response gradient was summarised as the percentage-point difference between the highest and lowest tertiles, and a gradient was classified as monotonic where prevalence increased across successive tertiles without inversion. Differences in newborn outcomes between extreme tertiles were additionally tested by independent samples t-tests with Cohen's d, and associations between each of the six domain scores and each newborn outcome were tested by Pearson correlation. Effect sizes were interpreted against conventional benchmarks [34]. Statistical significance was set at a two-sided alpha of 0.05.

Independent associations were estimated by binary logistic regression, fitting a separate model for each binary outcome with the MII exposure plus six covariates selected a priori from the determinant analysis: household wealth quintile, education level, Muslim religion, travel time, maternal age and parity, with Western Province as an additional dummy. Covariate selection followed the Andersen behavioural model, in which enabling resources such as wealth, education and geographic access are expected to dominate predisposing characteristics such as religion and parity [71].

Each model was estimated using the Male Involvement Index (MII) both as a continuous measure and as tertiles, allowing comparison of per-unit effects and graded differences. Outcomes were analysed through five sequential models: crude, wealth-adjusted, education-adjusted, travel-time-adjusted, and fully adjusted models, with changes in the highest-versus-lowest tertile effect used to assess attenuation and potential mediation. All 500 dyads had complete regression data, so no imputation was required. Structural missingness was handled through predefined coding, while non-applicable MII items were excluded when calculating domain scores. Multicollinearity was assessed using variance inflation factors and correlation diagnostics. Because of the multistage cluster design, intra-cluster correlations and design effects were calculated, and models were fitted with cluster-robust standard errors using both field clusters and districts. Results based on the 15 districts were interpreted cautiously because the small number of clusters may produce unreliable variance estimates. Interactions between household wealth and male involvement were tested using likelihood ratio tests, with wealth-stratified results provided descriptively. Finally, because newborn outcomes were non-significant, post hoc power and minimum detectable differences were calculated to assess whether the analyses had sufficient statistical power to detect meaningful effects.

2.7. Ethical Consideration

Ethical clearance was granted by the Njala University Institutional Review Board and the Sierra Leone Ethics and Scientific Review Committee, with written authorisation from the Ministry of Health and Sanitation and all participating District Health Management Teams. Written informed consent was obtained from literate participants and witnessed oral consent with thumbprint attestation, verified by an impartial witness independent of the research team, from participants with limited literacy. Participation was voluntary, and refusal carried no consequence for access to services. A trained intimate partner violence referral protocol operated at every site. Identifiers were held separately from responses, and all electronic data were encrypted to the AES-256 standard.

3. Results and Discussion

3.1. Distribution of the Sample Across Involvement Tertiles

A total of 500 mother-partner dyads were enrolled and distributed across involvement tertiles as follows: tertile 1 (low) n = 176, tertile 2 (moderate) n = 160 and tertile 3 (high) n = 164. Baseline characteristics by tertile are

shown in Table 1. Mean MII composite rose from 12.44 in the lowest tertile to 45.84 in the highest. Higher tertiles were characterised by greater educational attainment, greater household wealth and shorter travel times: the proportion of women with no formal schooling fell from 50.0% to 12.8% across tertiles, the proportion in the two poorest wealth quintiles from 52.8% to 26.2%, and mean travel time from 66.6 to 40.9 minutes. Maternal age, by contrast, did not vary monotonically with involvement, which is consistent with the null age correlation reported in the companion paper. This patterning establishes the confounding structure that the adjusted models address (Section 3.5). Overall, 345 women (69.0%) achieved four or more antenatal contacts, 347 (69.4%) delivered in a facility and 371 (74.2%) had a skilled birth attendant.

Table 1. Baseline characteristics of respondents by Male Involvement Index tertile (N = 500 dyads)

Characteristic	T1 low (n = 176)	T2 moderate (n = 160)	T3 high (n = 164)	Test statistic
MII composite, mean (SD)	12.44 (3.87)	25.39 (4.10)	45.84 (10.83)	By construction
Maternal age (years), mean (SD)	24.3 (8.1)	26.9 (8.7)	25.5 (8.4)	r = 0.065, p = 0.148
No formal education, n (%)	88 (50.0)	45 (28.1)	21 (12.8)	F = 25.411, p < 0.001
Wealth quintile 1 or 2, n (%)	93 (52.8)	64 (40.0)	43 (26.2)	F = 9.138, p < 0.001
Muslim religion, n (%)	120 (68.2)	96 (60.0)	99 (60.4)	t = −1.415, p = 0.158
Primigravid, n (%)	96 (54.5)	76 (47.5)	95 (57.9)	r = −0.033, p = 0.457
Travel time (min), mean (SD)	66.6 (77.9)	52.2 (62.9)	40.9 (48.3)	r = −0.181, p < 0.001
Western Area Urban residence, n (%)	15 (8.5)	14 (8.8)	24 (14.6)	t = 2.473, p = 0.014

MII = Male Involvement Index. Tertiles were derived from the observed distribution of the women's-report composite.

Test statistics in the final column are drawn from the determinant analysis of the same cohort reported in the companion paper and describe the association of each characteristic with the MII composite as a continuous variable; they are not tests of difference across the three tertile groups. F statistics are one-way analyses of variance of the MII composite across the five categories of the named variable (df = 4, 495); r denotes the Pearson correlation of the characteristic with the MII composite; t denotes the independent samples t-test of the MII composite between the two groups defined by the characteristic (df = 498). They are presented here to characterise the confounding structure addressed in the adjusted models. Maternal age and parity do not order monotonically with involvement, consistent with their non-significant bivariate correlations.

3.2. Psychometric Properties of the Male Involvement Index

Because the reliability and validation status of the exposure measure bears on every estimate that follows, the psychometric results are presented before the substantive findings (Table 2). Internal consistency of the 30-item women's instrument was good (Cronbach's alpha 0.855), as was that of the six-domain composite (0.857); the corresponding values for the men's instrument were 0.782 and 0.776. The item set was well suited to dimension reduction: the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.956, which falls in the range Kaiser described as marvellous, and Bartlett's test of sphericity was highly significant ($\chi^2 = 4029.4$, df = 435, $p < 0.001$). Principal components analysis of the 30 items yielded a dominant first component with an eigenvalue of 8.36 accounting for 27.9% of total variance, followed by a marked drop to 1.20 for the second component, a pattern consistent with a strong general involvement factor overlaid by domain-specific variance. Corrected domain-total correlations were positive and substantial for all six domains, ranging from 0.435 for decision-making partnership to 0.821 for logistical support.

Table 2. Psychometric properties of the Male Involvement Index (n = 500)

Property	Women's report	Men's report	Interpretation
Internal consistency (Cronbach's alpha)			
Full 30-item scale	0.855	0.782	Good / acceptable
Six-domain composite	0.857	0.776	Good / acceptable
Cognitive engagement	0.319	0.234	Formative domain
Financial support	0.805	0.728	Reflective, coherent
Logistical support	0.798	0.705	Reflective, coherent
Psychosocial support	0.815	0.745	Reflective, coherent
Decision-making partnership	0.063	0.038	Formative domain
Clinical accompaniment	0.207	0.073	Formative (discrete events)
Corrected domain-total correlation			
Range across six domains	0.435 - 0.821	—	All positive and substantial
Sampling adequacy and structure			
Kaiser-Meyer-Olkin measure	0.956	—	Marvellous
Bartlett's test of sphericity	$\chi^2 = 4029.4$, df = 435	—	$p < 0.001$
First component eigenvalue (% variance)	8.36 (27.9%)	—	Dominant general factor
Second component eigenvalue	1.19	—	Marked drop after first

Domain-level alphas were heterogeneous. Financial, logistical and psychosocial support behaved as coherent reflective scales (alpha 0.798 to 0.815 in the women's instrument). Cognitive engagement (0.319), clinical accompaniment (0.207) and decision-making partnership (0.063) did not. This is a predictable consequence of item content rather than a defect of construction: the accompaniment items index discrete and non-interchangeable events, such as attending a specific

antenatal contact or being present at delivery, and the decision-making items index who decided across five distinct decisions that need not covary. For domains of this formative character, alpha is not an appropriate index of quality, since the items are constituents of the construct rather than exchangeable indicators of a common latent trait [79]. The practical implication is that the composite and the three reflective domains support the interpretations offered here, whereas the three low-alpha domain scores should be read as descriptive counts of behaviour and not as precise scale scores. This is the principal reason why the domain-level correlations reported in Section 3.9 are treated as exploratory.

This evaluation was conducted on the analysis sample itself. It demonstrates that the instrument performed coherently in this dataset; it does not constitute independent validation, and it cannot rule out the possibility that the index would behave differently in another Sierra Leonean population. Independent psychometric validation, including confirmatory factor analysis in a separate sample and test-retest assessment, remains the necessary next step and is recorded as a limitation in Section 5.

Alpha for the six-domain composite treats the six domain scores as the items. Corrected domain-total correlations are computed for each domain against the sum of the remaining five and are reported for the women's instrument, the primary exposure. Kaiser-Meyer-Olkin, Bartlett's test and the principal components analysis were computed on the 30-item inter-item correlation matrix of the women's instrument. Low alphas for the cognitive, decision-making and accompaniment domains reflect the formative, non-interchangeable character of their items rather than poor construction; alpha is not an appropriate quality index for such domains [79]. This evaluation was conducted on the analysis sample and is internal rather than independent validation.

3.3. Male Partner Involvement and Maternal Healthcare Outcomes

All three primary maternal outcomes showed a monotonically ascending crude gradient across involvement tertiles, with no inversion at any level (Table 3). Attendance at four or more antenatal contacts rose from 60.8% in the lowest tertile to 69.4% in the middle and 77.4% in the highest, a gradient of 16.6 percentage points ($\chi^2 = 11.010$, df = 2, p = 0.004; Cramér's V = 0.148). Facility-based delivery rose from 63.6% to 68.8% to 76.2%, a gradient of 12.6 percentage points ($\chi^2 = 6.376$, df = 2, p = 0.041; V = 0.113). Skilled birth attendance rose from 68.8% to 73.1% to 81.1%, a gradient of 12.3 percentage points ($\chi^2 = 6.903$, df = 2, p = 0.032; V = 0.117). All three effect sizes were small by conventional criteria (V = 0.113 to 0.148). Tests for linear trend across the ordered tertiles were significant for all three outcomes (per-tertile odds ratio 1.486, p = 0.001 for ANC4+; 1.348, p = 0.012 for facility delivery; 1.385, p = 0.010 for skilled attendance), and the continuous specification returned the same result (crude per-unit odds ratios 1.022, 1.019 and 1.024, all p < 0.01). The graded pattern is therefore a property of the data and not an artefact of categorisation.

This dose-response finding is the principal descriptive contribution of the analysis, though its interpretation is substantially qualified by the adjusted results presented in Section 3.5. Almost all prior estimates of the involvement-outcome relationship rest on a single dichotomous exposure, which can establish only that involved and uninvolved men differ [14, 15]. By grading exposure, the present study shows that the crude relationship is ordered, that each successive tertile of involvement is associated with higher utilisation, and that this holds across three related endpoints without inversion at any level. Consistency of gradient across multiple related outcomes is a stronger form of evidence than any single contrast. The magnitudes are also policy-relevant: a 16.6 percentage-point difference in antenatal attendance between the lowest and highest involvement tertiles is comparable to the effect sizes reported for several supply-side quality interventions, and the direction and approximate magnitude are consistent with the pooled institutional delivery odds ratio of 2.20 reported in the 2026 meta-analysis [13]. They are also consistent with the smaller West African primary literature: cross-sectional work from Ghana and Nigeria reports higher service utilisation among women whose partners provide financial and logistical support [20,21], though without the graded exposure that would permit a dose-response reading. Ghanaian work also cautions that accompaniment is not universally welcomed by women themselves, some of whom experience a husband's presence in the clinic as a constraint on their own social space [39]. Ethnographic work in Sierra Leone cautions, however, that accompaniment is not the locally salient expression of male support [69], and a recent scoping review of rural sub-Saharan Africa argues that men's participation is constituted relationally rather than individually [70].

None of the three newborn outcomes reached significance in the same tertile analysis; these results are reported in Table 3 for completeness and are addressed in full under Research Question 2 in Section 3.9. Early breastfeeding initiation differed by 4.2 percentage points between extreme tertiles (58.0% versus 62.2%; $\chi^2 = 1.287$, p = 0.525; V = 0.051), and postnatal care utilisation showed a small inverse difference of 1.9 percentage points (73.9% versus 72.0%; $\chi^2 = 1.350$, p = 0.509; V = 0.052).

Table 3. Maternal and newborn outcomes by Male Involvement Index tertile with dose-response gradient

Outcome	Total %	T1 low %	T2 mod %	T3 high %	Gradient T3 − T1	χ^2	df	p	V
Primary maternal outcomes									
Four or more antenatal contacts	69.0	60.8	69.4	77.4	+16.6 pp	11.010	2	0.004	0.148
Facility-based delivery	69.4	63.6	68.8	76.2	+12.6 pp	6.376	2	0.041	0.113
Skilled birth attendance	74.2	68.8	73.1	81.1	+12.3 pp	6.903	2	0.032	0.117

Outcome	Total %	T1 low %	T2 mod %	T3 high %	Gradient T3 − T1	χ^2	df	p	V
Secondary newborn outcomes									
Early breastfeeding initiation (<1 h)	61.2	58.0	63.8	62.2	+4.2 pp	1.287	2	0.525	0.051
Postnatal care within 48 h	74.4	73.9	77.5	72.0	−1.9 pp	1.350	2	0.509	0.052
Child survival to time of survey	94.0	94.9	94.4	92.7	−2.2 pp	0.789	2	0.674	0.040

pp = percentage points; V = Cramér's V (0.10 small, 0.30 medium). Gradient is the difference in prevalence between the highest and lowest involvement tertiles. T1 n = 176, T2 n = 160, T3 n = 164. All three primary maternal outcomes show a monotonically ascending gradient with no tertile inversion. Tests for linear trend across the ordered tertiles were significant for all three primary outcomes and non-significant for all three newborn outcomes.

Table 4. Maternal healthcare utilisation and mean MII score by household wealth quintile

Wealth quintile	n	Facility delivery %	ANC4+ %	Skilled birth attendance %	MII composite mean (SD)	Test statistic
Q1 (poorest)	100	34.0	59.0	39.0	20.70 (11.91)	
Q2	100	55.0	59.0	67.0	25.40 (14.60)	FD: $\chi^2 = 110.621$, $p < 0.001$
Q3	100	80.0	70.0	83.0	30.67 (17.48)	SBA: $\chi^2 = 101.068$, $p < 0.001$
Q4	100	87.0	75.0	90.0	28.98 (16.45)	ANC4+: $\chi^2 = 18.981$, $p < 0.001$
Q5 (wealthiest)	100	91.0	82.0	92.0	31.95 (14.12)	MII: $F = 9.138$, $p < 0.001$
Q1 to Q5 range	—	57.0 pp	23.0 pp	53.0 pp	+11.25 points	df = 4 (χ^2); 4,495 (F)
Ratio to involvement gradient	—	4.5×	1.4×	4.3×	—	Descriptive ratio only

ANC4+ = four or more antenatal contacts; FD = facility delivery; SBA = skilled birth attendance; MII = Male Involvement Index; pp = percentage points. Wealth quintiles were constructed by principal components analysis of household assets with equal allocation (n = 100 per quintile). The gradient in mean MII across wealth quintiles is not strictly monotonic, with Q4 (28.98) falling below Q3 (30.67). The final row divides each wealth-quintile prevalence difference by the corresponding involvement-tertile difference from Table 3 (facility delivery 57.0 ÷ 12.6 = 4.52; ANC4+ 23.0 ÷ 16.6 = 1.39; skilled attendance 53.0 ÷ 12.3 = 4.31). These are descriptive comparisons of crude prevalence differences within the same sample, not ratios of adjusted effect estimates, and carry no causal implication.

3.4. Maternal Healthcare Utilisation and Mean MII Score by Household Wealth Quintile

Household wealth produced a far steeper gradient than involvement (Table 4). Facility-based delivery rose from 34.0% in the poorest quintile to 91.0% in the wealthiest, a difference of 57.0 percentage points ($\chi^2 = 110.621$, df = 4, $p < 0.001$). This is 4.5 times the corresponding 12.6-point involvement gradient for the same outcome, the ratio being obtained by dividing one prevalence difference by the other (57.0/12.6 = 4.5). The quantity is a descriptive comparison of two crude prevalence differences observed in the same sample and in the same outcome; it is not a ratio of adjusted effect estimates, and it does not imply that either exposure causes the difference attributed to it. It is reported because a policymaker choosing between two demand-side levers needs to know the relative size of the disparities each is associated with, and because the two gradients are not otherwise commensurable. Skilled birth attendance showed a gradient of comparable steepness, rising from 39.0% to 92.0%, a difference of 53.0 percentage points ($\chi^2 = 101.068$, df = 4, $p < 0.001$), which is 4.3 times the 12.3-point involvement gradient for that outcome. Antenatal attendance was less stratified, rising from 59.0% to 82.0%, a gradient of 23.0 points ($\chi^2 = 18.981$, df = 4, $p < 0.001$), only 1.4 times the 16.6-point involvement gradient. Mean MII composite also rose across wealth quintiles, from 20.70 in the poorest to 31.95 in the wealthiest, an increase of 11.25 points ($F = 9.138$, df = 4,495, $p < 0.001$), though the rise is not strictly monotonic: the fourth quintile (28.98) falls below the third (30.67).

The differential steepness of these three gradients is itself informative. Antenatal attendance, which is free at the point of use and requires only repeated short journeys, is the least stratified by wealth. Facility delivery and skilled attendance, which require a single journey at an unpredictable hour and frequently entail payment for supplies, transport and informal charges, are the most stratified. The pattern is what one would expect if the binding constraint were the cost of reaching care in an emergency rather than the cost of care itself.

This comparison carries the clearest policy message of the study. Sierra Leone abolished user fees for pregnant women in 2010, and facility deliveries rose substantially thereafter [24,25]. Yet within this sample 34.0% of women in the poorest quintile delivered in a facility, compared with 91.0% in the wealthiest. Fee abolition removed the price at the facility door but not the cost of reaching it: transport, medicines, delivery supplies and forgone daily income all remain. The finding is consistent with multi-country evidence that wealth-based inequality in the maternal continuum persists across sub-Saharan Africa even where formal fees have been removed [26,40,41], and with national analyses showing that only a small minority of Sierra Leonean women complete the full

continuum of care [27,42]. National survey data confirm the same pattern at population level [61], and the Ebola epidemic of 2014 to 2016 demonstrated how rapidly utilisation in Sierra Leone can contract when the cost or perceived risk of reaching a facility rises [62]. The political constraint remains binding: the Safe Motherhood and Reproductive Health Care Bill, tabled in 2024, has been stalled in parliamentary committee since its reading was suspended following organised religious opposition [63]. Because mean involvement also rises with wealth, the poorest households face compound disadvantage, being simultaneously least able to reach a facility and least likely to have an involved partner. Male engagement programming directed at these households without accompanying financial protection is unlikely to close a 57-point gap.

3.5. Adjusted Odds Ratios for Maternal and Newborn Outcomes from Five Binary Logistic Regression Models (n = 500)

In the fully adjusted model for each of the five outcomes, the per-unit odds ratio for the MII composite was near null for every outcome, ranging from 0.998 to 1.012, with all p-values above 0.12 (Table 5). The tertile specification of the same models tells the same story in the metric of the graded contrast: the adjusted odds ratio for the highest versus the lowest involvement tertile was 1.563 (95% CI: 0.923 - 2.646; p = 0.096) for ANC4+, 0.883 (95% CI: 0.497 - 1.567; p = 0.670) for facility delivery and 0.915 (95% CI: 0.501 - 1.670; p = 0.771) for skilled birth attendance. The crude gradients reported in Section 3.3 therefore did not survive adjustment. Household wealth quintile, by contrast, remained strongly and independently associated with facility delivery (AOR = 2.228, 95% CI: 1.853 - 2.679; p < 0.001), skilled birth attendance (AOR = 2.154, 95% CI: 1.775 - 2.613; p < 0.001) and antenatal attendance (AOR = 1.265, 95% CI: 1.091 - 1.466; p = 0.002). Muslim religion was associated with lower odds of facility delivery relative to Christian faith after adjustment (AOR = 0.624, 95% CI: 0.394 - 0.992; p = 0.046), although this association was absent for the other four outcomes. Model fit varied widely: McFadden's pseudo R-squared was 0.188 for facility delivery and 0.179 for skilled birth attendance, but below 0.01 for both newborn outcomes. The sequential models in Table 6 identify which covariate absorbs the crude association. For facility delivery, the crude odds ratio of 1.832 for the highest versus lowest tertile fell to 1.014 on the addition of wealth quintile alone, an attenuation of 97.6% on the log-odds scale; education, travel time and the remaining covariates together moved the estimate only marginally further. For skilled birth attendance the corresponding figure was 85.2% for wealth alone, rising to 98.0% once education was added. For ANC4+, wealth accounted for 25.0% and education for a further 22.2%, leaving a residual adjusted odds ratio of 1.563 that did not reach significance. The answer to the question of what explains the crude gradient is therefore household wealth, with education second, and this is the empirical basis for the comparative claim made under Research Question 3.

Three alternative explanations for the discrepancy between the crude and adjusted results were examined. First, categorisation into tertiles did not manufacture a spurious crude association: the continuous specification of the exposure produced crude per-unit odds ratios of 1.022 (95% CI: 1.008 - 1.036), 1.019 (95% CI: 1.006 - 1.033) and 1.024 (95% CI: 1.009 - 1.039) for the three primary outcomes, all significant, and the tests for linear trend agreed. The crude association is real; it is simply not independent of wealth. Second, the attenuation is not attributable to collinearity between involvement and wealth, since the variance inflation factor for the MII composite was 1.252 and the highest value in any model was 1.734 (Table 8), far below any conventional threshold for concern. Third, the relationship between involvement and outcome does not differ by wealth: the multiplicative wealth-by-involvement interaction was non-significant for every outcome, whether the exposure was entered continuously (likelihood ratio p = 0.25 to 0.94) or as tertiles for the three primary outcomes (p = 0.30 to 0.83). Descriptively, the facility-delivery gradient across involvement tertiles was −1.0 percentage points among women in the two poorest quintiles and +3.3 points among the remainder, which is to say approximately absent in both strata once wealth is held broadly constant.

The near-null adjusted estimates require careful interpretation and should not be read as refuting the tertile findings in the sense of showing them to be false; the crude gradients are correctly estimated and correctly reported. What the adjusted models establish is that the graded association is not independent of household resources. Wealth and education are, in the companion analysis of the same cohort, among the strongest determinants of involvement itself. They are antecedent common causes of both involvement and utilisation, and adjusting for them is therefore confounding control rather than mediation analysis; the attenuation indicates that the crude gradient was confounded by household resources. The sequential adjustment reported here is not a formal mediation decomposition, and because odds ratios are non-collapsible, part of the attenuation is arithmetic rather than causal. Both are reported here, and the two together give the fuller picture: male involvement is associated with maternal healthcare utilisation, but in this population, it shows no association independent of the household resources that predict both. This is not a peculiarity of the present data but a generic feature of male involvement research in low-income settings, where involvement is itself an expression of household resources, and where education and wealth predict service utilisation independently across the region [43,44]. Women's own decision-making authority operates in the same direction: multilevel analyses across high-fertility African settings link married women's autonomy to service utilisation [65], and validated empowerment indices predict fewer reported barriers to obtaining permission to seek care [66]. This is why critical assessments of the male involvement evidence base caution against reading involvement as unambiguously beneficial without attention to whose authority it expresses [67,68]. Studies in this field would be better served by reporting both unadjusted graded contrasts and formal mediation decomposition rather than adjusted coefficients alone.

The adjusted religion association merits caution rather

than emphasis. It was present for only one of five outcomes and modest in magnitude. Given the concentration of Muslim respondents in the northern provinces, where geographic access is poorest, residual confounding by unmeasured features of place is the most parsimonious explanation, and the finding should not be read as a religious effect. Multilevel Demographic and Health Survey analyses across West Africa similarly find that apparent religious differentials in maternal service use attenuate substantially once community-level access is modelled [45]. Comparable determinant structures have been reported in southern Ethiopia [72], in Nigerian analyses of antenatal non-use [73] and in Ghanaian work on barriers to male accompaniment [74], which suggests the confounding pattern observed here is regional rather than local.

Table 5. Adjusted odds ratios for maternal and newborn outcomes from five binary logistic regression models (n = 500)

Predictor	ANC4+ (95% CI)	Facility delivery (95% CI)	Skilled birth attendance (95% CI)	Early breastfeeding (95% CI)	Postnatal care (95% CI)
MII composite (per unit)	1.012 (0.997 - 1.027)	0.999 (0.983 - 1.015)	1.003 (0.986 - 1.020)	1.001 (0.988 - 1.014)	0.998 (0.983 - 1.012)
MII tertile 2 vs 1	1.223 (0.758 - 1.974)	0.810 (0.475 - 1.383)	0.795 (0.459 - 1.376)	1.221 (0.772 - 1.932)	1.256 (0.746 - 2.116)
MII tertile 3 vs 1	1.563 (0.923 - 2.646)	0.883 (0.497 - 1.567)	0.915 (0.501 - 1.670)	1.147 (0.707 - 1.859)	0.919 (0.539 - 1.566)
Wealth quintile (per level)	1.263 (1.088 - 1.466)	2.227 (1.850 - 2.680)	2.156 (1.775 - 2.619)	1.028 (0.896 - 1.180)	0.954 (0.818 - 1.112)
Education level (per level)	1.174 (1.000 - 1.379)	1.042 (0.873 - 1.245)	1.057 (0.879 - 1.272)	1.040 (0.896 - 1.207)	1.014 (0.859 - 1.196)
Muslim religion	0.828 (0.548 - 1.250)	0.625 (0.394 - 0.992)	0.664 (0.411 - 1.072)	1.179 (0.810 - 1.716)	0.973 (0.639 - 1.481)
Travel time (per min)	1.000 (0.997 - 1.003)	0.998 (0.995 - 1.001)	0.997 (0.994 - 1.000)	1.000 (0.997 - 1.003)	0.999 (0.996 - 1.002)
McFadden pseudo R^2	0.049	0.188	0.179	0.009	0.004

ANC4+ = four or more antenatal contacts; MII = Male Involvement Index. Reference categories are the lowest involvement tertile, Christian religion and non-Western province. Maternal age, parity and Western Province were included in all models but are not shown; none reached significance. No cases were excluded; no predictor contained missing values. Wealth quintile: $p = 0.002$ for ANC4+, $p < 0.001$ for facility delivery and skilled birth attendance. Muslim religion and facility delivery: $p = 0.046$. All per-unit MII estimates $p > 0.12$.

3.6. Sequential Adjustment: Decomposition of the Crude Association between the Highest Involvement Tertile and Each Primary Maternal Outcome

The adjusted estimates are also reported in the metric of the graded contrast. These derive from a parallel model in which the composite is entered as tertile indicators in place of the continuous term, with all other covariates unchanged. Tertile 3 versus 1: $p = 0.096$ (ANC4+), 0.670 (facility delivery), 0.771 (skilled birth attendance), 0.578 (early breastfeeding), 0.756 (postnatal care) (Table 5). Near-null adjusted MII estimates reflect adjustment for wealth and education, both of which are determinants of involvement and therefore lie on the causal pathway; Table 6 identifies which covariate absorbs the crude association.

Each model adds the named covariate to those above it; the full model additionally includes Muslim religion, maternal age, parity and Western Province. Attenuation is the proportional reduction in the log odds ratio relative to the crude estimate, so that a value exceeding 100% denotes an adjusted estimate that has crossed the null. Wealth quintile alone accounts for 97.6% of the crude facility-delivery association and 85.2% of the crude skilled-attendance association. Because wealth and education are antecedent common causes of both involvement and utilisation, these steps should be read as progressive control of confounding; the attenuation indicates that the crude gradient was confounded by household resources.

Table 6. Sequential adjustment: decomposition of the crude association between the highest involvement tertile and each primary maternal outcome

Outcome	Model	OR (T3 vs T1)	95% CI	Attenuation from crude
ANC4+	Crude	2.213	1.376 - 3.559	— ($p = 0.001$)
	+ wealth quintile	1.815	1.110 - 2.966	25.0% ($p = 0.017$)
	+ education	1.521	0.905 - 2.558	47.2% ($p = 0.114$)
	+ travel time	1.535	0.910 - 2.589	46.1% ($p = 0.108$)
	Full model	1.563	0.923 - 2.646	43.8% ($p = 0.096$)
Facility delivery	Crude	1.832	1.141 - 2.939	— ($p = 0.012$)
	+ wealth quintile	1.014	0.593 - 1.735	97.6% ($p = 0.958$)
	+ education	0.955	0.543 - 1.681	> 100% ($p = 0.873$)
	+ travel time	0.920	0.521 - 1.622	> 100% ($p = 0.772$)
	Full model	0.883	0.497 - 1.567	> 100% ($p = 0.670$)
Skilled birth attendance	Crude	1.950	1.178 - 3.229	— ($p = 0.009$)
	+ wealth quintile	1.104	0.629 - 1.937	85.2% ($p = 0.731$)
	+ education	1.014	0.561 - 1.833	98.0% ($p = 0.964$)
	+ travel time	0.962	0.530 - 1.745	> 100% ($p = 0.898$)
	Full model	0.915	0.501 - 1.670	> 100% ($p = 0.771$)

3.7. Sensitivity of the Dose-response Gradient to Alternative Exposure Specifications

Three alternative exposure specifications were

examined (Table 7). Direction was preserved throughout: all three primary maternal outcomes rose from the lowest to the highest involvement group under every specification. Magnitude and significance were not. Substituting the men's self-report composite attenuated the gradients sharply and removed significance from all three: antenatal attendance fell from a 16.6-point gradient to 1.1 points (p = 0.97), facility delivery from 12.6 to 9.2 points (p = 0.18) and skilled attendance from 12.3 to 6.5 points (p = 0.38). Restricting the analysis to the 205 couples whose two reports placed them in the same tertile produced larger gradients for facility delivery (16.4 points, p = 0.049) and skilled attendance (16.9 points, p = 0.033), though none of the three retained monotonicity on the reduced sample. Tertiles of the couple-mean composite reproduced the primary result closely, with gradients of 12.6, 11.4 and 11.5 points, all monotonic and all significant.

The pattern across specifications is informative in its own right. Attenuation towards the null under the men's self-report is what non-differential exposure misclassification predicts, and the companion paper documents the misclassification directly: 295 of 500 couples (59.0%) are placed in different tertiles depending on which partner is asked. That the antenatal gradient collapses almost entirely under the men's instrument, while the delivery gradients survive in reduced form, is consistent with men recalling discrete events such as attending a birth more reliably than they recall a schedule of contacts spread across months. The strengthening of the gradients among concordant couples points the same way: where the two accounts agree, the exposure is measured with less error and the association is correspondingly larger. Taken together, these results suggest that the primary specification is conservative, and they echo the spousal discordance documented in reproductive health research elsewhere [46,47,48].

3.8. Design-based and Model Diagnostics for the Adjusted Analyses (n = 500)

The robustness of the adjusted estimates to the sampling design and to model assumptions is summarised in Table 8. Intra-cluster correlation at district level was modest for the primary outcomes (0.027 to 0.062) and negligible for the newborn outcomes, giving design effects of 1.85 to 3.00 for the former and 1.07 to 1.19 for the latter; the design effect for the MII composite itself was 4.21, reflecting genuine geographic patterning of involvement. The planning design effect of 2.0 used in the sample size calculation was therefore reasonable for the primary outcomes and conservative for the newborn outcomes. Refitting all models with cluster-robust standard errors changed no substantive conclusion. Using the 50 field clusters, the per-unit MII confidence intervals were essentially unchanged, and the wealth associations remained highly significant. Using the 15 districts, the wealth associations likewise remained significant (facility delivery AOR = 2.227, 95% CI: 1.825 - 2.717, p < 0.001), while the confidence interval for the ANC4+ tertile contrast narrowed sufficiently to exclude the null (AOR = 1.563, 95% CI: 1.098 - 2.226, p = 0.013). That single result is not treated as evidence of an effect, because cluster-robust variance estimation with as few as 15 clusters is known to understate the true standard error, and no other specification places this contrast below alpha. Multicollinearity was absent, with all variance inflation factors between 1.03 and 1.73.

Table 7. Sensitivity of the dose-response gradient to alternative exposure specifications

Specification	Outcome	Low %	Mid %	High %	Gradient	χ^2	p	Monotonic
1. Women's report (primary), n = 500	ANC4+	60.8	69.4	77.4	+16.6 pp	11.010	0.004	Yes
	Facility delivery	63.6	68.8	76.2	+12.6 pp	6.376	0.041	Yes
	Skilled birth attendance	68.8	73.1	81.1	+12.3 pp	6.903	0.032	Yes
2. Men's self-report, n = 500	ANC4+	68.6	68.7	69.8	+1.1 pp	0.064	0.97	Yes
	Facility delivery	64.9	70.0	74.1	+9.2 pp	3.490	0.18	Yes
	Skilled birth attendance	71.3	74.0	77.8	+6.5 pp	1.926	0.38	Yes
3. Both partners agree (same tertile), n = 205	ANC4+	61.2	72.1	68.8	+7.7 pp	1.866	0.39	No
	Facility delivery	57.6	55.8	74.0	+16.4 pp	6.027	0.049	No
	Skilled birth attendance	62.4	60.5	79.2	+16.9 pp	6.848	0.033	No
4. Couple-mean composite, n = 500	ANC4+	61.3	71.9	73.9	+12.6 pp	7.164	0.028	Yes
	Facility delivery	61.9	73.1	73.3	+11.4 pp	6.696	0.035	Yes
	Skilled birth attendance	66.7	77.8	78.2	+11.5 pp	7.505	0.023	Yes

ANC4+ = four or more antenatal contacts; pp = percentage points. All chi-square tests have 2 degrees of freedom. Specification 1 is the primary analysis reported in Table 3. Specification 3 restricts to the 205 couples (41.0%) placed in the same tertile by both instruments. Specification 4 uses tertiles of the mean of the two composites. Direction is preserved under every specification; magnitude and statistical significance are not.

Table 8. Design-based and model diagnostics for the adjusted analyses (n = 500)

Diagnostic	ANC4+	Facility delivery	Skilled birth attendance	Early breastfeeding	Postnatal care
Intra-cluster correlation (district)	0.027	0.062	0.053	0.002	0.006
Design effect, 1 + (m − 1)ρ	1.85	3.00	2.69	1.07	1.19
MII per-unit AOR, model-based CI	1.012 (0.997 - 1.027)	0.999 (0.983 - 1.015)	1.003 (0.986 - 1.020)	1.001 (0.988 - 1.014)	0.998 (0.983 - 1.012)
MII per-unit AOR, robust CI (50 clusters)	1.012 (0.997 - 1.026)	0.999 (0.985 - 1.013)	1.003 (0.988 - 1.019)	1.001 (0.989 - 1.014)	0.998 (0.982 - 1.013)
MII per-unit AOR, robust CI (15 districts)	1.012 (0.999 - 1.024)	0.999 (0.982 - 1.016)	1.003 (0.984 - 1.023)	1.001 (0.987 - 1.016)	0.998 (0.978 - 1.018)
Wealth AOR, robust CI (15 districts)	1.263 (1.081 - 1.475)	2.227 (1.825 - 2.717)	2.156 (1.738 - 2.674)	1.028 (0.917 - 1.153)	0.954 (0.838 - 1.086)
Wealth × MII interaction, LR test p	0.250	0.935	0.666	0.574	0.426
Wealth × MII tertile interaction, LR test p	0.299	0.828	0.538	—	—
Maximum variance inflation factor	1.73	1.73	1.73	1.73	1.73

AOR = adjusted odds ratio; LR = likelihood ratio; MII = Male Involvement Index. Intra-cluster correlations were estimated by one-way analysis of variance with district as the grouping factor; the design effect uses the average district size of 33.3 dyads. The corresponding values for the MII composite itself are ρ = 0.100 and a design effect of 4.21. Robust confidence intervals derive from cluster-robust (sandwich) variance estimation. Results with 15 clusters are anti-conservative by construction and are reported for completeness rather than as the preferred inference. Variance inflation factors ranged from 1.025 (Muslim religion) to 1.734 (maternal age); the value for the MII composite was 1.252 and for wealth quintile 1.156. The highest pairwise covariate correlation was 0.635, between maternal age and parity; the MII composite correlated 0.405 with education and 0.238 with wealth quintile.

3.9. Male Partner Involvement and Newborn Health Outcomes

Direct comparison of the extreme tertiles confirmed the null pattern for all three newborn endpoints (Table 9). Early breastfeeding initiation was 58.0% in the lowest tertile and 62.2% in the highest ($t = -0.796$, $p = 0.427$; $d = 0.09$); postnatal care within 48 hours was 73.9% and 72.0% ($t = 0.396$, $p = 0.693$; $d = 0.04$); and child survival to survey was 94.9% and 92.7% ($t = 0.842$, $p = 0.401$; $d = 0.09$). All effect sizes were negligible. All 18 correlations between the six individual domain scores and the three newborn outcomes were negligible, ranging from −0.065 to +0.046 with a median absolute value of 0.026; the largest single coefficient was −0.065, between financial support and child survival, and none reached significance (all $p \geq 0.144$). The adjusted tertile contrasts told the same story, with odds ratios for the highest versus lowest tertile of 1.147 (95% CI: 0.707 - 1.859) for early breastfeeding and 0.919 (95% CI: 0.539 - 1.566) for postnatal care.

The power of the study to detect differences in these outcomes was therefore examined. At the realised group sizes of 176 and 164, a two-sided test at alpha = 0.05 with 80% power would have required a difference of 14.4 percentage points for early breastfeeding, 12.2 points for postnatal care and 4.9 points for child survival. The observed differences were 4.2, 1.9 and 2.2 points respectively, and the power actually achieved was 12.1%, 5.9% and 13.3%. These are not findings of no association; they are findings that the design could not have distinguished a modest association from none. The survival endpoint is the starkest case, since a prevalence of 94.9% in the lowest tertile leaves only 5.1 percentage points of attainable improvement, and the 4.9 points required for adequate power would consume almost all of it. Detection of any realistic increase in this endpoint was therefore not possible at this sample size; for a decrease, the minimum detectable difference was 8.9 points.

Five further considerations bear on the interpretation. First, the study was powered for the primary maternal utilisation outcomes rather than for newborn endpoints, whose lower variance and, in the case of survival, rarity of the adverse event demand substantially larger samples. Second, there is a temporal mismatch between a retrospective composite exposure spanning the whole pregnancy and an outcome such as breastfeeding initiation determined within the first hour after birth, particularly where the median recall interval is 17 months and timing of initiation is known to be recalled poorly [49]. Third, the hypothesised pathway is indirect and mediated rather than direct: paternal involvement is expected to act on newborn outcomes through the circumstances of delivery and through maternal wellbeing, and mediated pathways attenuate the total association observable in a single cross-sectional contrast. A South African study that modelled this pathway explicitly found that postnatal father involvement improved maternal depression but did not act on exclusive breastfeeding either directly or through maternal mental health [50]. Fourth, measurement limitations compound this, since the three low-alpha domains reported in Table 2 are precisely those most plausibly linked to perinatal behaviour, so attenuation by exposure misclassification is expected. Fifth, a ceiling effect operates on the survival endpoint, at 94.0% overall, while postnatal care at 74.4% leaves limited room for a large difference, compressing the range within which any difference could appear. This null pattern converges with community-based Ethiopian studies that similarly found no association between male involvement and postnatal care utilisation or early breastfeeding [22,23]. Qualitative work from Malawi and Ghana indicates that postnatal involvement is shaped by facility arrangements and community expectation rather than by the antenatal

behaviours a composite index captures [75,76], and systematic review evidence from prevention of mother-to-child transmission programmes reaches the same conclusion across the region [77].

It should not be inferred from this that paternal engagement is irrelevant to newborn feeding. Regional evidence indicates that early initiation is shaped principally by the circumstances of delivery, notably whether birth occurred in a facility and who attended it [51,52], both of which were associated with involvement in crude analysis in the present study, although not after adjustment for household wealth. Quasi-experimental work from Ethiopia has shown that father-directed education can raise early initiation and exclusive breastfeeding [53], and cluster-randomised trials of peer and postnatal counselling have established that the behaviour is modifiable [54,55]. What these studies share, and what the present design lacks, is measurement anchored to the days surrounding birth rather than to the pregnancy as a whole.

The concurrent qualitative strand of the parent study documented provider accounts in which husbands who recognised neonatal danger signs initiated emergency care that preserved survival and recorded four neonatal deaths occurring in contexts of absent male emergency transport. These accounts do not constitute quantitative evidence, but they indicate that the pathway is plausible and that the appropriate next step is a prospective cohort enrolled at first antenatal contact with time-anchored postnatal measures rather than a further cross-sectional analysis. A prospective Kenyan cohort of HIV-infected pregnant women found higher HIV-free survival at six weeks among infants whose fathers attended antenatal clinic (97.7% versus 91.3%) [78]; that mechanism operates largely through prevention of vertical transmission and is not directly transferable to a general obstetric population, but it illustrates the prospective, time-anchored design that the present cross-sectional structure could not replicate.

Table 9. Newborn health outcomes by Male Involvement Index tertile, with statistical power

Newborn outcome	T1 low % (n = 176)	T3 high % (n = 164)	Difference (pp)	t	p	d	Difference detectable at 80% power	Achieved power
Early breastfeeding initiation (<1 h)	58.0	62.2	+4.2	−0.796	0.427	0.09	14.5 pp	12.1%
Postnatal care within 48 h of delivery	73.9	72.0	−1.9	0.396	0.693	0.04	12.2 pp	5.9%
Child survival to time of survey	94.9	92.7	−2.2	0.842	0.401	0.09	5.0 pp	13.3%

pp = percentage points; d = Cohen's d. All three comparisons are non-significant at alpha = 0.05 and all effect sizes are negligible. Survival was ascertained at a median of 17 months after delivery and therefore captures infant and early-childhood rather than strictly neonatal survival. The minimum detectable difference is computed for a two-sided two-proportion test at alpha = 0.05 and 80% power at the realised group sizes, taking the observed lowest-tertile prevalence as the baseline; achieved power is computed for the difference actually observed. The ceiling at 94.9% in the lowest tertile leaves at most 5.1 percentage points of attainable improvement in survival, against the 5.0 points required for adequate power, which makes detection of any realistic effect statistically infeasible at this sample size.

4. Conclusion and Recommendation

The study found a significant crude gradient between male partner involvement and maternal healthcare utilisation, including ANC4+, facility delivery, and skilled birth attendance, but these associations did not persist after adjustment. Household wealth accounted for 97.6% of the crude facility-delivery association and 85.2% of the crude skilled-attendance association, with wealth gradients 4.5 and 4.3 times larger than the corresponding male-involvement gradients. Male involvement showed no clear association with newborn outcomes, although statistical power was limited (5.9% to 13.3%). Because the study was cross-sectional, the findings indicate associations rather than causal relationships. The attenuation after adjustment is consistent with wealth and education being associated with both male involvement and healthcare utilisation. Therefore, crude and adjusted estimates provide complementary information and should be reported together. The findings indicate that male engagement should complement financial protection, including transport assistance, maternity waiting homes, and reduction of out-of-pocket costs, particularly given the 57-percentage-point wealth gap. Interventions should also use gender-transformative approaches that promote male support while protecting women's autonomy and decision-making [56,57,59]. Future research should use prospective cohort designs, time-specific postnatal assessments, and mediation analysis. Independent validation of the Male Involvement Index (MII) in another Sierra Leonean sample is also recommended.

5. Limitations of the Study

The study is limited by its cross-sectional design, self-reported data, and long recall period, which may introduce bias and prevent causal conclusions. The newly developed Male Involvement Index requires further independent validation. The sample was not nationally representative, excluded Karene District, and the small number of districts limited the reliability of some statistical estimates. Finally, the newborn analyses were underpowered, meaning the non-significant findings should be regarded as inconclusive rather than evidence of no association.

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Conflicts of Interest

The authors declare no conflicts of interest.

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