JOURNAL OF COMMUNITY SYSTEMS FOR HEALTH
2026, VOL. 3
https://doi.org/10.36368/jcsh.v3i1.1324

STUDY PROTOCOL

Extreme heat, exclusive breastfeeding and maternal mental health in northern Senegal: a population health intervention research protocol for the SPRINT-Sen study

Jean-Marc Goudet[1*], Adama Faye[2], Sandrine Anquetin[3], Emmanuel Bonnet[4], Makhan Danfakha[2], Muhamed Nazmul Islam[1,5], Sarah Louart[6], Veronique Filippi[7], Pauline Gluski[4], Sari Kovats[8], Fatimata Sow[1,4], Labaly Touré[4,9], Zahidul Quayyum[10], Valéry Ridde[1,11]

[1]Université Paris Cité, Institut de recherche pour le développement (IRD), Université Sorbonne Paris Nord, Inserm U1348, Centre Population et Développement (Ceped UMR 196), 45 rue des Saints-Pères, F-75006, Paris, France.
[2]Université Cheikh Anta Diop, Dakar, Sénégal
[3]IGE, Grenoble-INP, Université Grenoble Alpes, IRD, CNRS, Grenoble, France
[4]UMR 215 Prodig, CNRS, Université Paris 1 Panthéon-Sorbonne, AgroParisTech, Institut de recherche pour le développement (IRD), Aubervilliers, France
[5]SAJIDA Foundation, Dhaka, Bangladesh
[6]Université Rennes, EHESP, CNRS, Inserm, Arènes - UMR 6051, RSMS (Recherche sur les Services et Management en Santé), Rennes, France
[7]Department of Infectious Disease Epidemiology and International Health, London School of Hygiene & Tropical Medicine, London, UK
[8]Department of Public Health, Environments and Society, London School of Hygiene & Tropical Medicine, London, UK
[9]Université du Sine Saloum, El-Hâdj Ibrahima Niass, Sénégal
[10]BRAC James P Grant School of Public Health, BRAC University, Dhaka, Bangladesh
[11]Institut Convergences Migrations, Aubervilliers, France

***Corresponding author:** jeanmarcgoudet@gmail.com

Received 5 December 2025; Accepted 2 April 2026; Published 30 April 2026

Abstract

Introduction: Extreme heat has always been a public health challenge in the Sahel, with growing evidence of its adverse effects on maternal, newborn, and child health (MNCH), including mental health. In Senegal's Matam region, high seasonal temperatures may affect exclusive breastfeeding (EBF) practices and maternal mental health through direct effects of heat perceptions and knowledge. SPRINT-Sen aims to co-design, implement, and evaluate a community-based, population health intervention to improve EBF and maternal mental health under a hot and arid climate.

Methods: SPRINT-Sen is a population health intervention research (PHIR) study using a quasi-experimental longitudinal design with four independent cross-sectional surveys in an open cohort. The impact evaluation follows a pre–post design using a mixed-method approach for acceptability and process evaluation. Eligible participants are pregnant women and mothers of infants aged 0–12 months. The co-designed intervention will combine (1) EBF promotion adapted to extreme heat conditions; (2) maternal mental health support through promotion and psychosocial activities; and (3) continuous temperature monitoring to inform a heat warning system. The primary outcome is EBF at six months. Secondary outcomes include maternal mental health impacts such as anxiety, stress, and interpersonal conflict. Meteorological and thermal mapping will assess environmental exposure.

Results: The study will generate evidence on the mechanisms and implementation of heat-EBF interventions and heat-related mental health impacts among MNCH. Findings will inform efforts to strengthen a heat-resilient health system through community-based solutions. Knowledge transfer will be supported through co-dissemination with stakeholders and integration into maternal health and climate adaptation policies.

Conclusions: SPRINT-Sen will provide novel and context-specific evidence on the feasibility,

implementation and effectiveness of an integrated intervention addressing both maternal mental health and EBF in the context of extreme heat. The findings will inform adaptation strategies for MNCH programmes and contribute to global discussions on PHIR in Sahelian contexts.

Keywords: Extreme heat, maternal, mental, health, intervention, rural, urban, protocol, Senegal

Abstract in Español at the end of the article

INTRODUCTION

This article presents the protocol for SPRINT-Sen (Strengthening Preparations and Resilience in Temperature community adaptation for women's health in Senegal), a population health intervention study aimed at strengthening exclusive breastfeeding and promoting maternal mental health among pregnant and breastfeeding women exposed to extreme heat in the Matam region, northeastern Senegal.

Climate change, extreme heat and maternal and neonatal health

African countries are among the most affected by climate change: regional temperatures have risen almost twice as fast as the global mean, and heatwaves are becoming more frequent and severe [1]. Despite contributing the least to global greenhouse gas emissions, low-income countries bear disproportionate 'loss and damage' [2]. Extreme Heat (EH) represents now a major climate-related risk to population and health systems, affecting morbidity and mortality across the life course [3] and disproportionately affecting children, older adults, outdoor workers, and pregnant women [4].

For epidemiological studies, heat exposure metrics must reflect local climate variability and the specific heat-health relationships under investigation. Most maternal and child health studies define EH as temperatures above the 95th percentile of the local seasonal distribution [5], although alternative metrics may be more appropriate for some outcomes. In this study, we will develop location-specific heat thresholds for Matam based on local temperature distributions and observed associations with exclusive breastfeeding practices (EBF) and maternal mental health. EH affects maternal and child health through multiple pathways, including physical environment, physiological, nutritional, behavioural, social, economic, and health-system mechanisms [6]. Prolonged exposure to high temperatures may overwhelm the thermoregulatory mechanisms during pregnancy [7], and systematic reviews link high temperature exposure to increased maternal morbidity, including preterm birth [8,9], hypertensive disorders, preeclampsia, congenital anomalies and psychiatric admissions [10–12]. The risk of preterm birth, especially in the third trimester [13,14], may be partly mitigated by greener environments [8]. Around the time of birth, EH exposure is also associated with a higher risk of stillbirths and pre-term birth, including in sub-Saharan Africa [3,9,11,15], both leading contributors to global neonatal mortality [9]. These adverse outcomes generate substantial health and economic burdens, particularly in resource-limited settings [16,17]. Limited research has examined health inequities in resource-constrained settings affected by extreme heat. Yet structural disparities likely shape differential exposure, vulnerability, and maternal physical and mental health outcomes.

Extreme heat and maternal mental health

In the general population, high ambient temperatures have been associated with higher risks of mental health outcomes, including anxiety and depression [2,18], suicide and suicide attempts [19–22], interpersonal violence and conflicts [23–25], gender-based violence [26] and increased emergency hospitalisation for severe mental illness [27]. Socio-economic and environmental factors partly mediate these associations.

Although few studies have directly examined rising temperatures and perinatal mental health [28], emerging evidence suggests that exposure to high temperatures during pregnancy may adversely affect maternal mental health [29]. Reported outcomes include heightened stress [29,30], increased risk of anxiety and depression [2,18], and perinatal mood and anxiety disorders (PMAD) [31]. Qualitative studies in Burkina Faso and Kenya have shown that heat disrupts infant care and sleep and contributes to maternal anxiety [30,32].

Indirect pathways may also link heat exposure to perinatal mental health. Preterm birth and low birth weight, both associated with high temperatures, increase the risk of postnatal depression [33], and heat has been linked to an increase in intimate partner violence [25]. Maternal health and mental health are closely interrelated: maternal distress may alter breast-milk quality [34] and reduce breastfeeding success [35], and breastfeeding intention has been associated with postpartum depression [36].

Our pilot qualitative study in Matam (Senegal) suggests potential pathways through which high temperatures may affect maternal mental health. Women reported that heat interfered with infant care, particularly by disrupting sleep, leading to fatigue and a greater burden of household tasks. These stressors, compounded by economic pressures during the hot season, appeared to exacerbate PMAD and interpersonal conflict at household and at health-centre levels [37].

Extreme heat in Senegal

In Senegal, heat waves represent a growing public health challenge [38–41]. The northeastern Matam region experiences the highest temperatures in Senegal, with average maximum temperatures exceeding 41°C [42].

High temperatures have been shown to have acute effects on mortality and morbidity. Sy et al. [42] documented a 13.7% increase in health centre consultations in the Matam department during the hot season, compared with the rest of the year, over the period 2009 - 2019. During the 2013 heatwave, Matam recorded the highest proportion of deaths in the country, with women disproportionately affected [42]. A recent study using 2017-2022 data found a three-to-five-day lag between heat peaks and hospital admissions in Matam [43]. Atmospheric dust load is also included as a climate-related risk to health, as an environmental exposure that may precede or exacerbate heat waves [44].

Exclusive breastfeeding: challenges in Senegal

Exclusive breastfeeding (EBF) is defined by WHO as feeding infants exclusively breast milk without supplementary food or water, except for specific treatment. WHO and UNICEF advise maintaining EBF for the first six months [45], as its benefits for mothers and children have been demonstrated [46] and increase with duration and exclusivity [47]. EBF is also among the most cost-effective interventions for reducing child mortality in resource-constrained settings [48].

Globally, approximately 48% of infants are exclusively breastfed for the first six months of life [49]. In Senegal, 34% of mothers maintain exclusive breastfeeding for the full six-month period [50]. Between 2010 and 2019, the Matam region recorded the lowest EBF rates, with a mean of 31% [51]. Approximately 58% of women reported receiving counselling on infant feeding during antenatal consultations [50]. Four main factors are associated with EBF practices in Senegal: women's literacy and skilled birth assistance were positively associated, whereas maternal occupation and media access were negatively associated [51]. Other studies have reported the influence of cultural factors, health professional training, and heat on breastfeeding practices [52–54]. Research in Burkina Faso similarly found that time spent breastfeeding was lower on hot days among infants under three months [55]. Seasonal factors, therefore, appear to influence breastfeeding behaviours: women tend to spend less time breastfeeding when temperatures are high, and EBF practices may also be constrained by competing demands on women's time [55].

Beyond environmental factors, breastfeeding practices are shaped by healthcare service, socioeconomic position and cultural factors [48]. A systematic review in LMICs found that cultural practices, household economic status, and other context-specific factors strongly influence decisions about introducing water or other fluids during breastfeeding [56].

The low prevalence of EBF in Matam is likely to be multifactorial. It may partly be explained by heat stress and related perceptions, water scarcity leading to maternal dehydration and concerns about milk quality and production, and broader seasonal patterns. Perceptions of heat emerged as a key factor: many women viewed high temperatures as a barrier to EBF, believing that infants require additional fluids. These findings highlight the complex interplay of structural, contextual and individual determinants shaping EBF practices, and underscore the need for interventions that address heat perceptions and adaptive strategies at multiple levels [57,58].

Maternal mental health in Senegal: bridging the gap

Limited data exist on maternal mental health in Senegal, and the subject remains largely under-documented [59]. A recent study in Dakar reported a high prevalence of postpartum depression (PPD) at 25 %, mainly linked to dissatisfaction with pregnancy care and stressful life events during pregnancy [60]. Pregnancy-specific anxiety (PSA) was estimated at 45.8 %, with low social support identified as the primary risk factor [61]. Mental health services are scarce, and training frontline staff presents a major challenge; however, a pilot e-learning platform for midwives and nurses has shown promising results [62]. These findings emphasise the importance of systematic screening, community-based psychosocial support, and clearly defined referral pathways for maternal mental health within Senegal's primary healthcare system.

Conceptual frameworks for the SPRINT-Sen intervention

Several frameworks describe how EH affects maternal, newborn, and child health [6,10,63,64]. However, only one explicitly includes maternal health outcomes and the need for multi-sectoral responses to climate hazards [64]. For this study, we adapted an existing framework [6] (Figure 1) that illustrates both the direct and indirect pathways through which EH may influence EBF practices and maternal mental health.

To date, only two published intervention studies worldwide have directly addressed EBF practices under extreme-heat conditions [65,66], and none have assessed maternal mental-health outcomes. Meanwhile, recent recommendations emphasise the importance of integrating maternal mental health into perinatal care, with strong evidence supporting the effectiveness of peer support in reducing symptoms of perinatal depression [67]. Although this approach has not yet been tested in climate-hazard contexts, it provides a relevant and scalable foundation for addressing mental health needs in our intervention.

SPRINT-Sen is a population health intervention study that tackles extreme-heat impacts on exclusive breastfeeding and maternal mental health among pregnant and lactating women, with an equity focus. It delivers a complex, multi-component intervention combining:

(i) community-based activities, (ii) in-home and health centres thermal surveillance, and (iii) knowledge translation, and evaluates both its implementation and its impacts. Figure 1 shows the components targeted by the SPRINT-Sen intervention, marked with orange target symbols.

Policy context and knowledge gaps

In 2023, the WHO issued an urgent call to action on climate change and maternal-child health [68], recognising mental health as a cross-cutting issue [69,70]. There is now a clear imperative to align global and national strategies with approaches that simultaneously address climate resilience, gender responsiveness, and health equity [71].

Senegal has adopted the Baby-friendly Hospital Initiative (BFHI) to strengthen breastfeeding support [72] and participates in the regional 'Stronger With Breastmilk Only' initiative launched in 2021 [73], which aims to achieve at least 50% of EBF by 2025 [53]. The Ministry of Health has set goals for 2025 to mitigate the health effects of climate change through multisectoral approaches and promote health-enhancing behaviours [74]. However, data suggest that this target has not yet been achieved.

Despite growing evidence on the health impacts of EH, significant knowledge gaps remain regarding EBF practices in hot environments [75]. Few climate adaptation studies focus on interventions specifically designed to support EBF during EH. Furthermore, there is a need for context-specific evidence and culturally grounded strategies to support EBF as temperatures continue to rise [5]. In terms of mental health, limited data exists to explain the social, psychological and biological mechanisms underlying EH's impact on mental health [76]. Sleep disruption mediates the relationship between EH and mental health [77–79], while sleep disturbances during pregnancy are themselves a known risk factor for poor maternal mental health [80]. Advancing heat-mental health research will require moving beyond epidemiological associations to directly measure temperature exposures and identify mechanistic pathways that can inform preventive interventions [81].

Study objectives

SPRINT-Sen is structured around five specific objectives:

1. To analyse the association between environmental temperature and selected maternal and child health outcomes - including maternal mental health disorders, pregnancy-related complications, and neonatal morbidity - using meteorological data (temperature and humidity) and routine health facility data (2020 onwards) in the Matam region.

2. To qualitatively assess the consequences of extreme heat on urban and rural populations in Matam locality, identify factors that moderate the experience of heat, and document coping strategies developed by communities and health professionals.

3. To implement a prospective micro-surveillance system to monitor indoor temperatures at households/health centres and outdoors, accounting for built environment characteristics and social inequalities in resilience.

4. To co-design, implement, and evaluate community-based and health-system preventive interventions to enhance exclusive breastfeeding practices and support maternal mental health during the hot season.

5. To translate evidence generated into policy recommendations for local and national decision-making.

METHODS AND ANALYSIS

Study design

SPRINT-Sen is a population health intervention research (PHIR) study using a mixed-methods design [82]. In line with the Medical Research Council (MRC) and PHIR frameworks for complex interventions, we combine effectiveness evaluation with theory-driven evaluation to generate comprehensive evidence for decision-making [83].

Mixed-methods sequence

We employ a mixed-methods approach to elucidate both the what and the how of intervention effects in a heat-stressed, complex social-ecological system [84]. Figure 2 provides an overview of the mixed-methods design across the three key phases of the study. This multiphase approach supports triangulation, contextual understanding, and the identification of change mechanisms.

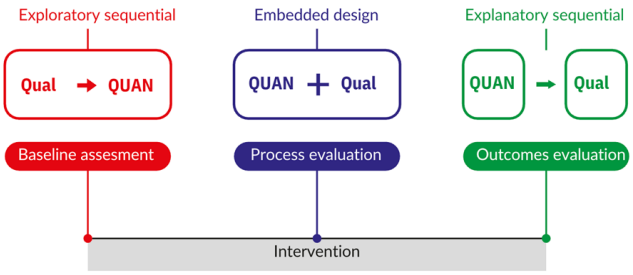

Figure 2. Mixed-methods study design in SPRINT-Sen.

The study follows an integrated mixed-methods design structured across three complementary and sequential phases. First, an exploratory sequential phase (Objectives 1 and 2) combines qualitative assessment of lived heat experiences with epidemiological time-series analyses to generate baseline evidence. Second, an embedded design (Objectives 3 and 4) integrates quantitative micro-surveillance with qualitative process evaluation, including realist evaluation, during intervention implementation. Third, an explanatory sequential phase (Objective

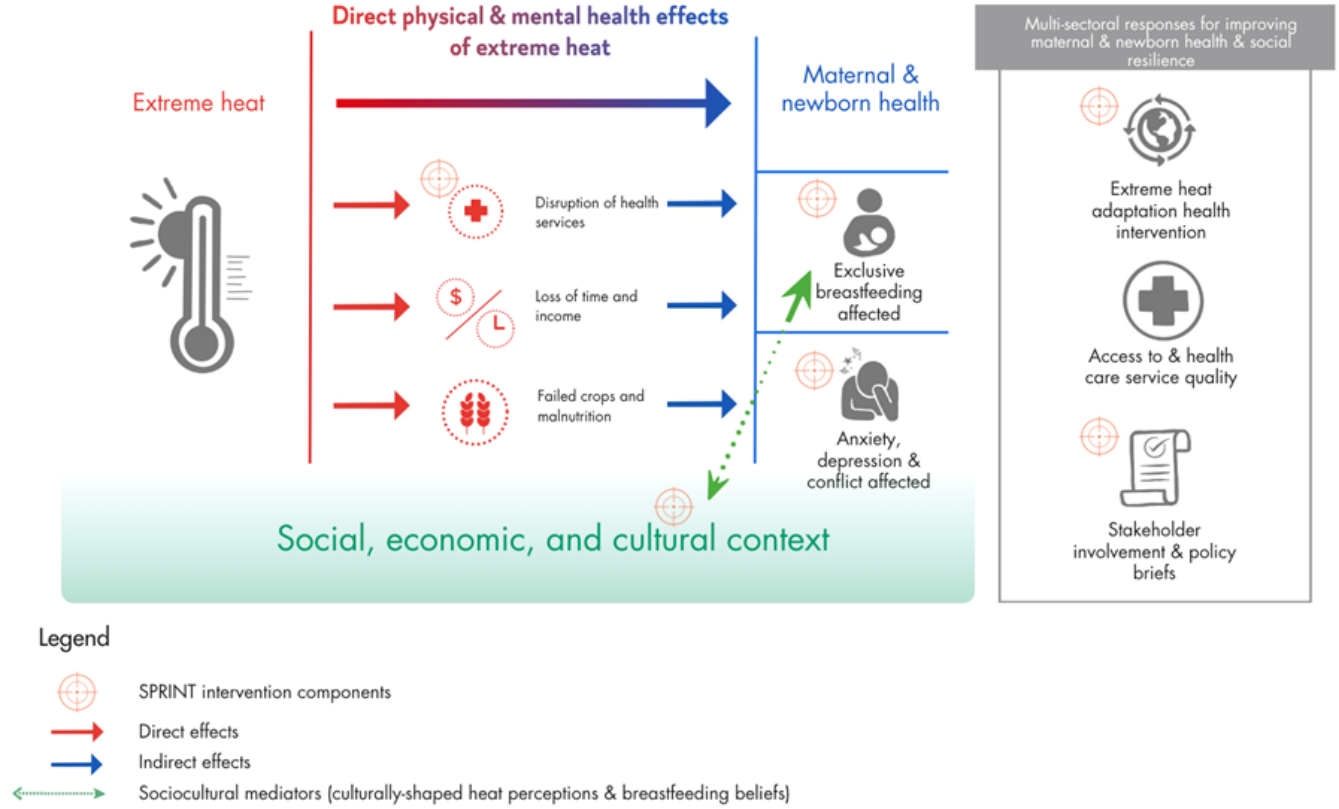

Figure 1. Conceptual framework (adapted from Roos et al. 2021 [6]).

4) includes quantitative outcome evaluation followed by qualitative interpretation to contextualize findings. Objective 5 (knowledge translation and policy engagement) is transversal and implemented throughout all phases to ensure continuous stakeholder involvement and policy relevance.

Objective 1 will be addressed through an ecological time-series analysis, using retrospective meteorological data and routine health facility records to examine the association between temperature variations and morbidity outcomes among women and children in the Matam region.

Objective 2 will adopt a qualitative exploratory design, including in-depth interviews and focus group discussions with urban and rural community members, including pregnant and breastfeeding women, health professionals, and local leaders. The aim is to understand the lived experiences of EH, identify barriers and coping strategies, and examine the factors that shape heat vulnerability and resilience.

Objectives 3 to 5 correspond to the three interlinked components of the intervention. The overall intervention will be evaluated using a before-after design. A randomized controlled trial was considered but not retained due to the high risk of contamination, the limited number of independent clusters, budget constraints and ethical concerns related to withholding preventive measures in a high-vulnerability setting. The evaluation will also incorporate a realist evaluation approach to explore the mechanisms through which the intervention produces observed outcomes in specific context.

Objective 3 consists of implementing a prospective micro-surveillance system to monitor environmental exposure and informs preventive responses. Objective 4 involves the co-design, implementation, and evaluation of community-based and health-system preventive strategies. The co-design phase will follow a structured co-design approach, including workshops with mothers and relatives, community actors, and health professionals, guided by intervention mapping principles [85] and behavioural change frameworks [86].

For objective 4, we will conduct four repeated cross-sectional surveys (approximately 1,200 women per round) at key time points: baseline during the hot season, baseline during the cooler season, during intervention implementation, and one year after implementation to assess sustained effects. This quasi-experimental design enables comparison across seasonal contrasts and intervention phases, while accounting for variations in environmental exposure and implementation intensity across sites [87,88].

Objective 5 focuses on knowledge translation and policy engagement and is implemented throughout the project as a cross-cutting component.

Study setting and population

The study will be conducted in the Matam region of northern Senegal. Within this region, four main sites in urban and rural settings, covering nearly 50,000 inhabitants, have been selected in the Matam health dis-

trict, including one located in the urban municipality of Matam town (see Figure 3 below). These sites were selected to capture environmental diversity based on their relative proximity to the Senegal River (near vs. far), to a health centre, and to allow for the enrolment of at least 300 houses per site. Site selection was conducted using random spatial sampling.

Eligibility criteria

The study population comprises pregnant women and mothers of infants under 12 months old living in selected localities of the Matam district. Women are eligible if they are aged 15 or above, are pregnant at any trimester or breastfeeding an infant under 12 months, and can give informed consent in Wolof, Pulaar, or French. Women who are not present at the time of the survey visit will not be included in that specific survey round. If they are younger than 15 years or are unable to provide informed consent in one of the study languages they will be excluded. The lower age limit of 15 years was selected to reflect the epidemiology of adolescent pregnancy in the region. For participants aged 15–17 years, assent and parental consent procedures will be applied in accordance with ethical guidelines.

Sampling

The study is powered to detect a 5 percentage-point increase in the primary outcome — exclusive breastfeeding for infants aged 6 months (yes/no) — between the baseline and post-intervention surveys. Based on an estimated baseline EBF prevalence of 31% in the region [50], and assuming a total sample of approximately 1,200 breastfeeding women across all four survey rounds, this study will achieve >80% power to detect a 10% absolute increase in EBF at a 5% significance level, accounting for design effects and clustering by site. This sample size calculation applies to the evaluation of the preventive intervention (objective 4) and is based on expected changes in EBF prevalence during periods of extreme heat. EBF will be defined according to WHO guidelines [89], based on maternal report of feeding practices in the previous 24 hours (for children under 6 months), since birth, and retrospectively up to 12 months postpartum. This approach allows for the estimation of both point prevalence and duration of EBF.

Household sampling will be based on a thermal aerial image captured by a drone (AMVIC 3T©), which will generate a thermal emission map of the study areas. To account for variability in household thermal environments, the sampling design incorporates stratification by village and roof type, considered a key determinant of indoor temperature exposure. The sampling frame was established through a prior census combining drone imagery, photointerpretation of orthomosaics to classify roof types (primarily zinc/sheet metal and concrete slab), and ground-truth field verification. Household selection will be proportional to the distribution of roof types observed in each locality. The sampling design therefore follows a multi-stage cluster approach (village and household), with stratification by roof type to ensure that variability in household thermal configurations is adequately represented. Each selected household will be equipped with a thermal sensor and included in the indoor temperature monitoring system.

Within each of the four selected sites, an exhaustive household listing will be conducted. All households located within the defined geographic boundaries will constitute the sampling frame for participant recruitment. To reach the required sample size of 1,200 women per survey round, the sampling frame will be expanded to include additional villages within the district. In total, approximately 1,100 households will be monitored, which is expected to yield 1,200 eligible women per round, as multiple eligible women may reside within the same household.

Intervention description

Co-design approach

The co-design process pertains to Objective 4 and aims to develop and implement preventive strategies to enhance exclusive breastfeeding and support maternal mental health during periods of extreme heat. The intervention will address gaps identified through Objectives 1 and 2, including epidemiological evidence of heat-related maternal and child health burdens and qualitative findings on lived heat experiences, barriers to exclusive breastfeeding, and existing coping strategies. Intervention development will follow the Intervention Mapping framework [90] which will guide the systematic needs assessment, identification of behavioural and contextual determinants, and selection of appropriate behaviour change techniques. The Godin framework for health behaviour change [91] will inform the identification of key determinants such as beliefs, perceived risks, social norms, self-efficacy, and behavioural intentions related to breastfeeding and adaptation practices during extreme heat. Two core elements will be co-designed: awareness and capacity building. The intervention will be co-designed with local stakeholders, community members, and health professionals to ensure sociocultural appropriateness [92]. We will adopt a structured two-step approach to meaningful engagement [93], which includes: (i) defining the collaborative arena to prepare for participation and promote active engagement, and (ii) designing involvement mechanisms that prioritize user perspectives and value critical feedback [93].

To operationalize this approach, we will implement contextually-appropriate participatory tools, such as community dialogue circles or photovoice [94]. Across every study phase, we will systematically track participation with the 'Involvement Matrix' [79] to ensure participation remains meaningful. Community members will act as "advisors", aligned with the study design and sociocultural context [79]. Finally, we will assess the co-design phase using the PROSECO framework [95], which offers a structured approach to evaluating

Figure 3. Map of the study area in the Matam Region, Senegal.

co-design processes in public health interventions.

We will pay close attention to avoid reinforcing guilt, pressure, or the normative image of the "good mother", as negative effects have been documented in EBF campaigns in both Western countries [96,97] and the Global South [98]. A key priority is to avoid idealised maternal archetypes [99], by respecting rather than displacing mothers' experiential knowledge [100] and by resisting the transformation of exclusive breastfeeding as a 'moral imperative' imposed by Northern or international institutions [100,101]. Mothers' lived experiences will guide the intervention through a co-design process, addressing gaps between knowledge and practice and positioning breastfeeding as a 'meeting point' where different forms of knowledge can productively interface [98]. For maternal mental health outcomes, women's perspectives will likewise be at the centre of the intervention, and we will explicitly avoid both stigma and the medicalisation of well-being. The intervention will systematically integrate local and cultural practices when developing community-based actions [102,103].

Logic model and strategic elements of the intervention

Figure 4 presents the logic model of SPRINT-Sen intervention, which aims to reduce the impact of extreme heat on exclusive breastfeeding and maternal mental health. The programme theory will be developed using a realist evaluation approach. The intervention will be co-designed with community members and stakeholders and is expected to comprise three interlinked components: (1) a heat-health surveillance and early warning system to monitor temperature exposure and generate alerts; (2) the co-design of community-based and health system prevention strategies, including the devel-

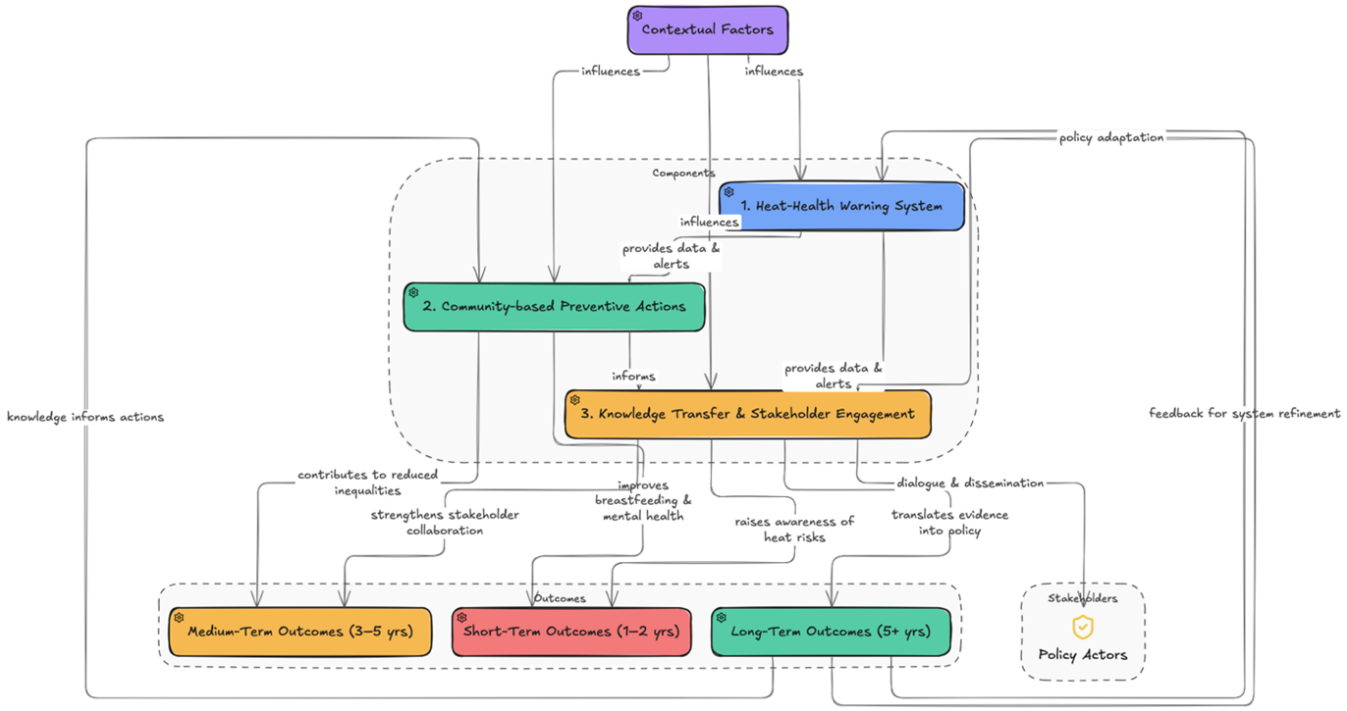

Figure 4. SPRINT-Sen simplified logic model.

opment of a health warning system; and (3) knowledge transfer through stakeholder engagement and dissemination. Short (within 1- 2years), mid-term (3-5 years), and long-term (beyond 5 years) outcomes are expected to improve health behaviours, reduced health inequities, and sustainable policy integration at local and national levels. Researcher reflexivity will be embedded throughout the process [104–106]. This reflexive approach will help us critically examine our own positionality (gender, social, cultural, racial) and its influence on the intervention co-design and implementation, ensuring that power dynamics and cultural assumptions are continuously interrogated and addressed [107]. Contextual factors—including environmental, economic, cultural, institutional, and political dimensions—may influence the implementation and outcomes of the intervention.

Exposures

SPRINT-Sen examines two main exposures: environmental heat exposure and intervention exposure. The first refers to heat exposure, assessed using a combination of daily meteorological data, health centres outdoors temperatures and household-level indoor temperature measurements. Built environment characteristics such as roofing materials, vegetation cover, housing density, etc., will also be incorporated to capture microclimatic variability and structural vulnerability.

The second exposure concerns the implementation status of the community-based intervention. It includes site-level variation in intervention timing, intensity, and type of activities delivered. These two dimensions of exposure—environmental and interventional—will be analysed both independently and jointly to explore their effects and potential interactions on maternal mental health and exclusive breastfeeding outcomes.

Outcome measures

Primary outcome

The primary outcome is the prevalence of exclusive breastfeeding among infants under 6 months, as defined by WHO criteria [45]. At each of the four survey rounds, we will interview every breastfeeding woman with an infant aged 0–12 months; EBF prevalence will then be calculated for two subgroups: i) infants < 6 months (status) and ii) infants 6–12 months (retrospective status for the first six months of life). This approach will allow us to estimate both point prevalence (age-specific) and cumulative prevalence of EBF, from which we will calculate the overall percentage of EBF across the sample, before-after the intervention. The EBF indicators will be analysed in relation to two main exposures: 1) heat exposure, and 2) the implementation status of the community-based intervention.

Secondary outcomes

Maternal mental health outcomes include anxiety and depressive symptoms, sleep disorder, suicidal risk, and inter-personal conflict each measured separately with validated screening instruments.

Cost (direct and indirect costs) of the implementation process, DALYs averted, and the budgetary impact analysis will be measured and estimated for the economic evaluation.

Table 1 shows the key outcome concepts and their operationalisation for SPRINT-Sen.

Data collection and analysis

Data collection

Data will be collected at four strategic time points (Figure 5):

- baseline 1– heat season, pre-intervention
- baseline 2 – cold season, pre-intervention
- implementation – heat season, during intervention
- follow-up – heat season, 12 months post-implementation

We use an open cohort, meaning that pregnant or breastfeeding women (up to 12 months postpartum) may enrol at any of the four survey rounds and remain in the study until their infant reaches 12 months of age. The endline survey is conducted 12 months after Measure 3 (during the intervention phase) to enable comparison under similar heat-exposure conditions. For women enrolled during the intervention, follow-up may be extended up to 18 months post-inclusion to assess sustained effects on maternal mental health outcomes (Figure 6).

Participants are grouped based on their timing of enrolment relative to the intervention phases:

- Subgroup 1: pre-intervention
- Subgroup 2: during intervention (up to 6 months)
- Subgroup 3: post-intervention (0 and 12-month follow-up)

Subgroup 1 includes women enrolled during the pre-intervention phase, with an approximately six-month interval before intervention rollout to allow for co-design, preparation, and completion of the second baseline survey. The repeated cross-sectional survey is designed to capture breastfeeding practices and the multifactorial determinants of perinatal mental health outcomes, which are largely transitory, as well as factors influencing heat exposure shaped by seasonal patterns and the built environment. This design enables comparative analysis of outcomes from early pregnancy through the first year after birth.

Objective 1. Describe recent heat trends and heat-sensitive morbidity

To assess the association between ambient temperature and health outcomes in women and chidren, we will conduct an ecological time-series analysis using routine health facility data and meteorological records (2020–present). Temperature exposure will be characterized using indicators such as daily mean, minimum, and maximum temperature, as well as heat indices adapted to or constructed for the local climatic context. Health outcomes will be derived from routine health facility data (e.g., daily counts of consultations in health centres). Associations will be estimated using time-series regression models, including distributed lag non-linear models (DLNM), which allow the estimation of delayed and non-linear effects of temperature exposure. Meteorological data will be obtained from national weather stations (ANACIM) and complemented with satellite data, while health data will be sourced from local health centres. Analyses will assess inter-village inequalities. Spatial analyses will identify geographic disparities in temperature exposure and heat-vulnerability hotspots across the Matam district. We will apply spatial clustering methods and stratify by village characteristics (e.g., roof type, vegetation cover, river access, etc.). Time-series models will be used to assess short-term associations between temperature and specific maternal and neonatal outcomes, including maternal mental health consultations, pregnancy-related complications, and neonatal morbidity, while controlling for seasonality and temporal autocorrelation. Attributable fractions will be calculated to estimate the burden of heat-related illness among women and children. Previous studies have quantified the burden of health outcomes attributable to non-optimal temperatures using distributed lag non-linear models and attributable fraction methods [111–114], although evidence remains limited in African settings [115] and for maternal health outcomes [116].

Objective 2. Assess the consequences of EH and identify health adaptation strategies

Phase 1: Contextualisation, baseline and pre-implementation (Months 0 to 11, Measures 1 and 2)

At baseline, the qualitative data collection will aim to understand the determinants of exclusive breastfeeding, maternal mental health burden, and strategies for resilience to extreme heat among mothers, households, and health professionals. We will employ a multiple-case study approach [117] in which the four selected study sites constitute the analytical cases. Each site represents a distinct socio-environmental and health-system context, allowing comparative analysis of households' adaptation and resilience strategies during extreme heat events. To analyse the local context, we will deploy multiple data collection methods:

- Focus group discussions with community members and health workers
- Individual in-depth interviews with key informants
- Structured observations of health facilities and household practices
- Concept mapping to visualize local understandings of heat-health relationships

To address inherent inequalities within villages, the study will focus on local and individual constraints and how different population sub-groups may deploy differential adaptation strategies. The analytical approach will

employ a comparative perspective using heuristic tools to identify configurations and their regularities [118]. We will conduct cross-case analysis to "discover patterns of invariance and constant association" [118]. We will adopt a realist evaluation approach to reconstruct the intervention theory using multiple sources, including the logic model, empirical data and a validation workshop. This process will help clarifying assumptions about mechanisms, expected effects, and contextual factors influencing their activation [119]. Qualitative interviews with mothers and health personnel will explore adaptive behaviours to extreme heat and identify pathways for change. Using context–mechanism–outcome (CMO) configurations, the analysis will examine how contexts shape responses and outcomes [120]. Qualitative findings will be shared with communities through validation workshops to strengthen content validity. Credibility, rigor, triangulation, rich descriptions, and respondent validation will guide data collection and analysis, as recommended for case studies [117].

Table 1. Concepts and their operationalisation in the SPRINT-Sen study.

Concept	Operationalization
Exclusive breastfeeding	Maternal report of infant feeding in the previous 24 h, coded per WHO/UNICEF criteria as only breastmilk, no other liquids or solids, among infants < 6 months [89]. Questions will be adapted from the DHS module.
Heat-related morbidity	Physical or mental health condition directly caused or exacerbated by elevated ambient temperatures, based on clinical diagnoses recorded in health facility registers (e.g., heat stroke, dehydration, hypertension in pregnancy, acute diarrhoeal infant disease, anxiety, sleep disturbance, etc.)
Anxiety	GAD-7 (Generalized anxiety disorder) score ≥ 10 over the past 2 weeks, indicating moderate or higher generalized anxiety symptoms [108].
Sleep quality	ISI (Insomnia index) score ≥ 15 over the past 2 weeks, indicating poor sleep quality [109].
Suicidal risk	Any positive response to MINI (Mini International Neuropsychiatric Interview) suicidality items C1–C5 (thoughts, plans or preparations) within the past month; C6 documents any lifetime suicide attempt [110].
Interpersonal conflict	Any reported tension between the woman and her household, or with health personnel/at the health centre.
Costs of resources and inputs used for the implementation	Direct and indirect costs of all resources required for the implementation process, including those used for warning systems, from the health-care providers perspective.
DALYs	Disability-Adjusted Life Years attributable to mental health outcomes (anxiety, depression, interpersonal conflict) and heat-related morbidities.

A quantitative survey will be conducted in both the hot and cooler seasons to measure the impact of EH on maternal physical and mental health, using standardised instruments and context adapted tools informed by the literature and qualitative findings (Appendix). These data will establish the baseline values for both outcomes (EBF rates and mental health status), and when the survey is repeated in subsequent waves, will allow us to track seasonal variation and detect any changes attributable to the intervention.

The integration of qualitative and quantitative findings will contribute to refining the program theory prior to implementation and better understand the studied phenomenon.

Objective 3. Implement a prospective micro-surveillance system (years 1-2)

A two-year prospective study using satellite remote sensing and aerial data (drones equipped with thermal sensors) will help capture intra-village differences in heat exposures and enable prospective monitoring in connection with the intervention. Temperature monitoring will be conducted both indoors (within households) and at the local level (village or study neighbourhood) and will be cross-referenced with data from the ANACIM weather station located in Matam. Approximately 1,100 households will be equipped with RAK © thermal sensors capable of measuring temperature, humidity, and atmospheric pressure every hour. This frequency is sufficient to capture daily temperature peaks relevant for heat–health analyses while ensuring long-term operational feasibility. These measurements will be transmitted via a LoRaWAN © network to a self-powered server that securely stores the data and transmits it via 4G to a RGPD-compliant hosting service. A dynamic dashboard will provide real-time visualization of the data, displaying maps, tables, and graphs of hourly readings. Temperature and humidity data collected by the household sensors will be used to estimate various indicators of heat exposure. This measure is particularly relevant, as it is the combination of heat and humidity that determines the level of health risk. Alerts will be au-

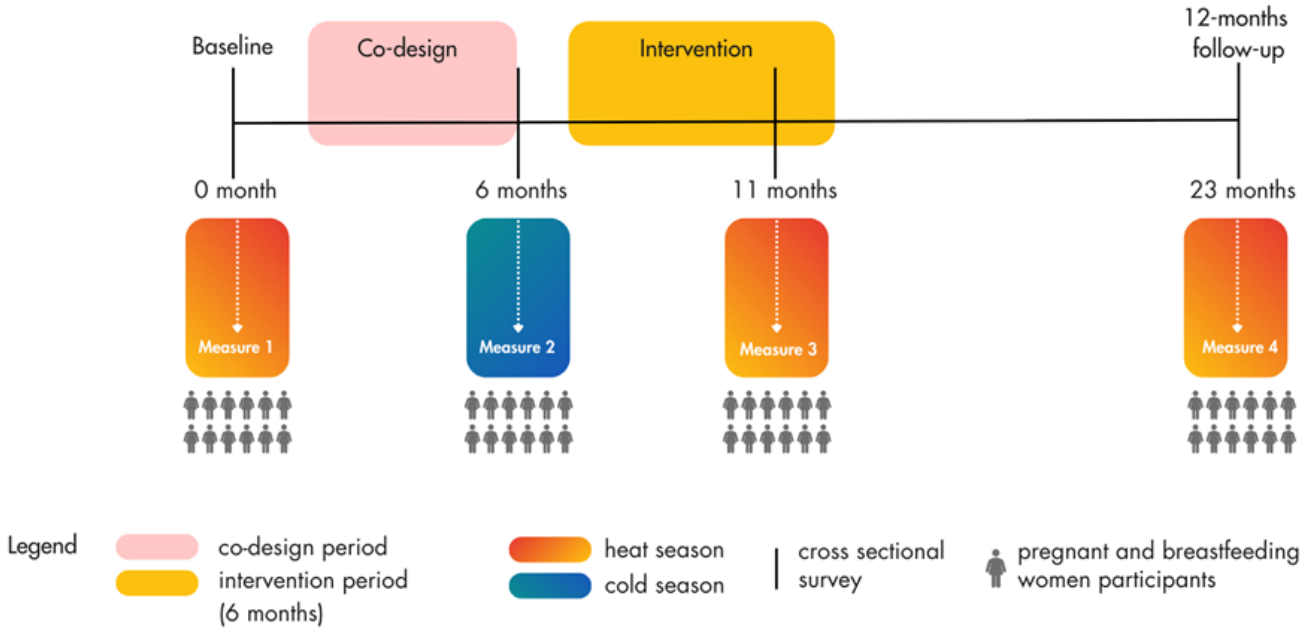

Figure 5. Data collection timeline and intervention phase of the SPRINT-Sen study.

tomatically triggered and sent to project managers whenever predefined thresholds are exceeded. Temperature thresholds will not rely solely on predefined percentiles or standard cut-offs. Locally relevant thresholds will be empirically derived by modelling exposure–response relationships between heat metrics (e.g., temperature and humidity-based indices) and selected maternal and neonatal outcomes. These empirically derived thresholds will be compared with standard heat indicators (e.g., Heat Index, Humidex or Wet Bulb Index) to assess their relative performance and contextual relevance. Sensitivity analyses and internal validation across time periods and sites will be conducted to ensure robustness.

Moreover, dust load will be analysed using data from the ground-based observation network SNO INDAAD (with continuous measurements in Bambey since 2006) and/or from CAMS (Copernicus Atmosphere Monitoring Service) reanalysis products.

These data will enable us to compare multiple heat indicators to better characterise heat impacts, including the concept of high-impact weather events [121], which accounts not only the occurrence of a strong or extreme hazard, but also situations where both exposure to hazard and vulnerability to that exposure are extreme. Furthermore, we will develop indoor heat metrics, tailored to the daily living conditions of populations exposed to sustained high ambient temperatures.

Objective 4. Co-design, implement and evaluate community-based intervention

Phase 2: Intervention implementation (Months 6 to 11, Measure 3)

The community-based intervention will focus on prevention through two core elements: community sensitization to heat-related risks, and capacity strengthening of mothers and health professionals to support exclusive breastfeeding and maternal mental health in the context of extreme heat. The measured variables will align with the dimensions of the Roos et al. (2021) and Chersich et al. (2023) framework and our primary intervention outcome: the rate of exclusive breastfeeding at six months. We will assess breastfeeding practices for infants under 6 months using the French version of the WHO questionnaire, which will be translated into local languages (Wolof and Pulaar), and will inquire about all foods and liquids consumed during the previous 24 hours (day and night) [122]. For infants above 6 months and under 12 months, we will adapt the FeedCat Tool [123] to determine the timing of introduction of non-breastfeeding, capturing both the months at first introduction and the types of complementary foods given. Complementary measures will be collected to comprehensively assess mothers' knowledge and practice of breastfeeding, including early initiation, frequency of breastfeeding, continuing breastfeeding (6-11months), supplementation practices, and colostrum feeding, as recommended by WHO and studies assessing breastfeeding [124,125]. For pregnant women, we will assess breastfeeding intention using Godin's framework [91], which will be compared with actual breastfeeding practices through follow-up. These measurements will be conducted at baseline (hot season, and cooler season just before the intervention), during the intervention, and endline.

Mental health will be assessed as a secondary outcome of the intervention, with a focus on acute and subacute manifestations during periods of extreme heat. Standardised and validated tools will be used, including the GAD-7 (Generalized Anxiety Disorder-7) for anxiety, the IPVS-Toolkit for interpersonal conflicts, the Mini International Neuropsychiatric Interview for suicide risk assessment, the WHO-5 (Wellbeing Index) to enable in-

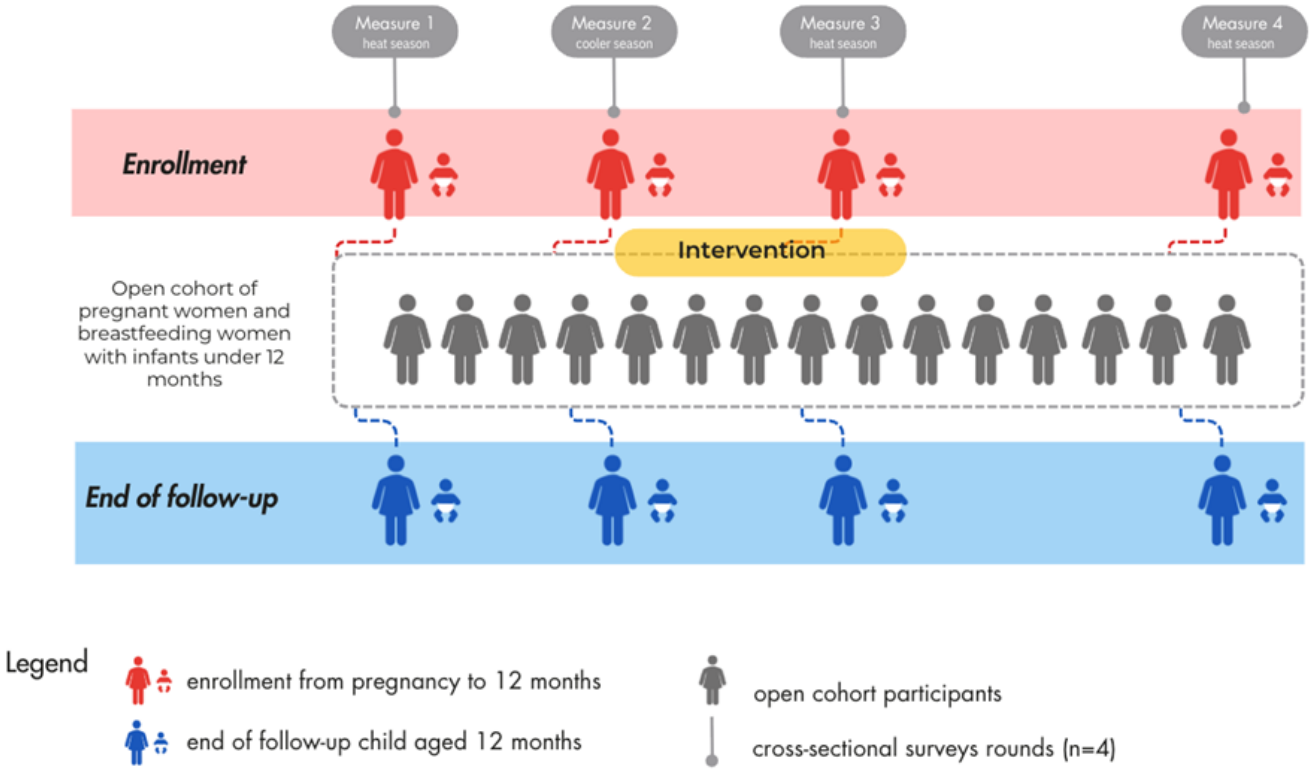

Figure 6. Structure of the open cohort and timeline of repeated.

ternational comparisons. To attribute changes in mental health outcomes to heat exposures, we will combine i) comparisons across four repeated cross-sectional surveys conducted in different climatic periods, and ii) a tailored heat exposure index that integrates indoor and outdoor temperature data with built environment characteristics.

The questionnaires will be adapted based on the qualitative findings and existing literature on recommended actions in extreme heat contexts [126–128]. We will also measure prospective and retrospective acceptability of critical neonatal prevention interventions in periods of extreme heat [129]. To evaluate extreme heat impacts on maternal and child health, the questionnaire will incorporate elements from Nakstad et al. [39] conceptual framework, addressing: mental and physical health status, socioeconomic characteristics, extreme heat risks, knowledge, attitudes, health prevention practices (breastfeeding, danger signs, isolation, etc.) and housing and environmental characteristics. Quantitative variables will be described using means, standard deviations, and medians if the distribution is non-normal.

The intervention evaluation will also assess acceptability, reach, fidelity and implementation. Acceptability refers to participants' and health professionals' perceived appropriateness and satisfaction with the intervention components. It will be evaluated using Sekhon et al. framework of acceptability [130] adapted to the Senegalese context [131]. Reach will assess the proportion and characteristics of eligible women and households exposed to the intervention activities. It will be assessed by using both quantitative data (coverage indicators) and qualitative insights on access and inclusion. Fidelity will examine the extent to which the intervention components are delivered as intended, including adherence to planned content and frequency. It will be assessed using the CORE Fidelity Method, embedded within the broader co-adaptation process framework [132,133], to measure the extent to which the intervention is delivered as intended while allowing for necessary contextual adaptations. This is critical for distinguishing between effects attributable to the intervention itself and those attributable to its implementation. Implementation processes will document contextual facilitators, barriers, and adaptations occurring during delivery. It will be explored through the Consolidated Framework for Implementation Research (CFIR) [134] using a qualitative approach adapted to French speaking countries [135]. Finally, the realist evaluation will test the intervention theory formulated during the previous stage, based on initial field insights. By examining how specific contexts trigger or inhibit mechanisms, it will help explain not only whether the intervention works, but also how, for whom, and under which conditions. In addition, we will construct an intensity of implementation variable across sites and over time to capture variation in strength, frequency and reach of the intervention in different villages. This proxy 'dose' indicator will support dose-response analysis between implementation intensity and outcomes and mimic a concurrent group

evaluation.

The micro surveillance system could also become part of the intervention: sensors would trigger alerts whenever preset temperature thresholds are exceeded, promptly informing the community so they can implement preventive measures.

Phase 3: Post-intervention and follow-up (measure 4)

Intervention effectiveness will be measured using a difference-in-differences approach, comparing outcomes between baseline and final survey. Results will be compared using McNemar's test for paired measurements. Binary outcomes (exclusive breastfeeding) will be analysed using mixed-effects logistic regression, accounting for village-level clustering and repeated measures within individuals. Maternal mental health outcomes will be measured using validated instruments. Depending on the structure of each scale and the distribution of the resulting scores, outcomes will be analysed as continuous, ordinal, or categorical variables using appropriate mixed-effects models. Repeated measurements collected at baseline, during the intervention, and at 12-months follow-up will be analysed using generalized estimating equations (GEE) for population-averaged effects and mixed-effects models for subject-specific trajectories. Analyses will examine dose-response relationships between intervention intensity and outcomes to explore heterogeneity in intervention effects in across sites. Models will adjust for maternal age, parity, socioeconomic status, and heat exposure intensity. Sensitivity analyses will include multiple imputation for missing data and per-protocol analysis.

Throughout data collection and analysis, the research team will maintain reflexive journals documenting methodological decisions, challenges encountered, and potential biases. This reflexivity will strengthen the credibility of findings and enhance transparency about the knowledge production process [104].

Objective 5. Knowledge transfer

The project aims to generate actionable evidence from scientific knowledge. Thus, it is essential to consider the science of using science [136] to design specific activities that promote research results. All team members will receive knowledge transfer training through specialized Massive Open Online Course (MOOC) [137]. A knowledge transfer plan will be developed with stakeholders' participation, specifying the nature of knowledge to translate, target audiences, and culturally appropriate dissemination approaches, and its implementation will be qualitatively evaluated [138]. Our primary audiences include: (1) mothers and community members, reached through tools adapted to low-literacy contexts; (2) health professionals, engaged through practice guidelines and training modules; and (3) policymakers at district, regional and national levels influenced through deliberative dialogues. Beyond peer-reviewed publications, we will prioritize proven knowledge translation tools for the climate-health nexus [139].

Anticipated limitations

This study presents several anticipated limitations. The quasi-experimental design may limit causal inference compared with randomized approaches. Exclusive breastfeeding data rely on maternal self-report and may be subject to recall or social desirability bias. Contextual variability and seasonal fluctuations may affect implementation and exposure measurement. Finally, findings may be context-specific to the Matam region. Nevertheless, the mixed-methods design and repeated seasonal measurements aim to strengthen contextual validity and interpretation. Finally, the implementation of community-based interventions may introduce variability in participation and exposure across sites.

Conclusion

SPRINT-Sen addresses the intersection of extreme heat and maternal-child health in the Sahel, focusing on Matam, Senegal. Using retrospective analysis, prospective micro-surveillance, and community co-designed interventions, it will generate evidence on the relationship between extreme heat, exclusive breastfeeding, and maternal mental health. By combining interdisciplinary methods with participatory research, the study will develop and test culturally grounded solutions to reinforce community resilience and health system capacity, including a cost-effectiveness analysis. Built-in feedback loops – from community to policy makers – it will ensure real-time translation of evidence into concrete adaptation strategies to improve maternal and child health outcomes in vulnerable communities facing accelerating climate change.

Ethics and dissemination

This study protocol received ethical approval from Comité National d'Ethique pour la Recherche en Santé (CNERS) in Senegal (n°0000158/MSAS/CNERS/SP, June 25, 2024), and from the Ethics committee of the London School and Hygiene and Tropical Medicine (LSHTM) (n°31204). Written informed consent will be obtained from all participants, with particular attention to pregnant women and young mothers to ensure voluntary participation and full understanding of the study's purpose, procedures, and rights. For participants under 18 years of age, written informed consent will be obtained from a parent or legal guardian, in addition to the assent of the adolescent participant, in accordance with national ethical regulations and the requirements of the ethics committee.

Primary risks include potential psychological distress when discussing heat-related health challenges and concerns regarding household-level surveillance data. To mitigate these, we have established: (1) a referral pathway to mental health services; (2) Weather surveillance data collected at household levels will be aggregated without personal identifiers.

Data will be stored on encrypted servers at Humanum [140] and Institut de la Recherche pour le

Développement (IRD) servers, in line with the FAIR principles — Findability, Accessibility, Interoperability, and Reusability —which guide data management [141]. It will also comply with Senegalese data protection law and align with the European Union's General Data Protection Regulation (GDPR), including requirements for data collection, storage and use, including anonymization, encryption and formal data-sharing agreements [142]. Compliance with GDPR and risk assessment have been validated through a Data Protection Impact Assessment (DPIA) conducted at IRD [143].

Results will be shared via open-access peer-reviewed articles, communications, policy briefs, community workshops, and disseminated to local and national stakeholders. Participants will receive plain-language summaries, and key findings will be integrated into training materials for community health workers and health and environmental plans.

DECLARATIONS

AI utilization

The authors occasionally used an AI translation tool to improve language quality and correct parts of the English translation. All outputs were reviewed and edited, and the authors take full responsibility for the manuscript.

Competing interests

The authors declare no conflicts of interest.

Funding

The SPRINT-Sen study is part of the broader SPRINT project (Strengthening Preparations and Resilience in Temperature community adaptation for women's health in Bangladesh and Senegal). This research is funded by the Foundation for Medical Research (FRM) and has received financial support from French National Institute of Health and Medical Research (Inserm) through the Climate change and health booster program, as well as the Thematic Institute of Public Health for the implementation and monitoring. Additional support was provided by the Paris Public Health Institute, the French Red Cross Foundation (FCR), and the Fondation de France. This project also received support from the French State through the National Research Agency (ANR) under the Investments for the Future Programme (ANR-21-EXES-0002) and was also partly funded under the project ANR-24-CE36-1129-01.
Further information on the SPRINT project is available at https://www.heatsprint.org/

Author contributions

The first author (JMG) drafted the initial version and finalised the manuscript. The second author (AF), as co-principal investigator in Senegal, co-led the study design and contributed substantially to all main sections. The last author (VR) is the principal investigator who secured the main funding for the study. All other co-authors are listed alphabetically to acknowledge their collective contributions to the manuscript (writing and review).

Acknowledgements

We would like to thank Paige Gaskins (graphic designer) for enhancing the study diagrams. We also thank all stakeholders and community representatives who contributed to the development of this protocol.

ORCIDs

Jean-Marc Goudet 0000-0003-3355-7940
Sandrine Anquetin 0000-0001-5127-1650
Emmanuel Bonnet 0000-0001-6735-5330
Makhan Danfakha 0009-0009-6082-3600
Muhamed Nazmul Islam 0000-0001-9831-6086
Sarah Louart 0000-0001-5330-7434
Veronique Filippi 0000-0003-1331-3391
Pauline Gluski 0009-0007-6953-1052
Sari Kovats 0000-0002-4823-8099
Fatimata Sow 0009-0008-4072-8000
Labaly Touré 0009-0008-0939-2019
Zahidul Quayyum 0000-0002-2276-4576
Valéry Ridde 0000-0001-9299-8266

ABSTRACT IN SPANISH

Calor extremo, lactancia materna exclusiva y salud mental materna en el norte de Senegal: protocolo de investigación en intervenciones de salud poblacional para el estudio SPRINT-Sen

Introducción: El calor extremo ha sido siempre un desafío de salud pública en el Sahel, y existe cada vez más evidencia de sus efectos adversos sobre la salud materna, n eonatal e infantil (SMNI), incluida la salud mental. En la región de Matam, en Senegal, las altas temperaturas estacionales pueden afectar las prácticas de lactancia materna exclusiva (LME) y la salud mental materna a través de los efectos directos de la percepción del calor y del conocimiento sobre este. SPRINT-Sen tiene como objetivo codiseñar, implementar y evaluar una intervención comunitaria de salud poblacional para mejorar la LME y la salud mental materna en un clima cálido y árido.

Métodos: SPRINT-Sen es un estudio de investigación en intervenciones de salud poblacional (IISP) que utiliza un diseño longitudinal cuasiexperimental con cuatro encuestas transversales independientes en una cohorte abierta. La evaluación de impacto sigue un diseño pre-post y utiliza un enfoque de métodos mixtos para evaluar la aceptabilidad y el proceso de implementación. Las participantes elegibles son mujeres embarazadas y madres de lactantes de 0 a 12 meses. La intervención codiseñada combinará: (1) promoción de la LME adaptada a condiciones de calor extremo; (2) apoyo a la salud mental materna mediante actividades de promoción y apoyo psicosocial; y (3) monitoreo continuo de la temperatura para informar un sistema de alerta por calor. El resultado principal es la LME a los seis meses. Los resultados secundarios incluyen efectos sobre la salud mental materna, como ansiedad, estrés y conflicto interpersonal. La exposición ambiental será evaluada mediante datos meteorológicos y cartografía térmica.

Resultados: El estudio generará evidencia sobre los mecanismos y la implementación de intervenciones relacionadas con calor y LME, así como sobre los efectos del calor en la salud mental dentro de la SMNI. Los hallazgos orientarán los esfuerzos para fortalecer un sistema de salud resiliente al calor mediante soluciones comunitarias. La transferencia de conocimientos se apoyará mediante la codifusión con las partes interesadas y su integración en políticas de salud materna y adaptación al cambio climático.

Conclusiones: SPRINT-Sen aportará evidencia novedosa y específica al contexto sobre la factibilidad, la implementación y la efectividad de una intervención integrada que aborda tanto la salud mental materna como la LME en el contexto del calor extremo. Los hallazgos informarán estrategias de adaptación para programas de SMNI y contribuirán a los debates globales sobre las IISP en contextos sahelianos.

Palabras clave: Calor extremo, materno, salud mental, intervención, rural, urbano, protocolo, Senegal

REFERENCES

[1] Engdaw MM, Ballinger AP, Hegerl GC, Steiner AK. Changes in temperature and heat waves over Africa using observational and reanalysis data sets. Int J Climatol. 2022 Feb;42(2):1165–80. doi:10.1002/joc.7295.

[2] Lee H, Kim H, Pehlivan N. Chapter 8 - Heat exposure and mental health in the context of climate change. In: Guo Y, Li S, editors. Heat Exposure and Human Health in the Context of Climate Change [Internet]. Elsevier; 2023 [cited 2023 Feb 21]. p. 155–87. doi:10.1016/B978-0-12-819080-7.00008-2.

[3] Ebi KL, Capon A, Berry P, Broderick C, Dear R de, Havenith G, et al. Hot weather and heat extremes: health risks. Lancet. 2021 Aug 21;398(10301):698–708. doi:10.1016/S0140-6736(21)01208-3.

[4] Cissé G, McLeman R, Adams H, Aldunce P, Bowen K, Campbell-Lendrum D, et al. Health, Wellbeing and the Changing Structure of Communities. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Cambridge, UK and New York, NY, USA; 2022. p. 1041–170.

[5] Bekkar B, DeNicola N, Girma B, Potarazu S, Sheffield P. Pregnancy and newborn health - heat impacts and emerging solutions. Semin Perinatol. 2023 Dec 1;47(8):151837. doi:10.1016/j.semperi.2023.151837.

[6] Roos N, Kovats S, Hajat S, Filippi V, Chersich M, Luchters S, et al. Maternal and newborn health risks of climate change: A call for awareness and global ac-

tion. Acta Obstet Gynecol Scand. 2021;100(4):566–70. doi:10.1111/aogs.14124.

[7] Samuels L, Nakstad B, Roos N, Bonell A, Chersich M, Havenith G, et al. Physiological mechanisms of the impact of heat during pregnancy and the clinical implications: review of the evidence from an expert group meeting. Int J Biometeorol. 2022 Aug 1;66(8):1505–13. doi:10.1007/s00484-022-02301-6.

[8] Ye T, Guo Y, Huang W, Zhang Y, Abramson MJ, Li S. Heat exposure, preterm birth, and the role of greenness in Australia. JAMA Pediatr. 2024 Apr 1;178(4):376–83. doi:10.1001/jamapediatrics.2024.0001.

[9] McElroy S, Ilango S, Dimitrova A, Gershunov A, Benmarhnia T. Extreme heat, preterm birth, and stillbirth: A global analysis across 14 lower-middle income countries. Environ Int. 2022 Jan 1;158:106902. doi:10.1016/j.envint.2021.106902.

[10] Chersich MF, Scorgie F, Filippi V, Luchters S, Climate Change and Heat-Health Study Group. Increasing global temperatures threaten gains in maternal and newborn health in Africa: A review of impacts and an adaptation framework. Int J Gynaecol Obstet. 2023;160(2):2. doi:10.1002/ijgo.14381.

[11] Lakhoo DP, Brink N, Radebe L, Craig MH, Pham MD, Haghighi MM, et al. A systematic review and meta-analysis of heat exposure impacts on maternal, fetal and neonatal health. Nat Med. 2024 Nov 5;1–1. doi:10.1038/s41591-024-03395-8.

[12] Haghighi MM, Wright CY, Ayer J, Urban MF, Pham MD, Boeckmann M, et al. Impacts of high environmental temperatures on congenital anomalies: A systematic review. Int J Environ Res Public Health. 2021 May 5;18(9):4910. doi:10.3390/ijerph18094910.

[13] Guo Y, Chen P, Xie Y, Wang Y, Mu Y, Zhou R, et al. Association of daytime-only, nighttime-only, and compound heat waves with preterm birth by urban-rural area and regional socioeconomic status in China. JAMA Netw Open. 2023 Aug 11;6(8):e2326987. doi:10.1001/jamanetworkopen.2023.26987.

[14] Kim SE, Hashizume M, Armstrong B, Gasparrini A, Oka K, Hijioka Y, et al. Mortality risk of hot nights: A nationwide population-based retrospective study in Japan. Environ Health Perspect. 2023 May;131(5):57005. doi:10.1289/EHP11444.

[15] Hanson C, de Bont J, Annerstedt KS, Alsina M del R, Nobile F, Roos N, et al. A time-stratified, case–crossover study of heat exposure and perinatal mortality from 16 hospitals in sub-Saharan Africa. Nat Med. 2024 Sep 3;1–8. doi:10.1038/s41591-024-03245-7.

[16] Liu Y, Saha S, Hoppe BO, Convertino M. Degrees and dollars – Health costs associated with suboptimal ambient temperature exposure. Sci Total Environ. 2019 Aug 15;678:702–11. doi:10.1016/j.scitotenv.2019.04.398.

[17] Chen F, Zhang X, Chen Z. Behind climate change: Extreme heat and health cost. Struct Change Econ Dyn. 2023 Mar;64:101–10. doi:10.1016/j.strueco.2022.12.007.

[18] Thompson R, Hornigold R, Page L, Waite T. Associations between high ambient temperatures and heat waves with mental health outcomes: a systematic review. Public Health. 2018 Aug 1;161:171–91. doi:10.1016/j.puhe.2018.06.008.

[19] Hertzog L, Charlson F, Tschakert P, Morgan GG, Norman R, Pereira G, et al. Suicide deaths associated with climate change-induced heat anomalies in Australia: a time series regression analysis. BMJ Ment Health. 2024 Jan;27(1):e301131. doi:10.1136/bmjment-2024-301131.

[20] Parks RM, Bennett JE, Tamura-Wicks H, Kontis V, Toumi R, Danaei G, et al. Anomalously warm temperatures are associated with increased injury deaths. Nat Med. 2020 Jan;26(1):65–70. doi:10.1038/s41591-019-0721-y.

[21] Park J, Oh J, Lee W, Kim Y, Park JH, Kim H, et al. Association of ambient temperatures with suicide attempts and violence with the future projections under climate change scenarios: a nationwide time-stratified case-crossover study in South Korea. BMC Public Health. 2025 Feb 5;25(1):457. doi:10.1186/s12889-025-21660-4.

[22] Lehmann F, Alary PE, Rey G, Slama R. Association of daily temperature with suicide mortality: A comparison with other causes of death and characterization of possible attenuation across 5 decades. Am J Epidemiol. 2022 Nov 19;191(12):2037–50. doi:10.1093/aje/kwac150.

[23] Chersich MF, Swift CP, Edelstein I, Breetzke G, Scorgie F, Schutte F, et al. Violence in hot weather: Will climate change exacerbate rates of violence in South Africa? S Afr Med J. 2019 Jun 28;109(7):447. doi:10.7196/SAMJ.2019.v109i7.14134.

[24] Mahendran R, Xu R, Li S, Guo Y. Interpersonal violence associated with hot weather. Lancet Planet Health. 2021 Sep 1;5(9):e571–2. doi:10.1016/S2542-5196(21)00210-2.

[25] Zhu Y, He C, Bell M, Zhang Y, Fatmi Z, Zhang Y, et al. Association of ambient temperature with the prevalence of intimate partner violence among partnered women in low- and middle-income South Asian countries. JAMA Psychiatry. 2023 Sep 1;80(9):952–61. doi:10.1001/jamapsychiatry.2023.1958.

[26] Daalen KR van, Kallesøe SS, Davey F, Dada S, Jung L, Singh L, et al. Extreme events and gender-based violence: a mixed-methods systematic review. Lancet Planet Health. 2022 Jun 1;6(6):e504–23. doi:10.1016/S2542-5196(22)00088-2.

[27] Nori-Sarma A, Sun S, Sun Y, Spangler KR, Oblath R, Galea S, et al. Association between ambient heat and risk of emergency department visits for mental health among US adults, 2010 to 2019. JAMA Psychiatry. 2022 Apr 1;79(4):341–9. doi:10.1001/jamapsychiatry.2021.4369.

[28] Barkin JL, Van Rhijn S, Johnson CM. The connection between climate change and perinatal mental health. Front Psychiatry. 2025 Jan 21;15:1515895. doi:10.3389/fpsyt.2024.1515895.

[29] Lin Y, Hu W, Xu J, Luo Z, Ye X, Yan C, et al. Association between temperature and maternal stress during pregnancy. Environ Res. 2017 Oct;158:421–30. doi:10.1016/j.envres.2017.06.034..

[30] Kadio K, Filippi V, Congo M, Scorgie F, Roos N, Lusambili A, et al. Extreme heat, pregnancy and women's well-being in Burkina Faso: an ethnographical study. BMJ Glob Health. 2024 Feb 21;8(Suppl 3):e014230. doi:10.1136/bmjgh-2023-014230.

[31] Runkle JD, Sugg MM, Berry A, Reed C, Cowan K, Wertis L, et al. Association of Psychiatric Emergency Visits and Warm Ambient Temperature during Pregnancy: A Time-Stratified Case-Crossover Study. Environ Health Perspect. 2024 Jun;132(6):067001. doi:10.1289/EHP13293.

[32] Scorgie F, Lusambili A, Luchters S, Khaemba P, Filippi V, Nakstad B, et al. "Mothers get really exhausted!" The lived experience of pregnancy in extreme heat: Qualita-

tive findings from Kilifi, Kenya. Soc Sci Med. 2023 Oct 1;335:116223. doi:10.1016/j.socscimed.2023.116223.

[33] Vigod S, Villegas L, Dennis C, Ross L. Prevalence and risk factors for postpartum depression among women with preterm and low birth weight infants: a systematic review. BJOG. 2010 Apr;117(5):540–50. doi:10.1111/j.1471-0528.2009.02493.x.

[34] Kawano A, Emori Y. The relationship between maternal postpartum psychological state and breast milk secretory immunoglobulin A level. J Am Psychiatr Nurses Assoc. 2015 Jan;21(1):23–30. doi:10.1177/1078390314566882.

[35] Fairlie TG, Gillman MW, Rich-Edwards J. High pregnancy-related anxiety and prenatal depressive symptoms as predictors of intention to breastfeed and breastfeeding Initiation. J Womens Health (Larchmt). 2009 Jul;18(7):945–53. doi:10.1089/jwh.2008.0998.

[36] Borra C, Iacovou M, Sevilla A. New evidence on breastfeeding and postpartum depression: The importance of understanding women's intentions. Matern Child Health J. 2015 Apr 1;19(4):897–907. doi:10.1007/s10995-014-1591-z.

[37] Goudet JM, Danfakha M, Sow F, Diop M, Gluski P, Bonnet E, et al. 'Enervements' under extreme heat. Social mechanisms linking heat exposure to maternal mental distress in Matam, Northern Senegal. In: Poster. Paris; 2025. Available from: https://hal.science/hal-05272671v1/file/Poster_GOUDET-WH25.pdf.

[38] Faye M, Dème A, Diongue AK, Diouf I. Impact of different heat wave definitions on daily mortality in Bandafassi, Senegal. PLoS One. 2021;16(4):4. doi:10.1371/journal.pone.0249199.

[39] Nakstad B, Filippi V, Lusambili A, Roos N, Scorgie F, Chersich MF, et al. How climate change may threaten progress in neonatal health in the African region. Neonatology. 2022;119(5):644–51. doi:10.1159/000525573.

[40] World Health Organisation. Protecting maternal, newborn and child health from the impacts of climate change: call for action [Internet]. 2023 [cited 2024 Apr 2]. Report No. Available from: https://www.who.int/publications-detail-redirect/9789240085350

[41] Abdullah AYMd, Bhuian MdH, Kiselev G, Dewan A, Hassan QK, Rafiuddin M. Extreme temperature and rainfall events in Bangladesh: A comparison between coastal and inland areas. Int J Climatol. 2022;42(6):3253–73. doi:10.1002/joc.6911.

[42] Sy I, Cissé B, Ndao B, Touré M, Diouf AA, Sarr MA, et al. Heat waves and health risks in the northern part of Senegal: analysing the distribution of temperature-related diseases and associated risk factors. Environ Sci Pollut Res Int. 2022 Nov;29(55):55. doi:10.1007/s11356-022-21205-x.

[43] Toure M, Thiaw WM, Sy I, Bekele E, Gueye O, Bhuiyan MAE, et al. Machine learning based prediction of heatwave related hospitalizations: A case study in Matam, Senegal [Internet]. Preprints; 2025 [cited 2025 Mar 25]. Available from: https://www.preprints.org/manuscript/202503.1797/v1 doi:10.20944/preprints202503.1797.v1.

[44] Diouf S, Sambou MJG, Deme A, Fall P, Gueye D, Mignot J, et al. Dust content modulation and spring heat waves in Senegal (2003–2022). Atmosphere (Basel). 2024 Dec;15(12):1413. doi:10.3390/atmos15121413.

[45] World Health Organisation. The optimal duration of exclusive breastfeeding: A systematic review [Internet]. Geneva, Switzerland: World Health Organisation; 2001 [cited 2025 Feb 3]. p. 52. Report No.: WHO/NHD/01.08; WHO/FCH/CAH/01.23. Available from: https://iris.who.int/bitstream/handle/10665/67208/WHO_NHD_01.08.pdf?sequence=1

[46] Victora CG, Bahl R, Barros AJD, França GVA, Horton S, Krasevec J, et al. Breastfeeding in the 21st century: epidemiology, mechanisms, and lifelong effect. Lancet. 2016 Jan 30;387(10017):475–90. doi:10.1016/S0140-6736(15)01024-7.

[47] Eidelman AI. Breastfeeding and the use of human milk: An analysis of the American Academy of Pediatrics 2012 breastfeeding policy statement. Breastfeed Med. 2012 Oct;7(5):323–4. doi:10.1089/bfm.2012.0067.

[48] Rollins NC, Bhandari N, Hajeebhoy N, Horton S, Lutter CK, Martines JC, et al. Why invest, and what it will take to improve breastfeeding practices? Lancet. 2016 Jan 30;387(10017):491–504. doi:10.1016/S0140-6736(15)01044-2.

[49] UNICEF, WHO. Global breastfeeding scorecard 2023 [Internet]. New York, Geneva: UNICEF & WHO; 2023. p. 9. Report No. Available from: https://www.unicef.org/media/150586/file/Global%20breastfeeding%20scorecard%202023.pdf.

[50] ANSD, ICF. Enquête Démographique et de Santé Continue 2023. Rapport des indicateurs clés [Internet]. Dakar, Sénégal et Rockville, Maryland, USA: Ministère de l'Economie, du Plan et de la Coopération; 2023. p. 57. Report No. Available from: https://www.ansd.sn/sites/default/files/2025-10/EDSC%202023_Rapport%20final_30_Octobre_2025_OK.pdf

[51] Camara M, Ndiaye I, Gueye B, Dramé A, Bassoum O, Toure A, et al. Evolution of exclusive breastfeeding practices according to continuous Demographic and Health Surveys (DHS-C) from 2010-2011 to 2019 and associated factors in Senegal. World J Public Health. 2024 May 10;9:156–77. doi:10.11648/j.wjph.20240902.16.

[52] Boye S. L'allaitement au sénégal : entre normes sociales et pratiques singulières. [Dakar, Sénégal]: UCAD; 2016.

[53] Alive & Thrive, UNICEF. Factors influencing the practice of exclusive breastfeeding and other infant feeding practices in the first six months of life in West and Central Africa [Internet]. 2022 [cited 2025 Jan 10]. p. 67. Report No. Available from: https://breastmilkonly.com/sites/default/files/2022-03/literature.review-breastfeeding.in_.westcentralafrica_fr_march2022.pdf

[54] Diagne-Guèye NR, Diack-Mbaye A, Dramé M, Diagne I, Fall AL, Camara B, et al. Connaissances et pratiques de mères sénégalaises vivant en milieu rural ou suburbain sur l'alimentation de leurs enfants, de la naissance à l'âge de six mois. J Pediatr Pueric. 2011;24(4):161–6. doi:10.1016/j.jpp.2010.12.001.

[55] Part C, Filippi V, Cresswell JA, Ganaba R, Hajat S, Nakstad B, et al. How do high ambient temperatures affect infant feeding practices? A prospective cohort study of postpartum women in Bobo-Dioulasso, Burkina Faso. BMJ Open. 2022 Oct 5;12(10):e061297. doi:10.1136/bmjopen-2022-061297.

[56] Edney JM, Kovats S, Filippi V, Nakstad B. A systematic review of hot weather impacts on infant feeding practices in low-and middle-income countries. Front Pediatr.

2022 Sep 6;10:930348. doi:10.3389/fped.2022.930348.
[57] Rollins NC, Bhandari N, Hajeebhoy N, Horton S, Lutter CK, Martines JC, et al. Why invest, and what it will take to improve breastfeeding practices? Lancet. 2016 Jan 30;387(10017):491–504. doi:10.1016/S0140-6736(15)01044-2.
[58] Howells M, Palmquist AEL, Josefson C, Dancause K, Quinn E, Daniels L, et al. Climate change, evolution, and reproductive health: The impact of water insecurity and heat stress on pregnancy and lactation. Evol Med Public Health. 2025 Jan 1;13(1):125–39. doi:10.1093/emph/eoaf008.
[59] Guèye M, Thiam H, Sylla A. Troubles psychopathologiques de la gravido-puerpéralité. Psychopathol Afr. 2007 [cited 2025 Jul 25];34(1):51–84. Available from: https://www.africabib.org/rec.php?RID=322724988
[60] Seck S, Camara M, Kane RW, Baldé DB, Bâ EHM, Koundoul A, et al. Prevalence and associated factors of postpartum depression: A study conducted in health centres in Dakar (Senegal). Open J Psychiatry. 2024 Jan 25;14(1):1. doi:10.4236/ojpsych.2024.141004.
[61] Seck S. Factors associated with pregnancy-specific anxiety: A study conducted in Dakar. J Psychiatry Ment Health. 2024.
[62] Bruand PE, Gelle T, Makhtar Ba EH, Diegane Tine JA, Ndao AF, Kleinebreil L, et al. Evaluating the effects of mental health e-learning on the knowledge, attitudes and practices of allied and healthcare professionals in Senegal. Clin Epidemiol Glob Health. 2024 Nov 1;30:101821. doi:10.1016/j.cegh.2024.101821.
[63] World Health Organisation. Report of a scoping meeting for the selection of indicators to monitor the impact of extreme heat on maternal, newborn and child health [Internet]. 1st ed. Geneva: World Health Organization; 2024. 1 p. Available from: https://iris.who.int/bitstream/handle/10665/378102/9789240079830-eng.pdf.
[64] Schulte C, Erhardt-Ohren B, Prata N. A scoping review of natural disasters, environmental hazards, and maternal health: Are all potential outcomes accounted for in conceptual frameworks? PLoS Clim. 2025 Jan 10;4(1):e0000558. doi:10.1371/journal.pclm.0000558.
[65] Lusambili AM, Kadio K, Chersich MC, Luchters S, Kouanda S, Hajat S, et al. The CHAMNHA project: defining heat impacts on maternal and neonatal health and testing adaptive interventions in Burkina Faso and Kenya. ISEE Conf Abstr. 2021 Aug 23. doi:10.1289/isee.2021.O-SY-049..
[66] Kadio K, Congo M, Sana A, Filippi V, Roos N, Scorgie F, et al. Intervention co-design to reduce the impact of heat exposure on pregnant and postpartum women and newborns in Burkina Faso. Health Policy Plan. 2025 May 28;czaf030. doi:10.1093/heapol/czaf030.
[67] Vigod SN, Frey BN, Clark CT, Grigoriadis S, Barker LC, Brown HK, et al. Canadian network for mood and anxiety treatments 2024 clinical practice guideline for the management of perinatal mood, anxiety, and related disorders: Guide de pratique 2024 du Canadian network for mood and anxiety treatments pour le traitement des troubles de l'humeur, des troubles anxieux et des troubles connexes périnatals. Can J Psychiatry. 2025 Feb 12;70(6):429–89. doi:10.1177/07067437241303031.
[68] Mbaye I. Perception des impacts du changement climatique et stratégie d'adaptation en milieu périurbain de la ville de Ziguinchor au Sénégal. VertigO. 2015 May 12;15(1). doi:10.4000/vertigo.16005.
[69] Hayes K, Poland B. Addressing mental health in a changing climate: Incorporating mental health indicators into climate change and health vulnerability and adaptation assessments. Int J Environ Res Public Health. 2018;15(9):9. doi: 10.3390/ijerph15091806.
[70] Arman N, Salam Shaoli S, Hossain S. Mental health and climate change in Bangladesh. Int Rev Psychiatry. 2022 Jul 4;34(5):5. doi:10.1080/09540261.2022.2093100.
[71] Achrekar A, Akselrod S, Clark H, Barron GC, Charles M, Dain K, et al. Delivering health for all: the critical role of gender-responsive health systems. Lancet Glob Health. 2024 Mar 7;0(0). doi:10.1016/S2214-109X(24)00120-7.
[72] WHO, UNICEF. Ten steps to successful breastfeeding [Internet]. 2018 [cited 2025 Jan 13]. Available from: https://www.who.int/teams/nutrition-and-food-safety/food-and-nutrition-actions-in-health-systems/ten-steps-to-successful-breastfeeding
[73] Alive & Thrive. Senegal launches stronger with breastmilk only regional initiative [Internet]. 2021 [cited 2025 Jan 13]. Available from: https://www.aliveandthrive.org/en/news/senegal-launches-stronger-with-breastmilk-only-regional-initiative
[74] MSAS. Lettre de politique sectorielle du MSAS 2025-2029 [Internet]. Dakar, Sénégal: Ministère de la Santé et de l'Action Sociale; 2025. p. 75. Report No. Available from: https://www.sante.gouv.sn/sites/default/files/Lettre%20de%20Politique%20Sectorielle%20du%20MSAS%202025-2029%20Signe%CC%81.pdf
[75] Almroth S, Bidinger PD. No need for water supplementation for exclusively breast-fed infants under hot and arid conditions. Trans R Soc Trop Med Hyg. 1990;84(4):602–4. doi:10.1016/0035-9203(90)90056-k.
[76] Baecker L, Iyengar U, Piccolo MCD, Mechelli A. Impacts of extreme heat on mental health: Systematic review and qualitative investigation of the underpinning mechanisms. J Clim Change Health. 2025 Mar;22:100446. doi: https://doi.org/10.1016/j.joclim.2025.100446
[77] Mullins JT, White C. Temperature and mental health: Evidence from the spectrum of mental health outcomes. J Health Econ. 2019 Dec;68:102240. doi:10.1016/j.jhealeco.2019.102240.
[78] Minor K, Bjerre-Nielsen A, Jonasdottir SS, Lehmann S, Obradovich N. Rising temperatures erode human sleep globally. One Earth. 2022 May 20;5(5):534–49. doi:10.1016/j.oneear.2022.04.008.
[79] Chevance G, Minor K, Vielma C, Campi E, O'Callaghan-Gordo C, Basagaña X, et al. A systematic review of ambient heat and sleep in a warming climate. Sleep Med Rev. 2024 Jun 1;75:101915. doi:10.1016/j.smrv.2024.101915.
[80] Bangsgaard RB, Høgh S, Borgsted C, Cvetanovska E, Pinborg A, Hegaard H, et al. Sleep quality in late pregnancy is associated with maternal mental health in the early postpartum period. Eur J Obstet Gynecol Reprod Biol. 2025 Jul;311:113980. doi:10.1016/j.ejogrb.2025.113980.
[81] Wortzel JR, Lawrance EL, Minor K, Boyle HK, Wortzel JD, Bell ML, et al. Advancing heat-related mental health research: moving beyond epidemiological links. Lancet Planet Health. 2025 Oct 13;0(0). doi:10.1016/j.lanplh.2025.101341.
[82] Alla F, Cambon L, Ridde V. Population health interven-

tion research. Concepts, methods, applications. [Internet]. IRD Éditions. 2024. 187 p. (Santé globale). Available from: https://www.editions.ird.fr/produit/699/9782709930048/population-health-intervention-research

[83] Skivington K, Matthews L, Simpson SA, Craig P, Baird J, Blazeby JM, et al. A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. BMJ. 2021 Sep 30;374:n2061. doi:10.1136/bmj.n2061.

[84] Creswell JW, Plano Clark VL. Designing and conducting mixed methods research. Third Edition. Los Angeles: SAGE; 2018. 492 p.

[85] Bartholomew Eldredge LK, editor. Planning health promotion programs: an intervention mapping approach. 2nd edn. San Francisco: Jossey-Bass; 2006. 767 p.

[86] Godin G. Les comportements dans le domaine de la santé: Comprendre pour mieux intervenir [Internet]. Presses de l'Université de Montréal; 2012 [cited 2024 Mar 11]. Available from: http://books.openedition.org/pum/8822 doi:10.4000/books.pum.8822.

[87] Schweizer ML, Braun BI, Milstone AM. Research methods in healthcare epidemiology and antimicrobial stewardship – quasi-experimental designs. Infect Control Hosp Epidemiol. 2016 Oct;37(10):1135–40. doi:10.1017/ice.2016.117.

[88] Shadish WR, Cook TD, Campbell DT. Experimental and quasi-experimental designs for generalized causal inference. Houghton, Mifflin and Company; 2002.

[89] World Health Organisation. Indicators for assessing infant and young child feeding practices: Definitions and measurement methods. 1st ed. Geneva: World Health Organization; 2021. 1 p.

[90] Fernandez ME, Ruiter RAC, Markham CM, Kok G. Intervention mapping: Theory- and evidence-based health promotion program planning: Perspective and examples. Front Public Health. 2019 Aug 14;7:209. doi:10.3389/fpubh.2019.00209.

[91] Godin G. Les comportements dans le domaine de la santé: comprendre pour mieux intervenir. Montréal: Les Presses de l'Université de Montréal; 2012. 326 p.

[92] Vargas C, Whelan J, Brimblecombe J, Allender S. Co-creation, co-design, co-production for public health – a perspective on definition and distinctions. Public Health Res Pract. 2022;32(2). doi:10.17061/phrp3222211.

[93] Romsland GI, Milosavljevic KL, Andreassen TA. Facilitating non-tokenistic user involvement in research. Res Involv Engagem. 2019 Jun 4;5(1):18. doi:10.1186/s40900-019-0153-3.

[94] Budig K, Diez J, Conde P, Sastre M, Hernán M, Franco M. Photovoice and empowerment: evaluating the transformative potential of a participatory action research project. BMC Public Health. 2018 Apr 2;18(1):432. doi:10.1186/s12889-018-5335-7.

[95] Longworth GR, Agnello DM, Chastin S, Davis A, Hidalgo ES, Baselga SV, et al. Evaluating the co-creation process in public health interventions: the PROSECO framework. Public Health. 2025 Aug;245:105783. doi:10.1016/j.puhe.2025.105783.

[96] Bayard C, Chouinard C. La promotion de l'allaitement maternel au Québec : regards critiques. Éditions du remue-ménage. Montréal; 2014. 207 p.

[97] Lee E. Health, morality, and infant feeding: British mothers' experiences of formula milk use in the early weeks. Sociol Health Illn. 2007;29(7):1075–90. doi:10.1111/j.1467-9566.2007.01020.x.

[98] Rakotomanana EFN, Rafiringa S, Mattern C. L'allaitement maternel comme recommandation internationale en santé à l'épreuve des savoirs locaux à Madagascar. Emulations. 2024 Jun 29 [cited 2025 Jan 10]. Available from: https://journals.openedition.org/emulations/2143

[99] Serre D. Le bébé 'superbe' : la construction de la déviance corporelle par les professionnel(le)s de la petite enfance. Sociétés Contemp. 1998;31(1):107–27. doi: https://doi.org/10.3917/soco.p1998.31n1.0107

[100] Vallières A. Médicalisation de l'alimentation du nourrisson au Canada. Une revue de littérature sociohistorique [Internet]. 2020. doi:10.3406/caf.2020.3419..

[101] Lee E. Breast-Feeding Advocacy, Risk Society and Health Moralism: A Decade's Scholarship. Sociol Compass. 2011;5(12):1058–69. doi:10.1111/j.1751-9020.2011.00424.x.

[102] Bandyopadhyay M. Impact of ritual pollution on lactation and breastfeeding practices in rural West Bengal, India. Int Breastfeed J. 2009 Mar 26;4(1):2. doi:10.1186/1746-4358-4-2.

[103] Shaikh U, Ahmed O. Islam and infant feeding. Breastfeed Med. 2006 Sep;1(3):164–7. doi:10.1089/bfm.2006.1.164.

[104] Tremblay MC, Parent AA. Reflexivity in PHIR: Let's have a reflexive talk! Can J Public Health. 2014 May 1;105(3):e221–3. doi:10.17269/cjph.105.4438.

[105] Alexander SA, Jones CM, Tremblay MC, Beaudet N, Rod MH, Wright MT. Reflexivity in Health Promotion: A Typology for Training. Health Promot Pract. 2020 Jul 1;21(4):499–509. doi:10.1177/1524839920912407.

[106] Ravalihasy A. L'évaluateur et l'évaluation d'impact d'une intervention comme levier potentiel de l'empowerment au niveau communautaire : un exercice réflexif à partir de l'intervention MAKASI. Glob Health Promot. 2024 Aug 1;17579759241258193. doi:10.1177/17579759241258193.

[107] Mao L, Mian Akram A, Chovanec D, Underwood ML. Embracing the spiral: Researcher reflexivity in diverse critical methodologies. Int J Qual Methods. 2016 Dec 1;15(1):1609406916681005. doi:10.1177/1609406916681005.

[108] Zhong QY, Gelaye B, Zaslavsky AM, Fann JR, Rondon MB, Sánchez SE, et al. Diagnostic validity of the generalized anxiety disorder - 7 (GAD-7) among pregnant women. PLoS One. 2015 Apr 27;10(4):e0125096. doi:10.1371/journal.pone.0125096.

[109] Morin CM, Belleville G, Bélanger L, Ivers H. The Insomnia Severity Index: Psychometric indicators to detect insomnia cases and evaluate treatment response. Sleep. 2011 May 1;34(5):601–8. doi:10.1093/sleep/34.5.601.

[110] Sheehan DV, Lecrubier Y, Sheehan KH, Amorim P, Janavs J, Weiller E, et al. The Mini-International Neuropsychiatric Interview (MINI): the development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. J Clin Psychiatry. 1998 [cited 2025 Aug 11];59(Suppl 20):22–33. Available from: https://www.psychiatrist.com/wp-content/uploads/2021/02/15175_mini-international-neuropsychiatric-interview-mini.pdf?utm_medium=email&utm_source

=transaction.
[111] Gasparrini A, Armstrong B, Kenward MG. Distributed lag non-linear models. Stat Med. 2010 Sep 20;29(21):2224–34. doi:10.1002/sim.3940.
[112] Gasparrini A, Leone M. Attributable risk from distributed lag models. BMC Med Res Methodol. 2014 Apr 23;14:55. doi:10.1186/1471-2288-14-55.
[113] Gasparrini A, Guo Y, Hashizume M, Lavigne E, Zanobetti A, Schwartz J, et al. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. Lancet. 2015 Jul 25;386(9991):369–75. doi:10.1016/S0140-6736(14)62114-0.
[114] Hajat S, Sarran CE, Bezgrebelna M, Kidd SA. Ambient temperature and emergency hospital admissions in people experiencing homelessness: London, United Kingdom, 2011-2019. Am J Public Health. 2023 Sep;113(9):981–4. doi:10.2105/AJPH.2023.307351.
[115] Kunene Z, Kapwata T, Mathee A, Sweijd N, Minakawa N, Naidoo N, et al. Exploring the association between ambient temperature and daily hospital admissions for diarrhea in Mopani District, Limpopo Province, South Africa. Healthcare (Basel). 2023 Apr 27;11(9). doi:10.3390/healthcare11091251.
[116] Ulrich SE, Sugg MM, Roy M, Runkle JD. Temperature extremes and maternal health: differential risks of severe maternal morbidity during heatwaves and coldwaves in North Carolina. Int J Biometeorol. 2026;70(2):45. doi:10.1007/s00484-025-03079-z.
[117] Aberdeen T. Yin, R. K. (2009). Case study research: Design and methods (4th Ed.). Thousand Oaks, CA: Sage. Can J Action Res. 2013 May 21;14(1):1. doi:10.33524/cjar.v14i1.73.
[118] Vancea M. RAGIN, Charles C. The comparative method: Moving beyond qualitative and quantitative strategies. Fuzzy-Set Social Science. Papers. 2007 Jan 1;80. doi:10.5565/rev/papers/v80n0.1835.
[119] Pawson R, Tilley N. Realistic evaluation. Reprinted. London: SAGE; 2010. 235 p.
[120] Louart S, Ridde V. Critical realism for health promotion evaluation. In: Jourdan D, Potvin L, editors. Global Handbook of Health Promotion Research, Vol. 3 [Internet]. Cham: Springer International Publishing; 2023 [cited 2025 Oct 31]. p. 49–59. Available from: https://link.springer.com/10.1007/978-3-031-20401-2_5 doi:10.1007/978-3-031-20401-2_5.
[121] Anquetin S, Ruin I, Molinié G, Carnel JS, Lafon B, Braud I, et al. 4 - High-impact weather events: Is a socio-hydrometeorological characterization possible? In: Lutoff C, Durand S, editors. Mobility in the Face of Extreme Hydrometeorological Events 1 [Internet]. Elsevier; 2018 [cited 2025 Aug 13]. p. 89–111. Available from: https://www.sciencedirect.com/science/article/pii/B9781785482892500045 doi:10.1016/B978-1-78548-289-2.50004-5.
[122] World Health Organization. Indicateurs pour évaluer les pratiques d'alimentation du nourrisson et du jeune enfant partie 2 : calcus [Internet]. Genève: Organisation mondiale de la Santé; 2011 [cited 2025 Aug 5]. Report No. Available from: https://iris.who.int/handle/10665/44767.
[123] Noel-Weiss J, Taljaard M, Kujawa-Myles S. Breastfeeding and lactation research: exploring a tool to measure infant feeding patterns. Int Breastfeed J. 2014 Apr 24;9:5. doi: 10.1186/1746-4358-9-5.
[124] World Health Organization. Allaitement maternel [Internet]. 2024 [cited 2025 Apr 14]. Available from: https://www.who.int/fr/health-topics/breastfeeding.
[125] Cresswell JA, Ganaba R, Sarrassat S, Somé H, Diallo AH, Cousens S, et al. The effect of the Alive & Thrive initiative on exclusive breastfeeding in rural Burkina Faso: a repeated cross-sectional cluster randomised controlled trial. Lancet Glob Health. 2019 Mar;7(3):e357–65. doi:10.1016/S2214-109X(18)30494-7.
[126] Nunes AR. Resilience: conceptualisations and challenges for effective heatwave public health planning. Public Health. 2024 May;230:113–21. doi:10.1016/j.puhe.2024.02.023.
[127] Kolokotroni M, Shittu E, Santos T, Ramowski L, Mollard A, Rowe K, Wilson E, de Brito Filho JP, Novieto D. Cool roofs: High tech low cost solution for energy efficiency and thermal comfort in low rise low income houses in high solar radiation countries. Energy Build. 2018 Oct 1;176:58-70. doi: 10.1016/j.enbuild.2018.07.005.
[128] Lusambili A, Khaemba P, Agoi F, Oguna M, Nakstad B, Scorgie F, et al. Process and outputs from a community codesign workshop on reducing impact of heat exposure on pregnant and postpartum women and newborns in Kilifi, Kenya. Front Public Health. 2023 Aug 31;11:1146048. doi: 10.3389/fpubh.2023.1146048.
[129] Ross NA, Tremblay SS, Graham K. Neighbourhood influences on health in Montréal, Canada. Soc Sci Med. 2004 Oct;59(7):1485–94. doi:10.1016/j.socscimed.2004.01.016.
[130] Sekhon M, Cartwright M, Francis JJ. Acceptability of healthcare interventions: an overview of reviews and development of a theoretical framework. BMC Health Serv Res. 2017 Jan 26;17(1):88. doi:10.1186/s12913-017-2031-8.
[131] Ravalihasy A, Faye A, Diallo AI, Gaye I, Ridde V. A social acceptability scale: Validation in the context of government measures to curb the COVID-19 pandemic in Senegal. Ann Epidemiol. 2024 Jun;94:49–63. doi:10.1016/j.annepidem.2024.04.004.
[132] de Boer J, Longworth GR, Delfmann LR, Belmon LS, Vogelsang M, Erikowa-Orighoye O, et al. Exploring co-adaptation for public health interventions: insights from a rapid review and interviews. BMC Public Health. 2025 Feb 14;25(1):614. doi:10.1186/s12889-025-21544-7.
[133] Edmunds SR, Frost KM, Sheldrick RC, Bravo A, Straiton D, Pickard K, et al. A method for defining the CORE of a psychosocial intervention to guide adaptation in practice: Reciprocal imitation teaching as a case example. Autism. 2022 Apr 1;26(3):601–14. doi:10.1177/13623613211064431.
[134] Sekhon M, Cartwright M, Francis JJ. Acceptability of healthcare interventions: an overview of reviews and development of a theoretical framework. BMC Health Serv Res. 2017 Jan 26;17(1):88. doi: 10.1186/s12913-017-2031-8.
[135] Pellet J, Pouzols S, Ridde V, Mabire C. Bridging the gap: translating and simplifying CFIR 2.0 for French practitioners in implementation science. Implement Sci Commun. 2025 Mar 28;6(1):29. doi:10.1186/s43058-025-00719-8.
[136] Langer L, Tripney J, Gough D, University of London, Social Science Research Unit, Evidence for Policy and Practice Information and Co-ordinating Centre. The sci-

ence of using science: researching the use of research evidence in decision-making. 2016.

[137] Equipe Renard. catalogue.edulib.org [Internet]. 2024 [cited 2025 Aug 1]. Transfert de connaissances : favoriser des pratiques et des politiques informées par la recherche. Available from: https://catalogue.edulib.org.

[138] Prihodova L, Guerin S, Tunney C, Kernohan WG. Key components of knowledge transfer and exchange in health services research: Findings from a systematic scoping review. J Adv Nurs. 2019 Feb;75(2):313–26. doi: https://doi.org/10.1111/jan.13836

[139] Ettinger J, Fine J, Thier K, Badullovich N, Kotcher J, Maibach E. Communicating with policy makers about climate change, health, and their intersection: a scoping review. Lancet Planet Health. 2025 Jan 1;9(1):e53–61. doi:10.1016/S2542-5196(24)00307-3.

[140] Huma-Num [Internet]. [cited 2026 Mar 31]. Available from: https://www.huma-num.fr/about-us/.

[141] Wilkinson MD, Dumontier M, Aalbersberg IjJ, Appleton G, Axton M, Baak A, et al. The FAIR Guiding Principles for scientific data management and stewardship. Sci Data. 2016 Mar 15;3(1):160018. doi:10.1038/sdata.2016.18.

[142] General Data Protection Regulation (GDPR) [Internet]. [cited 2026 Mar 31]. General Data Protection Regulation (GDPR) – Legal Text. Available from: https://gdpr-info.eu/.

[143] Data Protection Impact Assessments | Data Protection Commission [Internet]. [cited 2026 Mar 31]. Data Protection Impact Assessments | Data Protection Commission. Available from: https://www.dataprotection.ie/organisations/know-your-obligations/data-protection-impact-assessments.