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# BMJ Open

## How do high ambient temperatures affect infant feeding practices? A prospective cohort study of postpartum women in Bobo-Dioulasso, Burkina Faso

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3 **1 HOW DO HIGH AMBIENT TEMPERATURES AFFECT INFANT FEEDING**  
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5 **2 PRACTICES? A PROSPECTIVE COHORT STUDY OF POSTPARTUM WOMEN IN**  
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7 **3 BOBO-DIOULASSO, BURKINA FASO**  
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3 25 **ABSTRACT**  
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6 26 **Objective:** To examine the effects of high ambient temperature on infant feeding practices  
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8  
9 27 and childcare.  
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11  
12 28 **Design:** Secondary analysis of quantitative data from a prospective cohort study.  
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15 29 **Setting:** Community-based interviews in the commune of Bobo-Dioulasso, Burkina Faso.  
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17  
18 30 Exclusive breastfeeding is not widely practiced in Burkina Faso.  
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21 31 **Participants:** 866 women were interviewed over a 12-month period, with a 1:1 ratio of  
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23 32 urban:rural residence. Participants were between 20 weeks gestation and 22 weeks  
24  
25 33 postpartum at recruitment. Retention at the third (final) interview was 90%.  
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29 34 **Exposure:** Daily mean temperature (°C) measured at one weather station in Bobo-Dioulasso.  
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31 35 Meteorological data were obtained from publicly available archives.  
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35 36 **Primary outcome measures:** Self-reported time spent breastfeeding (minutes/day);  
36  
37 37 exclusive breastfeeding of infants under six months (no fluids other than breast milk provided  
38  
39 38 in past 24 hours); supplementary feeding of infants under 12 months (any fluid other than  
40  
41 39 breast milk provided in past 24 hours); time spent caring for children (minutes/day).  
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44  
45 40 **Results:** The population experienced year-round high temperatures (intra-annual range in  
46  
47 41 daily mean temperature 22.6–33.7°C). Breastfeeding decreased by 2.3 minutes/day (95% CI -  
48  
49 42 4.6 to 0.04,  $p=0.05$ ), and childcare increased by 0.6 minutes/day (0.06 to 1.2,  $p=0.03$ ), with  
50  
51 43 every 1°C increase in same-day mean temperature. Temperature interacted with infant age to  
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53 44 affect breastfeeding duration ( $p=0.02$ ), with a stronger (negative) association between  
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55 45 temperature and time spent breastfeeding as infants aged (4 days–57 weeks). There was no  
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3 46 strong evidence of association between temperature and exclusive breastfeeding or  
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5 47 supplementary feeding.  
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9 48 **Conclusions:** Women spend considerably less time breastfeeding (~25 minutes/day) during  
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11 49 the hottest, compared to coolest, times of the year. Climate change adaptation plans for health  
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13 50 should include advice to breastfeeding mothers during periods of high temperature.  
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3 51 **Strengths and limitations of this study**  
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- 6 52 • This is the first study to quantify acute effects of ambient heat on breastfeeding behaviour,  
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9 53 with extensive confounder control and sensitivity analysis.  
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11 54 • Multi-stage stratified sampling was used to select a population-representative cohort of  
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13 55 pregnant and postpartum women in the commune of Bobo-Dioulasso, Burkina Faso.  
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15 56 • Outcome measures relied on self-reports; however questions were embedded within an  
16  
17 57 extensive interview schedule, reducing the likelihood of response bias.  
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20 58 • The small sample size and short recruitment window may have limited our ability to detect  
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22 59 statistically significant associations.  
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## 60 INTRODUCTION

61 Climate change is a growing threat to population health in Africa,[1, 2] with heatwaves  
62 increasing in severity and duration, especially in the Sahel.[3] Maternal and neonatal health  
63 will be affected[4] through the adverse effects of heat on preterm birth,[5] stillbirth,[5] and  
64 maternal nutrition,[6] Mothers report difficulties with breastfeeding during periods of high  
65 temperature[7] and some women perceive breast milk as insufficient to hydrate babies in hot  
66 weather, causing mothers to supplement breast milk with water.[8-10]

67 Breastfeeding and, in particular, exclusive breastfeeding has well-established benefits for  
68 child health and development.[11-13] Breastfeeding reduces the risk of diarrhoea and  
69 respiratory infections among infants, and is associated with a higher intelligence quotient and  
70 reduced obesity in later life.[13] There are also benefits for maternal health, with nursing  
71 mothers at lower risk of breast and, potentially, ovarian cancers.[13] The World Health  
72 Organization recommends that infants are fed with breastmilk exclusively for the first six  
73 months and that no solids or other liquids are given during this period, including water.[14]  
74 However, the self-reported prevalence of exclusive breastfeeding is low in many African  
75 countries.[13, 15] In Burkina Faso, less than 25% of women reported exclusive breastfeeding  
76 of their young infants (less than six months old) in 2010-2015.[15]

77 Numerous factors influence infant feeding practices in Africa, including the competing time  
78 demands of women's domestic and agricultural workloads,[8, 16-18] which vary with season  
79 and weather conditions in rural settings,[19] In rural Ethiopia, infants were less likely to be  
80 exclusively breastfed for the recommended six months if rainfall was high during the primary  
81 agricultural season as demand for agricultural labour among nursing mothers increased.[19]  
82 In Burkina Faso, women work to supplement household income (particularly in agriculture,  
83 horticulture, and small trade) as well as undertaking important domestic responsibilities

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3 84 (including gathering food, water, fuel, and feeding livestock).[6] Most women work in the  
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5 85 informal sector.[20] Therefore, paid maternity leave is uncommon and many women return to  
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8 86 work early in the postpartum period.  
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11 87 Average monthly temperatures in Burkina Faso range between 25–33°C[21] and the impacts  
12  
13 88 on infant feeding practices are largely unknown. Several studies report seasonal patterns in  
14  
15 89 breastfeeding behaviour in other regions of Africa,[22-24] South America,[25] and South  
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17 90 Asia.[26] An older study in rural Egypt reported a higher incidence of prelacteal feeding in  
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19 91 warmer months, leading to a reduction in exclusive breastfeeding in succeeding weeks and an  
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21 92 increased incidence of diarrhoea in the first year of life.[27] However, such studies are  
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23 93 insufficient to demonstrate an effect of ambient temperature as demands on mothers and  
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25 94 other potentially important drivers (e.g. household food security) also vary seasonally. With  
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27 95 daily temperatures in West Africa expected to exceed 50°C in some regions,[28] such  
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29 96 research is essential so that maternal and child health programmes can be updated.  
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35 97 This study aims to examine the effects of outdoor temperature on infant feeding practices and  
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37 98 childcare provided by postpartum women in western Burkina Faso. We hypothesised that: (a)  
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39 99 Time spent breastfeeding is associated with same-day temperature (women may either  
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41 100 increase breastfeeding due to perceived dehydration or decrease breastfeeding due to  
42  
43 101 increased discomfort); (b) Women are less likely to breastfeed exclusively as temperatures  
44  
45 102 rise; (c) Women are more likely to provide supplementary fluids as temperatures rise; (d)  
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47 103 Time spent caring for children is associated with temperature.  
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## 51 104 **METHODS**

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55 105 We undertook secondary analyses of quantitative data from an observational prospective  
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57 106 cohort study of pregnant and postpartum women in Bobo-Dioulasso, Burkina Faso (the  
58  
59 107 PopDev study), which aimed to assess the impacts of pregnancy on income- and non-income-

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3 108 generating activities among women in Burkina Faso, and to identify interventions to increase  
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5 109 household income.[29]  
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## 8 9 110 **Participants**

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11 111 Multi-stage stratified (urban vs. rural) sampling was used to select a population-  
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13 112 representative cohort of pregnant and postpartum women (female sex) in the commune of  
14  
15 113 Bobo-Dioulasso. The 2006 census was used as the sampling frame. Participants were  
16  
17 114 sampled from 38 locality clusters (14 urban, 24 rural). Women were eligible to participate in  
18  
19 115 the PopDev study if aged 15-45 years and between seven months gestation and three months  
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21 116 postpartum at recruitment.[29] Sixty-two women did not meet the criteria for PopDev, but  
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23 117 were retained in the dataset for secondary analyses. The dataset used herein comprised 866  
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25 118 women aged 14-47 years who were between 20 weeks gestation and 22 weeks postpartum at  
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27 119 baseline.  
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## 33 34 120 **Setting**

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37 121 The commune of Bobo-Dioulasso is predominantly urban, with small agricultural settlements  
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39 122 and villages located in rural areas around the urban centre. The commune includes the second  
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41 123 largest city in Burkina Faso (Bobo-Dioulasso) with approximately 900,000 inhabitants.[30]  
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45 124 The commune has a tropical savannah climate,[31] with two distinct seasons; dry  
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47 125 (November–May) and rainy (June–October). During the dry season, average temperatures are  
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49 126 highest in March–May and lower in November–February.  
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## 52 53 127 **Data collection**

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56 128 Participants were interviewed in their homes at three time points: cohort entry, and three and  
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58 129 nine months thereafter. Retention at the nine-month visit was 90%. Several attempts were  
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3 130 made to interview each woman at each interview round. The reason for non-interview was  
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5 131 recorded, when possible. Eight hundred and 39 participants were recruited immediately  
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7 132 before/during the first round of interviews (29 November 2013 – 23 March 2014). Twenty-  
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9 133 seven women were recruited during the second or third round of interviews (04 March 2014 –  
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11 134 09 September 2014; 02 September 2014 – 12 November 2014, respectively). All interviews  
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13 135 occurred between 29 November 2013 and 12 November 2014, using structured  
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15 136 questionnaires to ensure the same wording of questions for all participants. All questions  
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17 137 were designed to be non-leading.

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22 138 During each interview, participants were asked to recall their activities on the previous day  
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24 139 (or two days previous when the day before interview was atypical). Using an exhaustive list  
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26 140 of activities, women were asked which activities they carried out and how many minutes  
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28 141 were spent on each activity. Breastfeeding, caring for children, income-generating work,  
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30 142 attending classes, and household chores were included in this list.

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35 143 At first interview following childbirth, participants were asked how many children were born  
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37 144 and the date of delivery. At interviews two and three, women were asked if they were still  
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39 145 breastfeeding and which, if any, additional fluids had been given to their baby/babies in the  
40  
41 146 past 24 hours. Questionnaires are available at: <https://datacompass.lshtm.ac.uk/id/eprint/64/>.

#### 147 **Meteorological data**

148 Daily meteorological data (mean, minimum and maximum temperature [°C], relative  
149 humidity [%], and windspeed [km/h]) were obtained from TuTiempo.net[32] for a single  
150 weather station in Bobo-Dioulasso, located in the industrial district (Zone Industrielle)  
151 (11°09'36.0"N 4°18'36.0"W). Eleven days of temperature data were missing over the study  
152 period and were excluded from the analysis.

## 153 **Data analyses**

154 All outcomes, exposure, potential confounding variables, and covariates are defined in table  
155 S1 (supplementary material). Key outcomes (self-reported breastfeeding duration, exclusive  
156 breastfeeding, supplementary feeding, and childcare duration on the day before interview)  
157 were examined in relation to daily mean temperature on the day before interview. Daily mean  
158 temperature correlated strongly with daily minimum ( $r=0.8$ ,  $p<0.001$ ) and maximum  
159 temperatures ( $r=0.89$ ,  $p<0.001$ ) and was considered the best approximation of overall  
160 exposure during the recall period.

161 The functional form of temperature-time use (breastfeeding, childcare) associations were  
162 determined by: (i) aggregating outcome data to daily level, (ii) fitting natural cubic splines of  
163 time to each outcome series (to adjust for seasonal patterns and trends unrelated to  
164 temperature), and (iii) examining locally-weighted smoothing of Pearson's standardised  
165 residuals from the fitted splines, plotted against daily mean temperature.

166 Multilevel linear regression was used to estimate the effects of daily mean temperature on  
167 time spent (i) breastfeeding, and (ii) caring for children. Interview contacts (level one) were  
168 nested within individual participants (level two), nested within the locality clusters from  
169 which the population was sampled (level three). Each level was defined as a random  
170 coefficient with random intercept.

171 Supplementary feeding and exclusive breastfeeding data were only available for interviews  
172 two and three. Data were restricted to interview two in order to reduce model complexity and  
173 to focus on the hottest months of the year. Associations with daily mean temperature were  
174 initially assessed by comparing a subset of women interviewed following one of the hottest  
175 days between March and June 2014 (>90<sup>th</sup> percentile of daily mean temperature) with a  
176 subset of women interviewed following one of the coolest days between March and June

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3 177 2014 (<10<sup>th</sup> percentile of daily mean temperature). Logistic regression was then used to test  
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5 178 for associations between mean temperature and the odds of (i) exclusive breastfeeding and  
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7 179 (ii) supplementary feeding, adjusting for important confounders and covariates (table S1).  
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11 180 Separate models (either multilevel or logistic) were developed for each outcome following a  
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13 181 forward stepwise process. Dummy variables adjusted for interview round (multilevel models  
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15 182 only) and month of data collection. Adjusting for month (rather than season) of interview  
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17 183 provided tighter control of possible confounders, such as household food security and fasting  
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19 184 during Ramadan. Other covariates were retained in the model if they were significantly  
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21 185 associated with the outcome ( $p < 0.05$ ), improved model fit (reduced the Akaike Information  
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23 186 Criterion by  $\geq 2\%$ ), and/or changed the temperature effect by  $\geq 10\%$ . Cases with missing data  
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25 187 were excluded from the analysis. Participants lost to follow-up were included in the analysis.  
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30 188 Interactions between mean temperature and: (i) infant age; (ii) urban/rural residence; and (iii)  
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32 189 roofing materials of the home were tested in all models. Final multilevel models were  
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34 190 specified with a first-order autoregressive correlation structure, allowing for unequal spacing  
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36 191 of interviews.  
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40 192 Sensitivity analyses involved re-specifying models with: (i) alternative levels of seasonal  
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42 193 control (dummy variables for 'season' rather than 'month'; natural cubic splines of calendar  
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44 194 time with three knots); and (ii) apparent, rather than observed, daily mean temperature  
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46 195 (accounting for relative humidity and wind speed).[33]  
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51 196 Sex-disaggregated analysis was not appropriate for this study as all participants were of  
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53 197 female sex. Gender-disaggregated analysis was not possible as gender information was not  
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55 198 collected in the primary (PopDev) study.  
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3 199 Analyses were done in R 4.0.4,[34] using RStudio and the following R packages: lme4;[35]  
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5 200 nlme;[36] stats;[34] splines;[34] effects;[37] ggplot2;[38] HeatStress;[33] Hmisc.[39]  
6  
7

## 8 201 **Patient and public involvement**

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11 202 Stakeholders were involved during development of the original proposal in June 2012. The  
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13 203 objectives and plans for the primary (PopDev) study were discussed with representatives  
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15 204 from the community and reproductive health NGOs, as well as health professionals and  
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17 205 policy makers at local and national levels, by means of a workshop, email, and telephone.  
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21 206 Stakeholders from the policy or associative arena presented their policies at the workshop to  
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23 207 inform a group discussion on how best the study objectives could respond to their  
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25 208 information needs. In another exercise, stakeholders were asked to identify one positive, one  
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27 209 negative, and one surprising thing about the proposed study, which yielded particularly useful  
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29 210 information when developing the proposal. We received feedback on substantive and  
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31 211 methodological aspects of the project, and on communication issues, which was used to  
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33 212 shape the study objectives and methodologies. One such change was the inclusion of the  
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35 213 detailed daily activity questionnaire used in the secondary analysis herein.  
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41 214 The interview schedule was piloted with members of the community. Feedback on interview  
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43 215 duration, meaningfulness and clarity of questions, and perceived gaps, was used to refine the  
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45 216 wording of questions and to add/remove items. At the end of the primary (PopDev) study, a  
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47 217 stakeholder consultation workshop took place to discuss the findings and their implications  
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49 218 for cross-sectoral interventions, involving policy makers from different ministries and NGO  
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51 219 staff.  
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56 220 Pregnant and postpartum women, as well as community members, in the Kaya and Bogodogo  
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58 221 health districts of Burkina Faso were involved before the secondary study began. In-depth  
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3 222 interviews with pregnant and postpartum women ( $n=40$ ), and focus group discussions with  
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5 223 community members, were undertaken in October–November 2020.[7] The objectives for the  
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7 224 secondary analysis were developed and informed by the lived experiences of postpartum  
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9 225 women reported during this qualitative work. Specifically, women described how hot weather  
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11 226 impedes breastfeeding due to excessive sweating and the discomfort of both mothers and  
12  
13 227 their babies.[7]  
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18 228 Qualitative findings were discussed with stakeholders in maternal and neonatal health,  
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20 229 climate change adaptation, as well as pregnant and postpartum women and community  
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22 230 members, during a co-design workshop in Ouagadougou, Burkina Faso. Here, breastfeeding  
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24 231 messaging was highlighted as an important area of focus for future research and interventions  
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26 232 aimed at reducing the impact of heat stress on childbearing women and their newborn infants.  
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29 233 We will continue our engagement with community members in the Kaya and Bogodogo  
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31 234 health districts and will disseminate our findings through meetings, written summaries, and  
32  
33 235 audio-visual materials. We will also engage with health decision-makers and provide  
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35 236 summaries of the evidence and targeted policy briefs to support decision-makers in actions to  
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37 237 reduce the impact of extreme high temperatures on maternal and neonatal health.  
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## 41 42 238 **RESULTS** 43 44

45 239 The population experienced year-round high temperatures, with an intra-annual range in daily  
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47 240 mean temperature of 22.6–33.7°C. Figure S1 (supplementary material) shows daily minimum  
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49 241 and maximum temperatures throughout the study period.  
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53 242 Eight-hundred and fifty-nine participants birthed 881 children (837 singleton births; 22 twin  
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55 243 births). Six stillbirths, eight deaths in live born children, and 18 deaths in infants of unknown  
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57 244 status at birth were reported. Seven women were lost to follow up between pregnancy and the  
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59 245 postpartum period. The mean age of women at recruitment was 26.9 years ( $SD=6.2$  years),  
60



246 **Table 1. Cohort characteristics, activities, and average daily temperature at each interview round.**

|  |  | Interview round         |                          |                          |
|--|--|-------------------------|--------------------------|--------------------------|
|  |  | 1                       | 2                        | 3                        |
| Total interviewed (N)                              |  | 839                     | 810                      | 792                      |
| Cohort characteristics                             |  |                         |                          |                          |
|  | % urban [N] (NA)*                      | 49.9<br>[419] (0)       | 49.3<br>[390] (19)       | 49.7<br>[389] (10)       |
|  | % postpartum [N]                       | 49.5<br>[415]           | 100<br>[810]             | 100<br>[792]             |
|  | % working in informal sector [N] (NA)* | 37.6<br>[315] (1)       | 42.5<br>[343] (3)        | 48.9<br>[386] (2)        |
| Living arrangements                                |  |                         |                          |                          |
|  | % with partner full-time [N]           | 80.9<br>[679]           | 80.1<br>[649]            | 80.1<br>[634]            |
|  | % with partner periodically [N]        | 6.9<br>[58]             | 6.4<br>[52]              | 5.3<br>[42]              |
|  | % not living with partner [N]          | 2.5<br>[21]             | 4.3<br>[35]              | 3.2<br>[25]              |
|  | % not in a relationship [N]            | 0<br>[0]                | 8.8<br>[71]              | 7.7<br>[61]              |
|  | % unknown [N]                          | 9.7<br>[81]             | 0.4<br>[3]               | 3.8<br>[30]              |
| Postpartum women only                              |  |                         |                          |                          |
|  | % breastfeeding [N] (NA)*              | 100<br>[408] (7)        | 99.7<br>[782] (26)       | 99.7<br>[765] (25)       |
|  | % supplementary feeding [N] (NA)*      |                         | 80.2<br>[628] (27)       | 98.0<br>[752] (25)       |
| Time use (mins/day)                                | Breastfeeding (median [IQR]) (NA)*     | 120<br>[80–180] (11)    | 180<br>[120–180] (23)    | 240<br>[121–240] (26)    |
|  | Childcare (median [IQR]) (NA)*         | 30<br>[15–40] (5)       | 30<br>[20–40] (11)       | 20<br>[15–30] (21)       |
|  | Paid work/education (median [IQR])     | 0<br>[0–0]              | 0<br>[0–92]              | 300<br>[0–420]           |
|  | Domestic work (median [IQR])           | 180<br>[110–240]        | 215<br>[145–300]         | 180<br>[130–235]         |
| Infant age (weeks) (median [IQR]) (NA)*            |  | 5.7<br>[2.6–9.9] (17)   | 12.6<br>[6.4–19.0] (25)  | 33.9<br>[27.1–41.0] (31) |
| Daily mean temperature (°C) (median [range]) (NA)* |  | 27.9<br>[22.7–32.8] (0) | 27.0<br>[22.9–33.7] (11) | 27.2<br>[23.3–30.3] (0)  |

247 Number (N) of women and % of total interviewed at each survey round, or summary statistics  
 248 specified. \* Missing values were excluded from calculations. NA = N missing. Where NA is not  
 249 provided, N=0.

250 with a median gravidity of 3 pregnancies (IQR=2–5 pregnancies). Only 33 women (3.9%)  
 251 were formally employed at baseline, of which 21 women were eligible for (or benefiting

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3 252 from) maternity leave. Informal paid work was more common (see table 1). The most  
4  
5 253 common occupations reported at baseline were trade/sales/small business (253 of 839  
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7 254 women), agriculture/farming (236 women), and housekeeping (218 women). Most women  
8  
9 255 (808 of 839 interviewed at baseline) lived in houses with contemporary roof materials;  
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11  
12 256 primarily sheet metal (731 women) and timber (81 women).

15 257 The median time between first and second interviews was 92 days (IQR 80–108 days), and  
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17 258 149 days (IQR 141–155 days) between the second and third interviews. Total median follow-  
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19 259 up time was 236 days (IQR 227–257 days). One woman refused to participate during the  
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21 260 second round of interviews and one woman was travelling during the third round of  
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23 261 interviews. The reasons why other women were lost to follow-up ( $n=6$  at interview two,  $n=41$   
24  
25 262 at interview three) are unknown.

29 263 The vast majority of postpartum women reported breastfeeding their infants at each interview  
30  
31 264 round (table 1). However, the incidence of exclusive breastfeeding was low. Only 148 of 710  
32  
33 265 infants (20.8%) aged less than six months were exclusively breastfed on the day/night before  
34  
35 266 interview two, and only 11 of 157 (7%) were exclusively breastfed before interview three.

38  
39 267 On average, daily breastfeeding duration increased over time (figure 1a). After adjusting for  
40  
41 268 long-term trends, a slight decrease in breastfeeding duration was observed as temperatures  
42  
43 269 increased (figure 2a). Before adjusting for potential confounders (accounting only for the  
44  
45 270 longitudinal and nested structure of the data), breastfeeding was estimated to decrease by 5.6  
46  
47 271 minutes/day (95% CI -7.0 to -4.1,  $p<0.001$ ,  $n=783$  women) per 1°C increase in same-day  
48  
49 272 mean temperature. After controlling for important confounders (month of data collection,  
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51 273 interview round, singleton/multiple birth, residential area, and time spent on paid work or  
52  
53 274 education [minutes/day]), breastfeeding was estimated to decrease by 2.3 minutes/day (95%  
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55 275 CI -4.6 to 0.04,  $p=0.05$ ,  $n=783$  women) per 1°C increase in same-day mean temperature  
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3 276 (table S2). This estimate was for infants aged 0.6–57 weeks (median=18.6 weeks). However,  
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5 277 temperature interacted with infant age to affect breastfeeding duration ( $p=0.02$ ). Time spent  
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7 278 breastfeeding very young infants (four weeks) did not change with temperature. As infants  
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9 279 aged, women were predicted to spend increasingly less time breastfeeding at high  
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12 280 temperatures (figure 3).

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15 281 On average, women spent less time on childcare at interview three (table 1), which coincided  
16  
17 282 with the rainy and early dry/cooler seasons (figure 1b). After seasonal control, a slight increase  
18  
19 283 in childcare time was observed as temperatures increased (figure 2b). Before adjustment, we  
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21 284 estimated a 0.4-minute increase (0.1 to 0.8,  $p=0.02$ ,  $n=814$  women) in daily childcare per 1°C  
22  
23 285 increase in mean temperature. We estimated a 0.6-minute increase (0.06 to 1.2,  $p=0.03$ ,  $n=787$   
24  
25 286 women) in childcare per 1°C increase in temperature after adjusting for month, interview  
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27 287 round, singleton/multiple birth, infant age, maternal age, time spent on paid work or education  
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29 288 (minutes/day)], and women's living arrangements (table S3).

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32 289 A large proportion of women provided supplementary fluids to their infant (table 1); primarily  
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34 290 water, herbal tea and, in the rainy season, boiled water. Milk other than breastmilk was rarely  
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36 291 given. During interview round two (infant age 0–43 weeks), 30 of 43 women (70%) provided  
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38 292 supplementary fluids on a relatively cool day, whereas 77 of 86 women (90%) provided  
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40 293 supplementary fluids on a very hot day (figure 4a). Before adjusting for month or infant age,  
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42 294 there was some indication of a positive relationship between temperature and supplementary  
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44 295 feeding (OR=1.08, 0.99 to 1.18,  $p=0.08$ ,  $n=632$  women). After adjustment, the estimate was  
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46 296 no longer statistically significant, although the direction of association remained the same  
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48 297 (OR=1.06, 0.93 to 1.20,  $p=0.4$ ,  $n=604$  women). Infant age was the strongest predictor of  
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50 298 supplementary feeding (OR=1.15, 1.11 to 1.19,  $p<0.001$ ,  $n=604$  women).

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3 299 For women with infants aged less than six months at interview two, one third (12 of 36 women)  
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5 300 reported exclusive breastfeeding on a 'cool' day ( $<26.5^{\circ}\text{C}$ ); whereas, only 12% (nine of 76  
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7 301 women) reported exclusive breastfeeding on a very hot day ( $>32.5^{\circ}\text{C}$ ) (figure 4b). Before  
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9 302 confounder control, there was some evidence to suggest that women were less likely to  
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11 303 exclusively breastfeed as temperature increased (OR=0.92, 0.84 to 1.01,  $p=0.07$ ,  $n=576$   
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13 304 women). After controlling for month and infant age, there was no strong evidence of  
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15 305 association between daily mean temperature and exclusive breastfeeding (OR=0.93, 0.82 to  
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17 306 1.06,  $p=0.3$ ,  $n=576$  women).

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22 307 There was no evidence of an interaction between temperature and residential area (urban/rural)  
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24 308 or type of roofing materials on any outcome measured ( $p>0.05$ ).

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28 309 Estimated temperature effects were robust to sensitivity analyses. The main effect on  
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30 310 breastfeeding duration was very robust and increased in statistical significance with  
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32 311 alternative methods of seasonal control. The interaction between temperature and infant age  
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34 312 on breastfeeding duration, and the main effect of temperature on daily childcare duration,  
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36 313 were also fairly robust but with reduced significance.

## 37 38 39 40 314 **DISCUSSION**

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44 315 This study explored the impacts of high ambient temperature on infant feeding practices  
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46 316 among postpartum women in a low-income setting. We found a decrease in breastfeeding  
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48 317 duration as temperatures increased; approximating to a 25-minute reduction in breastfeeding  
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50 318 on the hottest, compared to coolest, days of the year. The extent of this impact largely  
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52 319 depended on the age of the infant. From approximately four months onwards, we predicted an  
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54 320 increasingly negative impact of high temperature on breastfeeding duration. For younger  
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56 321 infants, temperature had a lower impact. There was no strong evidence that exclusive  
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58 322 breastfeeding of young infants (aged less than six months) declines in very hot weather, or  
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3 323 that women are more likely to provide supplementary fluids to their infants (aged up to 12  
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5 324 months) as temperatures rise. However, women did tend to spend more time caring for their  
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8 325 children at high temperatures.  
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11 326 There may be several explanations for the reduction in breastfeeding duration as temperatures  
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13 327 rise in hot climates. Infants may demand less milk in order to limit heat-generation, or they  
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15 328 may become too uncomfortable to feed. Mothers in the Kaya and Bogodogo health districts  
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17 329 of Ouagadougou, Burkina Faso, report that their babies do not remain latched on during  
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19 330 extreme heat due to the babies' discomfort.[7] On the other hand, mothers may offer less  
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21 331 breastmilk due to their own discomfort under very hot conditions[7, 40] and/or due to a  
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23 332 misperception that babies require supplementary water, especially on hot days.[8-10]  
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28 333 It is not unusual for breastfeeding patterns to change in hot weather. Infants may refuse to  
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30 334 feed during the hottest part of the day and/or they may demand more frequent, but shorter,  
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32 335 feeds throughout the day.[41] In doing so, babies consume mostly low-fat milk and avoid  
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34 336 breast milk with a high fat content (i.e. afternoon/evening milk, last milk of a feed).[42]  
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36 337 Ideally, the total intake of breast milk over a 24-hour period would increase during extreme  
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38 338 hot weather in order to avoid infant dehydration. However, our findings tentatively suggest  
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40 339 the contrary.  
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45 340 Many women across the world report perceived inadequacy of milk supply as their main  
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47 341 reason for early weaning.[43] It is not clear if breast milk production is impacted by heat  
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49 342 exposure, either directly or indirectly. High temperatures may exacerbate water stress,  
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51 343 increasing the risk of dehydration among mothers in water-poor regions. However, the effects  
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53 344 of maternal dehydration on breast milk production in hot climates are largely unknown.[44,  
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55 345 45] Several studies have shown that exclusively breastfed infants maintain normal hydration  
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57 346 under hot conditions,[46-48] indicating that the quantity of breast milk is not affected.  
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3 347 However, field and experimental animal studies have shown that both the yield and  
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5 348 nutritional composition of ruminant milk decline under hot conditions.[49] Further, the milk  
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7 349 production capacity of animal mammary epithelial cells was found to decline following in  
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9 350 vitro exposure to high temperatures (41°C).[50] To our knowledge, no studies have examined  
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11 351 breast milk production in relation to temperature, but there is evidence that maternal stress  
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13 352 affects breast milk composition[51] and delays secretory activation.[52] Even if milk supply  
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15 353 is not adversely affected, high temperatures may contribute to women's perception of  
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17 354 inadequate milk supply.

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22 355 To our knowledge, this is the first study to quantify the acute effects of heat on breastfeeding,  
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24 356 an important global health outcome. Studies in South America, South Asia, and Africa show  
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26 357 seasonal differences in breastfeeding behaviour, with conflicting results.[22, 25-27] For  
27  
28 358 example, in Bihar, India, infants under six months were more likely to be exclusively  
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30 359 breastfed in the colder than warmer season.[26] Whereas, in rural Egypt, exclusive  
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32 360 breastfeeding of infants aged 6–11 months was more prevalent in the hot than cool  
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34 361 season.[22] However, such studies are not sufficient to demonstrate an effect of temperature  
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36 362 as seasonal patterns are rarely driven by temperature alone, and changes in work availability  
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38 363 and nutrition also need to be taken into account.

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44 364 The main strengths of this study are the longitudinal dataset, population-based sampling,  
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46 365 detailed questionnaire on activities, small loss to follow-up, and extensive confounder  
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48 366 control. The main limitations are the small sample size, which may have reduced our ability  
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50 367 to detect statistically significant associations (increasing the chances of a Type II error), and  
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52 368 the short recruitment window (ideally, the study would have been conducted over several  
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54 369 years). However, 2014 was a climatically typical year in Burkina Faso during 2010s.[21]  
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56 370 Although our outcome measurements relied on self-reports, women were not asked directly if  
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3 371 they breastfed their infant exclusively. Instead, this outcome was constructed from women's  
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5 372 recall of all fluids given to their child in the past 24 hours. Questions on infant feeding  
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7 373 practices and childcare were embedded within an extensive interview schedule, further  
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10 374 reducing the possibility of response bias. Nevertheless, our measurement of exclusive  
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12 375 breastfeeding was not optimal. Finally, the outcome of childcare refers to time spent with  
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14 376 children of all ages as this question was not specifically phrased to indicate the target  
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17 377 (newborn) child.

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20 378 Our findings are likely to be generalisable to Burkina Faso and other countries in the Sahel  
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22 379 region, which share the same temperature conditions and have similar levels of breastfeeding  
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24 380 uptake. Our findings may also be generalisable to other regions of Africa with a similar  
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26 381 climate and breastfeeding uptake if, as proposed, breastfeeding duration is reduced at high  
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28 382 temperatures due to infant or maternal discomfort and/or due to a perception that babies  
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30 383 require water in hot weather. Mothers in West and East African countries (Burkina Faso and  
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32 384 Kenya, respectively) report similar challenges when breastfeeding in extreme heat,[7,40] and  
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34 385 hot weather has been identified as a barrier to optimal infant feeding practices in the  
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36 386 Democratic Republic of the Congo (Central Africa)[8] and Ghana (West Africa).[9]

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39 387 Larger studies are needed to further examine the impacts of heat on infant feeding practices  
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42 388 in hot climates. Future research should consider temperature in relation to the number and  
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44 389 duration of individual breastfeeds, and to the volume of breast milk and supplementary fluids  
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46 390 consumed by infants, over a 24-hour period. Research should also seek to determine if high  
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48 391 temperatures impact on breast milk production. Actions should be taken to ensure that hot  
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50 392 weather does not negatively impact on breastfeeding behaviour. Effective interventions are  
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52 393 likely to require a multidimensional approach.[53] It is important that health workers and  
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3 394 mothers are informed about normal heat-induced changes in infant breastfeeding patterns so  
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5 395 that such changes are not misinterpreted as a need for supplementation.  
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## 8 396 **CONCLUSIONS**

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10  
11 397 Exclusive breastfeeding is an essential cornerstone for the wellbeing and survival of infants.  
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13 398 Our findings suggest a substantial decrease in breastfeeding duration during hot weather. This  
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15 399 finding is important as infants require increased hydration to cope physiologically with  
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17 400 increased heat, and the safest form of hydration for young infants is breast milk.  
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22 401 Larger studies are needed in Burkina Faso and beyond as climate change in Africa is  
23  
24 402 accelerating.[54] Without effective interventions, mothers may find it increasingly difficult to  
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26 403 breastfeed their infants as temperatures rise. Maternal and child health programmes in hot  
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28 404 climates should be updated to improve messaging and breastfeeding practices during extreme  
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30 405 hot weather.  
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11  
12  
13 410 PopDev study.  
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16 411 **Contributors**  
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19  
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21  
22 413 conducted the statistical analysis under the supervision of SH. All authors interpreted the  
23  
24 414 results. CP drafted the paper. All authors critically revised the paper for important intellectual  
25  
26 415 content and approved the final version for publication. All authors agreed to be accountable  
27  
28 416 for all aspects of the work.  
29  
30

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55 426 **Competing interests**  
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57

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3 428 **Ethics approval**  
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6 429 The study was approved by the Research Ethics Committees of Centre Muraz, Burkina Faso  
7  
8 430 (reference: A16-2013/CE-CM) and the London School of Hygiene & Tropical Medicine,  
9  
10 431 United Kingdom (reference: 6401). The free and informed consent of each participant was  
11  
12 432 obtained before each interview.  
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16 433 **Data sharing statement**  
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19 434 Individual-level deidentified participant data from the primary (PopDev) study are available  
20  
21 435 to researchers who have a valid research question, which is not being investigated by the  
22  
23 436 primary research team. A data sharing agreement will be required. All data requests should be  
24  
25 437 made via <https://datacompass.lshtm.ac.uk/id/eprint/64/>. The questionnaires, consent form,  
26  
27 438 data dictionary (codebook), and user guide are publicly available from  
28  
29 439 <https://datacompass.lshtm.ac.uk/id/eprint/64/>. Data have been available from 2018 with no  
30  
31 440 end date. Meteorological data are publicly available from TuTiempo  
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33 441 (<https://www.tutiempo.net/>). Statistical code is available from the corresponding author.  
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3 591 **Figure legends**  
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6 592 **Figure 1.** Average time spent (minutes per day) (a) breastfeeding and (b) caring for children  
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8 593 over time, with fitted natural cubic splines of time (dashed lines). Blue shading = dry, cooler  
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10 594 season (November–February), red shading = dry, hot season (March–May), green shading =  
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12 595 rainy season (June–October). Data source: PopDev study.[29]  
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18 597 **Figure 2.** Scatterplots of daily mean temperature (°C) and standardised residuals from fitted  
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20 598 trends (natural cubic splines of time) in the (a) breastfeeding and (b) childcare time-series, with  
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22 599 locally weighted smoothing (blue line) and 95% confidence intervals (grey shading).  
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27 601 **Figure 3.** Effects of daily mean temperature (°C) on time spent breastfeeding (minutes per day)  
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29 602 at specified infant ages (4, 13, 26, 52 weeks), as predicted from an autoregressive multilevel  
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31 603 linear model with confounder control and an interaction term between temperature and infant  
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33 604 age.  
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38 606 **Figure 4.** Incidence of (a) supplementary feeding and (b) exclusive breastfeeding in past 24h  
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40 607 among women interviewed following the hottest and coolest days of the season. Blue = days  
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42 608 below the 10<sup>th</sup> percentile of daily mean temperature between March–June 2014. Red = days  
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44 609 above the 90<sup>th</sup> percentile of daily mean temperature between March–June 2014.  
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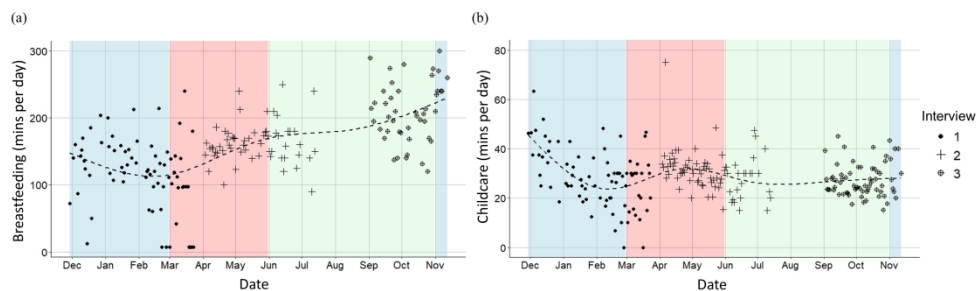


Figure 1. Average time spent (minutes per day) (a) breastfeeding and (b) caring for children over time, with fitted natural cubic splines of time (dashed lines). Blue shading = dry, cooler season (November–February), red shading = dry, hot season (March–May), green shading = rainy season (June–October). Data source: PopDev study.[29]

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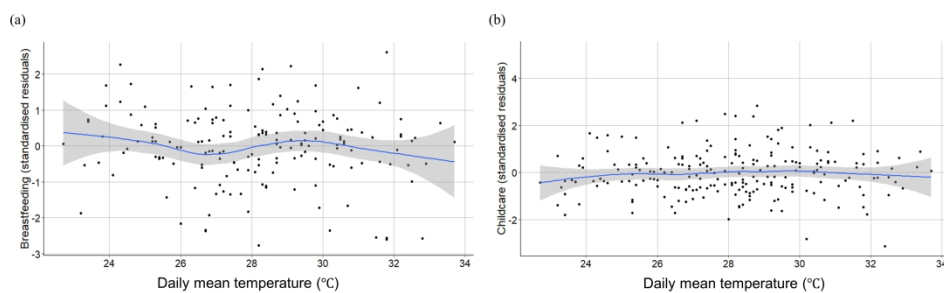


Figure 2. Scatterplots of daily mean temperature (°C) and standardised residuals from fitted trends (natural cubic splines of time) in the (a) breastfeeding and (b) childcare time-series, with locally weighted smoothing (blue line) and 95% confidence intervals (grey shading).

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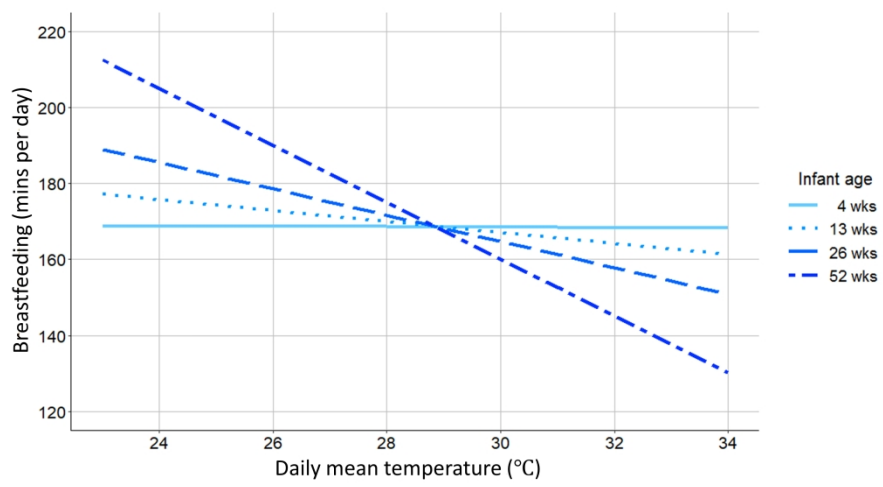


Figure 3. Effects of daily mean temperature (°C) on time spent breastfeeding (minutes per day) at specified infant ages (4, 13, 26, 52 weeks), as predicted from an autoregressive multilevel linear model with confounder control and an interaction term between temperature and infant age.

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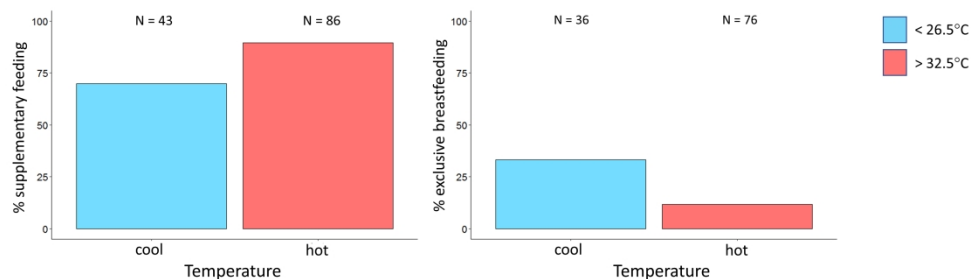


Figure 4. Incidence of (a) supplementary feeding and (b) exclusive breastfeeding in past 24h among women interviewed following the hottest and coolest days of the season. Blue = days below the 10th percentile of daily mean temperature between March–June 2014. Red = days above the 90th percentile of daily mean temperature between March–June 2014.

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**SUPPLEMENTAL MATERIAL**

**How do high ambient temperatures affect infant feeding practices? A prospective cohort study of postpartum women in Bobo-Dioulasso, Burkina Faso**

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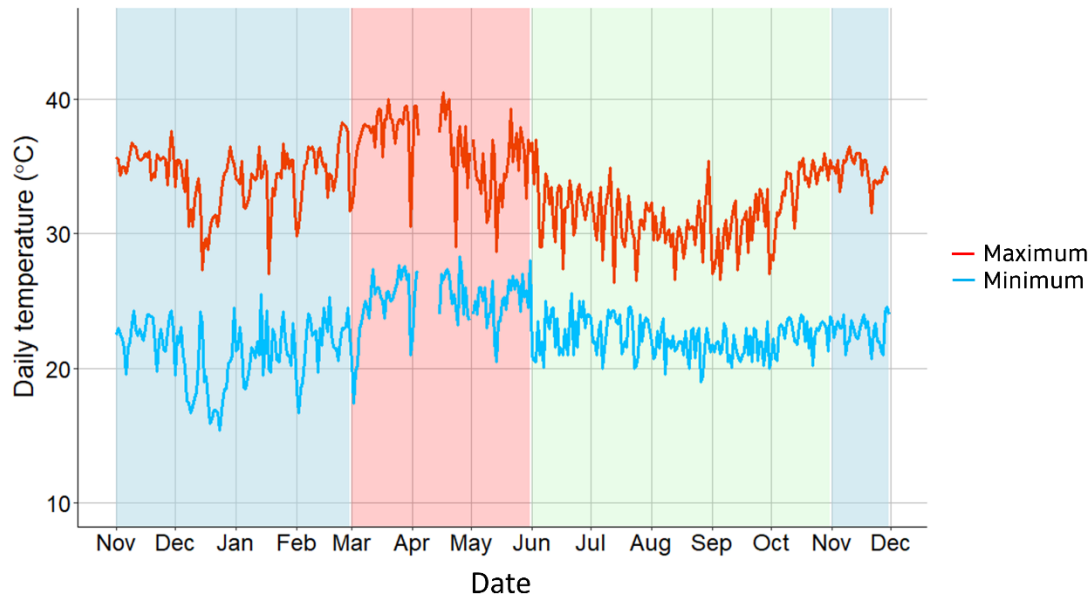
References ..... 5

**Table S1. Outcomes, exposure, potential confounders and covariates considered in all models.**

| Variable                               | Definition  | Units  | Type        | Model          |
|--|---|--|-------------|----------------|
| <b>Outcomes</b>                        |   |  |             |                |
| <i>Breastfeeding duration</i>          | Time spent breastfeeding infants aged 4+ days                                 | Minutes per day  | Continuous  | MLM (BF)       |
| <i>Exclusive breastfeeding</i>         | No liquids other than breast milk given in past 24h (infants aged <6 months)  | Yes, No  | Binary      | Logistic (EBF) |
| <i>Supplementary feeding</i>           | Any liquid other than breast milk given in past 24h (infants aged <12 months) | Yes, No  | Binary      | Logistic (SF)  |
| <i>Childcare duration</i>              | Time spent caring for (clothing, etc) children aged 0+ days                   | Minutes per day  | Continuous  | MLM (CH)       |
| <b>Exposure</b>                        |   |  |             |                |
| <i>Daily mean temperature</i>          | Mean temperature in Bobo-Dioulasso on day before interview                    | °C   | Continuous  | All            |
| <b>Confounders</b>                     |   |  |             |                |
| <i>Season/time trends</i>              | Seasonal patterns (unrelated to temperature) and long-term trends             | Month of interview   | Categorical | All            |
| <i>Interview round</i>                 | Interview (baseline, 3-months post-baseline, 9-months post-baseline)          | 1, 2, 3  | Categorical | BF, CH         |
| <i>Infant age</i>                      | Date of interview – Date of delivery  | Weeks  | Continuous  | All            |
| <i>Income-generating work</i>          | Time spent on professional or educational activities                          | Minutes per day  | Continuous  | All            |
| <i>Domestic work</i>                   | Time spent on domestic activities (excluding family care)                     | Minutes per day  | Continuous  | BF, EBF, SF    |
| <b>Covariates</b>                      |   |  |             |                |
| <i>Number born</i>                     | Singleton or multiple birth   | 1, 2   | Categorical | All            |
| <i>Gravidity</i>                       | Total number of pregnancies, including current                                | 1, 2–5, 6+ pregnancies   | Categorical | All            |
| <i>Maternal age</i>                    | Age of mother at baseline   | ≤ 19, 20–34, ≥ 35 years  | Categorical | All            |
| <i>Living arrangements</i>             | Mothers' living arrangements with partner at each interview                   | With partner full-time, With partner periodically, Not with partner, Not in a relationship | Categorical | CH             |
| <i>Residential area</i>                | Mother's area of residence  | Urban, Rural   | Categorical | All            |
| <i>Roofing materials</i>               | Roofing materials of mother's house   | Natural, Rudimentary, Contemporary   | Categorical | All            |
| <b>Interactions</b>                    |   |  |             |                |
| <i>Temperature * Residential area</i>  | Daily mean temperature and mother's area of residence                         | °C * Urban/Rural   | Interaction | All            |
| <i>Temperature * Infant age</i>        | Daily mean temperature and infant age   | °C * Weeks   | Interaction | All            |
| <i>Temperature * Roofing materials</i> | Daily mean temperature and roofing materials of mother's house                | °C * Natural/Rudimentary/Contemporary  | Interaction | All            |

MLM = Multilevel model. BF = Breastfeeding duration. CH = Childcare duration. SF = Supplementary feeding. EBF = Exclusive breastfeeding.





**Figure S1.** Daily maximum and minimum temperatures and seasons in Bobo-Dioulasso, Burkina Faso, between 1st Nov 2013 and 30th Nov 2014. Blue = dry, cooler season (November–February), red = dry, hot season (March–May), green = rainy season (June–October). Data source: TuTiempo.net [1].

**Table S2. Effect estimates, 95% confidence intervals, and *p*-values of each variable included in the autoregressive multilevel linear model for the exposure-response association between temperature and breastfeeding duration (minutes/day).**

| Variable  | Estimate | 95% CI  |        | <i>p</i> -value |
|---|----------|---------|--------|-----------------|
| Daily mean temperature (°C)                     | -2.29    | -4.63   | 0.04   | 0.05            |
| Interview round (reference: 1)                  |          |         |        |                 |
| 2   | 32.01    | -52.53  | 116.54 | 0.46            |
| 3   | 135.46   | 59.35   | 211.57 | <0.001          |
| Month of data collection (reference: January)   |          |         |        |                 |
| <i>February</i>                                 | -34.16   | -61.25  | -7.07  | 0.01            |
| <i>March</i>                                    | -61.79   | -89.14  | -34.45 | <0.001          |
| <i>April</i>                                    | -7.70    | -95.20  | 79.79  | 0.86            |
| <i>May</i>                                      | -22.75   | -106.68 | 61.18  | 0.59            |
| <i>June</i>                                     | -37.01   | -122.13 | 48.12  | 0.39            |
| <i>July</i>                                     | -37.57   | -135.16 | 60.02  | 0.45            |
| <i>September</i>                                | -89.72   | -167.34 | -12.09 | 0.02            |
| <i>October</i>                                  | -102.25  | -178.37 | -26.14 | <0.01           |
| <i>November</i>                                 | -66.34   | -136.35 | 3.66   | 0.06            |
| <i>December</i>                                 | -13.72   | -35.25  | 7.81   | 0.21            |
| Singleton/multiple birth (reference: singleton) |          |         |        |                 |
| <i>Multiple birth</i>                           | 70.46    | 48.43   | 92.49  | < 0.001         |
| Residential area (reference: rural)             |          |         |        |                 |
| <i>Urban</i>                                    | 18.26    | -5.76   | 42.29  | 0.13            |
| Income-generating activities (minutes/day)      | 0.02     | 0.00    | 0.04   | 0.02            |

**Table S3. Effect estimates, 95% confidence intervals, and *p*-values of each variable included in the autoregressive multilevel linear model for the exposure-response association between temperature and childcare duration (minutes/day).**

| Variable  | Estimate | 95% CI |       | <i>p</i> -value |
|---|----------|--------|-------|-----------------|
| Daily mean temperature (°C)                                   | 0.65     | 0.06   | 1.24  | 0.03            |
| Interview round (reference: 1)                                |          |        |       |                 |
| 2   | -8.09    | -34.64 | 18.47 | 0.55            |
| 3   | -15.25   | -36.13 | 5.63  | 0.15            |
| Month of data collection (reference: January)                 |          |        |       |                 |
| <i>February</i>   | -1.75    | -7.64  | 4.13  | 0.56            |
| <i>March</i>  | -4.36    | -10.33 | 1.60  | 0.15            |
| <i>April</i>  | 9.96     | -17.18 | 37.09 | 0.47            |
| <i>May</i>  | 8.99     | -17.90 | 35.87 | 0.51            |
| <i>June</i>   | 8.32     | -18.84 | 35.48 | 0.55            |
| <i>July</i>   | 3.48     | -25.75 | 32.71 | 0.82            |
| <i>September</i>  | 15.08    | -5.95  | 36.10 | 0.16            |
| <i>October</i>  | 12.88    | -8.13  | 33.90 | 0.23            |
| <i>November</i>   | 16.52    | -2.63  | 35.66 | 0.09            |
| <i>December</i>   | 14.34    | 8.75   | 19.92 | < 0.001         |
| Singleton/multiple birth (reference: singleton)               |          |        |       |                 |
| <i>Multiple birth</i>   | 17.43    | 11.53  | 23.33 | < 0.001         |
| Infant age (weeks)  | 0.09     | -0.04  | 0.21  | 0.17            |
| Maternal age (reference: 20-34 years)                         |          |        |       |                 |
| < 19 years  | -5.68    | -8.68  | -2.69 | < 0.001         |
| ≥ 35 years  | 0.29     | -2.39  | 2.97  | 0.83            |
| Income-generating activities (minutes/day)                    | -0.01    | -0.01  | -0.00 | 0.04            |
| Living arrangements (reference: Lives with partner full-time) |          |        |       |                 |
| <i>Lives with partner periodically</i>                        | -1.91    | -5.73  | 1.92  | 0.33            |
| <i>Does not live with partner</i>                             | -2.57    | -7.42  | 2.29  | 0.30            |
| <i>Not in a relationship</i>                                  | -8.68    | -12.47 | -4.89 | < 0.001         |

## References

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STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

|                              | Item No | Recommendation   | Page No                                |
|------------------------------|---------|--|--|
| <b>Title and abstract</b>    | 1       | (a) Indicate the study's design with a commonly used term in the title or the abstract<br>(b) Provide in the abstract an informative and balanced summary of what was done and what was found  | 1<br>3-4                               |
| <b>Introduction</b>          |         |  |  |
| Background/rationale         | 2       | Explain the scientific background and rationale for the investigation being reported   | 2-4                                    |
| Objectives                   | 3       | State specific objectives, including any prespecified hypotheses   | 7                                      |
| <b>Methods</b>               |         |  |  |
| Study design                 | 4       | Present key elements of study design early in the paper  | 7                                      |
| Setting                      | 5       | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection  | 8, 9                                   |
| Participants                 | 6       | (a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up<br>(b) For matched studies, give matching criteria and number of exposed and unexposed  | 8, 9<br>N/A                            |
| Variables                    | 7       | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable   | Table S1                               |
| Data sources/<br>measurement | 8*      | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group   | 8-9                                    |
| Bias                         | 9       | Describe any efforts to address potential sources of bias  | 8-9, 11                                |
| Study size                   | 10      | Explain how the study size was arrived at  | N/A                                    |
| Quantitative variables       | 11      | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why   | 10-11                                  |
| Statistical methods          | 12      | (a) Describe all statistical methods, including those used to control for confounding<br>(b) Describe any methods used to examine subgroups and interactions<br>(c) Explain how missing data were addressed<br>(d) If applicable, explain how loss to follow-up was addressed<br>(e) Describe any sensitivity analyses | 10-11<br>11<br>9, 11<br>11<br>11       |
| <b>Results</b>               |         |  |  |
| Participants                 | 13*     | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed.<br>(b) Give reasons for non-participation at each stage<br>(c) Consider use of a flow diagram                       | 13,<br>Table 1,<br>15, 16,<br>17<br>15 |
| Descriptive data             | 14*     | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders<br>(b) Indicate number of participants with missing data for each variable of interest<br>(c) Summarise follow-up time (eg, average and total amount)                         | Table 1,<br>13-15<br>Table 1<br>15     |
| Outcome data                 | 15*     | Report numbers of outcome events or summary measures over time   | Table 1,<br>15                         |

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| 3  | Main results             | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included |
| 4  |                          |    |  |
| 5  |                          |    |  |
| 6  |                          |    | (b) Report category boundaries when continuous variables were categorized  |
| 7  |                          |    |  |
| 8  |                          |    | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period   |
| 9  |                          |    |  |
| 10 | Other analyses           | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses   |
| 11 |                          |    |  |
| 12 |                          |    |  |
| 13 | <b>Discussion</b>        |    |  |
| 14 | Key results              | 18 | Summarise key results with reference to study objectives   |
| 15 | Limitations              | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias   |
| 16 |                          |    |  |
| 17 | Interpretation           | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence                                   |
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| 21 | Generalisability         | 21 | Discuss the generalisability (external validity) of the study results  |
| 22 |                          |    |  |
| 23 | <b>Other information</b> |    |  |
| 24 | Funding                  | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based  |
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\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.

# BMJ Open

## How do high ambient temperatures affect infant feeding practices? A prospective cohort study of postpartum women in Bobo-Dioulasso, Burkina Faso

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| <b>Primary Subject Heading</b>: | Public health   |
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3 **1 HOW DO HIGH AMBIENT TEMPERATURES AFFECT INFANT FEEDING**  
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5 **2 PRACTICES? A PROSPECTIVE COHORT STUDY OF POSTPARTUM WOMEN IN**  
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7 **3 BOBO-DIOULASSO, BURKINA FASO**  
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3 25 **ABSTRACT**  
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6 26 **Objective:** To examine the effects of high ambient temperature on infant feeding practices  
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8  
9 27 and childcare.  
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11  
12 28 **Design:** Secondary analysis of quantitative data from a prospective cohort study.  
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15 29 **Setting:** Community-based interviews in the commune of Bobo-Dioulasso, Burkina Faso.  
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17  
18 30 Exclusive breastfeeding is not widely practiced in Burkina Faso.  
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20  
21 31 **Participants:** 866 women (1:1 urban:rural) were interviewed over 12 months. Participants  
22  
23 32 were interviewed at three time points: cohort entry (when between 20 weeks gestation and 22  
24  
25 33 weeks postpartum), three and nine months thereafter. Retention at nine-month follow-up was  
26  
27 34 90%. Our secondary analysis focussed on postpartum women ( $n=857$ ).  
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30  
31 35 **Exposure:** Daily mean temperature ( $^{\circ}\text{C}$ ) measured at one weather station in Bobo-Dioulasso.  
32  
33 36 Meteorological data were obtained from publicly available archives (TuTiempo.net).  
34  
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36  
37 37 **Primary outcome measures:** Self-reported time spent breastfeeding (minutes/day);  
38  
39 38 exclusive breastfeeding of infants under six months (no fluids other than breast milk provided  
40  
41 39 in past 24 hours); supplementary feeding of infants aged 6-12 months (any fluid other than  
42  
43 40 breast milk provided in past 24 hours); time spent caring for children (minutes/day).  
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46  
47 41 **Results:** The population experienced year-round high temperatures (daily mean temperature  
48  
49 42 range= $22.6\text{--}33.7^{\circ}\text{C}$ ). Breastfeeding decreased by 2.3 minutes/day (95% CI -4.6 to 0.04,  
50  
51 43  $p=0.05$ ), and childcare increased by 0.6 minutes/day (0.06 to 1.2,  $p=0.03$ ), per  $1^{\circ}\text{C}$  increase in  
52  
53 44 same-day mean temperature. Temperature interacted with infant age to affect breastfeeding  
54  
55 45 duration ( $p=0.02$ ), with a stronger (negative) association between temperature and  
56  
57 46 breastfeeding as infants aged (0–57 weeks). Odds of exclusive breastfeeding very young  
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3 47 infants (0-3 months) tended to decrease as temperature increased (OR 0.88, 0.75 to 1.02,  
4  
5 48  $p=0.09$ ). There was no association between temperature and exclusive breastfeeding at 3-6  
6  
7  
8 49 months or supplementary feeding (6-12 months).  
9

10  
11 50 **Conclusions:** Women spent considerably less time breastfeeding (~25 minutes/day) during  
12  
13 51 the hottest, compared to coolest, times of the year. Climate change adaptation plans for health  
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15 52 should include advice to breastfeeding mothers during periods of high temperature.  
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3 53 **Strengths and limitations of this study**  
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- 6 54 • This is the first study to quantify acute effects of ambient heat on breastfeeding behaviour.  
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8  
9 55 • Multi-stage stratified sampling was used to select a population-representative cohort of  
10  
11 56 pregnant and postpartum women in the commune of Bobo-Dioulasso, Burkina Faso.  
12  
13  
14 57 • Detailed questionnaires enabled extensive confounder control.  
15  
16 58 • Outcome measures relied on self-reports, including time-use estimations; however  
17  
18 59 questions were embedded within an extensive interview schedule, reducing the likelihood  
19  
20 60 of response bias, and measures were used to assist participants with time estimations.  
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23 61 • The small sample size and short recruitment window may have limited our ability to detect  
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25 62 statistically significant associations.  
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## 63 INTRODUCTION

64 Climate change is a growing threat to population health in Africa, [1, 2] with heatwaves  
65 increasing in severity and duration, especially in the Sahel. [3] Maternal and neonatal health  
66 will be affected through the adverse effects of heat on preterm birth, [4, 5] stillbirth, [4, 5]  
67 and maternal nutrition. [6] Child wasting and malnutrition are expected to increase. [2] High  
68 temperatures may also reduce cognitive function [7] and interfere with daily activities,  
69 leading to a decline in emotional health and wellbeing. [8] Mothers may find it difficult to  
70 breastfeed their infants under extreme heat, [9] and may also change their behaviour due to  
71 perceived risks to health. For example, there is still a common misconception among  
72 postpartum women in several African countries that breast milk is not sufficient to hydrate  
73 babies during hot weather; leading to supplementary feeding of infants, with sometimes not  
74 potable water, [10-13] and a reduction in exclusive breastfeeding. [10]

75 Breastfeeding and, in particular, exclusive breastfeeding has well-established benefits for  
76 child health and development. [14-16] Breastfeeding reduces the risk of diarrhoea and  
77 respiratory infections among infants, and is associated with a higher intelligence quotient and  
78 reduced obesity in later life. [16] There are also benefits for maternal health, with nursing  
79 mothers at lower risk of breast and, potentially, ovarian cancers. [16] The World Health  
80 Organization (WHO) recommends that infants are fed with breastmilk exclusively for the  
81 first six months and that no solids or other liquids are given during this period, including  
82 water. [17] However, the self-reported prevalence of exclusive breastfeeding is low in many  
83 African countries. [16, 18] In Burkina Faso, less than 25% of women reported exclusive  
84 breastfeeding of their young infants (less than six months old) in 2010-2015. [18]

85 It is not unusual for breastfeeding patterns to change in hot weather. Infants may refuse to  
86 feed during the hottest part of the day, or they may demand more frequent, but shorter, feeds

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3 87 throughout the day. [19] In doing so, babies consume mostly low-fat milk (foremilk) and  
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5 88 avoid breast milk with a high fat content (i.e. afternoon/evening milk and hindmilk). [19, 20]  
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7  
8 89 Mothers must change their breastfeeding patterns to accommodate their infants' needs, and  
9  
10 90 may spend more time breastfeeding as temperatures rise. Conversely, women may spend less  
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12 91 time breastfeeding during periods of high temperature due to increased discomfort for both  
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14 92 mother and child, [9] increased provision of water (believed necessary to quench baby's thirst  
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16 93 in some African settings), [21] and/or associated health effects, such as low energy [8] and  
17  
18 94 heat exhaustion. [22]  
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20  
21

22 95 Infants and young children are particularly vulnerable to heat injury and dehydration due to a  
23  
24 96 greater surface area to body mass ratio. [23] Therefore, as temperatures rise in hot climates,  
25  
26 97 mothers may spend more time watching over their children and other children in the  
27  
28 98 household, keeping them hydrated, and tending to them when unwell. Such increased  
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30 99 demands on time may cause difficulties for mothers in low-income countries such as Burkina  
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32 100 Faso, where women work to supplement household income (particularly in agriculture,  
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34 101 horticulture, and small trade) as well as undertaking important domestic responsibilities  
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36 102 (including gathering food, water, fuel, and feeding livestock). [6] Most women work in the  
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38 103 informal sector, [24] therefore paid maternity leave is uncommon and many women return to  
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40 104 work early in the postpartum period.  
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45  
46 105 Average monthly temperatures in Burkina Faso range between 25–33°C [25] and the impacts  
47  
48 106 on infant care practices are largely unknown. Studies in South America, South Asia and  
49  
50 107 Africa show seasonal differences in breastfeeding behaviour, with conflicting results. [26-29]  
51  
52 108 For example, in Bihar, India, infants under six months were more likely to be exclusively  
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54 109 breastfed in the cooler than warmer season. [29] Whereas, in rural Egypt, exclusive  
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56 110 breastfeeding of infants aged 6–11 months was more prevalent in the hot than cool  
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3 111 season. [26] However, such studies are not sufficient to demonstrate an effect of ambient  
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5 112 temperature as the competing time demands of women's domestic and agricultural  
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8 113 workloads, [10, 30-33] as well as other potentially important drivers (e.g. household food  
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10 114 security), also vary with season and weather in rural settings. [33, 34] With daily  
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12 115 temperatures in West Africa expected to exceed 50°C in some regions, [35] further research  
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15 116 is essential so that maternal and child health programmes can be updated.

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18 117 This study aims to explore the effects of daily outdoor temperature on infant feeding practices  
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20 118 and childcare in western Burkina Faso. We hypothesised that: (a) Time spent breastfeeding is  
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22 119 associated with same-day temperature; (b) Women are less likely to breastfeed exclusively as  
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24 120 temperatures rise; (c) Women are more likely to provide supplementary fluids as  
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26  
27 121 temperatures rise; (d) Time spent caring for children increases with same-day temperature.

## 30 122 **METHODS**

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33 123 We undertook secondary analyses of quantitative data from an observational prospective  
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35 124 cohort study of pregnant and postpartum women in Bobo-Dioulasso, Burkina Faso (the  
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37  
38 125 PopDev study), which aimed to assess the impacts of pregnancy on income- and non-income-  
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40 126 generating activities among women in Burkina Faso, and to identify interventions to increase  
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42 127 household income. [36]

### 45 128 **Participants**

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49 129 Multi-stage stratified (urban vs. rural) sampling was used to select a population-  
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51 130 representative cohort of pregnant and postpartum women in the commune of Bobo-  
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54 131 Dioulasso. The 2006 census was used as the sampling frame to select locality clusters. It was  
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56 132 estimated that each cluster must contain a minimum of 300-330 households to identify 30  
57  
58 133 eligible participants per cluster. Thirty-eight locality clusters were identified (14 urban, 24  
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3 134 rural), and participants were recruited within households at cluster-level. Households were  
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5 135 visited per selected cluster using a modification of the World Health Organization's  
6  
7 136 Expanded Program on Immunization sampling methodology.  
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11 137 Women were eligible to participate in the PopDev study if aged 15-45 years and between  
12  
13 138 seven months gestation and three months postpartum at recruitment. [36] Sixty-two women  
14  
15 139 did not meet the criteria for PopDev, but were retained in the dataset for secondary analyses.  
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17 140 The full dataset comprised 866 women aged 14-47 years who were between 20 weeks  
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19 141 gestation and 22 weeks postpartum at baseline. All women who completed at least one  
20  
21 142 interview postpartum ( $n=857$ ) were included in the secondary analysis (see figure 1).  
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### 26 143 **Setting**

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29 144 The commune of Bobo-Dioulasso is predominantly urban, and includes the second largest  
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31 145 city in Burkina Faso (Bobo-Dioulasso) with approximately 900,000 inhabitants. [37] Small  
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33 146 settlements and villages, with a mainly agricultural focus, are located in rural areas  
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35 147 surrounding the large urban centre. All rural participants in this study resided within 40-50  
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37 148 km of the city.  
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41 149 The commune has a tropical savannah climate, [38] with two distinct seasons; dry  
42  
43 150 (November–May) and rainy (June–October). During the dry season, average temperatures are  
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45 151 highest in March–May and lower in November–February.  
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### 49 152 **Data collection**

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53 153 Participants were interviewed in their homes at three time points: cohort entry, and three and  
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55 154 nine months thereafter. Retention at the nine-month visit was 90%. Several attempts were  
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57 155 made to interview each woman at each interview round. The reason for non-interview was  
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59 156 recorded, when possible. Eight hundred and 39 participants were recruited immediately  
60



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3 157 before/during the first round of interviews (29 November 2013 – 23 March 2014). Twenty-  
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5 158 seven women were recruited during the second or third round of interviews (04 March 2014 –  
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8 159 09 September 2014; 02 September 2014 – 12 November 2014, respectively). All interviews  
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10 160 occurred between 29 November 2013 and 12 November 2014, using structured  
11  
12 161 questionnaires to ensure the same wording of questions for all participants. Interviews were  
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14 162 conducted in local languages (predominantly Dioula) and homogeneity in translations was  
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16 163 verified during interviewer training. All questions were designed to be non-leading.

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20 164 During each interview, participants were asked to recall their activities on the previous day  
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22 165 (or two days previous when the day before interview was atypical) and how many minutes  
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24 166 they had spent on each activity. The recall period was defined as, “between waking up  
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26 167 yesterday morning and waking up this morning”. Participants described their activities and  
27  
28 168 the interviewer categorised them using a pre-defined list, which was added to when needed.  
29  
30 169 Breastfeeding, caring for children (bathing/dressing, feeding, playing/watching, tending to  
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32 170 when unwell), income-generating work (e.g. agro-processing for trade, sale of products at  
33  
34 171 market, small business, office activities), attending classes (e.g. literacy courses), and  
35  
36 172 household chores (e.g. preparing meals, cleaning clothes, washing dishes, fetching water,  
37  
38 173 fetching fuel) were included in this list.

39  
40  
41  
42  
43  
44 174 To assist participants in time-use recall, women were initially asked to list all activities that  
45  
46 175 they had engaged in during a specific time of day (e.g. between waking up and midday).  
47  
48 176 Participants were then asked probing questions to assist them in estimating the duration of  
49  
50 177 each activity. For example, some women said that they woke with the call of the muezzin,  
51  
52 178 which enabled the interviewer to determine time of wake. Participants would then be asked if  
53  
54 179 they began their first listed activity immediately, or if they did something else first. The  
55  
56 180 interviewer asked when their first activity ended to which women responded, “to the first rays  
57  
58  
59  
60

1  
2  
3 181 of sunshine”, for example. Thus, the interviewer had adequate information to estimate time  
4  
5 182 duration of the first activity. Once participants had finalised their time-use estimates for the  
6  
7  
8 183 specified period, the process was repeated for the next time of day, until the full 24-hour  
9  
10 184 recall period was complete. Participants used a notebook to draft and revise time-use  
11  
12 185 estimates before final responses were recorded in the questionnaire. Indications of time  
13  
14 186 (particularly the path of the sun), combined with current events of life, served as benchmarks  
15  
16  
17 187 for time estimations.

18 188 At first interview following childbirth (interview round one or two), participants were asked  
19  
20  
21 189 how many children were born and the date of delivery. At interview rounds two and three,  
22  
23  
24 190 women were asked if they were still breastfeeding their baby; if their baby had anything else  
25  
26  
27 191 to drink in the past 24 hours; and which (if any) fluids had their baby been given to drink in  
28  
29  
30 192 the past 24 hours. These questions were used to construct binary study outcomes of exclusive  
31  
32 193 breastfeeding (still breastfeeding and no fluids other than breast milk provided in past 24  
33  
34 194 hours) and supplementary feeding (any fluids other than breast milk provided in past 24  
35  
36 195 hours).

37  
38  
39 196 Interviews included additional questions to those described above in order to fulfil the aims  
40  
41  
42 197 of the PopDev study. Each interview lasted approximately 45-60 minutes. Questionnaires are  
43  
44 198 available at: <https://datacompass.lshtm.ac.uk/id/eprint/64/>.

### 199 **Meteorological data**

20 200 Daily meteorological data (mean, minimum and maximum temperature [°C], relative  
21  
22 201 humidity [%], and windspeed [km/h]) were obtained from TuTiempo.net [39] for a single  
23  
24 202 weather station in Bobo-Dioulasso, located in the industrial district (Zone Industrielle)  
25  
26  
27 203 (11°09'36.0"N 4°18'36.0"W). Eleven days of temperature data were missing over the study  
28  
29  
30 204 period and were excluded from the analysis.

## 205 **Outcomes**

206 Four outcomes were assessed: (1) Breastfeeding duration: self-reported time spent  
207 breastfeeding on the day/night before interview (total minutes in 24 hours); (2) Exclusive  
208 breastfeeding: no liquids other than breast milk given in past 24 hours; (3) Supplementary  
209 feeding: any liquid other than breast milk given in past 24 hours; and (4) Childcare duration:  
210 self-reported time spent exclusively on childcare (including bathing/dressing, feeding,  
211 playing/watching, tending to when unwell) on the day/night before interview (total minutes in  
212 24 hours). Breastfeeding duration, exclusive breastfeeding, and supplementary feeding  
213 outcomes referred specifically to the target (newborn) infant. Childcare duration did not refer  
214 specifically to the newborn infant.

## 215 **Exposure**

216 The primary exposure was daily mean temperature (°C). Daily mean temperature correlated  
217 strongly with daily minimum ( $r=0.8$ ,  $p<0.001$ ) and maximum temperatures ( $r=0.89$ ,  $p<0.001$ )  
218 and was considered the best approximation of overall exposure during the recall period.  
219 Apparent daily mean temperature (°C) was calculated from daily mean temperature, relative  
220 humidity and windspeed, using the R HeatStress package, [40] to test the robustness of our  
221 findings.

## 222 **Data analyses**

223 Daily exposures were linked with outcomes at individual level, by date of interview minus  
224 one-day ( $t-1$ ) to reflect same-day temperature when activities were undertaken. Categorical  
225 outcomes, potential confounding variables and covariates (see table S1) were summarised as  
226 proportions (expressed as percentages). Continuous variables were summarised as mean  $\pm$

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2  
3 227 standard deviation (SD) if normally distributed, or as median and interquartile range if not  
4  
5 228 normally distributed. Summary statistics were stratified by interview round where applicable.  
6  
7

8  
9 229 The functional form of temperature-time use (breastfeeding, childcare) associations were  
10  
11 230 determined by aggregating outcome data to daily level, fitting natural cubic splines of time  
12  
13 231 (to adjust for seasonal patterns and trends unrelated to temperature), and examining locally-  
14  
15 232 weighted smoothing of Pearson's standardised residuals from the fitted splines, plotted  
16  
17 233 against daily mean temperature.  
18  
19

20  
21 234 Multilevel linear regression was then used to estimate the effects of daily mean temperature  
22  
23 235 on time spent (i) breastfeeding, and (ii) caring for children. This approach made use of all  
24  
25 236 available time-use data on breastfeeding and childcare, while accounting for the longitudinal  
26  
27 237 and nested structure of these data. Interview contacts (level one) were nested within  
28  
29 238 individual participants (level two), nested within the locality clusters from which the  
30  
31 239 population was sampled (level three). Each level was defined as a random coefficient with  
32  
33 240 random intercept to allow for correlation within-individuals and clusters. A first-order  
34  
35 241 autoregressive correlation structure allowed for unequal spacing of interviews.  
36  
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40 242 Separate models were developed for each outcome, and adjusted for interview round.

41  
42 243 Indicator terms were included for calendar month of interview to adjust for season and long-  
43  
44 244 term trends. Adjusting for month (rather than season) of interview provided tighter control of  
45  
46 245 possible confounders, such as household food security and fasting during Ramadan. Other  
47  
48 246 covariates (number born [singleton; multiple birth], infant age [weeks], maternal age [ $\leq 19$ ;  
49  
50 247  $20-34$ ;  $\geq 35$  years], gravidity [1; 2-5;  $\geq 6$  pregnancies], residential area [urban; rural], living  
51  
52 248 arrangements [with partner full-time; with partner periodically; not with partner; not in a  
53  
54 249 relationship], paid work or education [minutes/day], domestic work [minutes/day], and  
55  
56 250 roofing materials [natural; rudimentary; contemporary]; see table S1) were added to the  
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3 251 models one-by-one, following a forward stepwise process, and were retained in the model if  
4  
5 252 they were significantly associated with the outcome ( $p < 0.05$ ), improved model fit (reduced  
6  
7 253 the Akaike Information Criterion by  $\geq 2\%$ ), and/or changed the temperature effect by  $\geq 10\%$ .  
8  
9  
10 254 Cases with missing data were excluded from the analysis. Participants lost to follow-up were  
11  
12 255 included in the analysis.

13  
14  
15 256 We restricted our analyses of exclusive breastfeeding and supplementary feeding to infants  
16  
17 257 aged less than six months and 6-12 months, respectively. This follows from WHO's  
18  
19 258 recommendations that infants are breastfed exclusively for the first six months of life, and  
20  
21 259 that supplementary foods are only introduced thereafter. [17] Data were available for two  
22  
23 260 time points (interview rounds two and three). To reduce model complexity, these outcomes  
24  
25 261 were analysed cross-sectionally, at single time points: Exclusive breastfeeding at interview  
26  
27 262 round two, and supplementary feeding at interview round three, based on the age range of  
28  
29 263 infants at each round.

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34  
35 264 Logistic regression was used to test for associations between mean temperature and the odds  
36  
37 265 of (i) exclusive breastfeeding and (ii) supplementary feeding, adjusting for month of  
38  
39 266 interview, and other important confounders and covariates following the same process  
40  
41 267 described above. As the effects of temperature on exclusive breastfeeding may change as  
42  
43 268 infants age, [29] our exclusive breastfeeding analysis was age-stratified ( $< 3$  months; 3 to  $< 6$   
44  
45 269 months). Interactions between mean temperature and: (i) infant age; (ii) urban/rural  
46  
47 270 residence; and (iii) roofing materials of the home were tested in all models (both multilevel  
48  
49 271 and logistic).

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53  
54 272 Sensitivity analyses involved re-specifying models with: (i) alternative levels of seasonal  
55  
56 273 control (indicator variables for 'season' rather than 'month'; natural cubic splines of calendar  
57  
58 274 time with three knots); and (ii) apparent, rather than observed, daily mean temperature.  
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3 275 Analyses were done in R 4.0.4, [41] using RStudio and the following R packages: lme4; [42]  
4  
5 276 nlme; [43] stats; [41] splines; [41] effects; [44] ggplot2; [45] HeatStress; [40] Hmisc. [46]  
6  
7

## 8 277 **Patient and public involvement**

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11 278 Stakeholders were involved during development of the original proposal in June 2012. The  
12  
13 279 objectives and plans for the primary (PopDev) study were discussed with representatives  
14  
15 280 from the community and reproductive health NGOs, as well as health professionals and  
16  
17 281 policy makers at local and national levels, by means of a workshop, email, and telephone.  
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19  
20 282 Stakeholders from the policy or associative arena presented their policies at the workshop to  
21  
22 283 inform a group discussion on how best the study objectives could respond to their  
23  
24 284 information needs. In another exercise, stakeholders were asked to identify one positive, one  
25  
26 285 negative, and one surprising thing about the proposed study, which yielded particularly useful  
27  
28 286 information when developing the proposal. We received feedback on substantive and  
29  
30 287 methodological aspects of the project, and on communication issues, which was used to  
31  
32 288 shape the study objectives and methodologies.  
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39 289 The interview schedule was piloted with members of the community. Feedback on interview  
40  
41 290 duration, meaningfulness and clarity of questions, and perceived gaps, was used to refine the  
42  
43 291 wording of questions and to add/remove items. At the end of the primary (PopDev) study, a  
44  
45 292 stakeholder consultation workshop took place to discuss the findings and their implications  
46  
47 293 for cross-sectoral interventions, involving policy makers from different ministries and NGO  
48  
49 294 staff.  
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53

54 295 Pregnant and postpartum women, as well as community members, in the Kaya and Bogodogo  
55  
56 296 health districts of Burkina Faso were involved before the secondary study began. In-depth  
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58 297 interviews with pregnant and postpartum women ( $n=40$ ), and focus group discussions with  
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3 298 community members, were undertaken in October–November 2020. [9] The objectives for  
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5 299 the secondary analysis were developed and informed by the lived experiences of postpartum  
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8 300 women reported during this qualitative work. Specifically, women described how hot weather  
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10 301 impedes breastfeeding due to excessive sweating and the discomfort of both mothers and  
11  
12 302 their babies. [9]

13  
14  
15 303 Qualitative findings were discussed with stakeholders in maternal and neonatal health,  
16  
17 304 climate change adaptation, as well as pregnant and postpartum women and community  
18  
19  
20 305 members, during a co-design workshop in Ouagadougou, Burkina Faso. Here, breastfeeding  
21  
22 306 messaging was highlighted as an important area of focus for future research and interventions  
23  
24 307 aimed at reducing the impact of high temperatures on childbearing women and their newborn  
25  
26 308 infants. We will continue our engagement with community members in the Kaya and  
27  
28  
29 309 Bogodogo health districts and will disseminate our findings through meetings, written  
30  
31 310 summaries, and audio-visual materials. We will also engage with health decision-makers and  
32  
33 311 provide summaries of the evidence and targeted policy briefs to support decision-makers in  
34  
35 312 actions to reduce the impact of extreme high temperatures on maternal and neonatal health.

## 39 313 **RESULTS**

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43 314 The population experienced year-round high temperatures, with an intra-annual range in daily  
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45 315 mean temperature of 22.6–33.7°C. Figure S1 (supplementary material) shows daily minimum  
46  
47 316 and maximum temperatures throughout the study period.

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51 317 Eight-hundred and fifty-seven participants birthed 881 children (833 singleton births; 24 twin  
52  
53 318 births). Six stillbirths, eight deaths in live born children, and 18 deaths in infants of unknown  
54  
55 319 status at birth were reported. The mean age of women at recruitment was 26.9 years (SD=6.2  
56  
57 320 years), with a median gravidity of 3 pregnancies (IQR=2–5 pregnancies). Only 33 women

321 **Table 1. Cohort characteristics, activities, and average daily temperature at each interview round.**

|  | Interview round                           |                          |                          |                       |
|--|---|--------------------------|--------------------------|-----------------------|
|  | 1   | 2                        | 3                        |                       |
| Total interviewed (N)                              | 839                                       | 810                      | 792                      |                       |
| Cohort characteristics                             |   |                          |                          |                       |
| <i>% urban [N] (NA)*</i>                           | 49.9<br>[419] (0)                         | 49.3<br>[390] (19)       | 49.7<br>[389] (10)       |                       |
| <i>% postpartum [N]</i>                            | 49.5<br>[415]                             | 100<br>[810]             | 100<br>[792]             |                       |
| <i>% working in informal sector [N] (NA)*</i>      | 37.6<br>[315] (1)                         | 42.5<br>[343] (3)        | 48.9<br>[386] (2)        |                       |
| Living arrangements                                |   |                          |                          |                       |
| <i>% with partner full-time [N]</i>                | 80.9<br>[679]                             | 80.1<br>[649]            | 80.1<br>[634]            |                       |
| <i>% with partner periodically [N]</i>             | 6.9<br>[58]                               | 6.4<br>[52]              | 5.3<br>[42]              |                       |
| <i>% not living with partner [N]</i>               | 2.5<br>[21]                               | 4.3<br>[35]              | 3.2<br>[25]              |                       |
| <i>% not in a relationship [N]</i>                 | 0<br>[0]                                  | 8.8<br>[71]              | 7.7<br>[61]              |                       |
| <i>% unknown [N]</i>                               | 9.7<br>[81]                               | 0.4<br>[3]               | 3.8<br>[30]              |                       |
| Postpartum women only                              |   |                          |                          |                       |
| <i>% breastfeeding [N] (NA)*</i>                   | 100<br>[408] (7)                          | 99.7<br>[782] (26)       | 99.7<br>[765] (25)       |                       |
| <i>% supplementary feeding [N] (NA)*</i>           |   | 80.2<br>[628] (27)       | 98.0<br>[752] (25)       |                       |
| Time use<br>(self-reported<br>minutes/day)         | <i>Breastfeeding (median [IQR]) (NA)*</i> | 120<br>[80–180] (11)     | 180<br>[120–180] (23)    | 240<br>[121–240] (26) |
|  | <i>Childcare (median [IQR]) (NA)*</i>     | 30<br>[15–40] (5)        | 30<br>[20–40] (11)       | 20<br>[15–30] (21)    |
|  | <i>Paid work/education (median [IQR])</i> | 0<br>[0–0]               | 0<br>[0–92]              | 300<br>[0–420]        |
|  | <i>Domestic work (median [IQR])</i>       | 180<br>[110–240]         | 215<br>[145–300]         | 180<br>[130–235]      |
| Infant age (weeks) (median [IQR]) (NA)*            | 5.7<br>[2.6–9.9] (17)                     | 12.6<br>[6.4–19.0] (25)  | 33.9<br>[27.1–41.0] (31) |                       |
| Daily mean temperature (°C) (median [range]) (NA)* | 27.9<br>[22.7–32.8] (0)                   | 27.0<br>[22.9–33.7] (11) | 27.2<br>[23.3–30.3] (0)  |                       |

322 Number (N) of women and % of total interviewed at each survey round, or summary statistics  
 323 specified.

324 \* Missing values were excluded from calculations. NA = N missing. Where NA is not provided, N=0.

325 (3.9%) were formally employed at baseline, of which 21 women were eligible for (or

326 benefiting from) maternity leave. Informal paid work was more common (see table 1). Most



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3 327 women (808 of 839 interviewed at baseline) lived in houses with contemporary roof  
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5 328 materials; primarily sheet metal (731 women) and timber (81 women).  
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7  
8 329 Median time between first and second interviews was 92 days (IQR 80–108 days), and 149  
9  
10 330 days (IQR 141–155 days) between the second and third interviews. Total median follow-up  
11  
12 331 time was 236 days (IQR 227–257 days). One woman refused to participate during the second  
13  
14 332 round of interviews and one woman was travelling during the third round. The reasons why  
15  
16 333 other women were lost to follow-up ( $n=74$ ) are unknown.  
17  
18  
19  
20 334 The vast majority of postpartum women reported breastfeeding their infants at each interview  
21  
22 335 round (table 1). However, the incidence of exclusive breastfeeding was low. Only 148 of 710  
23  
24 336 infants (20.8%) aged less than six months were exclusively breastfed on the day/night before  
25  
26 337 interview two, and only 11 of 157 (7%) were exclusively breastfed before interview three.  
27  
28  
29  
30 338 On average, daily breastfeeding duration increased over time (figure 2a). After adjusting for  
31  
32 339 long-term trends, a slight decrease in breastfeeding duration was observed as temperatures  
33  
34 340 increased (figure 3a). Before adjusting for potential confounders (accounting only for the  
35  
36 341 longitudinal and nested structure of the data), breastfeeding was estimated to decrease by 5.6  
37  
38 342 minutes/day (95% CI -7.0 to -4.1,  $p<0.001$ ,  $n=783$  women) per 1°C increase in same-day  
39  
40 343 mean temperature. After controlling for important confounders (interview round, month of  
41  
42 344 interview, singleton/multiple birth, residential area, and time spent on paid work or education  
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44 345 [minutes/day]), breastfeeding was estimated to decrease by 2.3 minutes/day (95% CI -4.6 to  
45  
46 346 0.04,  $p=0.05$ ,  $n=783$  women) per 1°C increase in same-day mean temperature (table S2). This  
47  
48 347 estimate was for infants aged 0.6–57 weeks (median=18.6 weeks). However, temperature  
49  
50 348 interacted with infant age to affect breastfeeding duration ( $p=0.02$ ). Time spent breastfeeding  
51  
52 349 very young infants (four weeks) did not change with temperature. As infants aged, women  
53  
54 350 were predicted to spend increasingly less time breastfeeding at high temperatures (figure 4).  
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3 351 On average, women spent less time on exclusive childcare at interview three (table 1), which  
4  
5 352 coincided with the rainy and early dry/cooler seasons (figure 2b). After seasonal control, a  
6  
7 353 slight increase in childcare time was observed as temperatures increased (figure 3b). Before  
8  
9 354 adjustment, we estimated a 0.4-minute increase (0.1 to 0.8,  $p=0.02$ ,  $n=814$  women) in daily  
10  
11 355 childcare per 1°C increase in mean temperature. We estimated a 0.6-minute increase (0.06 to  
12  
13 356 1.2,  $p=0.03$ ,  $n=787$  women) in childcare per 1°C increase in temperature after adjusting for  
14  
15 357 interview round, calendar month, singleton/multiple birth, infant age, maternal age, women's  
16  
17 358 living arrangements, and time spent on paid work or education (minutes/day) (table S3).

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21  
22 359 There was suggestive evidence that very young infants (< 3 months) were less likely to be  
23  
24 360 exclusively breastfed as temperatures increased (unadjusted OR=0.88, 0.76 to 1.02,  $p=0.08$ ,  
25  
26 361  $n=338$ ; adjusted OR=0.88, 0.75 to 1.02,  $p=0.09$ ,  $n=331$ ). Whereas, there was no evidence that  
27  
28 362 daily mean temperature affected the odds of exclusive breastfeeding at 3-6 months, either  
29  
30 363 before (OR=0.98, 0.80 to 1.20,  $p=0.8$ ,  $n=237$ ) or after adjustment (OR=1.13, 0.86 to 1.52,  
31  
32 364  $p=0.4$ ,  $n=235$ ). Variability in daily mean temperature was similar for both groups (< 3 months  
33  
34 365 = 24.1–33.7°C; 3-6 months = 25.3–33.7°C), however the rate of exclusive breastfeeding was  
35  
36 366 higher among women with younger (< 3 months = 30% [120 of 396 women]) than older infants  
37  
38 367 (3-6 months = 9% [28 of 312 women]).

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44 368 A large proportion of women provided supplementary fluids to their infant (table 1); primarily  
45  
46 369 water, herbal tea and, in the rainy season, boiled water. Milk other than breastmilk was rarely  
47  
48 370 given. By 6-12 months, the provision of supplementary fluids was almost universal (99.2%  
49  
50 371 [605 of 610] infants). Therefore, analysis of association with daily mean temperature was not  
51  
52 372 feasible.

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56  
57 373 There was no evidence of an interaction between temperature and residential area (urban/rural)  
58  
59 374 or type of roofing materials on any outcome measured ( $p>0.05$ ).

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3 375 Estimated temperature effects were generally robust to sensitivity analyses. The main effect  
4  
5 376 on breastfeeding duration was very robust and increased in statistical significance with  
6  
7 377 alternative methods of seasonal control. The interaction effect between temperature and  
8  
9 378 infant age on breastfeeding duration, and the main effect of temperature on daily childcare  
10  
11 379 duration, were also fairly robust but with reduced significance. Redefining the exposure as  
12  
13 380 apparent (“feels-like”) daily mean temperature did not change the estimated effect on  
14  
15 381 exclusive breastfeeding of very young infants (< 3 months), but increased the statistical  
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17 382 significance of this finding.  
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## 22 383 **DISCUSSION**

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26 384 This study explored the impacts of high ambient temperature on infant feeding practices  
27  
28 385 among postpartum women in a low-income setting. We found a decrease in breastfeeding  
29  
30 386 duration as temperatures increased; approximating to a 25-minute reduction in breastfeeding  
31  
32 387 on the hottest, compared to coolest, days of the year. The extent of this impact largely  
33  
34 388 depended on the age of the infant. From approximately four months onwards, we predicted an  
35  
36 389 increasingly negative impact of high temperature on breastfeeding duration. For younger  
37  
38 390 infants, temperature had a lower impact. However, there was suggestive evidence that very  
39  
40 391 young infants (under three months) were less likely to be breastfed exclusively as  
41  
42 392 temperature increased.  
43  
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47

48 393 There may be several explanations for the reduction in breastfeeding duration as temperatures  
49  
50 394 rise in hot climates. Infants may demand less milk in order to limit heat-generation, or they  
51  
52 395 may become too uncomfortable to feed. [9] On the other hand, mothers may offer less breast  
53  
54 396 milk due to their own discomfort under very hot conditions [9, 47] and/or due to a  
55  
56 397 misperception that babies require supplementary water, especially on hot days. [10, 12, 13]  
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3 398 Despite efforts to improve breastfeeding practices in sub-Saharan Africa, [48] the belief that  
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5 399 breast milk is insufficient to hydrate babies and that water is needed to quench their thirst still  
6  
7 400 prevails in several societies. [12, 49-51] In the commune of Bobo-Dioulasso, provision of  
8  
9 401 supplementary fluids (particularly water) was widespread. More than 95% of infants aged  
10  
11 402 three months and older were given non-milk fluids in the 24 hours before interview. It is  
12  
13 403 recommended that infants under six months are breastfed more often in hot weather [52] and,  
14  
15 404 ideally, the total intake of breast milk over a 24-hour period would increase to avoid infant  
16  
17 405 dehydration. However, our findings tentatively suggest the contrary. Rather than increase  
18  
19 406 breastfeeding to prevent infant dehydration, the women in our study may have provided a  
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21 407 greater volume of supplementary fluids when temperatures increased.  
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27 408 The hot climate has been identified as a barrier to exclusive breastfeeding in the Democratic  
28  
29 409 Republic of the Congo, [10] southern Zimbabwe, [13] Ghana, [12], and Ethiopia [49], and  
30  
31 410 might (at least, partially) explain the very low rate of exclusive breastfeeding found herein. In  
32  
33 411 the cooler sub-tropical climate of Bihar, India, odds of exclusive breastfeeding was  
34  
35 412 significantly lower in summer than in winter or transitional seasons. Perceived thirst was  
36  
37 413 proposed as an underlying cause for the higher rates of supplementary feeding in warmer  
38  
39 414 months. [29] However, in contrast to our findings, the impact of season was greater for  
40  
41 415 infants aged 3-6 months than for infants under 3 months. [29] The warmer climate of Bobo-  
42  
43 416 Dioulasso, cultural values and beliefs around breastfeeding, [53] and the comparatively low  
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45 417 rate of exclusive breastfeeding in our study (8% vs. 70% of infants aged 3-6 months) likely  
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47 418 explain this discrepancy in findings.  
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53 419 Many women across the world report perceived inadequacy of milk supply as their main  
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55 420 reason for early weaning. [54] It is not clear if breast milk production is impacted by heat  
56  
57 421 exposure, either directly or indirectly. High temperatures may exacerbate water stress,  
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3 422 increasing the risk of dehydration among mothers in water-poor regions. However, the effects  
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5 423 of maternal dehydration on breast milk production in hot climates are largely unknown. [55,  
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7 424 56] Several studies have shown that exclusively breastfed infants maintain normal hydration  
8  
9 425 under hot conditions, [57-59] indicating that the quantity of breast milk is not affected.  
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11  
12 426 However, field and experimental animal studies have shown that both the yield and  
13  
14 427 nutritional composition of ruminant milk decline under hot conditions. [60] Further, the milk  
15  
16 428 production capacity of animal mammary epithelial cells was found to decline following in  
17  
18 429 vitro exposure to high temperatures (41°C). [61] To our knowledge, no studies have  
19  
20 430 examined breast milk production in relation to temperature, but there is evidence that  
21  
22 431 maternal stress affects breast milk composition [62] and delays secretory activation. [63]  
23  
24 432 Even if milk supply is not adversely affected, high temperatures may contribute to women's  
25  
26 433 perception of inadequate milk supply.  
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30  
31 434 The marginal increase in exclusive childcare time with temperature is not easily explainable  
32  
33 435 given the range of activities included in this outcome (e.g. bathing/dressing,  
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35 436 playing/watching, tending to when unwell). Tasks, such as dressing children, may take longer  
36  
37 437 under hot conditions due to excessive sweating and/or low energy levels. Increased effort  
38  
39 438 may be required to bathe or soothe children when temperatures rise, or women might spend  
40  
41 439 more time monitoring other children in the household.  
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45  
46 440 The main strengths of this study are the longitudinal dataset, population-based sampling,  
47  
48 441 detailed questionnaire on activities, small loss to follow-up, and extensive confounder  
49  
50 442 control. The main limitations are the small sample size, which may have reduced our ability  
51  
52 443 to detect statistically significant associations, and the short recruitment window (ideally, the  
53  
54 444 study would have been conducted over several years). However, 2014 was a climatically  
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56 445 typical year in Burkina Faso during 2010s. [25] We used meteorological data recorded at one  
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3 446 weather station in Bobo-Dioulasso, located in the urban centre. We could not assign  
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5 447 exposures to women's residential addresses, but daily variability in temperature exposures  
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7  
8 448 were likely to be consistent over the study area, even if absolute temperatures varied slightly.  
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10  
11 449 Measurements of breastfeeding and childcare duration relied on self-reported time-use  
12  
13 450 estimations. We put several measures in place to assist participants, including the recent and  
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15  
16 451 short (24-hour) recall period with questions aimed at establishing a 24-hour timeline.  
17  
18 452 However, it is possible that temperature affected participants' ability to estimate time, despite  
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20 453 the use of benchmarks (e.g. path of the sun). Time-use diaries and direct observation offer  
21  
22  
23 454 arguably more robust methods for future research, although each has limitations. Our  
24  
25 455 measurement of exclusive breastfeeding was not optimal, but women were not asked directly  
26  
27 456 if they breastfed their infant exclusively. Instead, this outcome was constructed from  
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29  
30 457 women's recall of all fluids given to their child in the past 24 hours. Questions on infant  
31  
32 458 feeding practices and childcare were embedded within an extensive interview schedule,  
33  
34 459 further reducing the possibility of response bias. Finally, the outcome of childcare is complex  
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36 460 and refers to time spent with children of all ages as this question was not specifically phrased  
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38  
39 461 to indicate the target (newborn) child.  
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41  
42 462 Larger studies are needed to further examine the impacts of heat on infant feeding practices  
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44 463 in hot climates. Future research should consider temperature in relation to the number and  
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46  
47 464 duration of individual breastfeeds, and to the volume of breast milk and supplementary fluids  
48  
49 465 consumed by infants, over a 24-hour period. Research should also seek to determine if high  
50  
51 466 temperatures impact on breast milk production. Actions should be taken to ensure that hot  
52  
53  
54 467 weather does not negatively impact on breastfeeding behaviour. Effective interventions are  
55  
56 468 likely to require a multidimensional approach. [64] It is important that health workers and  
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3 469 mothers are informed about normal heat-induced changes in infant breastfeeding patterns so  
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5 470 that such changes are not misinterpreted as a need for supplementation.  
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9 471 **CONCLUSIONS**

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12 472 Exclusive breastfeeding is an essential cornerstone for the wellbeing and survival of infants.

13  
14 473 Our findings suggest a substantial decrease in breastfeeding duration, and potentially lower

15  
16 474 odds of exclusive breastfeeding very young infants, during hot weather. These findings are

17  
18 475 important as infants require increased hydration to cope physiologically with increased heat,

19  
20 476 and the safest form of hydration for young infants is breast milk.  
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24 477 Larger studies are needed in Burkina Faso and beyond as climate change in Africa is

25  
26 478 accelerating. [65] Without effective interventions, mothers may find it increasingly difficult

27  
28 479 to breastfeed their infants as temperatures rise. Maternal and child health programmes in hot

29  
30 480 climates should be updated to improve messaging and breastfeeding practices during extreme

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32 481 hot weather.  
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12 486 PopDev study.  
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16 487 **Contributors**  
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19  
20 488 VF and SKovats conceived the study (secondary analysis). JAC and RG collected data. CP  
21  
22 489 conducted the statistical analysis under the supervision of SH. All authors (CP, VF, JAC, RG,  
23  
24 490 SH, BN, NR, KK, MC, AL, SK and SKovats) interpreted the results. CP drafted the paper.  
25  
26 491 All authors critically revised the paper for important intellectual content and approved the  
27  
28 492 final version for publication. All authors agreed to be accountable for all aspects of the work.  
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55 502 **Competing interests**  
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57

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3 504 **Ethics approval**  
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6 505 The study was approved by the Research Ethics Committees of Centre Muraz, Burkina Faso  
7  
8 506 (reference: A16-2013/CE-CM) and the London School of Hygiene & Tropical Medicine,  
9  
10 507 United Kingdom (reference: 6401). The free and informed consent of each participant was  
11  
12 508 obtained before each interview.  
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16 509 **Data sharing statement**  
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19 510 Individual-level deidentified participant data from the primary (PopDev) study are available  
20  
21 511 to researchers who have a valid research question, which is not being investigated by the  
22  
23 512 primary research team. A data sharing agreement will be required. All data requests should be  
24  
25 513 made via <https://datacompass.lshtm.ac.uk/id/eprint/64/>. The questionnaires, consent form,  
26  
27 514 data dictionary (codebook), and user guide are publicly available from  
28  
29 515 <https://datacompass.lshtm.ac.uk/id/eprint/64/>. Data have been available from 2018 with no  
30  
31 516 end date. Meteorological data are publicly available from TuTiempo  
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34 517 (<https://www.tutiempo.net/>). Statistical code is available from the corresponding author.  
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For peer review only

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3 685 **Figure legends**  
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6 686 **Figure 1.** Sampling flow chart for secondary analysis, showing number of interviews  
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9 687 conducted with pregnant (blue) and postpartum women (green) at each interview round (T).  
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11 688 Data from all interviews highlighted in green were included in the secondary analyses.  
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15 689 **Figure 2.** Average time spent (self-reported minutes/day) (a) breastfeeding and (b) caring for  
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17 children over time, with fitted natural cubic splines of time (dashed lines). Blue shading =  
18 690 dry, cooler season (Nov–Feb), red shading = dry, hot season (Mar–May), green shading =  
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20 691 rainy season (June–Oct).  $N$  = sample size. Data source: PopDev study. [36]  
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27 693 **Figure 3.** Scatterplots of daily mean temperature ( $^{\circ}\text{C}$ ) and standardised residuals from fitted  
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29 694 trends (natural cubic splines of time) in the (a) breastfeeding and (b) childcare time-series, with  
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31 695 locally weighted smoothing (blue line) and 95% confidence intervals (grey shading).  $N$  =  
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33 696 sample size.  
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38 697 **Figure 4.** Interaction effect of daily mean temperature ( $^{\circ}\text{C}$ ) and infant age on time spent  
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40 698 breastfeeding (self-reported minutes/day).  $N$  = sample size.  
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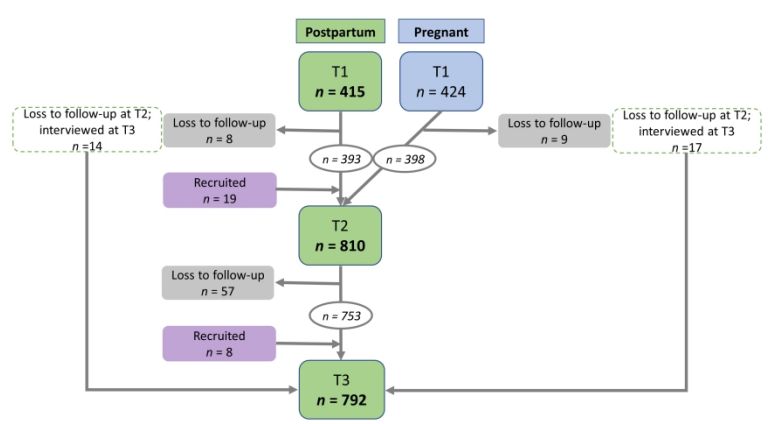


Figure 1. Sampling flow chart for secondary analysis, showing number of interviews conducted with pregnant (blue) and postpartum women (green) at each interview round (T). Data from all interviews highlighted in green were included in the secondary analyses.

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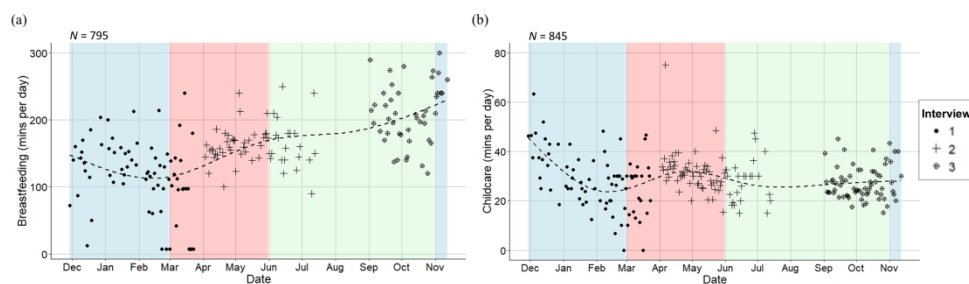


Figure 2. Average time spent (self-reported minutes/day) (a) breastfeeding and (b) caring for children over time, with fitted natural cubic splines of time (dashed lines). Blue shading = dry, cooler season (Nov–Feb), red shading = dry, hot season (Mar–May), green shading = rainy season (June–Oct).  $N$  = sample size. Data source: PopDev study. [37]

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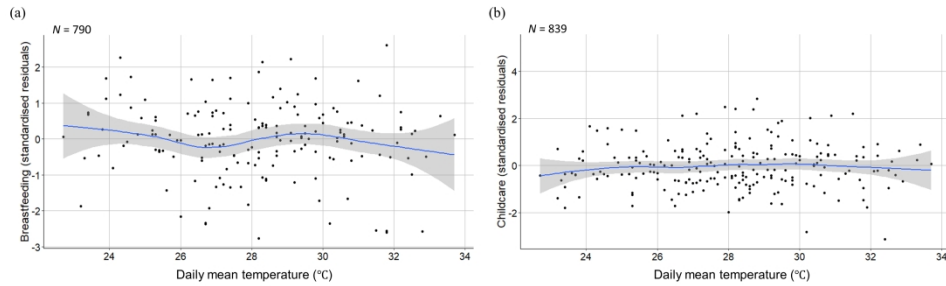


Figure 3. Scatterplots of daily mean temperature (°C) and standardised residuals from fitted trends (natural cubic splines of time) in the (a) breastfeeding and (b) childcare time-series, with locally weighted smoothing (blue line) and 95% confidence intervals (grey shading).  $N$  = sample size.

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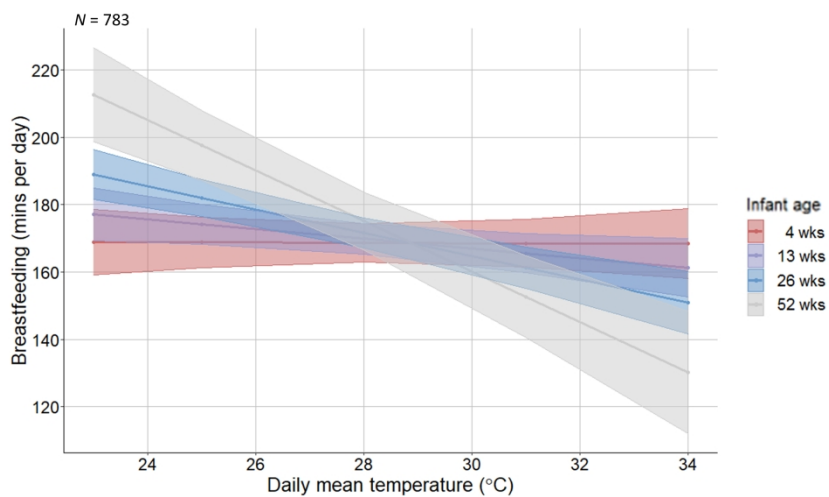


Figure 4. Interaction effect of daily mean temperature (°C) and infant age on time spent breastfeeding (self-reported minutes/day). *N* = sample size.

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**SUPPLEMENTAL MATERIAL**

**How do high ambient temperatures affect infant feeding practices? A prospective cohort study of postpartum women in Bobo-Dioulasso, Burkina Faso**

**Contents**

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Table S3. Effect estimates, 95% confidence intervals, and *p*-values of each variable included in the multilevel linear model of temperature-childcare association ..... 5

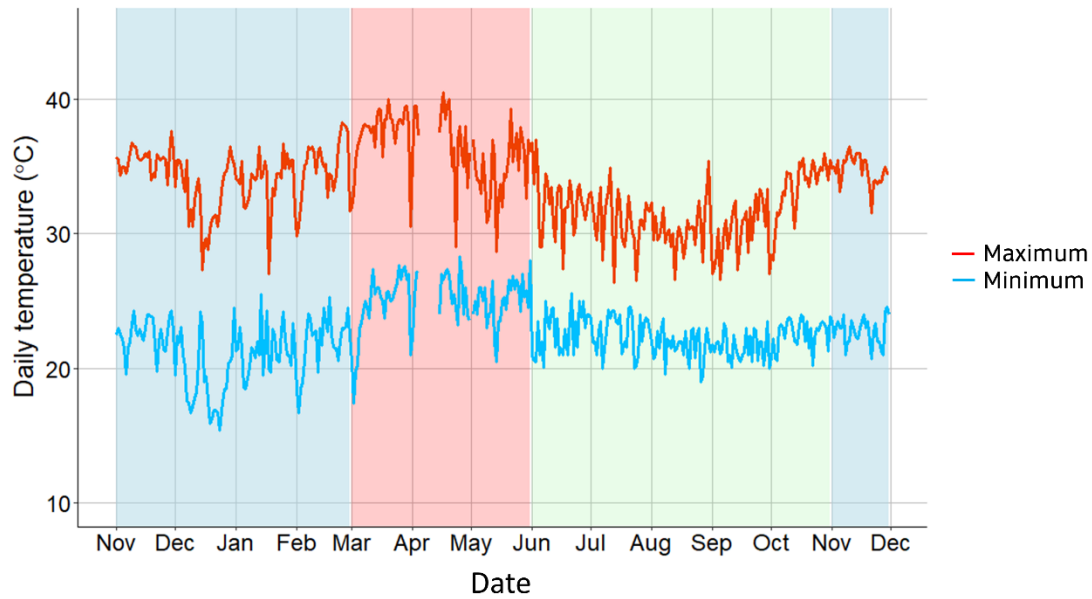
References ..... 5

For peer review only

**Table S1. Outcomes, exposure, potential confounders and covariates considered in all models.**

| Variable                               | Definition  | Units  | Type        | Model          |
|--|---|--|-------------|----------------|
| <b>Outcomes</b>                        |   |  |             |                |
| <i>Breastfeeding duration</i>          | Time spent breastfeeding infants aged 4+ days   | Minutes per day  | Continuous  | MLM (BF)       |
| <i>Exclusive breastfeeding</i>         | No liquids other than breast milk given in past 24h (infants aged <6 months)                      | Yes, No  | Binary      | Logistic (EBF) |
| <i>Supplementary feeding</i>           | Any liquid other than breast milk given in past 24h (infants aged 6-12 months)                    | Yes, No  | Binary      | Logistic (SF)  |
| <i>Childcare duration</i>              | Time spent caring for children (bathing/dressing, playing/watching, tending to when unwell, etc.) | Minutes per day  | Continuous  | MLM (CH)       |
| <b>Exposure</b>                        |   |  |             |                |
| <i>Daily mean temperature</i>          | Mean temperature in Bobo-Dioulasso on day before interview  | °C   | Continuous  | All            |
| <b>Confounders</b>                     |   |  |             |                |
| <i>Season/time trends</i>              | Seasonal patterns (unrelated to temperature) and long-term trends                                 | Month of interview   | Categorical | All            |
| <i>Interview round</i>                 | Interview (baseline, 3 months post-baseline, 9 months post-baseline)                              | 1, 2, 3  | Categorical | BF, CH         |
| <i>Infant age</i>                      | Date of interview – Date of delivery  | Weeks  | Continuous  | All            |
| <i>Income-generating work</i>          | Time spent on professional or educational activities  | Minutes per day  | Continuous  | All            |
| <i>Domestic work</i>                   | Time spent on domestic activities (excluding family care)   | Minutes per day  | Continuous  | BF, EBF, SF    |
| <b>Covariates</b>                      |   |  |             |                |
| <i>Number born</i>                     | Singleton or multiple birth   | 1, 2   | Categorical | All            |
| <i>Gravidity</i>                       | Total number of pregnancies, including current  | 1, 2–5, 6+ pregnancies   | Categorical | All            |
| <i>Maternal age</i>                    | Age of mother at baseline   | ≤ 19, 20–34, ≥ 35 years  | Categorical | All            |
| <i>Living arrangements</i>             | Mothers' living arrangements with partner at each interview                                       | With partner full-time, With partner periodically, Not with partner, Not in a relationship | Categorical | CH             |
| <i>Residential area</i>                | Mother's area of residence  | Urban, Rural   | Categorical | All            |
| <i>Roofing materials</i>               | Roofing materials of mother's house   | Natural, Rudimentary, Contemporary   | Categorical | All            |
| <b>Interactions</b>                    |   |  |             |                |
| <i>Temperature * Residential area</i>  | Daily mean temperature and mother's area of residence   | °C * Urban/Rural   | Interaction | All            |
| <i>Temperature * Infant age</i>        | Daily mean temperature and infant age   | °C * Weeks   | Interaction | All            |
| <i>Temperature * Roofing materials</i> | Daily mean temperature and roofing materials of mother's house                                    | °C * Natural/Rudimentary/Contemporary  | Interaction | All            |

MLM = Multilevel model. BF = Breastfeeding duration. CH = Childcare duration. SF = Supplementary feeding. EBF = Exclusive breastfeeding.



**Figure S1.** Daily maximum and minimum temperatures and seasons in Bobo-Dioulasso, Burkina Faso, between 1st Nov 2013 and 30th Nov 2014. Blue = dry, cooler season (November–February), red = dry, hot season (March–May), green = rainy season (June–October). Data source: TuTiempo.net [1].

**Table S2. Effect estimates, 95% confidence intervals, and *p*-values of each variable included in the autoregressive multilevel linear model for the exposure-response association between temperature and breastfeeding duration (minutes/day).**

| Variable  | Estimate | 95% CI  |        | <i>p</i> -value |
|---|----------|---------|--------|-----------------|
| Daily mean temperature (°C)                     | -2.29    | -4.63   | 0.04   | 0.05            |
| Interview round (reference: 1)                  |          |         |        |                 |
| 2   | 32.01    | -52.53  | 116.54 | 0.46            |
| 3   | 135.46   | 59.35   | 211.57 | <0.001          |
| Month of data collection (reference: January)   |          |         |        |                 |
| <i>February</i>                                 | -34.16   | -61.25  | -7.07  | 0.01            |
| <i>March</i>                                    | -61.79   | -89.14  | -34.45 | <0.001          |
| <i>April</i>                                    | -7.70    | -95.20  | 79.79  | 0.86            |
| <i>May</i>                                      | -22.75   | -106.68 | 61.18  | 0.59            |
| <i>June</i>                                     | -37.01   | -122.13 | 48.12  | 0.39            |
| <i>July</i>                                     | -37.57   | -135.16 | 60.02  | 0.45            |
| <i>September</i>                                | -89.72   | -167.34 | -12.09 | 0.02            |
| <i>October</i>                                  | -102.25  | -178.37 | -26.14 | <0.01           |
| <i>November</i>                                 | -66.34   | -136.35 | 3.66   | 0.06            |
| <i>December</i>                                 | -13.72   | -35.25  | 7.81   | 0.21            |
| Singleton/multiple birth (reference: singleton) |          |         |        |                 |
| <i>Multiple birth</i>                           | 70.46    | 48.43   | 92.49  | < 0.001         |
| Residential area (reference: rural)             |          |         |        |                 |
| <i>Urban</i>                                    | 18.26    | -5.76   | 42.29  | 0.13            |
| Income-generating activities (minutes/day)      | 0.02     | 0.00    | 0.04   | 0.02            |

**Table S3. Effect estimates, 95% confidence intervals, and *p*-values of each variable included in the autoregressive multilevel linear model for the exposure-response association between temperature and childcare duration (minutes/day).**

| Variable  | Estimate | 95% CI |       | <i>p</i> -value |
|---|----------|--------|-------|-----------------|
| Daily mean temperature (°C)                                   | 0.65     | 0.06   | 1.24  | 0.03            |
| Interview round (reference: 1)                                |          |        |       |                 |
| 2   | -8.09    | -34.64 | 18.47 | 0.55            |
| 3   | -15.25   | -36.13 | 5.63  | 0.15            |
| Month of data collection (reference: January)                 |          |        |       |                 |
| <i>February</i>   | -1.75    | -7.64  | 4.13  | 0.56            |
| <i>March</i>  | -4.36    | -10.33 | 1.60  | 0.15            |
| <i>April</i>  | 9.96     | -17.18 | 37.09 | 0.47            |
| <i>May</i>  | 8.99     | -17.90 | 35.87 | 0.51            |
| <i>June</i>   | 8.32     | -18.84 | 35.48 | 0.55            |
| <i>July</i>   | 3.48     | -25.75 | 32.71 | 0.82            |
| <i>September</i>  | 15.08    | -5.95  | 36.10 | 0.16            |
| <i>October</i>  | 12.88    | -8.13  | 33.90 | 0.23            |
| <i>November</i>   | 16.52    | -2.63  | 35.66 | 0.09            |
| <i>December</i>   | 14.34    | 8.75   | 19.92 | < 0.001         |
| Singleton/multiple birth (reference: singleton)               |          |        |       |                 |
| <i>Multiple birth</i>   | 17.43    | 11.53  | 23.33 | < 0.001         |
| Infant age (weeks)  | 0.09     | -0.04  | 0.21  | 0.17            |
| Maternal age (reference: 20-34 years)                         |          |        |       |                 |
| < 19 years  | -5.68    | -8.68  | -2.69 | < 0.001         |
| ≥ 35 years  | 0.29     | -2.39  | 2.97  | 0.83            |
| Income-generating activities (minutes/day)                    | -0.01    | -0.01  | -0.00 | 0.04            |
| Living arrangements (reference: Lives with partner full-time) |          |        |       |                 |
| <i>Lives with partner periodically</i>                        | -1.91    | -5.73  | 1.92  | 0.33            |
| <i>Does not live with partner</i>                             | -2.57    | -7.42  | 2.29  | 0.30            |
| <i>Not in a relationship</i>                                  | -8.68    | -12.47 | -4.89 | < 0.001         |

## References

- 1 TuTiempo. Clima Bobo-Dioulasso. Datos climáticos: 1973 - 2021. <https://www.tutiempo.net/clima/ws-655100.html>.

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

|                              | Item No | Recommendation   | Page No   |
|------------------------------|---------|--|---|
| <b>Title and abstract</b>    | 1       | (a) Indicate the study's design with a commonly used term in the title or the abstract<br>(b) Provide in the abstract an informative and balanced summary of what was done and what was found  | 1<br>3-4  |
| <b>Introduction</b>          |         |  |   |
| Background/rationale         | 2       | Explain the scientific background and rationale for the investigation being reported   | 6-8   |
| Objectives                   | 3       | State specific objectives, including any prespecified hypotheses   | 8   |
| <b>Methods</b>               |         |  |   |
| Study design                 | 4       | Present key elements of study design early in the paper  | 8   |
| Setting                      | 5       | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection  | 9-10  |
| Participants                 | 6       | (a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up<br>(b) For matched studies, give matching criteria and number of exposed and unexposed  | 8-9<br>N/A  |
| Variables                    | 7       | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable   | 12,<br>Table S1                                     |
| Data sources/<br>measurement | 8*      | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group   | 9-11  |
| Bias                         | 9       | Describe any efforts to address potential sources of bias  | 9, 10-<br>11,13                                     |
| Study size                   | 10      | Explain how the study size was arrived at  | N/A   |
| Quantitative variables       | 11      | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why   | 12-13,<br>14  |
| Statistical methods          | 12      | (a) Describe all statistical methods, including those used to control for confounding<br>(b) Describe any methods used to examine subgroups and interactions<br>(c) Explain how missing data were addressed<br>(d) If applicable, explain how loss to follow-up was addressed<br>(e) Describe any sensitivity analyses | 12-15<br>14<br>14<br>14<br>14                       |
| <b>Results</b>               |         |  |   |
| Participants                 | 13*     | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed.<br>(b) Give reasons for non-participation at each stage<br>(c) Consider use of a flow diagram                       | Figure 1,<br>Table 1,<br>18, 19<br>18<br>Figure 1   |
| Descriptive data             | 14*     | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders<br>(b) Indicate number of participants with missing data for each variable of interest<br>(c) Summarise follow-up time (eg, average and total amount)                         | Table 1,<br>16-18,<br>Figure<br>S1<br>Table 1<br>18 |



|    |                          |     |   |  |
|----|--------------------------|-----|---|--|
| 1  | Outcome data             | 15* | Report numbers of outcome events or summary measures over time  | Table 1,<br>Figure 2,<br>18                      |
| 2  |                          |     |   |  |
| 3  |                          |     |   |  |
| 4  |                          |     |   |  |
| 5  | Main results             | 16  | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included<br>(b) Report category boundaries when continuous variables were categorized<br>(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | 18-19,<br>Table<br>S2,<br>Table S3<br>N/A<br>N/A |
| 6  |                          |     |   |  |
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| 12 |                          |     |   |  |
| 13 | Other analyses           | 17  | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses  | 19, 20   |
| 14 |                          |     |   |  |
| 15 |                          |     |   |  |
| 16 | <b>Discussion</b>        |     |   |  |
| 17 | Key results              | 18  | Summarise key results with reference to study objectives  | 20   |
| 18 | Limitations              | 19  | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias  | 22-23  |
| 19 |                          |     |   |  |
| 20 |                          |     |   |  |
| 21 | Interpretation           | 20  | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence  | 20-24  |
| 22 |                          |     |   |  |
| 23 |                          |     |   |  |
| 24 |                          |     |   |  |
| 25 | Generalisability         | 21  | Discuss the generalisability (external validity) of the study results   | 23   |
| 26 |                          |     |   |  |
| 27 | <b>Other information</b> |     |   |  |
| 28 | Funding                  | 22  | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based   | 25   |
| 29 |                          |     |   |  |

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.