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# BMJ Open

## The effects of short birth interval on neonatal, infant and under-five child mortality in Ethiopia

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4 1 **The effects of short birth interval on neonatal, infant and**  
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7 2 **under-five child mortality in Ethiopia**  
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## 15 Abstract

16 **Objective** To assess the effect of short birth interval on neonatal, infant, and under-five  
17 mortality in Ethiopia.

18 **Design** A nationally representative cross-sectional survey.

19 **Setting** This study used data from the Ethiopia Demographic and Health Survey (EDHS) 2016.

20 **Participants** A total of 8,448 women who had at least two live births during the five years  
21 preceding the survey were included in the analysis.

22 **Outcome measures** Neonatal mortality (death of the child within 28 days of birth), infant  
23 mortality (death between birth and 11 months), and under-five mortality (death between birth  
24 and 59 months) were the outcome variables.

25 **Methods** Weighted logistic regression analysis based on inverse probability of treatment  
26 weights (IPTW) was used to estimate exposure effects adjusted for potential confounders.

27 **Results** The adjusted odds of neonatal mortality were about 50% higher among women with  
28 short birth interval (AOR=1.53, 95% CI= 1.13, 2.09) than those without. The odds of infant  
29 mortality were nearly two-fold higher (AOR=1.94, 95% CI= 1.39, 2.70) among women with  
30 short birth interval. The odds of under-five child mortality were also about two-fold higher  
31 (AOR=2.02, 95% CI= 1.48, 2.74) higher among women with short birth interval.

32 **Conclusion** Short birth interval has a significant effect on neonatal, infant, and under-five  
33 mortality in Ethiopia. Interventions targeting short birth interval are warranted to reduce  
34 neonatal, infant, and under-five mortality.

## 36 Introduction

37 Short birth interval, defined as a birth-to-birth interval of less than 33 months,<sup>1</sup> is a key public  
38 health problem with an estimated prevalence of 45.8% in Ethiopia.<sup>2</sup> Previous studies<sup>2-4</sup> have  
39 revealed the multifactorial nature of short birth interval, its spatial variation, and  
40 socioeconomic inequality in Ethiopia. Only about one-third of women in Ethiopia use modern  
41 contraceptives, which can prevent short birth interval.<sup>5</sup> Literature has also shown the effects of  
42 short birth interval may include, but are not limited to, preterm birth,<sup>6 7</sup> low birth weight,<sup>6 7</sup>  
43 small size for gestational age,<sup>6</sup> congenital anomalies,<sup>8 9</sup> autism,<sup>10</sup> miscarriage, preeclampsia,  
44 and premature rupture of membranes.<sup>11 12</sup>

45 Neonatal, infant, and under-five mortality are defined as the death of a child within 28 days of  
46 birth, before the age of 1 year, and before five years, respectively.<sup>5</sup> These mortality outcomes  
47 are regarded as a highly sensitive (proxy) measure of population health, a country's poverty  
48 and socioeconomic development status, and the availability and quality of health services and  
49 medical technology.<sup>13 14</sup>

50 The Sustainable Development Goal (SDG) 3.2 states that all countries should aim to reduce  
51 the neonatal mortality rate (NMR) to 12 deaths per 1000 live births or fewer, and reduce under-  
52 five mortality to 25 deaths per 1000 live births or fewer, by 2030.<sup>15</sup> The Growth and  
53 Transformation Plan of Ethiopia (GTPE) II also targets reductions in neonatal, infant, and  
54 under-five mortality rates, from 28 per 1000 live births, 44 per 1000 live births, and 64 per  
55 1000 live births in 2014/15 to 10, 20, and 30 per 1000 live births by 2019/20, respectively.<sup>16</sup>  
56 However, the 2016 Ethiopia Demographic and Health Survey (EDHS) report revealed that the  
57 neonatal, infant, and under-five mortality rates in Ethiopia were 29, 48, and 67 deaths per 1,000  
58 live births, respectively: still much higher than GTPE targets.<sup>5 16</sup>

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3 59 Literature from Ethiopia has shown that neonatal, infant, and under-five mortality are  
4  
5 60 associated with maternal education,<sup>17 18</sup> lack of antenatal care,<sup>19</sup> home delivery,<sup>20</sup> preterm  
6  
7 61 birth,<sup>19 21</sup> low birth weight,<sup>20 21</sup> multiple births,<sup>17 19 22 23</sup> sex of the child,<sup>17 19 22-25</sup> wealth status,<sup>26</sup>  
8  
9 62 <sup>27</sup> place of residence,<sup>20 23 24</sup> source of drinking water,<sup>27</sup> and lack of access to improved toilet  
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11 63 facility.<sup>28</sup>  
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15 64 Although previous studies<sup>17-19 23 24 27-31</sup> have suggested birth interval as one factor influencing  
16  
17 65 neonatal, infant, under-five mortality, these studies have several limitations. A key limitation  
18  
19 66 is that these studies<sup>17-19 23 24 27-31</sup> did not use the World Health Organization (WHO)  
20  
21 67 recommended<sup>1</sup> definition of short birth interval. Understanding the impact of short birth  
22  
23 68 interval on neonatal, infant, and under-five mortality, using the WHO definition,<sup>1</sup> is necessary  
24  
25 69 for the formulation of valid, consistent policies and health planning strategies and interventions  
26  
27 70 to improve child health outcomes. Second, women who were not eligible to provide birth  
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29 71 interval information (i.e., those who had given birth only once) were included in the analysis  
30  
31 72 of some studies.<sup>19 24 28</sup> This may result in underestimation or obscuration of the true effect of  
32  
33 73 birth interval on child mortality. Third, even among studies using the same definition of short  
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35 74 birth interval, findings have been inconsistent.<sup>19 24</sup> One of the studies using national data<sup>19</sup> did  
36  
37 75 not control for a range of potential confounders including maternal education, wealth status,  
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39 76 number of children, and region of residence, even though these data were available in the  
40  
41 77 datasets used for analysis. In addition, various studies did not consider short birth interval as a  
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43 78 potential predictor of neonatal,<sup>21 25 26 32-35</sup> infant,<sup>18 36 37</sup> and under-five mortality<sup>38-41</sup> in their  
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45 79 studies.  
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53 80 Generally, the effect of short birth interval, as per the most recent WHO recommendation,<sup>1</sup> on  
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55 81 neonatal, infant, and under-five mortality has not been investigated in Ethiopia. Evidence  
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57 82 regarding the effect of short birth interval is required for informed decision making by policy  
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3 83 makers and health program planners. This paper aimed to assess the effect of short birth interval  
4  
5 84 on neonatal, infant, and under-five mortality using the most recent WHO definition and  
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8 85 adjusting for a comprehensive set of potential confounders.  
9

## 10 86 **Methods**

### 11 12 13 87 **Study design**

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16 88 This analysis used data from the Ethiopia Demographic and Health Survey (EDHS) 2016. The  
17  
18 89 EDHS is a nationally representative cross-sectional study conducted in nine geographical  
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20 90 regions (Tigray, Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations  
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22 91 Nationalities and Peoples (SNNP), Gambela, and Harari) and two administrative cities (Addis  
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24 92 Ababa and Dire Dawa). A two-stage, stratified, clustered random sampling design was  
25  
26 93 employed to collect data from women who gave birth within the five years preceding the  
27  
28 94 survey. Further descriptions of the sampling procedure for the EDHS are presented elsewhere.<sup>5</sup>  
29  
30 95 A total of 8,448 women who had at least two live births during the five years preceding the  
31  
32 96 2016 survey were included in the analysis. When women had more than two births in the five  
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34 97 years preceding the survey, the birth interval between the most recent index child and the  
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36 98 immediately preceding child was considered for all the study participants.  
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### 40 41 99 **Variables**

#### 42 43 44 100 **Outcome variables**

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46 101 The outcome variables in the current study were neonatal mortality (death of the child within  
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48 102 28 days of birth), infant mortality (death between birth and 11 months), and under-five  
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50 103 mortality (death between birth and 59 months).<sup>5 42</sup> These outcomes were coded as binary  
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52 104 variables (1/0).  
53

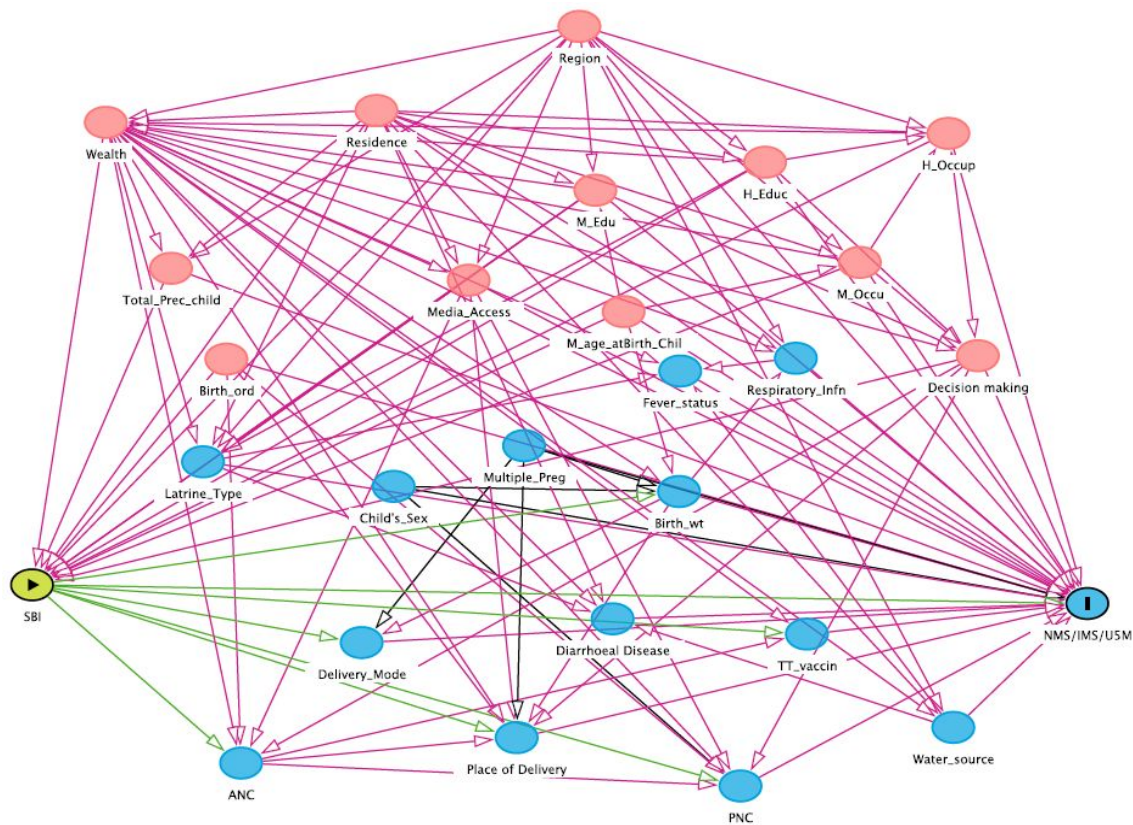
#### 54 55 56 105 **Treatment/exposure variable** 57 58 59 60



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3 106 Short birth interval was the treatment variable and was defined as a birth-to-birth interval of  
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5 107 less than 33 months as per the WHO definition.<sup>1</sup> Women's birth interval data were collected  
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7 108 by extracting the dates of birth of their biological children from children's birth/immunization  
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9 109 certificates, and/or requesting children's dates of birth from participating mothers. Further  
10  
11 110 information regarding birth interval data collection is annexed (Supplementary Material I) and  
12  
13 111 a detailed description is provided elsewhere.<sup>2 3 43</sup>

### 17 112 **Control variables**

18  
19 113 After reviewing relevant literature,<sup>2 17-20 22-24 27 28 38 44 45</sup> Direct Acyclic Graphs (DAGs) were  
20  
21 114 constructed using DAGitty 3.0<sup>46</sup> to identify confounders for the association between short  
22  
23 115 birth interval and child mortality. Adjustment for such confounders is necessary to estimate  
24  
25 116 the unbiased effect of SBI on neonatal, infant, and under-five mortality (figure 1). Identified  
26  
27 117 confounders were maternal age at the birth of the index child, maternal education, maternal  
28  
29 118 occupation, husband's education, husband's occupation, household wealth status, the total  
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31 119 number of the preceding child, place of residence (urban/rural), administrative regions, access  
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33 120 to media, and decision making autonomy. A list of all variables considered in the DAG is  
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35 121 provided in Supplementary Material II.  
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**Figure 1** Direct Acyclic Graph (DAG) used to select controlling variables

A yellowish-green circle with a triangle at its centre indicates the main treatment/exposure variable, a blue circle with a vertical bar at its centre indicates the outcome variable, light red circles indicate ancestors of exposure and outcome (i.e., confounders). Blue circles indicate the ancestors of the outcome variable. Green lines indicate a causal pathway. Red lines indicate open paths by which confounding may occur; this confounding can be removed by adjusting for one or several variables on the pathway.

M\_age\_atBirth\_chil= Maternal age at birth of the index child; M\_Edu= Maternal education; M\_Occu= Maternal Occupation; H\_Educ= Husband education; Birth\_wt=Birth weight; Respiratory\_infn= respiratory infection; Multiple\_preg= Multiple pregnancy; ANC=Antenatal care; PNC=Postnatal care; TT=Tetanus toxoid vaccination status; SBI= Short birth interval; NM=Neonatal mortality; IM=Infant mortality; U5M=Under-five mortal

## Data analyses

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3 136 Given the outcomes were relatively infrequent, the unbiased effect of short birth interval on  
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5 137 each outcome was estimated using propensity scores (PS) with stabilized inverse probability  
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7  
8 138 of treatment weighting (IPTW). A propensity score is defined as the probability of treatment  
9  
10 139 assignment given observed baseline covariates (described in Supplementary Material II).<sup>47</sup>  
11  
12 140 Propensity scores are used to estimate treatment effects on outcomes using observational data  
13  
14  
15 141 when confounding bias due to non-random treatment assignment is likely.<sup>48</sup> Inverse probability  
16  
17 142 of treatment weighting weights the entire study sample by the inverse of the propensity score;<sup>49</sup>  
18  
19 143 a differential amount of information is used from each participant, depending on their  
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21 144 conditional probability of receiving treatment. This means observations are less likely to be  
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23  
24 145 lost than when using matching for confounder adjustment.<sup>50 51</sup> Propensity scores are a robust  
25  
26 146 alternative to covariate adjustment when the outcome variable is rare, resulting in data sparsity  
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28 147 and estimation issues in multivariable models.<sup>51</sup> In this study, the weighted prevalence of the  
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30 148 outcome variables of neonatal, infant, and under-five mortality were 2.9% (95% CI: 2.39, 3.61)  
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32 149 4.8% (95% CI: 4.11, 5.58), and 5.5% (95% CI: 4.73, 6.44), respectively.  
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34  
35 150 The analysis procedure was as follows. First, the propensity score was estimated using a  
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37 151 logistic regression model in which treatment assignment (short birth interval vs. non-short birth  
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39 152 interval) was regressed on the 11 covariates identified using the DAG. The balance of measured  
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41 153 covariates/confounders was then assessed across treatment groups (i.e., women with short birth  
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43 154 interval) and comparison groups (i.e., women with non-short birth interval) before and after  
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45 155 weighting, by computing standardized differences.<sup>51 52</sup> For a continuous covariate, the  
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47 156 standardized difference<sup>52 53</sup> is defined as:

$$d = \frac{(\bar{x}_{treatment} - \bar{x}_{control})}{\sqrt{\frac{s_{treatment}^2 + s_{control}^2}{2}}}$$

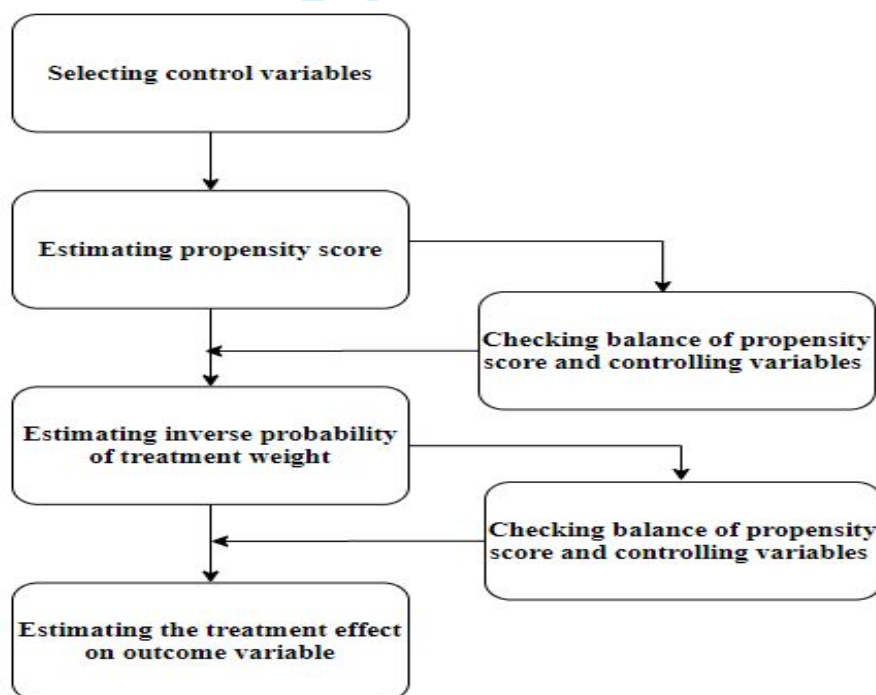
157 where  $\bar{x}_{treatment}$  and  $\bar{x}_{control}$  denote the sample mean of the covariate in treated and untreated  
 158 subjects, respectively and  $s_{treatment}^2$  and  $s_{control}^2$  denote the corresponding sample variances of  
 159 the covariate. The standardized difference<sup>52 53</sup> for a dichotomous variable is given as:

$$d = \frac{(\hat{p}_{treatment} - \hat{p}_{control})}{\sqrt{\frac{\hat{p}_{treatment}(1 - \hat{p}_{treatment}) + \hat{p}_{control}(1 - \hat{p}_{control})}{2}}}$$

160 where  $\hat{p}_{treatment}$  and  $\hat{p}_{control}$  denote the prevalence of the dichotomous variable in treated  
 161 and untreated subjects, respectively.

162 A standard difference less than 0.1 has been suggested as indicating a negligible difference in  
 163 the mean or prevalence of a covariate between treatment and control groups and was used  
 164 here.<sup>52</sup> In addition, kernel densities were plotted to graphically demonstrate the propensity  
 165 score balance in the treatment group (i.e., women with short birth interval) and control groups  
 166 (women with non-short birth interval). Balance in propensity scores was considered to be  
 167 achieved when the kernel density line for the treatment group and control group lay closer  
 168 together.<sup>54</sup> The inverse probability of treatment weights was then calculated as 1/PS for those  
 169 exposed to short birth interval and 1/(1 - PS) for those who were not. The sample was then  
 170 reweighted by the IPTW and the balance of the covariates checked in the reweighted  
 171 sample.<sup>48 55</sup> Stabilization of weights was made to preserve the sample size of the original  
 172 data, reduce the effect of weights of either treated subjects with low propensity scores or  
 173 untreated subjects with high propensity scores, and provides appropriate improve the  
 174 estimation of variance estimates and confidence intervals for the treatment effect.<sup>56</sup> Since  
 175 the EDHS employed a two-stage, stratified, clustered random sampling, which is a complex  
 176 sampling procedure, sampling weights were also used to adjust for the non-proportional  
 177 allocation of sample participants to different regions, including urban and rural areas, and  
 178 consider the possible differences in response rates.<sup>5</sup> Finally, a weighted logistic regression was  
 179 fit to estimate the effect of the treatment (short birth interval) on the outcome variables

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3 180 (neonatal, infant, and under-five mortality). Estimation of the treatment effect on outcome  
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5 181 variables in the final model used the grand weight, which was formed as the product of the  
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7 182 survey weight and the stabilized weight. Literature has shown that combining a propensity  
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9 183 score method and survey weighting is necessary to estimate unbiased treatment effects which  
10  
11 184 are generalizable to the original survey target population.<sup>57</sup> The treatment effect on the outcome  
12  
13 185 variables was expressed as adjusted odds ratios (AORs) with a 95% confidence interval (CI).  
14  
15 186 Statistical analysis was performed using Stata version 14 statistical software (*StataCorp. Stata*  
16  
17 187 *Statistical Software: Release 14. College Station, TX: StataCorp LP. 2015*). Figure 2 presents  
18  
19  
20  
21 188 a schematic summary of the overall analysis procedure.



189  
190 **Figure 2** Schematic presentation of the overall steps followed in the analysis

## 191 **Patient and public involvement**

192 Patients and/or the general public were not involved in the design, or conduct, or drafting of  
193 this secondary analysis.

194

## 195 **Results**

### 196 **Respondents' characteristics**

197 Table 1 illustrates the baseline characteristics of the study participants.

198 The occurrence of neonatal mortality differed with maternal age at birth, with mortality rates  
199 being higher among mothers aged  $\geq 35$  ( $p=0.021$ ). Neonatal mortality was also higher in rural  
200 than in urban areas ( $p=0.004$ ). Similarly, infant mortality and under-five mortality were  
201 somewhat higher in rural areas ( $p<0.001$ ). Under-five mortality was higher among uneducated  
202 mothers ( $p=0.027$ ) and in mothers without access to mass media ( $p=0.043$ ). Mortality at all  
203 ages was higher among infants with at least five siblings ( $p<0.0001$ ). Both infant and under-  
204 five mortality had slightly higher rates among wealthier families, although numbers were small.

**Table 1** The weighted distribution of neonatal, infant, and under-five child mortality by background characteristics, EDHS 2016

Variable	Neonatal Mortality		P-value	Infant Mortality		P-value	Under-five Mortality		P-value
	No (%)	Yes (%)		No (%)	Yes (%)		No (%)	Yes (%)	
Maternal age at the birth of the index child (in years)									
≤19	291 (3.2)	17 (5.8)	0.021	283 (3.1)	25 (6.5)	0.065	280 (3.1)	28 (6.0)	0.068
20-24	1950 (23.4)	52 (18.8)		1896 (23.2)	106 (23.7)		1877 (23.3)	125 (23.0)	
25-29	2587 (30.8)	67 (26.0)		2536 (30.8)	118 (27.6)		2516 (30.8)	138 (27.4)	
30-34	1836 (22.7)	59 (22.6)		1802 (22.9)	93 (21.0)		1781 (22.7)	114 (22.9)	
≥35	1533 (19.9)	56 (26.8)		1515 (20.0)	74 (21.2)		1500 (20.1)	89 (20.7)	
Maternal education									
Uneducated	5890 (73.9)	182 (75.0)	0.859	5759 (73.8)	313 (75.9)	0.157	5694 (73.9)	378 (75.5)	0.027
Primary	1744 (22.0)	54 (19.7)		1715 (22.0)	83 (20.8)		1704 (22.0)	94 (21.1)	
Secondary+	563 (4.1)	15 (5.3)		558 (4.2)	20 (3.3)		556 (4.1)	22 (3.4)	
Maternal occupation									
Not employed	5935 (72.9)	178 (74.6)	0.604	5807 (72.9)	306 (73.2)	0.575	5747 (72.9)	366 (73.6)	0.376
Employed	2267 (27.1)	73 (25.4)		2225 (27.1)	110 (26.8)		2207 (27.1)	128 (26.4)	
Husband education									
Uneducated	4186 (49.9)	145 (53.2)	0.092	4104 (50.0)	227 (50.1)	0.346	4057 (50.0)	274 (49.0)	0.154
Primary	2482 (37.3)	69 (34.6)		2437 (37.3)	114 (36.2)		2416 (37.3)	135 (37.1)	
Secondary+	1529 (12.8)	37 (12.2)		1491 (12.7)	75 (13.7)		1481 (12.7)	85 (13.9)	
Husband occupation									
Not employed	873 (7.7)	22 (6.6)	0.339	846 (7.6)	49 (7.7)	0.421	838 (7.6)	57 (7.4)	0.482
Employed	7324 (92.3)	229 (93.4)		7186 (92.4)	367 (92.3)		7116 (92.4)	437 (92.6)	
Wealth									
Poorest	3238 (25.4)	109 (15.6)	0.248	3163 (25.3)	184 (21.5)	0.015	3118 (25.3)	229 (22.2)	<0.001
Poorer	1430 (23.4)	48 (22.5)		1400 (23.4)	78 (22.2)		1390 (23.5)	88 (21.3)	
Middle	1167 (21.1)	36 (22.8)		1147 (21.3)	56 (20.0)		1136 (21.2)	67 (20.7)	
Richer	1025 (17.8)	30 (24.8)		1000 (17.7)	55 (23.3)		993 (17.6)	62 (23.7)	
Richest	1337 (12.3)	28 (14.3)		1322 (12.3)	43 (13.0)		1317 (12.3)	48 (12.1)	

Total number of preceding child									
≤2	2627 (31.0)	57 (27.0)	<0.001	2591 (31.0)	93 (27.1)	<0.001	2575 (31.1)	109 (26.4)	<0.001
3-4	2561 (30.6)	77 (22.0)		2505 (30.7)	133 (23.6)		2482 (30.7)	156 (24.6)	
≥5	3009 (38.4)	117 (50.9)		2936 (38.2)	190 (49.3)		2897 (38.2)	229 (49.0)	
Residence									
Urban	1264 (8.8)	22 (12.0)	0.004	1251 (8.9)	35 (8.7)	<0.001	1248 (9.0)	38 (7.7)	<0.001
Rural	6933 (91.2)	229 (88.0)		6781 (91.1)	381 (91.3)		6706 (91.0)	456 (92.3)	
Region									
Tigray	765 (6.0)	23 (6.1)	0.516	762 (6.1)	26 (4.1)	0.145	752 (6.1)	36 (5.3)	0.039
Afar	808 (1.0)	20 (0.7)		779 (1.0)	49 (1.2)		762 (1.0)	66 (1.4)	
Amhara	774 (18.7)	26 (22.2)		765 (18.8)	35 (17.9)		761 (18.9)	39 (17.2)	
Oromia	1270 (44.7)	37 (45.5)		1245 (44.6)	62 (47.9)		1235 (44.6)	72 (47.1)	
Somali	1231(5.0)	52 (6.3)		1210 (4.9)	73 (5.4)		1203 (4.9)	80 (5.1)	
Benishangul-Gumuz	711 (1.1)	24 (1.0)		690 (1.1)	45 (1.3)		682 (1.1)	53 (1.4)	
SNNPR***	1021 (21.2)	23 (16.0)		995 (21.1)	49 (20.4)		987 (21.1)	57 (20.9)	
Gambella,	541 (0.2)	16 (0.2)		531 (0.2)	26 (0.2)		522 (0.2)	35 (0.2)	
Harari	443 (0.2)	13 (0.2)		429 (0.2)	27 (0.2)		427 (0.2)	29 (0.2)	
Addis Ababa	246 (1.5)	6 (1.2)		245 (1.5)	7 (1.0)		245 (1.5)	7 (0.8)	
Dire Dawa	387 (0.4)	11 (0.4)	381(0.4)	17 (0.4)	378 (0.4)	20 (0.4)			
Access to mass media									
Yes	1408 (15.8)	36 (23.2)	0.240	1383 (15.9)	61 (20.2)	0.177	1376 (15.9)	68 (19.0)	0.043
No	6789 (84.2)	215 (76.8)		6649 (84.1)	355 (79.8)		6578 (84.1)	426 (81.0)	
Decision making autonomy									
Yes	6014 (77.7)	179 (74.9)	0.469	5898 (77.8)	295 (73.8)	0.258	5848	345	0.072
No	2183 (22.3)	72 (25.1)		2134 (22.2)	121 (26.2)		2106	149	

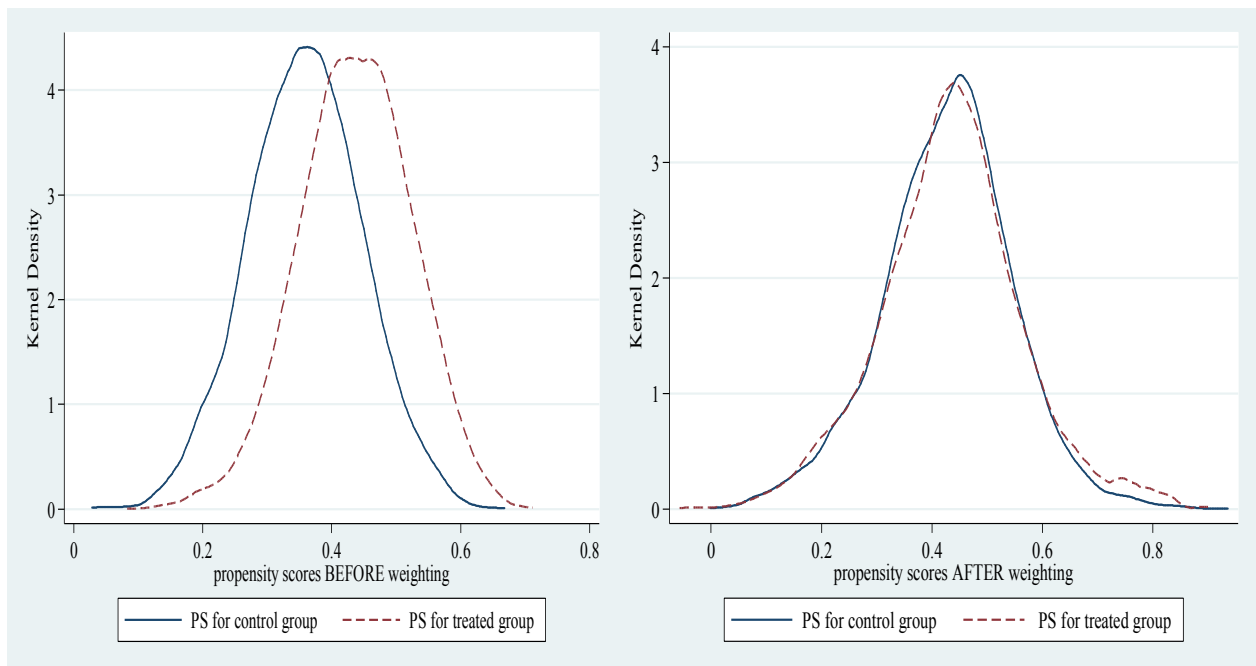
\*\*\*SNNPR= Southern Nations, Nationalities, and Peoples' Region; EDHS= Ethiopia Demographic and Health Survey



## Balance diagnostics

### Propensity score balance

Figure 3 presents the density plot of women in the treatment group (dashed lines) and control group (solid lines) before and after weighting. It reveals that an adequate balance of the propensity score distribution between the treatment groups after weighting (Figure 3).



**Figure 3** Balance of propensity scores before and after weighting across treatment and comparison groups

PS= propensity score

### Covariate balance

After weighting adjustment, standardized differences of covariates were all less than 0.1 (10%), showing comparability between women with and without short birth interval (Supplementary Material III).

### Treatment effect estimation

Table 2 presents the estimated effects of short birth interval on neonatal, infant, and under-five mortality. The adjusted estimated odds of neonatal mortality were 53% higher among women who experienced short birth interval (AOR=1.53, 95% CI= 1.13, 2.09) than those who did not. Similarly, the odds of infant mortality were 94% higher (AOR=1.94, 95% CI= 1.39, 2.70) among women who experienced short birth interval compared with women who did not. The odds of under-five child mortality were two times (AOR=2.02, 95% CI= 1.48, 2.74) higher among women who were exposed to short birth interval compared with women who were not.

**Table 2** The effect of short birth interval on neonatal, infant, and under-five mortality in Ethiopia, EDHS 2016

Treatment variable	Neonatal mortality		AOR (95% CI)
	No (%)*	Yes (%)*	
Short birth interval			
No	4166 (54.5)	95 (46.1)	Ref
Yes	4031 (45.5)	156 (53.9)	1.53 (1.13, 2.09)
	Infant mortality		
Short birth interval	No (%)	Yes (%)	
No	4126 (54.9)	135 (40.5)	Ref
Yes	3906 (45.1)	281 (59.5)	1.94 (1.39, 2.70)
	Under-Five mortality		
Short Birth interval	No (%)	Yes (%)	
No	4099 (55.1)	162 (39.3)	Ref
Yes	3855 (44.9)	332 (60.7)	2.02 (1.48, 2.74)

EDHS= Ethiopia Demographic and Health Survey; AOR= Adjusted Odds Ratio; CI= Confidence Interval; Ref= reference group; (%)\*=percentage are weighted

## Discussion

To our knowledge, this study provides the first comprehensive assessment of the effect of short birth interval on neonatal, infant, and under-five mortality using the WHO recommendation to define short birth interval and applying rigorous analytical techniques to adjust for potential confounders. This study provides evidence that short birth interval is associated with neonatal, infant, and under-five mortality in Ethiopia. These findings will help policy

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3 makers and program planners formulate targeted interventions to increase birth intervals and  
4 contribute to achieving the GTPE and SDGs target of reducing neonatal, infant, and under-  
5 five mortality.<sup>16 15</sup>  
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10 In this current study, short birth interval was found to be associated with higher odds of  
11 neonatal mortality. This finding is consistent with evidence from the previous studies<sup>22 24 58-</sup>  
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61 which have shown a higher risk of neonatal mortality among women with a short birth  
interval. However, the definition of short birth interval (i.e., <33 months) used in the current  
study was in line with the WHO definition and longer than those used in previous studies (i.e.,  
ranges from <18 to 24 months). Short birth interval could result in adverse neonatal child health  
outcomes, such as death, by causing maternal nutritional depletion, specifically folate  
depletion.<sup>62 63</sup> The maternal nutritional depletion hypothesis states that a short birth-to-  
pregnancy/birth interval worsens the mother's nutritional status because of inadequate time to  
recover from the physiological stresses of the subsequent pregnancy.<sup>64</sup> This may compromise  
maternal nutritional status and ability to support fetal growth, which could result in fetal  
malnutrition and increased risk of infection and death during childhood.<sup>62</sup> Women with short  
birth interval may also be less likely to attend postnatal care, which is vital for early detection  
and treatment of neonatal and maternal health problems. Evidence has shown that the majority  
of mothers and newborns in low- and middle-income countries do not receive optimal postnatal  
care<sup>65</sup>, yet close to half of the newborn deaths occurred within the first 24 hours after birth, a  
critical time where mothers and their babies should get their first postnatal care.<sup>66</sup>

Our study found that infant mortality was 94% higher among women who experienced short  
birth interval compared with women who did not. Our finding was consistent with evidence  
from Ethiopia,<sup>17 31</sup> Kenya,<sup>67 68</sup> Nepal,<sup>69</sup> and Iran<sup>70</sup> although the cut-off point for short birth  
interval in the current study was longer than the previous studies. The abovementioned  
previous studies also documented that the risk of infant mortality was higher among women

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3 who experienced short birth interval compared with women who did not. One of the possible  
4 reasons for the effect of short birth interval on infant mortality could be low maternal  
5 motivation to breastfeed (for example, if the pregnancy was unintended).<sup>71</sup> Maternal  
6 perception of being undernourished due to a short birth interval may also influence her infant  
7 feeding choices, such as the duration and intensity of breastfeeding and supplemental  
8 feeding of the infant. This could in turn affect infants' nutritional status, their resistance to  
9 infection, and may expose them to death.<sup>71-74</sup> The abovementioned links between short birth  
10 interval and neonatal mortality also apply to infant mortality.  
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15 Short birth interval doubled the odds of under-five mortality compared with non-short birth  
16 interval. Despite not using the WHO recommendation<sup>1</sup> of less than 33 months to define short  
17 birth interval, the existing literature<sup>23 29 58 59 75</sup> also supported our finding. The likely mechanism  
18 through which short birth interval affects under-five mortality could be competition between  
19 closely spaced siblings for limited household resources, maternal attention, and cross-  
20 infection.<sup>71</sup> Moreover, children born within a short birth interval may not receive their  
21 vaccination at all or complete their booster series, which is one of the risk factors that  
22 exposed children to the infectious disease and its associated death.<sup>76-78</sup> Women with short  
23 birth interval could be burdened with caring for highly dependent children<sup>72</sup> and other  
24 domestic activities. As a result, they may lack the time and motivation to take children to  
25 the health facility for vaccination and other services.  
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48 The results of this study need to be interpreted within the limitations of the observational  
49 study design. Due to the cross-sectional nature of the study, temporal associations between  
50 short birth interval and neonatal, infant, and under-five mortality may not be established.  
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53 One of the strengths of the current study was its use of data from a nationally representative  
54 survey with a large sample size. In addition, this study used robust statistical methods to  
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3 estimate the unbiased effect of the treatment group (short birth interval) on the outcome  
4 variables (neonatal, infant, and under-five mortality), by using causal diagrams to identify  
5 confounders a priori. The application of DAGs,<sup>79-81</sup> a graphical tool used to identify  
6 confounding variables by specifying causal paths among treatment/exposure, outcome, and  
7 other causally related variables was another strength of this study.  
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## 15 **Conclusion**

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19 This study provides evidence that short birth interval has a significant effect on neonatal,  
20 infant, and under-five mortality in Ethiopia. Interventions aiming to reduce neonatal, infant,  
21 and under-five mortality in Ethiopia should target the prevention of short birth interval.  
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23 These could be achieved through creating awareness on the optimum birth interval and the  
24 negative impacts of shorter birth intervals on the health of children. Further expanding the  
25 availability and accessibility of family planning services also help women achieve optimum  
26 birth interval. Birth interval counseling as per the WHO recommendation should be  
27 integrated into the maternal and child health services as part of the child survival  
28 intervention.  
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## Contributors

All authors (DMS, CC, EGH, and DL) contributed to the design of the study and the interpretation of data. DM performed the data analysis and drafted the manuscript. All authors (DMS, CC, EGH, and DL) read, critically revised, and approved the final manuscript.

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## Competing interests

The authors declare that they have no competing interests.

## Ethics approval

The 2016 EDHS was approved by the National Research Ethics Review Committee of Ethiopia (NRERC) and ICF Macro International. Permission from The DHS Program was obtained to use the 2016 EDHS data for further analysis. This analysis was also approved by The University of Newcastle Human Research Ethics Committee (H-2018-0332).

## Consent for publication

Not required

## Provenance and peer review

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## Data availability statement

The dataset is available from The DHS Program repository at the following link:

[https://www.dhsprogram.com/data/dataset/Ethiopia\\_Standard-DHS\\_2016.cfm?flag=0](https://www.dhsprogram.com/data/dataset/Ethiopia_Standard-DHS_2016.cfm?flag=0).

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## Supplemental Material I

Women's birth interval data were collected through extracting the date of birth of their biological children data from children's birth /immunization certificate, and/or asking information regarding their children's date of birth from the women. Mothers were asked to confirm the accuracy of the information before documenting children's date of birth from children's birth/immunization certificates. This crosschecking was performed to avoid errors, since in some cases the documented birth date may represent the date when the birth was recorded, rather than the actual birth date. In the absence of children's birth certificates, information regarding children's date of birth was obtained from their mothers. Birth interval was computed in months. Further information regarding birth interval data collection can be found elsewhere



Supplemental Material II

Table 1 Variables included in Direct Acyclic Graph

Category	Variables	Definition
Maternal background characteristics	Age at first marriage	The age of the woman at their first marriage, which was considered as a continuous variable
	Age at birth of the index Neonate/Infant/child	The age of the woman during the time she gave birth to the index neonate, which was considered as a continuous variable
	Educational level	Maximum educational level (1= Uneducated, 2=Primary and 3=Secondary+ ( or Educated and Uneducated)
	Employment status	Employed/not employed based on women’s response to the question “have you been employed in the last 12 months” (1=Not Employed; 2=Employed))
	Place of residence	The place where the women live (1=Urban; 2=Rural)
	Region	Region of residence where women live (1=Tigray, 2=Afar, 3=Amhara, 4=Oromia, 5=Somali, 6=Benishangul-Gumuz, 7=SNNPR*, 8=Gambella, 9=Harari, 10=Addis Ababa, 11=Dire Dawa) *SNNPR= Southern Nations, Nationalities, and Peoples' Region
	Number of living children	Total number of living children the women had ever had
	Decision making autonomy	Coded as ‘yes’ if she reported being involved in all decisions regarding her own health care, major household purchases and visits to her family or relatives (1=Yes, 2=No).
Husband background characteristics	Husband’s education	Maximum educational level of the husband (1= Uneducated, 2= Primary and 3= Secondary+)
	Husband’s occupation	
Household characteristics	Access to media	1=Access to media, 2= Not have access to media
	Wealth index	The wealth index provided with the dataset was used. DHS program provides a composite index of household amenities based on the principal component analysis (PCA) and classified the population into

		quintiles: (1st quintile (Poorest); 2nd quintile; 3rd quintile; 4th quintile and 5th quintile (Richest). A quintile is used as a measure of its relative socioeconomic level (i.e., 1=Poorest; 2=Poorer; 3=Middle; 4=Richer; 5=Richest)
<b>Maternal health status and healthcare-related variables</b>	Antenatal care	Women's antenatal care utilization categorized as no visit, at least one visit, $\geq$ four visits
	Delivery care	Delivery assisted by physician, nurse, midwife, health officer, and health extension worker; categorized as Yes/No
	Postnatal care	Women received check-up at least once within 48 hours after delivery by a skilled provider; categorized as Yes/No
	TT immunization	Women received at least two doses of the immunization during pregnancy (1=Yes, 2=No)
<b>Neonatal, infant and child characteristics</b>	Sex	1=Male, 2=Female
	Type of birth	1=Singleton, 2 = Multiple
	Birth weight	Based on mother's report that the birth weight was in one of the following categories (below average, average, above average)
	Mode of delivery	Whether the delivery was assisted by caesarean delivery or not (1= Non-Caesarean section, 2=Caesarean section)
	Total children born before the index child	The total children born the index child was considered as a continuous variable  Total number children born before the index child was considered as a continuous variable. This was done after checking for the linearity assumption with the log-odds of short birth interval, which is a binary response variable. Multicollinearity was also checked among the exposure variables using the variance inflation factor (VIF). If the values of VIF were lower than 10, then the collinearity problem was considered to be unlikely. The VIF for birth order was 18.15 and for the total number of children born before the index child was 16.26, which indicates the presence of collinearity. Therefore, we removed

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		the variable birth order from the model and the VIF became less than 3 for each variable included in the model.
	Birth order	Birth order is the order number of the births from first to last. Twins are given the same birth order, but the birth order of a child born after twins will be the total number of births preceding plus one.
	Diarrhoeal Disease	1= Yes, 2=No
	Fever	1=Yes, 2=No
	Respiratory infection	1=Yes, 2=No
<b>Environmental factors</b>	Source of water	1= Piped water, 2= Other improved (protected spring and well, and rain water), 3= Unimproved (river, pond, unprotected spring and well).
	Latrine facility	1 = Improved (access to flush toilet, ventilated improved pit latrine, traditional pit latrine with a slab, or composting toilet and does not share this facility with other households), 2=unimproved.

### Supplemental Material III

**Table 2** Standardized difference before and after weighting the propensity score

Variable	Standardized difference	
	Before weighting	After weighting
Maternal age at the birth of the index child (in years)*	-0.384	0.016
Maternal education		
Uneducated	0.203	0.000
Primary	-0.130	-0.008
Maternal occupation		
Not employed	0.143	0.004
Husband education		
Uneducated	0.153	0.007
Primary	-0.056	0.005
Husband occupation		
Not employed	0.156	0.006
Wealth		
Poorest	0.334	-0.009
Poorer	-0.017	0.011
Middle	-0.069	0.007
Richer	-0.082	-0.002
Total number of preceding child*	0.211	-0.010
Residence		
Urban	-0.225	-0.007
Region		
Tigray	-0.209	0.004
Afar	0.198	0.005
Amhara	-0.286	0.013
Oromia	0.024	0.002
Somali	0.409	-0.005
Benishangul-Gumuz	0.013	-0.007
SNNPR**	-0.057	-0.003
Gambella,	-0.109	-0.005
Harari	-0.002	-0.010
Addis Ababa	-0.170	0.015
Access to mass media		
Yes	-0.194	-0.002
Decision making autonomy		
No	0.069	-0.015

\*Maternal age at the birth of the index child (in years) and total number of the preceding child were considered as continuous variables; \*\*SNNPR= Southern Nations, Nationalities, and Peoples' Region

### Interpretation of the standardized difference

When the standardized difference is  $<0.1$ , it indicates a negligible difference in the mean or prevalence of a covariate between treatment and control groups. Therefore, the standardized difference after weighting shows the balance in covariates between the treatment and control group.

For peer review only

## STROBE 2007 (v4) Statement—Checklist of items for the study

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3 & 4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ 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	6
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8, 9, and 10
		(b) Describe any methods used to examine subgroups and interactions	10
		(c) Explain how missing data were addressed	N/A
		(d) If applicable, describe analytical methods taking account of sampling strategy	8, 9, & 10
		(e) Describe any sensitivity analyses	8 & 9
<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	11, 12, & 13
		(b) Give reasons for non-participation at each stage	5
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11, 12, & 13
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	
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	15
		(b) Report category boundaries when continuous variables were categorized	N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	15 & 16
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	17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16 & 17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17 & 18
<b>Other information</b>			
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	19

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**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 [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

**The effects of short birth interval on neonatal, infant and under-five child mortality in Ethiopia: a nationally representative observational study using inverse probability of treatment weighting**

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-047892.R1
Article Type:	Original research
Date Submitted by the Author:	13-May-2021
Complete List of Authors:	Shifti, Desalegn Markos; St Paul's Hospital Millennium Medical College; The University of Newcastle Faculty of Health and Medicine, Centre for Women's Health Research Chojenta, Catherine; The University of Newcastle Faculty of Health and Medicine, Centre for Women's Health Research Holliday, Elizabeth; The University of Newcastle Faculty of Health and Medicine, Centre for Clinical Epidemiology and Biostatistics Loxton, Deborah; The University of Newcastle, Faculty of Health and Medicine, Centre for Women's Health Research
<b>Primary Subject Heading</b>:	Public health
Secondary Subject Heading:	Epidemiology, Obstetrics and gynaecology, Paediatrics, Reproductive medicine
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, Maternal medicine < OBSTETRICS, Community child health < PAEDIATRICS

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4 1 **The effects of short birth interval on neonatal, infant and**  
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18 5 Desalegn Markos Shifti<sup>1,2,\*</sup>, Catherine Chojenta<sup>2</sup>, Elizabeth G. Holliday<sup>3</sup>, Deborah Loxton<sup>2</sup>  
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## 17 **Abstract**

18 **Objective** To assess the effect of short birth interval on neonatal, infant, and under-five  
19 mortality in Ethiopia.

20 **Design** A nationally representative cross-sectional survey.

21 **Setting** This study used data from the Ethiopia Demographic and Health Survey (EDHS) 2016.

22 **Participants** A total of 8,448 women who had at least two live births during the five years  
23 preceding the survey were included in the analysis.

24 **Outcome measures** Neonatal mortality (death of the child within 28 days of birth), infant  
25 mortality (death between birth and 11 months), and under-five mortality (death between birth  
26 and 59 months) were the outcome variables.

27 **Methods** Weighted logistic regression analysis based on inverse probability of treatment  
28 weights (IPTW) was used to estimate exposure effects adjusted for potential confounders.

29 **Results** The adjusted odds of neonatal mortality were about 85% higher among women with  
30 short birth interval (AOR=1.85, 95% CI= 1.19, 2.89) than those without. The odds of infant  
31 mortality were two-fold higher (AOR=2.16, 95% CI= 1.49, 3.11) among women with short  
32 birth interval. The odds of under-five child mortality were also about two times higher  
33 (AOR=2.26, 95% CI= 1.60, 3.17) higher among women with short birth interval.

34 **Conclusion** Short birth interval has a significant effect on neonatal, infant, and under-five  
35 mortality in Ethiopia. Interventions targeting short birth interval are warranted to reduce  
36 neonatal, infant, and under-five mortality.

### 38 **Strengths and limitations of this study**

- 39 • The application of IPTW mimics a randomized clinical trial by matching two comparison  
40 groups using a conditional probability of receiving exposure (short birth interval in this  
41 case) given a set of covariates.
- 42 • The study has also additional strengths, such as using data from a nationally representative  
43 survey with large sample size.
- 44 • The application of DAGs, a graphical tool used to identify minimum adjustment sets, which  
45 defined the set of explanatory variables for the propensity scores model was another  
46 strength of this study.
- 47 • Due to the cross-sectional nature of the study, temporal associations between short birth  
48 interval and neonatal, infant, and under-five mortality may not be established.
- 49 • The second limitation of our study could be associated with the nonrandomized design of  
50 the study. Propensity scores based analysis, IPTW, cannot account for unknown  
51 confounders in the same way that a randomised trial can. As a result, the effect of residual  
52 confounders may not be avoided.

## 54 Introduction

55 Short birth interval, defined as a birth-to-birth interval of less than 33 months,<sup>1</sup> is a key public  
56 health problem with an estimated prevalence of 45.8% in Ethiopia.<sup>2</sup> Previous studies<sup>2-4</sup> have  
57 revealed the multifactorial nature of short birth interval, its spatial variation, and  
58 socioeconomic inequality in Ethiopia. Only about one-third of women in Ethiopia use modern  
59 contraceptives, which can prevent short birth interval.<sup>5</sup> Literature has also shown the effects of  
60 short birth interval may include, but are not limited to, preterm birth,<sup>6 7</sup> low birth weight,<sup>6 7</sup>  
61 small size for gestational age,<sup>6</sup> congenital anomalies,<sup>8 9</sup> autism,<sup>10</sup> miscarriage, preeclampsia,  
62 and premature rupture of membranes.<sup>11 12</sup>

63 Neonatal, infant, and under-five mortality are defined as the death of a child within 28 days of  
64 birth, before the age of 1 year, and before five years, respectively.<sup>5</sup> These mortality outcomes  
65 are regarded as a highly sensitive (proxy) measure of population health, a country's poverty  
66 and socioeconomic development status, and the availability and quality of health services and  
67 medical technology.<sup>13 14</sup>

68 The Sustainable Development Goal (SDG) 3.2 states that all countries should aim to reduce  
69 the neonatal mortality rate (NMR) to 12 deaths per 1000 live births or fewer, and reduce under-  
70 five mortality to 25 deaths per 1000 live births or fewer, by 2030.<sup>15</sup> The Growth and  
71 Transformation Plan of Ethiopia (GTPE) II also targets reductions in neonatal, infant, and  
72 under-five mortality rates, from 28 per 1000 live births, 44 per 1000 live births, and 64 per  
73 1000 live births in 2014/15 to 10, 20, and 30 per 1000 live births by 2019/20, respectively.<sup>16</sup>  
74 However, the 2019 Ethiopia Mini Demographic and Health Survey (EMDHS) report revealed  
75 that the neonatal, infant, and under-five mortality rates in Ethiopia were 30, 43, and 55 deaths  
76 per 1,000 live births, respectively: still much higher than GTPE targets.<sup>16 17</sup>

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3 77 Literature from Ethiopia has shown that neonatal, infant, and under-five mortality are  
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5 78 associated with maternal education,<sup>18 19</sup> lack of antenatal care,<sup>20</sup> home delivery,<sup>21</sup> preterm  
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7 79 birth,<sup>20 22</sup> low birth weight,<sup>21 22</sup> multiple births,<sup>18 20 23 24</sup> sex of the child,<sup>18 20 23-26</sup> wealth status,<sup>27</sup>  
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9 80 <sup>28</sup> place of residence,<sup>21 24 25</sup> sources of drinking water,<sup>28</sup> and lack of access to an improved toilet  
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11 81 facility.<sup>29</sup>  
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15 82 Although previous studies<sup>18-20 24 25 28-32</sup> have suggested birth interval as one factor influencing  
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17 83 neonatal, infant, under-five mortality, these studies have several limitations. A key limitation  
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19 84 is that these studies<sup>18-20 24 25 28-32</sup> did not use the World Health Organization (WHO)  
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21 85 recommended<sup>1</sup> definition of short birth interval. Understanding the impact of short birth  
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23 86 interval on neonatal, infant, and under-five mortality, using the WHO definition,<sup>1</sup> is necessary  
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25 87 for the formulation of valid, consistent policies and health planning strategies and interventions  
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27 88 to improve child health outcomes. Second, women who were not eligible to provide birth  
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29 89 interval information (i.e., those who had given birth only once) were included in the analysis  
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31 90 of some studies.<sup>20 25 29</sup> This may result in underestimation or obscuration of the true effect of  
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33 91 birth interval on child mortality. Third, even among studies using the same definition of short  
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35 92 birth interval, findings have been inconsistent.<sup>20 25</sup> One of the studies using national data<sup>20</sup> did  
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37 93 not control for a range of potential confounders including maternal education, wealth status,  
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39 94 number of children, and region of residence, even though these data were available in the  
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41 95 datasets used for analysis. Similarly, another previous study<sup>30</sup> that used national data did not  
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43 96 condition on maternal occupation, husband education, husband occupation, the total number of  
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45 97 preceding child, regions, access to mass media, and women's decision making autonomy. In  
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47 98 addition, various studies did not consider short birth interval as a potential predictor of  
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49 99 neonatal,<sup>22 26 27 33-36</sup> infant,<sup>19 37 38</sup> and under-five mortality<sup>39-42</sup> in their studies.  
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3 100 Generally, the effect of short birth interval, as per the most recent WHO recommendation,<sup>1</sup> on  
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5 101 neonatal, infant, and under-five mortality has not been investigated in Ethiopia. Evidence  
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7 102 regarding the effect of short birth interval is required for informed decision making by policy  
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9 103 makers and health program planners. This paper aimed to assess the effect of short birth interval  
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11 104 on neonatal, infant, and under-five mortality using the most recent WHO definition and  
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13 105 adjusting for a comprehensive set of potential confounders.  
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## 16 17 106 **Methods**

### 18 19 20 107 **Study design and study area**

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22  
23 108 This analysis used data from the Ethiopia Demographic and Health Survey (EDHS) 2016. The  
24  
25 109 EDHS is a nationally representative cross-sectional study conducted in nine geographical  
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27 110 regions (Tigray, Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations  
28  
29 111 Nationalities and Peoples (SNNP), Gambela, and Harari) and two administrative cities (Addis  
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31 112 Ababa and Dire Dawa). A two-stage, stratified, clustered random sampling design was  
32  
33 113 employed to collect data from women who gave birth within the five years preceding the  
34  
35 114 survey. Further descriptions of the sampling procedure for the EDHS are presented elsewhere.<sup>5</sup>  
36  
37  
38 115 A total of 8,448 women who had at least two live births during the five years preceding the  
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40 116 2016 survey were included in the analysis. When women had more than two births in the five  
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42 117 years preceding the survey, the birth interval between the most recent index child and the  
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44 118 immediately preceding child was considered for all the study participants.  
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### 48 119 **Variables**

#### 49 50 120 **Outcome variables**

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53 121 The outcome variables in the current study were neonatal mortality (death of the child within  
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55 122 28 days of birth), infant mortality (death between birth and 11 months), and under-five  
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3 123 mortality (death between birth and 59 months).<sup>5 43</sup> These outcomes were coded as binary  
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5 124 variables (1/0).

### 8 125 **Treatment/exposure variable**

10 126 Short birth interval was the treatment variable and was defined as a birth-to-birth interval of  
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12  
13 127 less than 33 months as per the WHO definition.<sup>1</sup> A preceding birth interval, the amount of time  
14  
15 128 between the birth of the child under study (index child) and the immediately preceding birth,  
16  
17 129 was considered in this study. Women's birth interval data were collected through extracting  
18  
19 130 the date of birth of their biological children data from children's birth /immunization certificate,  
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21  
22 131 and/or asking information regarding their children's date of birth from the women. Mothers  
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24 132 were asked to confirm the accuracy of the information before documenting children's date of  
25  
26 133 birth from children's birth/immunization certificates. This crosschecking was performed to  
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28  
29 134 avoid errors, since in some cases the documented birth date may represent the date when the  
30  
31 135 birth was recorded, rather than the actual birth date. In the absence of children's birth  
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33 136 certificates, information regarding children's date of birth was obtained from their mothers.  
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36 137 Further information regarding birth interval data collection is provided elsewhere.<sup>2 3 44</sup>

### 38 138 **Control variables**

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41 139 After reviewing relevant literature,<sup>2 18-21 23-25 28 29 39 45 46</sup> Direct Acyclic Graphs (DAGs) were  
42  
43 140 constructed using DAGitty 3.0<sup>47</sup> to identify confounders for the association between short  
44  
45 141 birth interval and neonatal, infant, and under-five child mortality. Adjustment for such  
46  
47 142 confounders is necessary to estimate the unbiased effect of SBI on neonatal, infant, and  
48  
49 143 under-five mortality (figure 1). DAG is a formal system of mapping variables and the direction  
50  
51  
52 144 of causal relationships among them.<sup>48 49</sup> This graphical representation of causal effects among  
53  
54 145 variables helps understand whether bias is potentially reduced or increased when conditioning  
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56  
57 146 on covariates. Moreover, it illustrates covariates that lie in the causal pathway between the  
58  
59 147 treatment and outcomes, which should not be included in the analysis as a confounder. These



1  
2  
3 148 variables are indicated by green lines in Figure 1. This is because a propensity score that  
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5 149 includes covariates affected by the treatment (i.e., variables on the causal pathway between  
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7 150 treatment and outcome) obscures part of the treatment effect that one is trying to estimate.<sup>50</sup>  
8  
9 151 Identified confounders were maternal age at the birth of the index child, maternal education,  
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11 152 maternal occupation, husband's education, husband's occupation, household wealth status,  
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13 153 survival status of the preceding child, the total number of the preceding child, place of residence  
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15 154 (urban/rural), regions, access to media, and decision making autonomy. A list of all variables  
16  
17 155 considered in the DAG is provided in Supplementary Material I.  
18  
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22 156 A yellowish-green circle with a triangle at its centre indicates the main treatment/exposure  
23  
24 157 variable, a blue circle with a vertical bar at its centre indicates the outcome variable, light red  
25  
26 158 circles indicate ancestors of exposure and outcome (i.e., confounders). Blue circles indicate the  
27  
28 159 ancestors of the outcome variable. Green lines indicate a causal pathway. Red lines indicate  
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30 160 open paths by which confounding may occur; this confounding can be removed by adjusting  
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32 161 for one or several variables on the pathway.  
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35

36 162 M\_age\_atBirth\_chil= Maternal age at birth of the index child; M\_Edu= Maternal education;  
37  
38 163 M\_Occu= Maternal Occupation; H\_Educ= Husband education; H\_Occup= Husband  
39  
40 164 occupation; Birth\_wt=Birth weight; Total\_Prec\_child=Total number of preceding child;  
41  
42 165 Respiratory\_infn= respiratory infection; Prev\_Chi\_Survival=Previous child survival;  
43  
44 166 Multiple\_preg= Multiple pregnancy; ANC=Antenatal care; PNC=Postnatal care;  
45  
46 167 TT\_vaccin=Tetanus toxoid vaccination status; SBI= Short birth interval; NM=Neonatal  
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48 168 mortality; IM=Infant mortality; U5M=Under-five mortal  
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## 52 169 **Data analyses**

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55 170 Participants' characteristics were described using frequency with percent. P-values were  
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57 171 calculated using Pearson's chi-squared test. Given that the outcomes (i.e., neonatal, infant, and  
58  
59 172 under-five mortality) were relatively infrequent, the unbiased effect of short birth interval on  
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3 173 each outcome was estimated using propensity scores (PS) with a stabilized method of inverse  
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5 174 probability of treatment weighting (IPTW). A previous study<sup>51</sup> has shown that IPTW with  
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7 175 stabilized weights preserves the sample size of the original data, provides an appropriate  
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9 176 estimation of the variance of the main effect, and maintains an appropriate type I error rate.  
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11 177 The other methods, such as IPTW with normalized weight and greedy algorithm with 1:1  
12  
13 178 matching methods, are discussed elsewhere.<sup>52-54</sup> A propensity score is defined as the  
14  
15 179 probability of treatment assignment given observed baseline covariates (described in  
16  
17 180 Supplementary Material II).<sup>54</sup> Propensity scores are used to estimate treatment effects on  
18  
19 181 outcomes using observational data when confounding bias due to non-random treatment  
20  
21 182 assignment is likely.<sup>50</sup> Inverse probability of treatment weighting weights the entire study  
22  
23 183 sample by the inverse of the propensity score;<sup>55</sup> a differential amount of information is used  
24  
25 184 from each participant, depending on their conditional probability of receiving treatment. This  
26  
27 185 means observations are less likely to be lost than when using matching for confounder  
28  
29 186 adjustment.<sup>56 57</sup> Propensity scores are a robust alternative to covariate adjustment when the  
30  
31 187 outcome variable is rare, resulting in data sparsity and estimation issues in multivariable  
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33 188 models.<sup>57</sup> In this study, the weighted prevalence of the outcome variables of neonatal, infant,  
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35 189 and under-five mortality were 2.9% (95% CI: 2.39, 3.61), 4.8% (95% CI: 4.11, 5.58), and 5.5%  
36  
37 190 (95% CI: 4.73, 6.44), respectively.

38  
39 191 The analysis procedure was as follows. First, the propensity score was estimated using a  
40  
41 192 logistic regression model in which treatment assignment (short birth interval vs. non-short birth  
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43 193 interval) was regressed on the 11 covariates identified using the DAG. The balance of measured  
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45 194 covariates/confounders was then assessed across treatment groups (i.e., women with short birth  
46  
47 195 interval) and comparison groups (i.e., women with non-short birth interval) before and after  
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49 196 weighting, by computing standardized differences (Supplementary Material II).<sup>57 58</sup> For a  
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51 197 continuous covariate, the standardized difference<sup>58 59</sup> is defined as:  
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$$d = \frac{(\bar{x}_{treatment} - \bar{x}_{control})}{\sqrt{\frac{s_{treatment}^2 + s_{control}^2}{2}}}$$

198 where  $\bar{x}_{treatment}$  and  $\bar{x}_{control}$  denote the sample mean of the covariate in treated and untreated  
 199 subjects, respectively and  $s_{treatment}^2$  and  $s_{control}^2$  denote the corresponding sample variances of  
 200 the covariate. The standardized difference<sup>58 59</sup> for a dichotomous variable is given as:

$$d = \frac{(\hat{p}_{treatment} - \hat{p}_{control})}{\sqrt{\frac{\hat{p}_{treatment}(1 - \hat{p}_{treatment}) + \hat{p}_{control}(1 - \hat{p}_{control})}{2}}}$$

201 where  $\hat{p}_{treatment}$  and  $\hat{p}_{control}$  denote the prevalence of the dichotomous variable in treated  
 202 and untreated subjects, respectively.

203 A standard difference less than 0.1 has been suggested as indicating a negligible difference in  
 204 the mean or prevalence of a covariate between treatment and control groups and was used  
 205 here.<sup>58</sup> In addition, kernel densities were plotted to graphically demonstrate the propensity  
 206 score balance in the treatment group (i.e., women with short birth interval) and control groups  
 207 (women with non-short birth interval). Balance in propensity scores was considered to be  
 208 achieved when the kernel density line for the treatment group and control group lay closer  
 209 together.<sup>60</sup> The inverse probability of treatment weights was then calculated as 1/PS for those  
 210 exposed to short birth interval and 1/(1 - PS) for those who were not. The sample was then  
 211 reweighted by the IPTW and the balance of the covariates checked in the reweighted  
 212 sample.<sup>50 61</sup> Stabilization of weights was made to preserve the sample size of the original  
 213 data, reduce the effect of weights of either treated subjects with low propensity scores or  
 214 untreated subjects with high propensity scores, and provides appropriate improve the  
 215 estimation of variance estimates and confidence intervals for the treatment effect.<sup>51</sup> Since  
 216 the EDHS employed a two-stage, stratified, clustered random sampling, which is a complex  
 217 sampling procedure, sampling weights were also used to adjust for the non-proportional

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3 218 allocation of sample participants to different regions, including urban and rural areas, and  
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5 219 consider the possible differences in response rates.<sup>5</sup> Finally, a weighted logistic regression was  
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7 220 fit to estimate the effect of the treatment (short birth interval) on each outcome variable  
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9 221 (neonatal, infant, and under-five mortality). Estimation of the treatment effect on outcome  
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11 222 variables in the final model used the grand weight, which was formed as the product of the  
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13 223 survey weight and the stabilized weight. Literature has shown that combining a propensity  
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15 224 score method and survey weighting is necessary to estimate unbiased treatment effects which  
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17 225 are generalizable to the original survey target population.<sup>62</sup> The treatment effect on the outcome  
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19 226 variables was expressed as adjusted odds ratios (AORs) with a 95% confidence interval (CI).  
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21 227 Statistical analysis was performed using Stata version 14 statistical software (*StataCorp. Stata*  
22  
23 228 *Statistical Software: Release 14. College Station, TX: StataCorp LP. 2015*). Figure 2 presents  
24  
25 229 a schematic summary of the overall analysis procedure.

## 30 230 **Patient and public involvement**

31 231 Patients and/or the general public were not involved in the design, or conduct, or drafting of  
32  
33 232 this secondary analysis.

## 34 233 **Results**

### 35 234 **Respondents' characteristics**

36 235 Table 1 illustrates the baseline characteristics of the study participants. The occurrence of  
37  
38 236 neonatal mortality differed with maternal age at birth, with mortality rates being higher among  
39  
40 237 mothers aged  $\geq 35$  ( $p=0.021$ ). Neonatal mortality was also higher in rural than in urban areas  
41  
42 238 ( $p=0.004$ ). Similarly, infant mortality and under-five mortality were somewhat higher in rural  
43  
44 239 areas ( $p<0.001$ ). Under-five mortality was higher among uneducated mothers ( $p=0.027$ ) and in  
45  
46 240 mothers without access to mass media ( $p=0.043$ ). Mortality at all ages was higher among  
47  
48 241 infants with at least five siblings ( $p<0.0001$ ). Both infant and under-five mortality were slightly  
49  
50 242 higher among women from the richer household

243 **Table 1** The weighted distribution of neonatal, infant, and under-five child mortality by background characteristics, EDHS 2016

Variable	Neonatal Mortality		P-value	Infant Mortality		P-value	Under-five Mortality		P-value
	No (%)	Yes (%)		No (%)	Yes (%)		No (%)	Yes (%)	
Maternal age at the birth of the index child (in years)									
≤19	291 (3.2)	17 (5.8)	0.021	283 (3.1)	25 (6.5)	0.065	280 (3.1)	28 (6.0)	0.068
20-24	1950 (23.4)	52 (18.8)		1896 (23.2)	106 (23.7)		1877 (23.3)	125 (23.0)	
25-29	2587 (30.8)	67 (26.0)		2536 (30.8)	118 (27.6)		2516 (30.8)	138 (27.4)	
30-34	1836 (22.7)	59 (22.6)		1802 (22.9)	93 (21.0)		1781 (22.7)	114 (22.9)	
≥35	1533 (19.9)	56 (26.8)		1515 (20.0)	74 (21.2)		1500 (20.1)	89 (20.7)	
Maternal education									
Uneducated	5890 (73.9)	182 (75.0)	0.859	5759 (73.8)	313 (75.9)	0.157	5694 (73.9)	378 (75.5)	0.027
Primary	1744 (22.0)	54 (19.7)		1715 (22.0)	83 (20.8)		1704 (22.0)	94 (21.1)	
Secondary+	563 (4.1)	15 (5.3)		558 (4.2)	20 (3.3)		556 (4.1)	22 (3.4)	
Maternal occupation									
Not employed	5935 (72.9)	178 (74.6)	0.604	5807 (72.9)	306 (73.2)	0.575	5747 (72.9)	366 (73.6)	0.376
Employed	2267 (27.1)	73 (25.4)		2225 (27.1)	110 (26.8)		2207 (27.1)	128 (26.4)	
Husband education									
Uneducated	4186 (49.9)	145 (53.2)	0.092	4104 (50.0)	227 (50.1)	0.346	4057 (50.0)	274 (49.0)	0.154
Primary	2482 (37.3)	69 (34.6)		2437 (37.3)	114 (36.2)		2416 (37.3)	135 (37.1)	
Secondary+	1529 (12.8)	37 (12.2)		1491 (12.7)	75 (13.7)		1481 (12.7)	85 (13.9)	
Husband occupation									
Not employed	873 (7.7)	22 (6.6)	0.339	846 (7.6)	49 (7.7)	0.421	838 (7.6)	57 (7.4)	0.482
Employed	7324 (92.3)	229 (93.4)		7186 (92.4)	367 (92.3)		7116 (92.4)	437 (92.6)	
Wealth									
Poorest	3238 (25.4)	109 (15.6)	0.248	3163 (25.3)	184 (21.5)	0.015	3118 (25.3)	229 (22.2)	<0.001
Poorer	1430 (23.4)	48 (22.5)		1400 (23.4)	78 (22.2)		1390 (23.5)	88 (21.3)	
Middle	1167 (21.1)	36 (22.8)		1147 (21.3)	56 (20.0)		1136 (21.2)	67 (20.7)	
Richer	1025 (17.8)	30 (24.8)		1000 (17.7)	55 (23.3)		993 (17.6)	62 (23.7)	
Richest	1337 (12.3)	28 (14.3)		1322 (12.3)	43 (13.0)		1317 (12.3)	48 (12.1)	

1										
2										
3										
4	Total number of preceding									
5	child									
6	≤2	2627 (31.0)	57 (27.0)	<0.001	2591 (31.0)	93 (27.1)	<0.001	2575 (31.1)	109 (26.4)	<0.001
7	3-4	2561 (30.6)	77 (22.0)		2505 (30.7)	133 (23.6)		2482 (30.7)	156 (24.6)	
8	≥5	3009 (38.4)	117 (50.9)		2936 (38.2)	190 (49.3)		2897 (38.2)	229 (49.0)	
9	Residence									
10	Urban	1264 (8.8)	22 (12.0)	0.004	1251 (8.9)	35 (8.7)	<0.001	1248 (9.0)	38 (7.7)	<0.001
11	Rural	6933 (91.2)	229 (88.0)		6781 (91.1)	381 (91.3)		6706 (91.0)	456 (92.3)	
12										
13	Region									
14	Tigray	765 (6.0)	23 (6.1)	0.516	762 (6.1)	26 (4.1)	0.145	752 (6.1)	36 (5.3)	0.039
15	Afar	808 (1.0)	20 (0.7)		779 (1.0)	49 (1.2)		762 (1.0)	66 (1.4)	
16	Amhara	774 (18.7)	26 (22.2)		765 (18.8)	35 (17.9)		761 (18.9)	39 (17.2)	
17	Oromia	1270 (44.7)	37 (45.5)		1245 (44.6)	62 (47.9)		1235 (44.6)	72 (47.1)	
18	Somali	1231(5.0)	52 (6.3)		1210 (4.9)	73 (5.4)		1203 (4.9)	80 (5.1)	
19	Benishangul-Gumuz	711 (1.1)	24 (1.0)		690 (1.1)	45 (1.3)		682 (1.1)	53 (1.4)	
20	SNNPR***	1021 (21.2)	23 (16.0)		995 (21.1)	49 (20.4)		987 (21.1)	57 (20.9)	
21	Gambella,	541 (0.2)	16 (0.2)		531 (0.2)	26 (0.2)		522 (0.2)	35 (0.2)	
22	Harari	443 (0.2)	13 (0.2)		429 (0.2)	27 (0.2)		427 (0.2)	29 (0.2)	
23	Addis Ababa	246 (1.5)	6 (1.2)		245 (1.5)	7 (1.0)		245 (1.5)	7 (0.8)	
24	Dire Dawa	387 (0.4)	11 (0.4)		381(0.4)	17 (0.4)		378 (0.4)	20 (0.4)	
25										
26	Access to mass media									
27	Yes	1408 (15.8)	36 (23.2)	0.240	1383 (15.9)	61 (20.2)	0.177	1376 (15.9)	68 (19.0)	0.043
28	No	6789 (84.2)	215 (76.8)		6649 (84.1)	355 (79.8)		6578 (84.1)	426 (81.0)	
29										
30	Decision making autonomy									
31	Yes	6014 (77.7)	179 (74.9)	0.469	5898 (77.8)	295 (73.8)	0.258	5848	345	0.072
32	No	2183 (22.3)	72 (25.1)		2134 (22.2)	121 (26.2)		2106	149	
33										
34										

244 \*\*\*SNNPR= Southern Nations, Nationalities, and Peoples' Region; EDHS= Ethiopia Demographic and Health Survey

## 245 **Balance diagnostics**

## 246 **Propensity score balance**

247 Figure 3 presents the density plot of women in the treatment group (dashed lines) and control  
248 group (solid lines) before and after weighting. It reveals that an adequate balance of the  
249 propensity score distribution between the treatment groups after weighting (Figure 3).

## 250 **Covariate balance**

251 After weighting adjustment, standardized differences of covariates were all less than 0.1 (10%),  
252 showing comparability between women with and without short birth interval  
253 (Supplementary Material II).

## 254 **Treatment effect estimation**

255 The prevalence of short birth interval in Ethiopia was 45.8% (95% CI: 42.91–48.62). Table 2  
256 presents the estimated effects of short birth interval on neonatal, infant, and under-five  
257 mortality. The adjusted estimated odds of neonatal mortality were 85% higher among women  
258 who experienced short birth interval (AOR=1.85, 95% CI=1.19, 2.89) than those who did not.  
259 Similarly, the odds of infant mortality were two times higher (AOR=2.16, 95% CI=1.49, 3.11)  
260 among women who experienced short birth interval compared with women who did not. The  
261 odds of under-five child mortality were two times (AOR=2.26, 95% CI= 1.60, 3.17) higher  
262 among women who were exposed to short birth interval compared with women who were not.

263

**Table 2** The effect of short birth interval on neonatal, infant, and under-five mortality in Ethiopia, EDHS 2016

Treatment variable	Neonatal mortality		AOR (95% CI)
	No (%)*	Yes (%)*	
Short birth interval			
No	4166 (54.5)	95 (46.1)	Ref
Yes	4031 (45.5)	156 (53.9)	1.85 (1.19, 2.89)
	Infant mortality		
Short birth interval	No (%)	Yes (%)	
No	4126 (54.9)	135 (40.5)	Ref
Yes	3906 (45.1)	281 (59.5)	2.16 (1.49, 3.11)
	Under-Five mortality		
Short Birth interval	No (%)	Yes (%)	
No	4099 (55.1)	162 (39.3)	Ref
Yes	3855 (44.9)	332 (60.7)	2.26 (1.60, 3.17)

EDHS= Ethiopia Demographic and Health Survey; AOR= Adjusted Odds Ratio; CI= Confidence Interval; Ref= reference group; (%)\*=percentage are weighted

## Discussion

To our knowledge, this study provides the first comprehensive assessment of the effect of short birth interval on neonatal, infant, and under-five mortality using the WHO recommendation to define short birth interval and applying rigorous analytical techniques to adjust for potential confounders. This study provides evidence that short birth interval is associated with neonatal, infant, and under-five mortality in Ethiopia. These findings will help policy makers and program planners formulate targeted interventions to increase birth intervals and contribute to achieving the GTPE and SDGs target of reducing neonatal, infant, and under-five mortality.<sup>16 15</sup>

In this current study, short birth interval was found to be associated with higher odds of neonatal mortality. This finding is consistent with evidence from the previous studies<sup>23 25 63-66</sup> which have shown a higher risk of neonatal mortality among women with a short birth interval. However, the definition of short birth interval (i.e., <33 months) used in the current



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3 282 study was in line with the WHO definition and longer than those used in previous studies (i.e.,  
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5 283 ranges from <18 to 24 months). Short birth interval could result in adverse neonatal child health  
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8 284 outcomes, such as death, by causing maternal nutritional depletion, specifically folate  
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10 285 depletion.<sup>67 68</sup> The maternal nutritional depletion hypothesis states that a short birth-to-  
11  
12 286 pregnancy/birth interval worsens the mother's nutritional status because of inadequate time to  
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14  
15 287 recover from the physiological stresses of the subsequent pregnancy.<sup>69</sup> This may compromise  
16  
17 288 maternal nutritional status and ability to support fetal growth, which could result in fetal  
18  
19 289 malnutrition and increased risk of infection and death during childhood.<sup>67</sup> Women with short  
20  
21 290 birth interval may also be less likely to attend postnatal care, which is vital for early detection  
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23  
24 291 and treatment of neonatal and maternal health problems. Evidence has shown that the majority  
25  
26 292 of mothers and newborns in low- and middle-income countries do not receive optimal postnatal  
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28  
29 293 care<sup>70</sup>, yet close to half of the newborn deaths occurred within the first 24 hours after birth, a  
30  
31 294 critical time where mothers and their babies should get their first postnatal care.<sup>71</sup>  
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33  
34 295 Our study found that infant mortality was two times higher among women who experienced  
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36 296 short birth interval compared with women who did not. Our finding was consistent with  
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38 297 evidence from Ethiopia,<sup>18 32</sup> Kenya,<sup>72 73</sup> Nepal,<sup>74</sup> and Iran<sup>75</sup> although the cut-off point for  
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40  
41 298 short birth interval in the current study was longer than the previous studies. The  
42  
43 299 abovementioned previous studies also documented that the risk of infant mortality was  
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45 300 higher among women who experienced short birth interval compared with women who did  
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47  
48 301 not. One of the possible reasons for the effect of short birth interval on infant mortality could  
49  
50 302 be low maternal motivation to breastfeed (for example, if the pregnancy was unintended).<sup>76</sup>  
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52 303 Maternal perception of being undernourished due to a short birth interval may also influence  
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54 304 her infant feeding choices, such as the duration and intensity of breastfeeding and  
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57 305 supplemental feeding of the infant. This could in turn affect infants' nutritional status, their  
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3 306 resistance to infection, and may expose them to death.<sup>76-79</sup> The abovementioned links  
4  
5 307 between short birth interval and neonatal mortality also apply to infant mortality.  
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8 308 Short birth interval doubled the odds of under-five mortality compared with non-short birth  
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10 309 interval. Despite not using the WHO recommendation<sup>1</sup> of less than 33 months to define short  
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12 310 birth interval, the existing literature<sup>24 30 63 64 80</sup> also supported our finding. The likely mechanism  
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14 311 through which short birth interval affects under-five mortality could be competition between  
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16 312 closely spaced siblings for limited household resources, maternal attention, and cross-  
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18 313 infection.<sup>76</sup> Moreover, children born within a short birth interval may not receive their  
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20 314 vaccination at all or complete their booster series, which is one of the risk factors that  
21  
22 315 exposed children to the infectious disease and its associated death.<sup>81-83</sup> Women with short  
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24 316 birth interval could be burdened with caring for highly dependent children<sup>77</sup> and other  
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26 317 domestic activities. As a result, they may lack the time and motivation to take children to  
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28 318 the health facility for vaccination and other services.  
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34 319 The results of this study need to be interpreted within the limitations of the observational  
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36 320 study design. Due to the cross-sectional nature of the study, temporal associations between  
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38 321 short birth interval and neonatal, infant, and under-five mortality may not be established.  
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40 322 The second limitation of our study could be associated with the nonrandomized design of  
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42 323 the study. Propensity scores based analysis, IPTW, cannot account for unknown confounders  
43  
44 324 in the same way that a randomised trial can. As a result, the effect of residual confounders  
45  
46 325 may not be avoided. However, the application of IPTW mimics a randomized clinical trial  
47  
48 326 by matching two comparison groups using a conditional probability of receiving exposure  
49  
50 327 (short birth interval in this case) given a set of covariates. The study has also additional  
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52 328 strengths, such as using data from a nationally representative survey with large sample size.  
53  
54 329 The application of DAGs,<sup>48 49 84</sup> a graphical tool used to identify minimum adjustment sets,  
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3 330 which defined the set of explanatory variables for the propensity scores model was another  
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5 331 strength of this study.  
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## 8 332 **Conclusion**

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12 333 This study provides evidence that short birth interval has a significant effect on neonatal,  
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14 334 infant, and under-five mortality in Ethiopia. Interventions aiming to reduce neonatal, infant,  
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16 335 and under-five mortality in Ethiopia should target the prevention of short birth interval.  
17  
18 336 These could be achieved through creating awareness on the optimum birth interval and the  
19  
20 337 negative impacts of shorter birth intervals on the health of children. Further expanding the  
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22 338 availability and accessibility of family planning services also help women achieve optimum  
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24 339 birth interval. Birth interval counseling as per the WHO recommendation should be  
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26 340 integrated into the maternal and child health services as part of the child survival  
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28 341 intervention.  
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57  
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## 351 **Contributors**

352 All authors (DMS, CC, EGH, and DL) contributed to the design of the study and the  
353 interpretation of data. DM performed the data analysis and drafted the manuscript. All  
354 authors (DMS, CC, EGH, and DL) read, critically revised, and approved the final  
355 manuscript.

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## 358 **Competing interests**

359 The authors declare that they have no competing interests.

## 360 **Ethics approval**

361 The 2016 EDHS was approved by the National Research Ethics Review Committee of  
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## 365 **Consent for publication**

366 Not required

## 367 **Provenance and peer review**

368 Not commissioned; externally peer reviewed.

## 369 **Data availability statement**

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2  
3 370 The dataset is available from The DHS Program repository at the following link:  
4  
5 371 [https://www.dhsprogram.com/data/dataset/Ethiopia\\_Standard-DHS\\_2016.cfm?flag=0](https://www.dhsprogram.com/data/dataset/Ethiopia_Standard-DHS_2016.cfm?flag=0).  
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4 590 **Figure Legend**  
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7 591 **Figure 1** Direct Acyclic Graph (DAG) used to select controlling variables  
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10 592 **Figure 2** Schematic presentation of the overall steps followed in the analysis  
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13 593 **Figure 3** Balance of propensity scores before and after weighting across treatment and  
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15 594 comparison groups  
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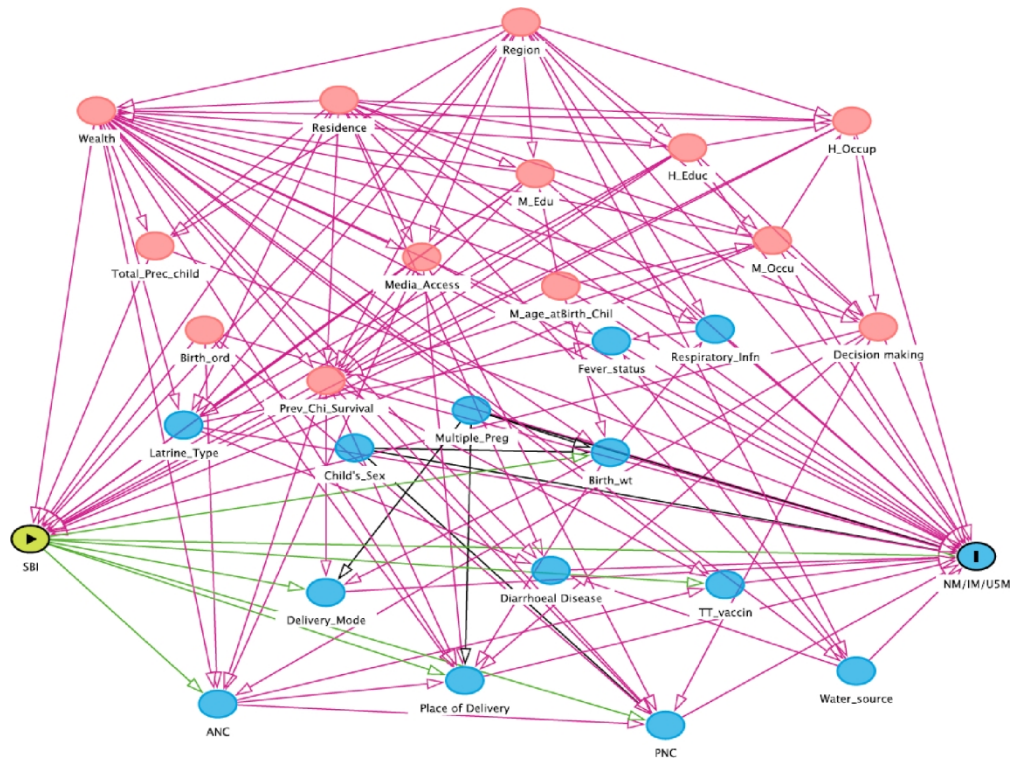


Figure 1 Direct Acyclic Graph (DAG) used to select controlling variables

157x118mm (300 x 300 DPI)

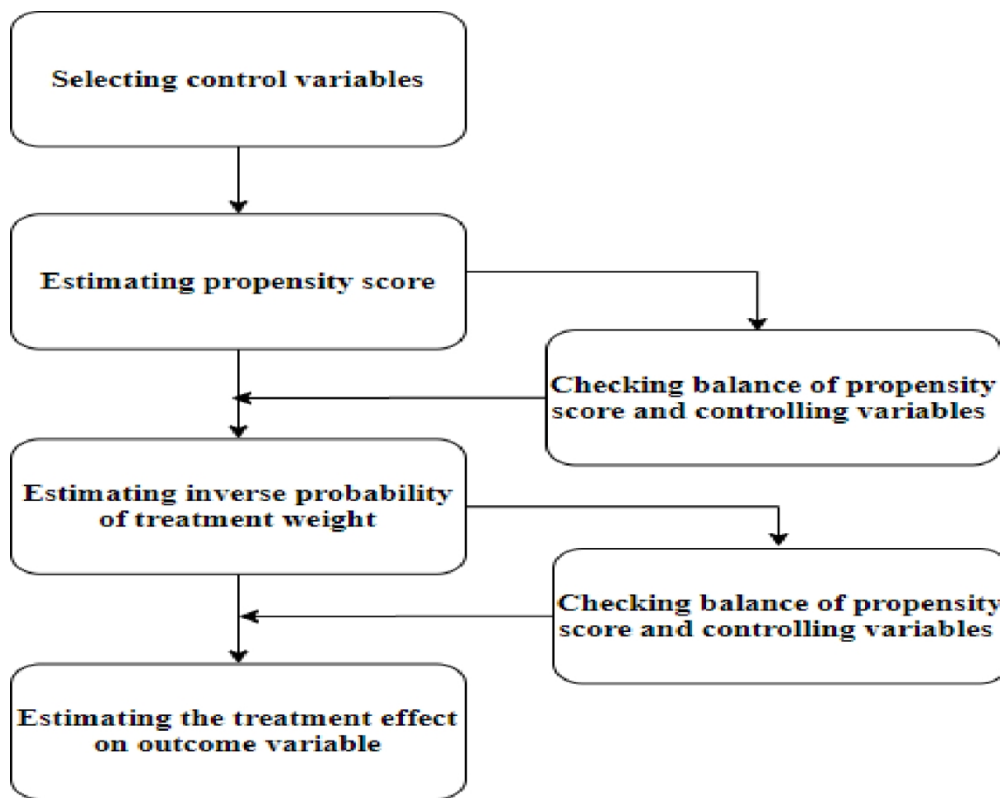


Figure 2 Schematic presentation of the overall steps followed in the analysis

115x90mm (300 x 300 DPI)



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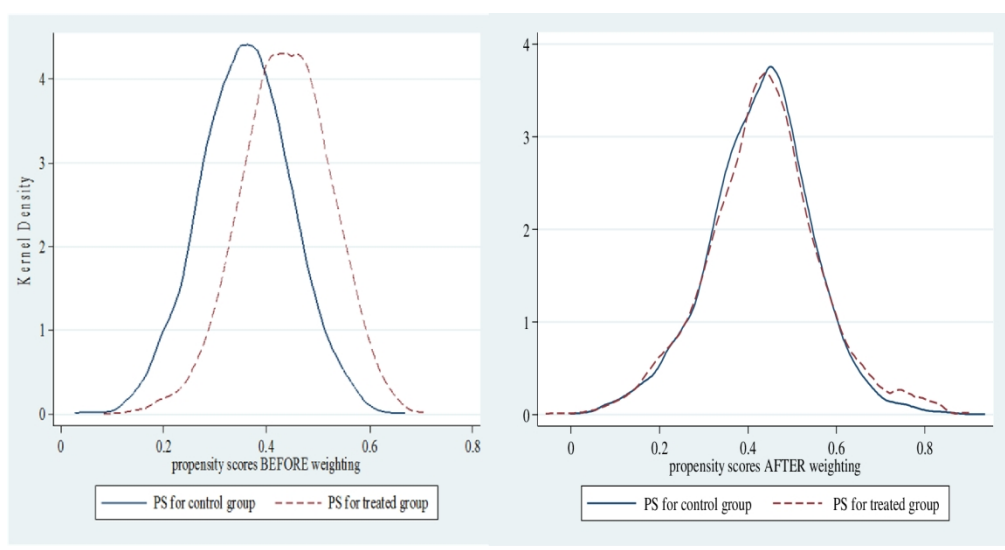


Figure 3 Balance of propensity scores before and after weighting across treatment and comparison groups; PS=propensity score

165x87mm (300 x 300 DPI)

## Supplemental Material I

**Table 1** Variables included in Direct Acyclic Graph

Category	Variables	Definition
<b>Maternal background characteristics</b>	Maternal age at birth of the index child (in years)	Maternal age at birth of the index child, which was considered as a continuous variable. It was also categorized the descriptive section of the results (1= $\leq 19$ , 2= 20-24, 3=25-29, 4=30-34, and 5= $\geq 35$ ).
	Educational level	Maximum educational level (1= Uneducated, 2=Primary and 3=Secondary+)
	Employment status	Maternal employment status (1=Not Employed; 2=Employed))
	Place of residence	Place of residence (1=Urban; 2=Rural)
	Region	Region of residence (1=Tigray, 2=Afar, 3=Amhara, 4=Oromia, 5=Somali, 6=Benishangul-Gumuz, 7=SNNPR*, 8=Gambella, 9=Harari, 10=Addis Ababa, 11=Dire Dawa) *SNNPR= Southern Nations, Nationalities, and Peoples' Region
	Decision making autonomy	Coded as 'yes' if the women were involved in all decisions regarding their own health care, major household purchases and visits to her family or relatives (1=Yes, 2=No).
<b>Husband background characteristics</b>	Husband's education	Maximum educational level of the husband (1= Uneducated, 2= Primary, 3= Secondary+)
	Husband's occupation	1= Not employed, 2=Employed
<b>Household characteristics</b>	Access to media	1=Access to media, 2= Have no access to media
	Wealth index	The wealth index provided with the dataset was used. DHS program provides a composite index of household amenities based on the principal component analysis (PCA) and classified the population into quintiles: (1st quintile (Poorest); 2nd quintile; 3rd quintile; 4th quintile and 5th quintile (Richest). A quintile is used as a measure of its relative socioeconomic level (i.e., 1=Poorest; 2=Poorer; 3=Middle; 4=Richer; 5=Richest)

<b>Maternal health status and healthcare-related variables</b>	Antenatal care	Women’s antenatal care utilization categorized as 1=No visit, 2=At least one visit, 3= ≥ Four visits
	Place of delivery	1= Health facilities, 2=Home
	Postnatal care	Women received check-up at least once within 48 hours after delivery by a skilled provider; categorized as 1=Yes, 2=No
	TT vaccination	Women received at least two doses of the immunization during pregnancy (1=Yes, 2=No)
<b>Neonatal, infant and child characteristics</b>	Sex	Child sex (1=Male, 2=Female)
	Multiple pregnancy	1=Yes, 2=No
	Birth weight	1=Below average, 2=Average, 3=Above average
	Mode of delivery	1= Caesarean section, 2= Non caesarean section
	Survival status of the preceding child	1= Yes, 2=No
	Total number of children born before the index child	Total number of children born before the index child was considered as a continuous variable. For the descriptive statistics, this variable was categorized into 1= ≤2, 2= 3-4, and 3= ≥5.  This was done after checking for the linearity assumption with the log-odds of short birth interval, which is a binary response variable. Multicollinearity was also checked among the exposure variables using the variance inflation factor (VIF). When the values of VIF were lower than 10, then the collinearity problem was considered unlikely. The VIF for birth order was 18.15 and for the total number of children born before the index child was 16.26, which indicates the presence of collinearity. Therefore, we removed the variable birth order from the model and the VIF became less than 3 for each variable included in the model.
	Birth order	Birth order is the order number of the births from first to last. Twins are given the same birth order, but the birth order of a child born after twins will be the total number of births preceding plus one.
	Diarrhoeal Disease	1= Yes, 2=No
Fever	1=Yes, 2=No	
Respiratory infection	1=Yes, 2=No	

<b>Environmental factors</b>	Source of water	1= Piped water, 2= Other improved (protected spring and well, and rain water), 3= Unimproved (river, pond, unprotected spring and well).
	Latrine facility	1 = Improved (access to flush toilet, ventilated improved pit latrine, traditional pit latrine with a slab, or composting toilet and does not share this facility with other households), 2=unimproved.

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## Supplemental Material II

**Table 2** Standardized difference before and after weighting the propensity score

Variable	Standardized difference	
	Before weighting	After weighting
Maternal age at the birth of the index child (in years)*	-0.392	0.022
Maternal education		
Uneducated	0.178	0.009
Primary	-0.112	-0.017
Maternal occupation		
Not employed	0.128	0.005
Husband education		
Uneducated	0.148	0.012
Primary	-0.041	0.003
Husband occupation		
Not employed	0.159	0.006
Wealth		
Poorest	0.332	-0.004
Poorer	-0.002	0.008
Middle	-0.070	0.005
Richer	-0.061	-0.007
Total number of preceding child*	0.207	-0.006
Survival status of preceding child		
Yes	-0.029	-0.004
Residence		
Urban	-0.239	-0.006
Region		
Tigray	-0.207	0.004
Afar	0.186	0.008
Amhara	-0.282	0.014
Oromia	-0.006	0.003
Somali	0.402	-0.003
Benishangul-Gumuz	0.061	-0.006
SNNPR**	-0.069	-0.005
Gambella,	-0.087	-0.009
Harari	-0.001	-0.009
Addis Ababa	-0.180	0.014
Access to mass media		
Yes	-0.201	-0.002
Decision making autonomy		
No	0.067	-0.009

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3 \*Maternal age at the birth of the index child (in years) and total number of the preceding  
4 child were considered as continuous variables; \*\*SNNPR= Southern Nations, Nationalities,  
5 and Peoples' Region  
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## STROBE 2007 (v4) Statement—Checklist of items for the study

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3, 4, 5, & 6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6, 7, & 8
Data sources/ 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	6, 7, & 8
Bias	9	Describe any efforts to address potential sources of bias	8, 9, & 10
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6, 7, & 8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8, 9, 10, & 11
		(b) Describe any methods used to examine subgroups and interactions	8, 9, 10, & 11
		(c) Explain how missing data were addressed	N/A
		(d) If applicable, describe analytical methods taking account of sampling strategy	8, 9, 10, & 11
		(e) Describe any sensitivity analyses	8, 9, 10, & 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	11, 12, & 13
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11, 12, & 13
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	9 and 11, 12, & 13
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	15
		(b) Report category boundaries when continuous variables were categorized	N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	15 & 16
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	17 & 18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15, 16, 17, & 18
Generalisability	21	Discuss the generalisability (external validity) of the study results	15, 16, 17, & 18
<b>Other information</b>			
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	19

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**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 [www.strobe-statement.org](http://www.strobe-statement.org).



# BMJ Open

## The effects of short birth interval on neonatal, infant and under-five child mortality in Ethiopia: a nationally representative observational study using inverse probability of treatment weighting

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Article Type:	Original research
Date Submitted by the Author:	05-Jul-2021
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<b>Primary Subject Heading</b>:	Public health
Secondary Subject Heading:	Epidemiology, Obstetrics and gynaecology, Paediatrics, Reproductive medicine
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, Maternal medicine < OBSTETRICS, Community child health < PAEDIATRICS

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4 1 **The effects of short birth interval on neonatal, infant and**  
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13 4 **probability of treatment weighting**  
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18 5 Desalegn Markos Shifti<sup>1,2,\*</sup>, Catherine Chojenta<sup>2</sup>, Elizabeth G. Holliday<sup>3</sup>, Deborah Loxton<sup>2</sup>  
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## 17 **Abstract**

18 **Objective** To assess the effect of short birth interval on neonatal, infant, and under-five  
19 mortality in Ethiopia.

20 **Design** A nationally representative cross-sectional survey.

21 **Setting** This study used data from the Ethiopia Demographic and Health Survey (EDHS) 2016.

22 **Participants** A total of 8,448 women who had at least two live births during the five years  
23 preceding the survey were included in the analysis.

24 **Outcome measures** Neonatal mortality (death of the child within 28 days of birth), infant  
25 mortality (death between birth and 11 months), and under-five mortality (death between birth  
26 and 59 months) were the outcome variables.

27 **Methods** Weighted logistic regression analysis based on inverse probability of treatment  
28 weights (IPTW) was used to estimate exposure effects adjusted for potential confounders.

29 **Results** The adjusted odds of neonatal mortality were about 85% higher among women with  
30 short birth interval (AOR=1.85, 95% CI= 1.19, 2.89) than those without. The odds of infant  
31 mortality were two-fold higher (AOR=2.16, 95% CI= 1.49, 3.11) among women with short  
32 birth interval. The odds of under-five child mortality were also about two times higher  
33 (AOR=2.26, 95% CI= 1.60, 3.17) higher among women with short birth interval.

34 **Conclusion** Short birth interval has a significant effect on neonatal, infant, and under-five  
35 mortality in Ethiopia. Interventions targeting short birth interval are warranted to reduce  
36 neonatal, infant, and under-five mortality.

### 38 **Strengths and limitations of this study**

- 39 • The application of inverse probability of treatment weights (IPTW) mimics a randomized  
40 clinical trial by matching two comparison groups using a conditional probability of  
41 receiving exposure (short birth interval in this case) given a set of covariates.
- 42 • The study has also additional strengths, such as using data from a nationally representative  
43 survey with a large sample size.
- 44 • The application of DAGs, a graphical tool used to identify minimum adjustment sets, which  
45 defined the set of explanatory variables for the propensity scores model was another  
46 strength of this study.
- 47 • Due to the cross-sectional nature of the study, temporal associations between short birth  
48 interval and neonatal, infant, and under-five mortality may not be established.
- 49 • Another limitation of our study could be associated with the nonrandomized design of the  
50 study—propensity score-based analysis, IPTW, cannot account for unknown confounders  
51 in the same way that a randomised trial can, so the effect of residual confounders may not  
52 be avoided.

## 54 Introduction

55 Short birth interval, defined as a birth-to-birth interval of less than 33 months,<sup>1</sup> is a key public  
56 health problem with an estimated prevalence of 45.8% in Ethiopia.<sup>2</sup> Previous studies<sup>2-4</sup> have  
57 revealed the multifactorial nature of short birth interval, its spatial variation, and  
58 socioeconomic inequality in Ethiopia. Only about one-third of women in Ethiopia use modern  
59 contraceptives, which can prevent short birth interval.<sup>5</sup> Literature has also shown the effects of  
60 short birth interval may include, but are not limited to, preterm birth,<sup>6 7</sup> low birth weight,<sup>6 7</sup>  
61 small sizes for gestational age,<sup>6</sup> congenital anomalies,<sup>8 9</sup> autism,<sup>10</sup> miscarriage,  
62 preeclampsia, and premature rupture of membranes.<sup>11 12</sup>

63 Neonatal, infant, and under-five mortality are defined as the death of a child within 28 days of  
64 birth, before the age of 1 year, and before five years, respectively.<sup>5</sup> These mortality outcomes  
65 are regarded as a highly sensitive (proxy) measure of population health, a country's poverty  
66 and socioeconomic development status, and the availability and quality of health services and  
67 medical technology.<sup>13 14</sup>

68 The Sustainable Development Goal (SDG) 3.2 states that all countries should aim to reduce  
69 the neonatal mortality rate (NMR) to 12 deaths per 1000 live births or fewer, and reduce under-  
70 five mortality to 25 deaths per 1000 live births or fewer, by 2030.<sup>15</sup> The Growth and  
71 Transformation Plan of Ethiopia (GTPE) II also targets reductions in neonatal, infant, and  
72 under-five mortality rates, from 28 per 1000 live births, 44 per 1000 live births, and 64 per  
73 1000 live births in 2014/15 to 10, 20, and 30 per 1000 live births by 2019/20, respectively.<sup>16</sup>  
74 However, the 2019 Ethiopia Mini Demographic and Health Survey (EMDHS) report revealed  
75 that the neonatal, infant, and under-five mortality rates in Ethiopia were 30, 43, and 55 deaths  
76 per 1,000 live births, respectively: still much higher than GTPE targets.<sup>16 17</sup>

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3 77 Literature from Ethiopia has shown that neonatal, infant, and under-five mortality are  
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5 78 associated with maternal education,<sup>18 19</sup> lack of antenatal care,<sup>20</sup> home delivery,<sup>21</sup> preterm  
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7 79 birth,<sup>20 22</sup> low birth weight,<sup>21 22</sup> multiple births,<sup>18 20 23 24</sup> sex of the child,<sup>18 20 23-26</sup> wealth status,<sup>27</sup>  
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9 80 <sup>28</sup> place of residence,<sup>21 24 25</sup> sources of drinking water,<sup>28</sup> and lack of access to an improved toilet  
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11 81 facility.<sup>29</sup>  
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15 82 Although previous studies<sup>18-20 24 25 28-32</sup> have suggested birth interval as one factor influencing  
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17 83 neonatal, infant, under-five mortality, these studies have several limitations. Of the key  
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19 84 limitations is that these studies<sup>18-20 24 25 28-32</sup> did not use the World Health Organization (WHO)  
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21 85 recommended<sup>1</sup> definition of short birth interval. Understanding the impact of short birth  
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23 86 interval on neonatal, infant, and under-five mortality, using the WHO definition,<sup>1</sup> is necessary  
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25 87 for the formulation of valid, consistent policies and health planning strategies and interventions  
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27 88 to improve child health outcomes. Second, women who were not eligible to provide birth  
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29 89 interval information (i.e., those who had given birth only once) were included in the analysis  
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31 90 of some studies.<sup>20 25 29</sup> This may result in underestimation or obscuration of the true effect of  
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33 91 birth interval on child mortality. Third, even among studies using the same definition of short  
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35 92 birth interval, findings have been inconsistent.<sup>20 25</sup> One of the studies using national data<sup>20</sup> did  
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37 93 not control for a range of potential confounders including maternal education, wealth status,  
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39 94 number of children, and region of residence, even though these data were available in the  
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41 95 datasets used for analysis. Similarly, another previous study<sup>30</sup> that used national data did not  
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43 96 condition on maternal occupation, husband education, husband occupation, the total number of  
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45 97 preceding children, regions, access to mass media, and women's decision making autonomy.  
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47 98 In addition, various studies did not consider short birth interval as a potential predictor of  
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49 99 neonatal,<sup>22 26 27 33-36</sup> infant,<sup>19 37 38</sup> and under-five mortality<sup>39-42</sup> in their studies.  
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3 100 Generally, the effect of short birth interval, as per the most recent WHO recommendation,<sup>1</sup> on  
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5 101 neonatal, infant, and under-five mortality has not been investigated in Ethiopia. Evidence  
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7 102 regarding the effect of short birth interval is required for informed decision making by policy  
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9 103 makers and health program planners. This paper aimed to assess the effect of short birth interval  
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11 104 on neonatal, infant, and under-five mortality using the most recent WHO definition and  
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13 105 adjusting for a comprehensive set of potential confounders.  
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## 16 17 106 **Methods**

### 18 19 20 107 **Study design and study area**

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23 108 This analysis used data from the Ethiopia Demographic and Health Survey (EDHS) 2016. The  
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25 109 EDHS is a nationally representative cross-sectional study conducted in nine geographical  
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27 110 regions (Tigray, Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations  
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29 111 Nationalities and Peoples (SNNP), Gambela, and Harari) and two administrative cities (Addis  
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31 112 Ababa and Dire Dawa). A two-stage, stratified, clustered random sampling design was  
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33 113 employed to collect data from women who gave birth within the five years preceding the  
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35 114 survey. Further descriptions of the sampling procedure for the EDHS are presented elsewhere.<sup>5</sup>  
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38 115 A total of 8,448 women who had at least two live births during the five years preceding the  
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40 116 2016 survey were included in the analysis. When women had more than two births in the five  
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42 117 years preceding the survey, the birth interval between the most recent index child and the  
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44 118 immediately preceding child was considered for all the study participants.  
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### 48 119 **Variables**

#### 49 50 120 **Outcome variables**

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53 121 The outcome variables in the current study were neonatal mortality (death of the child within  
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55 122 28 days of birth), infant mortality (death between birth and 11 months), and under-five  
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3 123 mortality (death between birth and 59 months).<sup>5 43</sup> These outcomes were coded as binary  
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5 124 variables (1/0).

### 8 125 **Treatment/exposure variable**

10 126 Short birth interval was the treatment variable and was defined as a birth-to-birth interval of  
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13 127 less than 33 months as per the WHO definition.<sup>1</sup> A preceding birth interval, the amount of time  
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15 128 between the birth of the child under study (index child) and the immediately preceding birth,  
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17 129 was considered in this study. Women's birth interval data were collected by extracting the date  
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19 130 of birth of their biological children data from the children's birth /immunization certificate,  
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22 131 and/or asking for information regarding their children's date of birth from the women. Mothers  
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24 132 were asked to confirm the accuracy of the information before documenting children's date of  
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26 133 birth from children's birth/immunization certificates. This crosschecking was performed to  
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29 134 avoid errors, since in some cases the documented birth date may represent the date when the  
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31 135 birth was recorded, rather than the actual birth date. In the absence of children's birth  
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33 136 certificates, information regarding children's date of birth was obtained from their mothers.  
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36 137 Further information regarding birth interval data collection is provided elsewhere.<sup>2 3 44</sup>

### 38 138 **Control variables**

40 139 After reviewing relevant literature,<sup>2 18-21 23-25 28 29 39 45 46</sup> Direct Acyclic Graphs (DAGs) were  
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43 140 constructed using DAGitty 3.0<sup>47</sup> to identify confounders for the association between short  
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45 141 birth interval and neonatal, infant, and under-five child mortality. Adjustment for such  
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47 142 confounders is necessary to estimate the unbiased effect of SBI on neonatal, infant, and  
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49 143 under-five mortality (figure 1). DAG is a formal system of mapping variables and the direction  
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52 144 of causal relationships among them.<sup>48 49</sup> This graphical representation of causal effects among  
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54 145 variables helps understand whether bias is potentially reduced or increased when conditioning  
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57 146 on covariates. Moreover, it illustrates covariates that lie in the causal pathway between the  
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59 147 treatment and outcomes, which should not be included in the analysis as a confounder. These

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3 148 variables are indicated by green lines in Figure 1. This is because a propensity score that  
4  
5 149 includes covariates affected by the treatment (i.e., variables on the causal pathway between  
6  
7  
8 150 treatment and outcome) obscures part of the treatment effect that one is trying to estimate.<sup>50</sup>  
9  
10 151 Identified confounders were maternal age at the birth of the index child, maternal education,  
11  
12 152 maternal occupation, husband's education, husband's occupation, household wealth status,  
13  
14 153 survival status of the preceding child, the total number of the preceding child, place of residence  
15  
16  
17 154 (urban/rural), regions, access to media, and decision making autonomy. A list of all variables  
18  
19 155 considered in the DAG is provided in Supplementary Material I.

20  
21  
22 156 A yellowish-green circle with a triangle at its centre indicates the main treatment/exposure  
23  
24 157 variable, a blue circle with a vertical bar at its centre indicates the outcome variable, light red  
25  
26  
27 158 circles indicate ancestors of exposure and outcome (i.e., confounders). Blue circles indicate the  
28  
29 159 ancestors of the outcome variable. Green lines indicate a causal pathway. Red lines indicate  
30  
31 160 open paths by which confounding may occur; this confounding can be removed by adjusting  
32  
33 161 for one or several variables on the pathway.

## 34 162 **Data analyses**

35  
36  
37  
38 163 Participants' characteristics were described using frequency with percent. P-values were  
39  
40 164 calculated using Pearson's chi-squared test. Given that the outcomes (i.e., neonatal, infant, and  
41  
42 165 under-five mortality) were relatively infrequent, the unbiased effect of short birth interval on  
43  
44 166 each outcome was estimated using propensity scores (PS) with a stabilized method of inverse  
45  
46 167 probability of treatment weighting (IPTW). A previous study<sup>51</sup> has shown that IPTW with  
47  
48 168 stabilized weights preserves the sample size of the original data, provides an appropriate  
49  
50 169 estimation of the variance of the main effect, and maintains an appropriate type I error rate.  
51  
52  
53 170 The other methods, such as IPTW with normalized weight and greedy algorithm with 1:1  
54  
55 171 matching methods, are discussed elsewhere.<sup>52-54</sup> A propensity score is defined as the  
56  
57 172 probability of treatment assignment given observed baseline covariates (described in  
58  
59  
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1  
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3 173 Supplementary Material II).<sup>54</sup> Propensity scores are used to estimate treatment effects on  
4  
5 174 outcomes using observational data when confounding bias due to non-random treatment  
6  
7 175 assignment is likely.<sup>50</sup> Inverse probability of treatment weighting weights the entire study  
8  
9 176 sample by the inverse of the propensity score;<sup>55</sup> a differential amount of information is used  
10  
11 177 from each participant, depending on their conditional probability of receiving treatment. This  
12  
13 178 means observations are less likely to be lost than when using matching for confounder  
14  
15 179 adjustment.<sup>56 57</sup> Propensity scores are a robust alternative to covariate adjustment when the  
16  
17 180 outcome variable is rare, resulting in data sparsity and estimation issues in multivariable  
18  
19 181 models.<sup>57</sup> In this study, the weighted prevalence of the outcome variables of neonatal, infant,  
20  
21 182 and under-five mortality were 2.9% (95% CI: 2.39, 3.61), 4.8% (95% CI: 4.11, 5.58), and 5.5%  
22  
23 183 (95% CI: 4.73, 6.44), respectively.

24  
25  
26 184 The analysis procedure was as follows. First, the propensity score was estimated using a  
27  
28 185 logistic regression model in which treatment assignment (short birth interval vs. non-short birth  
29  
30 186 interval) was regressed on the 11 covariates identified using the DAG. The balance of measured  
31  
32 187 covariates/confounders was then assessed across treatment groups (i.e., women with short birth  
33  
34 188 interval) and comparison groups (i.e., women with non-short birth interval) before and after  
35  
36 189 weighting, by computing standardized differences (Supplementary Material II).<sup>57 58</sup> For a  
37  
38 190 continuous covariate, the standardized difference<sup>58 59</sup> is defined as:

$$d = \frac{(\bar{x}_{treatment} - \bar{x}_{control})}{\sqrt{\frac{s_{treatment}^2 + s_{control}^2}{2}}}$$

39  
40  
41 191 where  $\bar{x}_{treatment}$  and  $\bar{x}_{control}$  denote the sample mean of the covariate in treated and untreated  
42  
43 192 subjects, respectively and  $s_{treatment}^2$  and  $s_{control}^2$  denote the corresponding sample variances of  
44  
45 193 the covariate. The standardized difference<sup>58 59</sup> for a dichotomous variable is given as:

$$d = \frac{(\hat{p}_{treatment} - \hat{p}_{control})}{\sqrt{\frac{\hat{p}_{treatment}(1 - \hat{p}_{treatment}) + \hat{p}_{control}(1 - \hat{p}_{control})}{2}}}$$

194 where  $\hat{p}_{treatment}$  and  $\hat{p}_{control}$  denote the prevalence of the dichotomous variable in treated  
 195 and untreated subjects, respectively.

196 A standard difference less than 0.1 has been suggested as indicating a negligible difference in  
 197 the mean or prevalence of a covariate between treatment and control groups and was used  
 198 here.<sup>58</sup> In addition, kernel densities were plotted to graphically demonstrate the propensity  
 199 score balance in the treatment group (i.e., women with short birth interval) and control groups  
 200 (women with non-short birth interval). Balance in propensity scores was considered to be  
 201 achieved when the kernel density line for the treatment group and control group lay closer  
 202 together.<sup>60</sup> The inverse probability of treatment weights was then calculated as 1/PS for those  
 203 exposed to short birth interval and 1/ (1 - PS) for those who were not. The sample was then  
 204 reweighted by the IPTW and the balance of the covariates checked in the reweighted  
 205 sample.<sup>50 61</sup> Stabilization of weights was made to preserve the sample size of the original  
 206 data, reduce the effect of weights of either treated subjects with low propensity scores or  
 207 untreated subjects with high propensity scores, and provides appropriate improve the  
 208 estimation of variance estimates and confidence intervals for the treatment effect.<sup>51</sup> Since  
 209 the EDHS employed a two-stage, stratified, clustered random sampling, which is a complex  
 210 sampling procedure, sampling weights were also used to adjust for the non-proportional  
 211 allocation of sample participants to different regions, including urban and rural areas, and  
 212 consider the possible differences in response rates.<sup>5</sup> Finally, a weighted logistic regression was  
 213 fit to estimate the effect of the treatment (short birth interval) on each outcome variable  
 214 (neonatal, infant, and under-five mortality). Estimation of the treatment effect on outcome  
 215 variables in the final model used the grand weight, which was formed as the product of the  
 216 survey weight and the stabilized weight. Literature has shown that combining a propensity

1  
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3 217 score method and survey weighting is necessary to estimate unbiased treatment effects which  
4  
5 218 are generalizable to the original survey target population.<sup>62</sup> The treatment effect on the outcome  
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7  
8 219 variables was expressed as adjusted odds ratios (AORs) with a 95% confidence interval (CI).  
9  
10 220 Statistical analysis was performed using Stata version 14 statistical software (*StataCorp. Stata*  
11  
12 221 *Statistical Software: Release 14. College Station, TX: StataCorp LP. 2015*). Figure 2 presents  
13  
14  
15 222 a schematic summary of the overall analysis procedure.

## 17 223 **Patient and public involvement**

18  
19  
20 224 Patients and/or the general public were not involved in the design, or conduct, or drafting of  
21  
22 225 this secondary analysis.

## 24 226 **Results**

### 27 227 **Respondents' characteristics**

28  
29  
30 228 Table 1 illustrates the baseline characteristics of the study participants. The occurrence of  
31  
32 229 neonatal mortality differed with maternal age at birth, with mortality rates being higher among  
33  
34 230 mothers aged  $\geq 35$  ( $p=0.021$ ). Neonatal mortality was also higher in rural than in urban areas  
35  
36 231 ( $p=0.004$ ). Similarly, infant mortality and under-five mortality were somewhat higher in rural  
37  
38 232 areas ( $p<0.001$ ). Under-five mortality was higher among uneducated mothers ( $p=0.027$ ) and in  
39  
40 233 mothers without access to mass media ( $p=0.043$ ). Mortality at all ages was higher among  
41  
42 234 infants with at least five siblings ( $p<0.0001$ ). Both infant and under-five mortality were slightly  
43  
44  
45 235 higher among women from the richer household  
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236 **Table 1** The weighted distribution of neonatal, infant, and under-five child mortality by background characteristics, EDHS 2016

Variable	Neonatal Mortality		P-value	Infant Mortality		P-value	Under-five Mortality		P-value
	No (%)	Yes (%)		No (%)	Yes (%)		No (%)	Yes (%)	
Maternal age at the birth of the index child (in years)									
≤19	291 (3.2)	17 (5.8)	0.021	283 (3.1)	25 (6.5)	0.065	280 (3.1)	28 (6.0)	0.068
20-24	1950 (23.4)	52 (18.8)		1896 (23.2)	106 (23.7)		1877 (23.3)	125 (23.0)	
25-29	2587 (30.8)	67 (26.0)		2536 (30.8)	118 (27.6)		2516 (30.8)	138 (27.4)	
30-34	1836 (22.7)	59 (22.6)		1802 (22.9)	93 (21.0)		1781 (22.7)	114 (22.9)	
≥35	1533 (19.9)	56 (26.8)		1515 (20.0)	74 (21.2)		1500 (20.1)	89 (20.7)	
Maternal education									
Uneducated	5890 (73.9)	182 (75.0)	0.859	5759 (73.8)	313 (75.9)	0.157	5694 (73.9)	378 (75.5)	0.027
Primary	1744 (22.0)	54 (19.7)		1715 (22.0)	83 (20.8)		1704 (22.0)	94 (21.1)	
Secondary+	563 (4.1)	15 (5.3)		558 (4.2)	20 (3.3)		556 (4.1)	22 (3.4)	
Maternal occupation									
Not employed	5935 (72.9)	178 (74.6)	0.604	5807 (72.9)	306 (73.2)	0.575	5747 (72.9)	366 (73.6)	0.376
Employed	2267 (27.1)	73 (25.4)		2225 (27.1)	110 (26.8)		2207 (27.1)	128 (26.4)	
Husband education									
Uneducated	4186 (49.9)	145 (53.2)	0.092	4104 (50.0)	227 (50.1)	0.346	4057 (50.0)	274 (49.0)	0.154
Primary	2482 (37.3)	69 (34.6)		2437 (37.3)	114 (36.2)		2416 (37.3)	135 (37.1)	
Secondary+	1529 (12.8)	37 (12.2)		1491 (12.7)	75 (13.7)		1481 (12.7)	85 (13.9)	
Husband occupation									
Not employed	873 (7.7)	22 (6.6)	0.339	846 (7.6)	49 (7.7)	0.421	838 (7.6)	57 (7.4)	0.482
Employed	7324 (92.3)	229 (93.4)		7186 (92.4)	367 (92.3)		7116 (92.4)	437 (92.6)	
Wealth									
Poorest	3238 (25.4)	109 (15.6)	0.248	3163 (25.3)	184 (21.5)	0.015	3118 (25.3)	229 (22.2)	<0.001
Poorer	1430 (23.4)	48 (22.5)		1400 (23.4)	78 (22.2)		1390 (23.5)	88 (21.3)	
Middle	1167 (21.1)	36 (22.8)		1147 (21.3)	56 (20.0)		1136 (21.2)	67 (20.7)	
Richer	1025 (17.8)	30 (24.8)		1000 (17.7)	55 (23.3)		993 (17.6)	62 (23.7)	
Richest	1337 (12.3)	28 (14.3)		1322 (12.3)	43 (13.0)		1317 (12.3)	48 (12.1)	

1										
2										
3										
4	Total number of preceding									
5	child									
6	≤2	2627 (31.0)	57 (27.0)	<0.001	2591 (31.0)	93 (27.1)	<0.001	2575 (31.1)	109 (26.4)	<0.001
7	3-4	2561 (30.6)	77 (22.0)		2505 (30.7)	133 (23.6)		2482 (30.7)	156 (24.6)	
8	≥5	3009 (38.4)	117 (50.9)		2936 (38.2)	190 (49.3)		2897 (38.2)	229 (49.0)	
9	Residence									
10	Urban	1264 (8.8)	22 (12.0)	0.004	1251 (8.9)	35 (8.7)	<0.001	1248 (9.0)	38 (7.7)	<0.001
11	Rural	6933 (91.2)	229 (88.0)		6781 (91.1)	381 (91.3)		6706 (91.0)	456 (92.3)	
12										
13	Region									
14	Tigray	765 (6.0)	23 (6.1)	0.516	762 (6.1)	26 (4.1)	0.145	752 (6.1)	36 (5.3)	0.039
15	Afar	808 (1.0)	20 (0.7)		779 (1.0)	49 (1.2)		762 (1.0)	66 (1.4)	
16	Amhara	774 (18.7)	26 (22.2)		765 (18.8)	35 (17.9)		761 (18.9)	39 (17.2)	
17	Oromia	1270 (44.7)	37 (45.5)		1245 (44.6)	62 (47.9)		1235 (44.6)	72 (47.1)	
18	Somali	1231(5.0)	52 (6.3)		1210 (4.9)	73 (5.4)		1203 (4.9)	80 (5.1)	
19	Benishangul-Gumuz	711 (1.1)	24 (1.0)		690 (1.1)	45 (1.3)		682 (1.1)	53 (1.4)	
20	SNNPR***	1021 (21.2)	23 (16.0)		995 (21.1)	49 (20.4)		987 (21.1)	57 (20.9)	
21	Gambella,	541 (0.2)	16 (0.2)		531 (0.2)	26 (0.2)		522 (0.2)	35 (0.2)	
22	Harari	443 (0.2)	13 (0.2)		429 (0.2)	27 (0.2)		427 (0.2)	29 (0.2)	
23	Addis Ababa	246 (1.5)	6 (1.2)		245 (1.5)	7 (1.0)		245 (1.5)	7 (0.8)	
24	Dire Dawa	387 (0.4)	11 (0.4)		381(0.4)	17 (0.4)		378 (0.4)	20 (0.4)	
25										
26	Access to mass media									
27	Yes	1408 (15.8)	36 (23.2)	0.240	1383 (15.9)	61 (20.2)	0.177	1376 (15.9)	68 (19.0)	0.043
28	No	6789 (84.2)	215 (76.8)		6649 (84.1)	355 (79.8)		6578 (84.1)	426 (81.0)	
29										
30	Decision making autonomy									
31	Yes	6014 (77.7)	179 (74.9)	0.469	5898 (77.8)	295 (73.8)	0.258	5848	345	0.072
32	No	2183 (22.3)	72 (25.1)		2134 (22.2)	121 (26.2)		2106	149	
33										
34										

237 \*\*\*SNNPR= Southern Nations, Nationalities, and Peoples' Region; EDHS= Ethiopia Demographic and Health Survey

## 238 **Balance diagnostics**

## 239 **Propensity score balance**

240 Figure 3 presents the density plot of women in the treatment group (dashed lines) and the  
241 control group (solid lines) before and after weighting. It reveals that an adequate balance of  
242 the propensity score distribution between the treatment groups after weighting (Figure 3).

## 243 **Covariate balance**

244 After weighting adjustment, standardized differences of covariates were all less than 0.1 (10%),  
245 showing comparability between women with and without short birth interval  
246 (Supplementary Material II).

## 247 **Treatment effect estimation**

248 The prevalence of short birth interval in Ethiopia was 45.8% (95% CI: 42.91–48.62). Table 2  
249 presents the estimated effects of short birth interval on neonatal, infant, and under-five  
250 mortality. The adjusted estimated odds of neonatal mortality were 85% higher among women  
251 who experienced short birth interval (AOR=1.85, 95% CI=1.19, 2.89) than those who did not.  
252 Similarly, the odds of infant mortality were two times higher (AOR=2.16, 95% CI=1.49, 3.11)  
253 among women who experienced short birth interval compared with women who did not. The  
254 odds of under-five child mortality were two times (AOR=2.26, 95% CI= 1.60, 3.17) higher  
255 among women who were exposed to short birth interval compared with women who were not.

256



258 **Table 2** The effect of short birth interval on neonatal, infant, and under-five mortality in  
 259 Ethiopia, EDHS 2016

Treatment variable	Neonatal mortality		AOR (95% CI)
	No (%)*	Yes (%)*	
Short birth interval			
No	4166 (54.5)	95 (46.1)	Ref
Yes	4031 (45.5)	156 (53.9)	1.85 (1.19, 2.89)
	Infant mortality		
Short birth interval	No (%)	Yes (%)	
No	4126 (54.9)	135 (40.5)	Ref
Yes	3906 (45.1)	281 (59.5)	2.16 (1.49, 3.11)
	Under-Five mortality		
Short Birth interval	No (%)	Yes (%)	
No	4099 (55.1)	162 (39.3)	Ref
Yes	3855 (44.9)	332 (60.7)	2.26 (1.60, 3.17)

260 EDHS= Ethiopia Demographic and Health Survey; AOR= Adjusted Odds Ratio; CI=  
 261 Confidence Interval; Ref= reference group; (%)\*=percentage are weighted

## 262 Discussion

263 To our knowledge, this study provides the first comprehensive assessment of the effect of short  
 264 birth interval on neonatal, infant, and under-five mortality using the WHO recommendation to  
 265 define short birth interval and applying rigorous analytical techniques to adjust for potential  
 266 confounders. This study provides evidence that short birth interval is associated with  
 267 neonatal, infant, and under-five mortality in Ethiopia. These findings will help policy  
 268 makers and program planners formulate targeted interventions to increase birth intervals and  
 269 contribute to achieving the GTPE and SDGs target of reducing neonatal, infant, and under-  
 270 five mortality.<sup>16 15</sup>

271 In this current study, short birth interval was found to be associated with higher odds of  
 272 neonatal mortality. This finding is consistent with evidence from the previous studies<sup>23 25 63-</sup>  
 273 <sup>66</sup> which have shown a higher risk of neonatal mortality among women with a short birth  
 274 interval. However, the definition of short birth interval (i.e., <33 months) used in the current

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3 275 study was in line with the WHO definition and longer than those used in previous studies (i.e.,  
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5 276 ranges from <18 to 24 months). Short birth interval could result in adverse neonatal child health  
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8 277 outcomes, such as death, by causing maternal nutritional depletion, specifically folate  
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10 278 depletion.<sup>67 68</sup> The maternal nutritional depletion hypothesis states that a short birth-to-  
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12 279 pregnancy/birth interval worsens the mother's nutritional status because of inadequate time to  
13  
14 280 recover from the physiological stresses of the subsequent pregnancy.<sup>69</sup> This may compromise  
15  
16 281 maternal nutritional status and ability to support fetal growth, which could result in fetal  
17  
18 282 malnutrition and increased risk of infection and death during childhood.<sup>67</sup> Women with short  
19  
20 283 birth interval may also be less likely to attend postnatal care, which is vital for early detection  
21  
22 284 and treatment of neonatal and maternal health problems. Evidence has shown that the majority  
23  
24 285 of mothers and newborns in low- and middle-income countries do not receive optimal postnatal  
25  
26 286 care<sup>70</sup>, yet close to half of the newborn deaths occurred within the first 24 hours after birth, a  
27  
28  
29 287 critical time where mothers and their babies should get their first postnatal care.<sup>71</sup>  
30  
31  
32  
33 288 Our study found that infant mortality was two times higher among women who experienced  
34  
35 289 short birth interval compared with women who did not. Our finding was consistent with  
36  
37 290 evidence from Ethiopia,<sup>18 32</sup> Kenya,<sup>72 73</sup> Nepal,<sup>74</sup> and Iran<sup>75</sup> although the cut-off point for  
38  
39 291 short birth interval in the current study was longer than the previous studies. The  
40  
41 292 abovementioned previous studies also documented that the risk of infant mortality was  
42  
43 293 higher among women who experienced short birth interval compared with women who did  
44  
45 294 not. One of the possible reasons for the effect of short birth interval on infant mortality could  
46  
47 295 be low maternal motivation to breastfeed (for example, if the pregnancy was unintended).<sup>76</sup>  
48  
49 296 Maternal perception of being undernourished due to a short birth interval may also influence  
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51 297 her infant feeding choices, such as the duration and intensity of breastfeeding and  
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53 298 supplemental feeding of the infant. This could in turn affect infants' nutritional status, their  
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3 299 resistance to infection, and may expose them to death.<sup>76-79</sup> The abovementioned links  
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5 300 between short birth interval and neonatal mortality also apply to infant mortality.  
6  
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8 301 Short birth interval doubled the odds of under-five mortality compared with non-short birth  
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10 302 interval. Despite not using the WHO recommendation<sup>1</sup> of less than 33 months to define short  
11  
12 303 birth interval, the existing literature<sup>24 30 63 64 80</sup> also supported our finding. The likely mechanism  
13  
14 304 through which short birth interval affects under-five mortality could be competition between  
15  
16 305 closely spaced siblings for limited household resources, maternal attention, and cross-  
17  
18 306 infection.<sup>76</sup> Moreover, children born within a short birth interval may not receive their  
19  
20 307 vaccination at all or complete their booster series, which is one of the risk factors that  
21  
22 308 exposed children to the infectious disease and its associated death.<sup>81-83</sup> Women with short  
23  
24 309 birth interval could be burdened with caring for highly dependent children<sup>77</sup> and other  
25  
26 310 domestic activities. As a result, they may lack the time and motivation to take children to  
27  
28 311 the health facility for vaccination and other services.  
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33  
34 312 The results of this study need to be interpreted within the limitations of the observational  
35  
36 313 study design. Due to the cross-sectional nature of the study, temporal associations between  
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38 314 short birth interval and neonatal, infant, and under-five mortality may not be established.  
39  
40 315 The second limitation of our study could be associated with the nonrandomized design of  
41  
42 316 the study. Propensity scores based analysis, IPTW, cannot account for unknown confounders  
43  
44 317 in the same way that a randomised trial can. As a result, the effect of residual confounders  
45  
46 318 may not be avoided. However, the application of IPTW mimics a randomized clinical trial  
47  
48 319 by matching two comparison groups using a conditional probability of receiving exposure  
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50 320 (short birth interval in this case) given a set of covariates. The study has also additional  
51  
52 321 strengths, such as using data from a nationally representative survey with large sample size.  
53  
54 322 The application of DAGs,<sup>48 49 84</sup> a graphical tool used to identify minimum adjustment sets,  
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1  
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3 323 which defined the set of explanatory variables for the propensity scores model was another  
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5 324 strength of this study.  
6  
7

## 8 325 **Conclusion**

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12 326 This study provides evidence that short birth interval has a significant effect on neonatal,  
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14 327 infant, and under-five mortality in Ethiopia. Interventions aiming to reduce neonatal, infant,  
15  
16 328 and under-five mortality in Ethiopia should target the prevention of short birth interval.  
17  
18 329 These could be achieved through creating awareness of the optimum birth interval and the  
19  
20 330 negative impacts of shorter birth intervals on the health of children. Further expanding the  
21  
22 331 availability and accessibility of family planning services also help women achieve optimum  
23  
24 332 birth interval. Birth interval counseling as per the WHO recommendation should be  
25  
26 333 integrated into the maternal and child health services as part of the child survival  
27  
28 334 intervention.  
29  
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31  
32

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50

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53  
54  
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56  
57 343 Health Survey (EDHS) data for further analysis.  
58  
59  
60

## 344 **Contributors**

345 All authors (DMS, CC, EGH, and DL) contributed to the design of the study and the  
346 interpretation of data. DMS performed the data analysis and drafted the manuscript. All  
347 authors (DMS, CC, EGH, and DL) read, critically revised, and approved the final  
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## 351 **Competing interests**

352 The authors declare that they have no competing interests.

## 353 **Ethics approval**

354 The 2016 EDHS was approved by the National Research Ethics Review Committee of  
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356 obtained to use the 2016 EDHS data for further analysis. This analysis was also approved  
357 by The University of Newcastle Human Research Ethics Committee (H-2018-0332).

## 358 **Consent for publication**

359 Not required

## 360 **Provenance and peer review**

361 Not commissioned; externally peer reviewed.

## 362 **Data availability statement**

1  
2  
3 363 The dataset is available from The DHS Program repository at the following link:  
4  
5 364 [https://www.dhsprogram.com/data/dataset/Ethiopia\\_Standard-DHS\\_2016.cfm?flag=0](https://www.dhsprogram.com/data/dataset/Ethiopia_Standard-DHS_2016.cfm?flag=0).  
6  
7  
8

## 9 365 **References**

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4 583 **Figure Legend**  
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7 584 **Figure 1** Direct Acyclic Graph (DAG) used to select controlling variables  
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9 585 M\_age\_atBirth\_chil= Maternal age at birth of the index child; M\_Edu= Maternal education;  
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11 586 M\_Occu= Maternal Occupation; H\_Educ= Husband education; H\_Occup= Husband  
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13 587 occupation; Birth\_wt=Birth weight; Total\_Prec\_child=Total number of preceding child;  
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15 588 Respiratory\_infn= respiratory infection; Prev\_Chi\_Survival=Previous child survival;  
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17 589 Multiple\_preg= Multiple pregnancy; ANC=Antenatal care; PNC=Postnatal care;  
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19 590 TT\_vaccin=Tetanus toxoid vaccination status; SBI= Short birth interval; NM=Neonatal  
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21 591 mortality; IM=Infant mortality; U5M=Under-five mortal  
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26 592 **Figure 2** Schematic presentation of the overall steps followed in the analysis  
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29 593 **Figure 3** Balance of propensity scores before and after weighting across treatment and  
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31 594 comparison groups  
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33 595 PS= propensity score  
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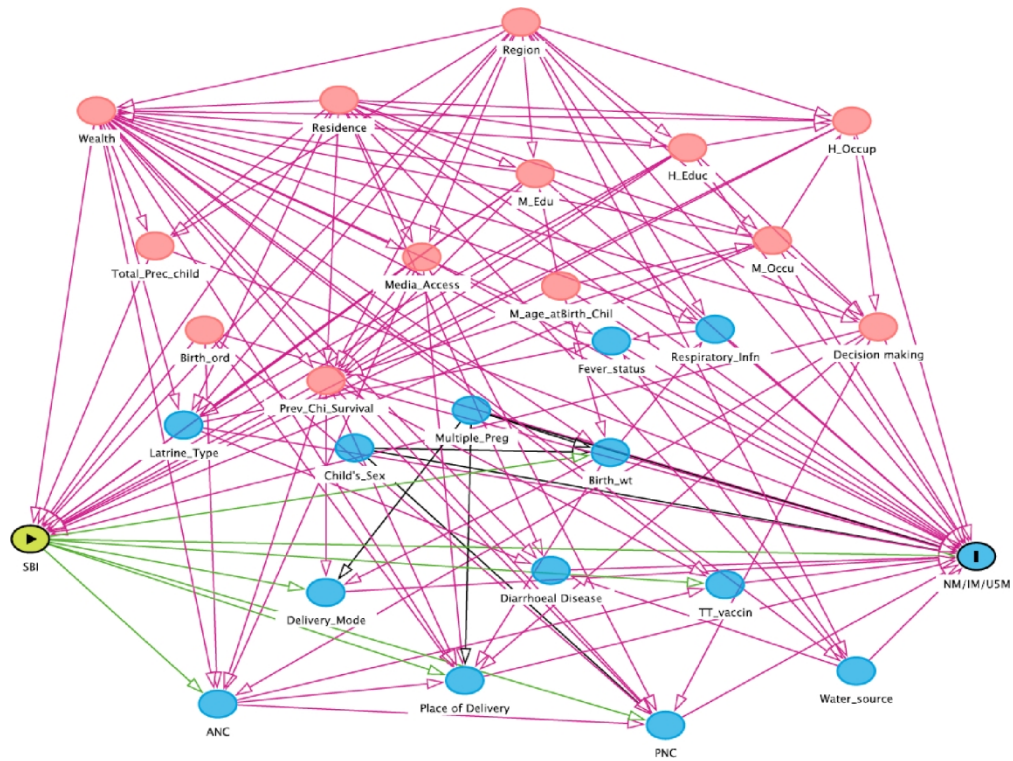


Figure 1 Direct Acyclic Graph (DAG) used to select controlling variables

157x118mm (300 x 300 DPI)



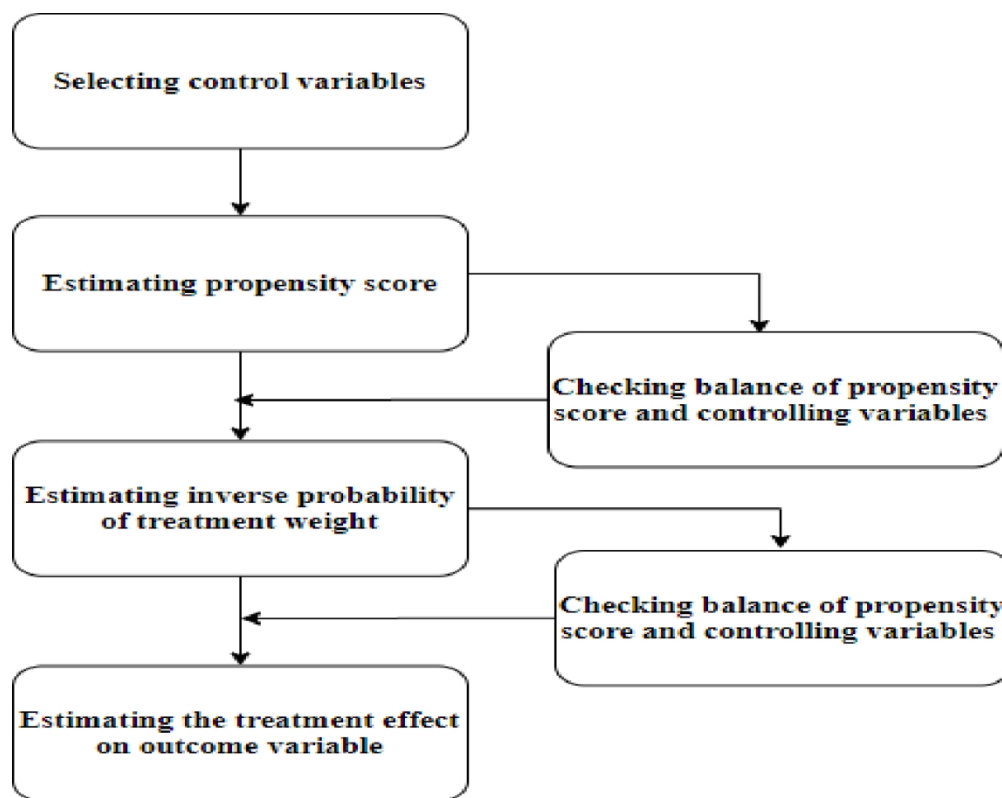


Figure 2 Schematic presentation of the overall steps followed in the analysis

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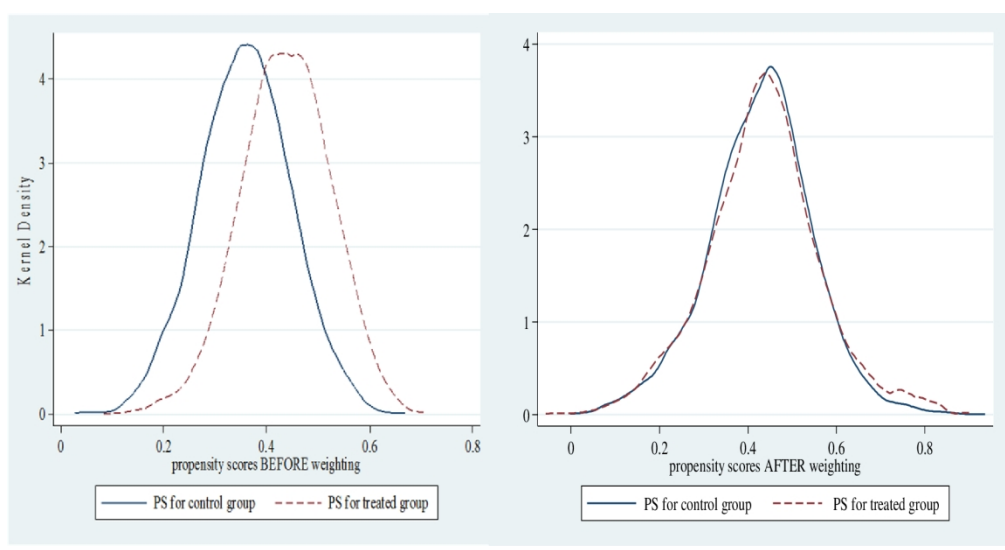


Figure 3 Balance of propensity scores before and after weighting across treatment and comparison groups; PS=propensity score

165x87mm (300 x 300 DPI)

## Supplemental Material I

**Table 1** Variables included in Direct Acyclic Graph

Category	Variables	Definition
<b>Maternal background characteristics</b>	Maternal age at birth of the index child (in years)	Maternal age at birth of the index child, which was considered as a continuous variable. It was also categorized the descriptive section of the results (1= $\leq 19$ , 2= 20-24, 3=25-29, 4=30-34, and 5= $\geq 35$ ).
	Educational level	Maximum educational level (1= Uneducated, 2=Primary and 3=Secondary+)
	Employment status	Maternal employment status (1=Not Employed; 2=Employed))
	Place of residence	Place of residence (1=Urban; 2=Rural)
	Region	Region of residence (1=Tigray, 2=Afar, 3=Amhara, 4=Oromia, 5=Somali, 6=Benishangul-Gumuz, 7=SNNPR*, 8=Gambella, 9=Harari, 10=Addis Ababa, 11=Dire Dawa) *SNNPR= Southern Nations, Nationalities, and Peoples' Region
	Decision making autonomy	Coded as 'yes' if the women were involved in all decisions regarding their own health care, major household purchases and visits to her family or relatives (1=Yes, 2=No).
<b>Husband background characteristics</b>	Husband's education	Maximum educational level of the husband (1= Uneducated, 2= Primary, 3= Secondary+)
	Husband's occupation	1= Not employed, 2=Employed
<b>Household characteristics</b>	Access to media	1=Access to media, 2= Have no access to media
	Wealth index	The wealth index provided with the dataset was used. DHS program provides a composite index of household amenities based on the principal component analysis (PCA) and classified the population into quintiles: (1st quintile (Poorest); 2nd quintile; 3rd quintile; 4th quintile and 5th quintile (Richest). A quintile is used as a measure of its relative socioeconomic level (i.e., 1=Poorest; 2=Poorer; 3=Middle; 4=Richer; 5=Richest)

<b>Maternal health status and healthcare-related variables</b>	Antenatal care	Women’s antenatal care utilization categorized as 1=No visit, 2=At least one visit, 3= ≥ Four visits
	Place of delivery	1= Health facilities, 2=Home
	Postnatal care	Women received check-up at least once within 48 hours after delivery by a skilled provider; categorized as 1=Yes, 2=No
	TT vaccination	Women received at least two doses of the immunization during pregnancy (1=Yes, 2=No)
<b>Neonatal, infant and child characteristics</b>	Sex	Child sex (1=Male, 2=Female)
	Multiple pregnancy	1=Yes, 2=No
	Birth weight	1=Below average, 2=Average, 3=Above average
	Mode of delivery	1= Caesarean section, 2= Non caesarean section
	Survival status of the preceding child	1= Yes, 2=No
	Total number of children born before the index child	Total number of children born before the index child was considered as a continuous variable. For the descriptive statistics, this variable was categorized into 1= ≤2, 2= 3-4, and 3= ≥5.  This was done after checking for the linearity assumption with the log-odds of short birth interval, which is a binary response variable. Multicollinearity was also checked among the exposure variables using the variance inflation factor (VIF). When the values of VIF were lower than 10, then the collinearity problem was considered unlikely. The VIF for birth order was 18.15 and for the total number of children born before the index child was 16.26, which indicates the presence of collinearity. Therefore, we removed the variable birth order from the model and the VIF became less than 3 for each variable included in the model.
	Birth order	Birth order is the order number of the births from first to last. Twins are given the same birth order, but the birth order of a child born after twins will be the total number of births preceding plus one.
	Diarrhoeal Disease	1= Yes, 2=No
	Fever	1=Yes, 2=No
Respiratory infection	1=Yes, 2=No	

<b>Environmental factors</b>	Source of water	1= Piped water, 2= Other improved (protected spring and well, and rain water), 3= Unimproved (river, pond, unprotected spring and well).
	Latrine facility	1 = Improved (access to flush toilet, ventilated improved pit latrine, traditional pit latrine with a slab, or composting toilet and does not share this facility with other households), 2=unimproved.

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## Supplemental Material II

**Table 2** Standardized difference before and after weighting the propensity score

Variable	Standardized difference	
	Before weighting	After weighting
Maternal age at the birth of the index child (in years)*	-0.392	0.022
Maternal education		
Uneducated	0.178	0.009
Primary	-0.112	-0.017
Maternal occupation		
Not employed	0.128	0.005
Husband education		
Uneducated	0.148	0.012
Primary	-0.041	0.003
Husband occupation		
Not employed	0.159	0.006
Wealth		
Poorest	0.332	-0.004
Poorer	-0.002	0.008
Middle	-0.070	0.005
Richer	-0.061	-0.007
Total number of preceding child*	0.207	-0.006
Survival status of preceding child		
Yes	-0.029	-0.004
Residence		
Urban	-0.239	-0.006
Region		
Tigray	-0.207	0.004
Afar	0.186	0.008
Amhara	-0.282	0.014
Oromia	-0.006	0.003
Somali	0.402	-0.003
Benishangul-Gumuz	0.061	-0.006
SNNPR**	-0.069	-0.005
Gambella,	-0.087	-0.009
Harari	-0.001	-0.009
Addis Ababa	-0.180	0.014
Access to mass media		
Yes	-0.201	-0.002
Decision making autonomy		
No	0.067	-0.009

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3 \*Maternal age at the birth of the index child (in years) and total number of the preceding  
4 child were considered as continuous variables; \*\*SNNPR= Southern Nations, Nationalities,  
5 and Peoples' Region  
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## STROBE 2007 (v4) Statement—Checklist of items for the study

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3, 4, 5, & 6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6, 7, & 8
Data sources/ 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	6, 7, & 8
Bias	9	Describe any efforts to address potential sources of bias	8, 9, & 10
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6, 7, & 8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8, 9, 10, & 11
		(b) Describe any methods used to examine subgroups and interactions	8, 9, 10, & 11
		(c) Explain how missing data were addressed	N/A
		(d) If applicable, describe analytical methods taking account of sampling strategy	8, 9, 10, & 11
		(e) Describe any sensitivity analyses	8, 9, 10, & 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	11, 12, & 13
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11, 12, & 13
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	9 and 11, 12, & 13
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	15
		(b) Report category boundaries when continuous variables were categorized	N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	15 & 16
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	17 & 18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15, 16, 17, & 18
Generalisability	21	Discuss the generalisability (external validity) of the study results	15, 16, 17, & 18
<b>Other information</b>			
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	19

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**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 [www.strobe-statement.org](http://www.strobe-statement.org).