1   **Effectiveness of mass screening for severe acute malnutrition using mid-upper arm**

2   **circumference: a prospective regression discontinuity design**

3

4   **Authors:**

5   Huiyu Hu[1], Mamadou Ouattara[2], Mamadou Bountogo[2], Valentin Boudo[2], Thierry Ouedraogo[2],

6   Clarisse Dah[2], Elodie Lebas[1], Till Bärnighausen[3,4], Benjamin F. Arnold[1,5,7], Kieran S. O'Brien[1,5,6,7],

7   Thomas M. Lietman[1,5,6,7], Ali Sié[2], Catherine E. Oldenburg[1,5,6,7]

8

9   **Affiliations:**

10   [1] Francis I Proctor Foundation, University of California, San Francisco, USA

11   [2] Centre de Recherche en Santé de Nouna, Burkina Faso

12   [3] Heidelberg Institute for Global Health, Heidelberg University, Germany

13   [4] Department of Global Health and Population, Harvard T.H. Chan School of Public Health, Boston,

14   USA

15   [5] Department of Ophthalmology, University of California, San Francisco, USA

16   [6] Institute for Global Health Sciences, University of California, San Francisco, USA

17   [7] Department of Epidemiology & Biostatistics, University of California, San Francisco, USA

18   **Corresponding author:**   Catherine E. Oldenburg, ScD, MPH
19   490 Illinois Street, 2nd Floor
20   San Francisco, CA 94158
21   catherine.oldenburg@ucsf.edu
22

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28

29   **Abbreviations**

30   SAM - Severe Acute Malnutrition

31   MUAC - Mid-Upper Arm Circumference

32   WHZ - Weight-for-Height Z-score

33   WAZ - Weight-for-Age Z-score

34   CMAM - Community-based Management of Acute Malnutrition

35   CHWs - Community Health Workers

36   RD - Regression Discontinuity

37   WHO - World Health Organization

38   MAM - Moderate Acute Malnutrition

39

40

41 **ABSTRACT**

42 **Background**

43 Severe Acute Malnutrition (SAM) is a major cause of morbidity and mortality in children under five,

44 particularly in sub-Saharan Africa. The World Health Organization (WHO) recommends using mid-

45 upper arm circumference (MUAC) for community-based screening due to its simplicity and cost-

46 effectiveness. This study assesses the impact of MUAC-based screening and referral by community

47 health workers (CHWs) on nutritional status and all-cause mortality in Burkina Faso.

48 **Methods**

49 A prospective regression discontinuity (RD) analysis was nested within the Community Health with

50 Azithromycin Treatment (CHAT) trial, a cluster-randomized controlled trial in Nouna District, Burkina

51 Faso. Children aged 6-59 months were screened using MUAC, and those with MUAC < 11.5 cm were

52 referred for SAM treatment. The effect of referral on subsequent MUAC measurements and 6-month

53 all-cause mortality was analyzed using data near the 11.5 cm threshold. Bandwidths were selected

54 using the Imbens-Kalyanaraman (IK) algorithm to optimize bias-variance tradeoff. Generalized linear

55 mixed-effects models were applied for analysis.

56 **Results**

57 Out of 65,554 children screened, 226 (0.34%) were referred for SAM. Using the IK-selected

58 bandwidth for MUAC, no significant effects on 6-month MUAC or mortality were observed. The mean

59 MUAC difference was 0.21 cm (95% CI: -0.22 – 0.65 cm), and the mortality odds ratio was 0.95 (95%

60 CI: 0.03 – 31.37). Sensitivity analyses using broader bandwidths yielded consistent results.

61 **Conclusions**

62 MUAC-based screening and referral did not significantly improve nutritional status or reduce mortality.

63 Improving SAM referral mechanisms and integrating community health support are necessary to

64 improve health outcomes for children with SAM.

65

66 **Key Message**

67 • We evaluated whether MUAC-based community screening and referral for Severe Acute

68 Malnutrition (SAM) improved nutritional status and reduced mortality among young children in

69 rural Burkina Faso using a prospective regression discontinuity design.

70 • MUAC screening and referral alone did not significantly affect subsequent nutritional outcomes or

71 all-cause mortality.

72 • These findings highlight the importance of strengthening referral completion and integrated

73 community-based care to ensure that screening translates into meaningful improvements in child

74 health.

Introduction

Globally, severe acute malnutrition (SAM) is a leading contributor to morbidity and mortality in

children under five years of age, (1) especially in sub-Saharan Africa and South Asia. In Burkina

Faso, malnutrition presents a significant challenge, with data indicating that 18% of children under the

age of five are underweight (low weight for age), 9% are wasted (low weight relative to height), and

25% are stunted (low height for age). (2) In the 2013 guideline for the management of SAM, the

World Health Organization (WHO) advised the use of mid-upper arm circumference (MUAC) for

community-based screening by community health workers (CHWs) for severe and moderate acute

malnutrition in children under five years old, using cut-offs of <11.5cm for SAM and <12.5cm for

moderate acute malnutrition (MAM). (3) MUAC is a simple, quick, and cost-effective tool that can be

used at the community level to screen children for acute malnutrition and facilitate referral to

nutritional programs. Its simplicity enables it to be used by CHWs and laypersons after minimal

training, (4) facilitating widespread screening in resource-limited settings. In many nutritional

programs, MUAC has been implemented as the sole criterion for admission and discharge, leading to

good rates of recovery and weight gain. (5,6) A previous study provided evidence indicating that

CHWs have a high capacity to accurately diagnose SAM using MUAC measurements. (7) While

MUAC has been widely adopted to assess SAM in community-based management of acute

malnutrition (CMAM) programs, the effectiveness of mass screening and referral for treatment for

SAM by CHWs is unclear.

Regression discontinuity (RD), a quasi-experimental design, allows for causal evaluation of

interventions that use threshold rules that are used to assign interventions based on the

measurement of a continuous variable (the "running variable"). (8–10) In the case of community

screening for acute malnutrition, MUAC is a continuous variable measured with noise that is used to

determine whether a child is referred for treatment of SAM based on the threshold of MUAC < 11.5

100 cm. In this study, we evaluated the effectiveness of CHW screening and referral to nutritional

101 programs for SAM on nutritional status and all-cause mortality, utilizing a prospective RD design

102 nested within a large cluster-randomized controlled trial.

103

104

105 **Methods**

106 **Parent trial design.** The Community Health with Azithromycin Treatment (CHAT) trial was a cluster

107 randomized trial evaluating twice yearly mass distribution of a single, oral dose of azithromycin

108 compared to placebo for prevention of all-cause mortality in children aged 1-59 months. Complete

109 methods and the primary outcome for the trial have been previously reported. (11,12) In brief, 341

110 communities in Nouna District, Burkina Faso were 1:1 randomized to biannual mass azithromycin

111 distribution or placebo to children aged 1-59 months. A door-to-door enumerative census was

112 conducted every 6 months, during which the vital status of each child was assessed and children

113 received study treatment (azithromycin or placebo). The study was conducted from August 2019 until

114 February 2023, corresponding to 6 rounds of census and treatment.

115

116 The study was reviewed and approved by the Institutional Review Board at the University of

117 California, San Francisco and the Comité d'Ethique pour la Recherche en Santé in Ouagadougou,

118 Burkina Faso. Written informed consent was obtained from at least one guardian of each child

119 enrolled in the study.

120

121 **Study setting.** CHAT was conducted in Nouna District, Burkina Faso, a rural and mostly agrarian

122 district in northwestern Burkina Faso near the Mali border. Burkina Faso is located in the Sahel,

123 which experiences highly seasonal rainfall from July through October, followed by an annual harvest

124 in November-December. Food insecurity, and thus acute malnutrition, are typically highest during the

125   rainy season while crops are growing. The rainy season also corresponds with the higher malaria

126   transmission season.

127

128   **Communities and participants.** All communities in Nouna District were eligible for inclusion in the

129   trial. After randomization, several communities were lost due to escalating political insecurity

130   occurring in the study area. (12) All children in the eligible age range (1 to 59 months) were eligible

131   for treatment during each twice-yearly treatment round. Children were censused up to 65 months of

132   age to evaluate mortality in the 6-month period following each round of treatment administration.

133   Because MUAC-based cutoffs are only validated and used for children ≥6 months of age, this

134   analysis was restricted to children who were 6-59 months of age at the time of first MUAC

135   measurement.

136

137   **Running variable measurement.** During each census, MUAC-based screening for SAM was

138   conducted by trained study census workers using standard MUAC tapes. Census workers used a

139   string to identify the midpoint of the child's upper arm, and then measured the circumference using

140   the MUAC tape. Numeric MUAC measurements were entered by the enumerator into a custom-

141   designed mobile data collection application designed specifically for the trial. The application was

142   flagged any child with a MUAC measurement below 11.5 cm, instructing the enumerator to refer the

143   child to a primary healthcare facility for diagnosis and enrollment in the nutritional program for

144   treatment of SAM. However, due to limitations linking census data with health facility records, the trial

145   did not track whether caregivers sought recommended care.

146

147   **Outcomes.** We assessed the effect of screening and referral to the nutritional program on two

148   outcomes: 1) subsequent MUAC measurement and 2) all-cause mortality. Both MUAC and all-cause

149   mortality were measured during each twice-yearly census round. Children were followed

150   longitudinally up to 65 months of age, although children over 59 months of age did not receive an

151 additional round of treatment. Therefore, a 59-month-old child who received MUAC measurements

152 would be included in the study until they were 65 months of age. MUAC measurements were

153 obtained as previously described. Deaths were included in the study if a child was recorded as alive

154 and living in the household during one census and died prior to the next census.

155

156 **Statistical analysis methods**

157

158 **Regression Discontinuity Design**

159 To evaluate the impact of MUAC screening on follow-up MUAC measurements and mortality, a RD

160 design was employed, using MUAC as the running variable with a threshold of 11.5 cm for

161 intervention eligibility (referral to the nutritional program). The RD design is a quasi-experimental

162 approach used to identify the causal effects of interventions by taking advantage of arbitrary threshold

163 rules. Due to a considerable amount of noise, children with a MUAC measurement of 11.4 cm and

164 11.6 cm are likely very similar in their risk of outcomes. Thus, in a narrow range around the threshold,

165 exchangeability can be a reasonable assumption, and causal effects can be identified by comparing

166 participants with measurements immediately above and below the threshold. In this study, the RD

167 design allows for the estimation of the causal effect of MUAC screening on children who are near the

168 cutoff for SAM referral (11.5 cm), offering an opportunity to compare outcomes for children just above

169 and just below the eligibility threshold.

170

171 Bandwidth selection in RD involves a bias-variance tradeoff. A wider bandwidth decreases the

172 variance of the estimates by increasing the number of observations but also increases the bias

173 because it relies on correctly specifying the functional form of the running variable above and below

174 the threshold. Conversely, narrower bandwidths minimize bias but reduce statistical power due to

175 smaller sample sizes. To find an optimal balance between bias and variance, the Imbens-

176 Kalyanaraman (IK) algorithm was implemented to select the optimal bandwidths for MUAC for each

177   outcome, enhancing the precision and validity of the estimates. (13) Additionally, three bandwidths

178   (10.5–12.5 cm, 9.5–13.5 cm, and 8.5–14.5 cm) were used for robustness checks and sensitivity

179   analyses, ensuring the consistency and reliability of the study's findings.

180

181   **Regression Discontinuity Assumptions.** In our study, assumptions for causal inference in RD were

182   assessed as follows: (9,10)

183   1) The MUAC served as our assignment variable, measured and reported continuously.

184   2) The intervention eligibility (referred or not referred to the nutritional program) was determined

185   by a clearly defined cut-off value of 11.5 cm in MUAC measurements.

186   3) The assignment variable, MUAC, measured continuously near the cut-off value, was assumed

187   to be not influenced by external factors.

188   4) MUAC and vital status were recorded for all eligible children during the census, regardless of

189   their exposure to the referral intervention.

190   5) We verified the presence of individuals both above and below the MUAC threshold within our

191   population, ensuring a viable comparison across the intervention cutoff.

192   6) To ensure the precision of our analysis, we undertook robustness checks that involved

193   employing models for the assignment variable, particularly MUAC, across different

194   bandwidths.

195

196   For the analysis, generalized linear mixed-effects models were utilized, incorporating three different

197   bandwidths selected from IK algorithm. Specifically, the regression model was fitted in following

198   forms:

199   1) 6-month followup MUAC as outcome:

200 $$MUAC_{fu} = \beta_0 + age + \beta_1 I[MUAC_{bl} < 11.5cm] + \beta_2(MUAC_{bl} - 11.5cm) + \beta_3(MUAC_{bl} - 11.5cm) * I[MUAC_{bl}$$

201 $$< 11.5cm] + u$$

202   2) Vital status at 6-month as outcomes

203 $log(odds\ ratio) = \beta\_0 + age\ + \beta\_1\ I[MUAC\_bl$

204 $< 11.5cm] + \beta\_2\ (MUAC\_bl - 11.5cm) + \beta\_3\ (MUAC\_bl - 11.5cm) * I[MUAC\_bl < 11.5cm] + u$

205

206 Where $I[MUAC_{bl} < 11.5cm]$ indicates whether a child was referred to the nutritional program or not,

207 β_1 is the difference in the cutoff, which is equivalent to the effect of eligibility of nutritional program

208 referral as defined by the threshold, β_2 is the slope of the line below the threshold, $\beta_2 + \beta_3$ is the

209 slope of the line above the threshold and u represents the random effects term, accounting for

210 unobserved heterogeneity at the individual level and the fact that one child could contribute to

211 multiple treatment phases. Considering that a child's age is associated with mortality and MUAC, the

212 baseline age was included in the models to reduce the variance. Analyses were completed in R

213 version 4.2.

214

215 As a sensitivity analysis, we additionally controlled for the study treatment arm (azithromycin vs.

216 placebo) as well as other baseline covariates, including distance to the nearest CSPS (health facility),

217 and the number of children under 5 years old in the household. A squared term for the running

218 variable was also included in the regression model to evaluate the robustness of the results.

219

220 **Result**

221 A total of 68,246 children 1-59 months were enrolled in the CHAT study. After excluding children

222 younger than 6 months for WHO-recommended age range for MUAC screening and those with a

223 MUAC below 6 cm as outliers, 226 out of 65,554 (0.34%) children were diagnosed with SAM and

224 referred at least once during the CHAT study period (Supplementary Figure 1).

225

226 Using the IK algorithm, we identified optimal bandwidths for each outcome. For MUAC at follow-up,

227 the optimal bandwidth was 0.70 cm (10.80–12.20 cm), with 158 observations below the cutoff (met

228   the criteria for SAM referral) and 2,743 above. For follow-up mortality, the optimal bandwidth was

229   0.62 cm (10.88–12.12 cm), with 148 observations below the cutoff and 2,480 above. Participants'

230   characteristics are shown in Table 1. Supplementary Figure 2 displays the MUAC distribution,

231   demonstrating continuity at the MUAC cutoff.

232

233   From the RD analysis to estimate discontinuity at the MUAC cut-off of 11.5 cm, we were unable to

234   demonstrate evidence of an effect of screening and referral for SAM on all-cause mortality or

235   nutritional status as measured by MUAC at 6 months, with results broadly consistent across

236   bandwidths in sensitivity analysis (Supplementary Table 1). Table 2 presents the estimation of the

237   causal effect of MUAC-based screening on MUAC and mortality using the IK-selected bandwidths, as

238   well as pre-specified bandwidths for robustness checks. Within the IK-selected bandwidth of 10.80–

239   12.20 cm for MUAC follow-up, the mean difference in MUAC at 6 months was 0.21 cm (95% CI: -0.22

240   to 0.65 cm). Similarly, for mortality at 6-month follow-up, within the IK-selected bandwidth of 10.88–

241   12.12 cm, the odds ratio (OR) was 0.95 (95% CI: 0.03 to 31.37), indicating no significant difference

242   between children referred to the nutritional program (below the threshold) and those not referred

243   (above the threshold). Supplementary Table 2 and 3 shows the estimation of causal effects of SAM

244   screening, incorporating adjustments for covariates (baseline age, distance to CSPS, number of

245   children (under 5) in household and treatment arm) and including a squared term in the regression

246   model for robustness checks. Both sensitivity analyses yielded consistent results, indicating that there

247   was no significant difference in mortality or MUAC outcomes referred to the nutritional program and

248   those not referred.

249

250   **Discussion**

251   In this prospective RD analysis nested in a cluster randomized trial, we did not find evidence that

252   MUAC-based screening and referral to nutritional programs improved MUAC measures 6 months

253   after screening. However, confidence intervals in particular for the mortality endpoint were wide, as

254   SAM was less common than expected during the study period and mortality is a rare event. At the

255   same time, since MUAC is continuous, this outcome was better powered than mortality, and

256   estimates consistently showed no evidence of effect. While children with SAM have a higher mortality

257   rate than children without SAM and this endpoint is an important indicator for SAM treatment

258   programs, (3,14) programs monitor response to treatment with MUAC, and children who are admitted

259   to nutritional programs are considered to have recovered when their MUAC increases to > 12.5 cm.

260   (3) Lack of an effect of screening and referral to the nutritional program on subsequent MUAC

261   measurements and mortality for children with SAM may suggest inadequate referral linkage,

262   indicating families affected by SAM require additional support. CHAT lacked mechanisms such as

263   follow-up visits to ensure SAM referral completion, and no data were collected on whether referred

264   children accessed care. Future studies should evaluate both screening effectiveness and referral

265   completion to improve SAM outcomes.

266

267   The findings of this analysis underscore the challenges in connecting referred SAM children to

268   appropriate care and raises questions about the effectiveness of screening alone in improving SAM

269   outcomes. While MUAC screening is widely endorsed and used globally, its success depends on the

270   presence of robust downstream referral and treatment pathways. A previous study estimated that the

271   average coverage of CMAM programs was only 38.3% in sub-Saharan Africa, identifying several

272   obstacles such as a lack of awareness about malnutrition and the programs themselves, along with

273   geographical and economic access barriers to health facilities. (15) In addition, structural barriers,

274   including poverty and lack of access to healthcare can limit caregivers' ability to follow through with

275   referrals and provide adequate care for their children. For example, an evaluation of a CMAM

276   program in Uganda, caregivers faced significant economic and social constraints that hindered their

277   ability to provide adequate care. (16) These structural barriers must be addressed to make

278   interventions more effective in contexts of extreme poverty in area like rural Burkina Faso.

279 To overcome these challenges, previous studies have identified effective intervention strategies. For

280 example, the integrated community case management (iCCM) approach involves integrating SAM

281 treatment with the existing curative tasks of CHWs, thereby enhancing treatment accessibility and

282 potentially improving recovery outcomes, particularly for children in rural areas. (17) Training

283 mothers/caregivers to regularly screen for SAM using MUAC presents a cost-effective strategy that

284 enhances coverage, helps early detection of SAM, and promotes engagement in seeking SAM

285 treatment. (18,19)

286

287 Additionally, the optimal indicator for detecting acute malnutrition may still require further

288 investigation. MUAC is widely used for SAM screening due to its simplicity and cost effectiveness.

289 However, ongoing debates in the literature suggest that relying solely on the current WHO-

290 recommended MUAC cutoff without incorporating weight-for-height (WHZ) as a screening tool may

291 lead to an underestimation of severe acute malnutrition cases. (20,21) Yet, WHZ measurement is

292 more complex, requiring calibrated scales and trained personnel, making it impractical for routine use

293 in community-based settings. Future research should explore integrating MUAC with other indicators

294 to improve the identification of malnutrition while considering the practical constraints of community-

295 based programs.

296

297 **Limitations**

298 The study faced several limitations that could impact the interpretation and generalization of findings.

299 First, fewer SAM cases and lower-than-expected mortality led to wide confidence intervals for the

300 mortality endpoint. RD analyses are often restricted to relatively narrow bandwidths, which further

301 limits statistical power. As a result, the mortality endpoint was very underpowered in this analysis, and

302 results were consistent with a wide range of effects. The study did not collect data on whether

303 referred children were linked to nutritional programs, leaving gaps in understanding whether those

304 identified through MUAC screening ultimately received care or what their outcomes were. Results of

305   this study should not be interpreted as evaluating the effectiveness of the nutritional programs

306   themselves, but rather of screening and referral to nutritional programs. Another significant limitation

307   was the absence of a mechanism within the study to screen and refer children with moderate acute

308   malnutrition (MAM; MUAC < 12.5 cm), which means our study could not assess the effectiveness of

309   the screening and referral process for children who fall into this category, which represents a crucial

310   aspect of comprehensive malnutrition management. Although children with MAM have increased risk

311   of progression to SAM and mortality, infrastructure for provision of MAM treatment does not exist as it

312   does for SAM. The CHAT trial was a large, simple trial, and as a result we were unable to collect data

313   on some outcomes, such as WHZ, that may have provided additional information on the effect of

314   screening and referral for SAM. Finally, the results of this analysis may not be generalizable to

315   settings with different distributions of acute malnutrition and child mortality. Further evaluations of the

316   effectiveness of mass screening and referral to nutritional programs are needed, particularly in

317   settings with a higher prevalence of SAM. These results highlight the need for adequately powered

318   evaluations to understand the impact of MUAC-based screening and referral on child health

319   outcomes, including nutrition and mortality, and other relevant indicators.

320

321   **Conclusion**

322   We found no evidence of an effect of mass screening using MUAC and referral to nutritional

323   programs for SAM on subsequent nutritional status or all-cause mortality in this prospective RD

324   design analysis. However, the prevalence of SAM was low, leading to uncertainty in estimates,

325   especially for analyses of mortality. The results of this study suggest that current screening and

326   referral mechanisms for SAM are not effectively improving outcomes for children with SAM, and

327   additional health systems strengthening that includes, for example, enhanced linkage to nutritional

328   programs via CHWs or other peer navigators, is needed.

329

345 # Tables and Figures

346 **Table 1. Baseline Characteristics**

347

	10.80 - 12.20 cm [1]	10.88 - 12.12 cm [2]
Number of records	2,901	2,628
Number of children	2,654	2,409
Baseline Age (in month, mean [SD])	18.7 (12.1)	18.7 (12.2)
Baseline MUAC (in month, mean [SD])	11.9 (0.3)	11.9 (0.2)
Number of SAM referrals (N [%])	158 (5.4%)	148 (5.6%)
Number of SAM children (N [%])	156 (5.9%)	146 (6.1%)
Number of female (N [%])	1489 (56.1%)	1333 (55.3%)

348 [1] The optimal bandwidth for Mean MUAC at 6 months, selected using the IK algorithm.

349 [2] The optimal bandwidth for Mortality at 6 months Odds Ratio selected using the IK algorithm.

350

351

352 **Table 2. Model outcomes Using IK-Selected Bandwidth**

Outcome	Estimate (95% CI)	P-value
Mean MUAC at 6 months (cm) [1]	0.21 (-0.22 – 0.65)	0.339
Mortality Odds Ratio (OR) [2]	0.95 (0.03 – 31.37)	0.978

353 [1] The optimal bandwidth for Mean MUAC at 6 months was 0.70 cm (10.80–12.20 cm), selected using the IK algorithm.

354 [2] The optimal bandwidth for Mortality at 6 months Odds Ratio was 0.62 cm (10.88–12.12 cm), selected using the IK
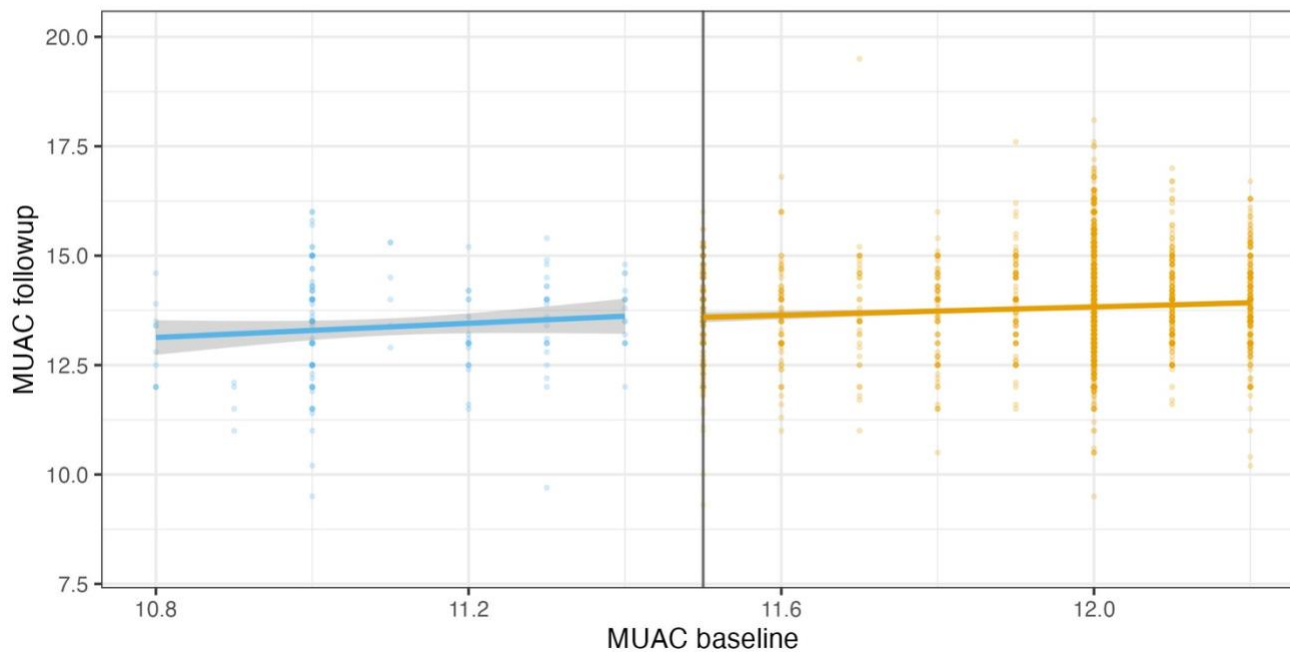
355 algorithm.

356

357   **Figure 1. Regression discontinuity results for MUAC at 6 months.**

IK-Selected Bandwidth for followup MUAC outcome: 10.80 to 12.20 cm
Slope below threshold = 0.94;
Slope above threshold = 0.36;
Difference at the cutoff = 0.21

358

359

360

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IK-Selected Bandwidth for followup MUAC outcome: 10.80 to 12.20 cm

Slope below threshold = 0.94;
Slope above threshold = 0.36;
Difference at the cutoff = 0.21