The PROBIT approach in estimating the prevalence of wasting: revisiting bias and precision

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Abstract

Background: The PROBIT methodology was presented in the 1995 World Health Organization Technical Report on Anthropometry as an alternative to the standard prevalence based method of measuring malnutrition in children. Theoretically the PROBIT method will always give a smaller standard error than the standard prevalence method in measuring malnutrition. A recent article by Dale et al. assessed the PROBIT method for measuring global acute malnutrition measure and found that the method was biased and the precision was superior only for sample sizes less than 150 when compared to the standard method. In a manner similar to Dale, our study further investigated the bias and precision of the PROBIT method for different sample sizes using simulated populations.

Results: The PROBIT method showed bias for each of the ten simulated populations, but the direction and magnitude of the average bias was changed depending on the simulated population. For a given simulated population, the average bias was relatively constant for all sample sizes drawn. The 95% half-width confidence interval was lower for the PROBIT method than the standard prevalence method regardless of the sample size or simulated population. The absolute difference in the confidence limits showed the most gains for the PROBIT method for the smaller samples sizes, but the ratio of confidence intervals was relatively constant across all sample sizes.

Conclusions: The PROBIT method will provide gains in precision regardless of the sample size, but the method may be biased. The direction and magnitude of the bias depends on the population it is drawn from.

Keywords: Child Malnutrition, Wasting, Weight-for-Height, Z-score, Probit, Surveys

Introduction

The measurement of population based estimates of malnutrition in children 6 to 59 months is a major component in assessing the nutrition levels in vulnerable populations. Typically, the prevalence of malnutrition is determined by taking a random survey sample of children from a population and indexing each selected child’s weight and height to the standard World Health Organization (WHO) Growth charts [1]. The resulting weight-for-height Z-scores (WHZ) are then compared to malnutrition thresholds; the number of children with WHZ less than the WHZ threshold is then counted and divided by the number of children in the sample. As a measure of precision, a 95% confidence limit around the estimate is calculated based on the sample size and sample design. This is the standard prevalence method of measuring malnutrition [1].

The 1995 WHO Technical Report 854 described the use of the PROBIT method to measure child anthropometry indicators in nutrition surveys as a more robust alternative to the standard prevalence-based approach [1]. The PROBIT method assumes the true distribution of WHZ comes from a normal distribution, so the distribution can be defined using the mean and the standard deviation (SD). Instead of counting the number of cases below a malnutrition WHZ threshold for a given sample, the PROBIT method estimates the prevalence of malnutrition indirectly by computing the area under the tail of the curve from \(-\infty\) to the threshold via the cumulative normal distribution function using the sample mean and standard deviation [2]. Alternatively, to reduce the influence of extreme values for a given
survey, robust estimators of the sample mean, such as Winsorized or trimmed means, can be used instead of the standard sample mean [3]. The principal assumption around the PROBIT method when estimating the prevalence of wasting is that the WHZ follow a normal distribution.

The advantage of the PROBIT method is that it will, theoretically, always produce a smaller standard error around a prevalence estimate than the standard prevalence method because it assumes a normal distribution [2]. The other advantage is the method is less vulnerable to field measurement errors of a child’s height and weight versus the standard method which counts cases in the tail of the distribution. The disadvantage of the PROBIT method is that the bias of the PROBIT methodology depends upon the deviation of the true population of WHZ from the assumed normal distribution of WHZ defined by the mean and standard deviation. The prevalence based method on the other hand, assuming no measurement error, will give an unbiased estimate of the true prevalence.

Using a simulation based approach; a recent paper by Dale et al. examined the difference in bias and precision between the PROBIT method and the standard prevalence method for estimating the prevalence of global acute malnutrition (GAM) as well as severe acute (SAM) and moderate acute malnutrition (MAM) [4]. Ignoring clustering, they created simulated true populations by inflating field nutrition surveys and then drawing repeated random samples at different fixed sample sizes to calculate the precision and bias for each method. The results were aggregated across the simulated true populations at each of the fixed sample sizes. The Dale study found that the precision for the PROBIT methodology for GAM based on WHZ was superior to the standard method only for sample sizes <150. The paper also stated that PROBIT method overestimated the prevalence of GAM, MAM and SAM and one can correct for it with the simple subtraction of the bias.

After reviewing the Dale article, the authors had concerns about the generalizability of the reported aggregated results. One concern was that the results of the Dale study contradicted the theoretical model in which the precision from the PROBIT method should always be superior to the standard prevalence method irrespective of the sample size and not solely for sample sizes <150. The other problem was that the aggregation of the bias and precision for multiple simulated populations may have masked individual population differences. We suspected that bias would vary by population depending on WHZ fit to the normal distribution and the magnitude of the prevalence.

Our study investigated the discrepancy between theoretically expected results of precision for the PROBIT method vs. the standard method and the ones reported by Dale. In addition we examined the variation of the bias of the PROBIT method by simulated population. We first examined the difference in precision between the two methods assuming a population with a perfect fit to the normal distribution. Next, using simulated populations from inflated field surveys in a similar manner as Dale, we examined the bias and precision around prevalence of the WHO defined threshold of WHZ < −2 (wasting) instead of GAM which is defined as a WHZ < −2 or the presence of edema. We used wasting as opposed to GAM because we wanted to look at the behavior of the estimates without edema. Instead of aggregating across simulated populations, we looked at the precision and bias from individual simulated populations of different categories of quality and magnitudes of wasting.

Methods

Perfect fit to normal distribution

First, to illustrate a theoretical perfect fit of WHZ, the precision for each method was calculated assuming an imaginary distribution of WHZ that perfectly fit a normal population with a mean of 0.71 and SD = 1. This results in a 10% prevalence estimate. For each method, the precision was calculated for 10 different sample sizes ranging from 50 to 900. The standard error (SE) for the prevalence method was calculated using the normal approximation to the binomial and the 95% Half-Width confidence interval (CI) was calculated by multiplying the SE*1.96. To calculate the 95% confidence intervals around the PROBIT estimate, the SE of the sample mean was calculated first along with 95% CI of the sample mean. Next, the cumulative normal distribution function was used to calculate the upper and lower bounds of the sample mean to obtain the confidence intervals around the PROBIT estimate.

Dale et al. PROBIT estimation

To compare the standard method vs. the PROBIT method, Dale et al. created simulated population data sets using a database of 560 cluster survey datasets taking only records with WHZ between −5 and +5. Ignoring the cluster design, they inflated each dataset to a population of 17,000 using random sampling with replacement. A true prevalence was calculated for each of the 560 simulated population datasets by counting the cases of malnutrition and dividing by 17,000. From each population of 17,000, they drew 150 samples of 15 different sample sizes ranging from 50 to 500 stepped up by 25 each time. The prevalence was calculated for every sample using the standard prevalence method of counting cases and the PROBIT method with three different estimators of the mean and SD: 1) median and SD = 1; 2) mean and the observed SD; and 3) mean and observed SD using a Box-Cox transformed data to help normalize the data [5].

To measure the performance of the PROBIT methodology vs. the standard prevalence method, they examined both the bias and precision. The bias was measured
Simulations to assess the standard and PROBIT methods

To investigate the performance of PROBIT in the measure-
ture of wasting compared to the standard prevalence
method, we used a total of 10 nutrition field surveys to
create simulated populations of WHZ. We included four
nutrition field surveys that were conducted by the US
Centers for Disease Control and Prevention in Bhutan-
ese refugee camps from 2007 through 2010 and used a
simple random sampling design—these were considered
good quality surveys with supervision at each stage of
the survey process [6]. The other six nutrition surveys
were randomly selected from a database of 390 surveys
provided by Action Against Hunger International (ACF
International) and the Food Security and Nutrition Ana-
lysis Unit for Somalia (FSNAU). The surveys were
administered by non-governmental organizations, were
conducted during 2001–2009, used cluster sampling
design, had a sample size of at least 400, and were of
variable data quality. To obtain a variety of simulation
surveys, the surveys were separated into six categories
by prevalence and quality prior to selection and one
survey per cell was randomly selected (Table 1). The
quality stratification was based on the SD of the WHZ
as previously described [1].

For all surveys, the WHZ were based on the 2006
WHO Growth Standards [7] and were generated using
the ENA software [8]. Extreme values were excluded
from the analysis based on the WHO flexible exclusion
range criteria, which defines an improbable value as a
WHZ of <−4 and >4 from the observed mean [1].

In a manner similar to Dale, we created 10 simulated
populations by inflating each of the surveys to a popula-
tion of 20,000 using simple random sampling with re-
placement. From each simulated population, we drew
1,000 samples for each of 10 different sample sizes
ranging from 50 to 500 incremented by 50. For each
sample, we calculated the prevalence using the stand-
ard method of counting the number of children with a
WHZ less than −2 and then the PROBIT method
using the observed mean and SD. We also examined a
robust estimator of the mean using Winsorization, but
it was not superior to using the observed mean and
SD; therefore, we have omitted those results from the
article [3].

To compare the properties for the two different
methods, we calculated the bias and precision for the
10 different sample size categories within each simu-
lated population. The bias for each sample was calcu-
lated by subtracting the sample estimate of wasting
prevalence from the true prevalence of the simulated
population and then calculating average bias within
each sample size category. The precision for each simu-
lated population was estimated by calculating the half-
width of the 95% CI (1.96 * SD) within each sample size
category (n = 1000); the SD is the standard deviation
of the sample prevalence estimates. Because the true
population mean of each simulated population is a con-
stant, the method we used to calculate the precision
around the PROBIT estimate is mathematically equiva-

tent to the 95% limits of agreement (mean error ±1.96 *
SD error) used in the Dale article.

To examine the magnitude of the bias relative to the
true value, the relative bias for the PROBIT was calcu-
lated for each simulation by dividing the average bias for
a given sample size by the true prevalence value. To show
the relative precision of the standard method to the PROBIT
method, we calculated the ratio of the 95% half-width CI
of the standard method to the PROBIT by dividing the
average 95% half-width CI of the standard method by the
average 95% half-width CI of the PROBIT.

To examine the deviations of the populations from the
normal distribution we calculated the skewness, kurtosis,
and the Shapiro-Wilk test for normality [9]. Significance
for the Shapiro-Wilk test was set at p < 0.05.

The analysis for this paper was generated using Excel
2010 and SAS/STAT software, Version 9.3 of the SAS
System for Windows [10].

Results

Perfect fit to normal distribution

The precision for PROBIT versus the standard method
assuming a WHZ distribution that fits the normal distribu-
tion perfectly are presented in Table 2. The ratio of the

| Table 2 The number of surveys by prevalence and quality categories from the ACF international and FSNAU databases (N = 390) |
|---------------------------------------------------------------|
| **Low Prevalence (Wasting ≤ 10%)** | **Medium prevalence (Wasting 10.1% to 20%)** | **High prevalence (Wasting >20%)** |
| High Quality SD* <1.1 | 3 | 48 | 28 |
| Low Quality SD ≥1.2 | 141 | 110 | 60 |

* SD, standard deviation.
half-width 95% CI of the standard method to the PROBIT was the same (1.7) regardless of the sample size. The half-width 95% CI for the PROBIT was smaller than standard prevalence for all the calculated sample sizes.

**Simulation results**

The descriptive statistics for the original datasets (used as a basis for the simulations) are presented in Table 3. The WHZ SD’s were similar for the four Nepal surveys (range: 0.91-0.93). By definition, all of the low quality surveys had a SD > =1.2 and the high quality surveys <1.1. Based on the Shapiro-Wilk test for normality, all of the low quality surveys as well as three of the four Nepal surveys were significantly non-normal. All of the surveys had a small amount of skewness ranging from −0.17 and 0.31. The kurtosis was also relatively small ranging from 0.15 to 0.75. All of the surveys had very few or no subjects with edema.

The bias for the PROBIT methods changed in magnitude and direction depending on the simulation survey used, but the magnitude of the bias for a given simulation dataset was relatively constant regardless of

| Data set | n<sup>b</sup> | Excluded<sup>c</sup> | GAM<sup>d</sup> Prevalence | Wasting Prevalence | Edema prevalence | Mean WHZ | SD WHZ | Shapiro-Wilk p | Kurtosis | Skewness |
|----------|-----|------|-----------------|-----------------|-----------------|--------|-------|-------------|----------|---------|
| Nepal 2007 | 497 | 0 | 4.2 | 4.2 | 0 | −0.49 | 0.92 | 0.389 | 0.26 | −0.16 |
| Nepal 2008 | 502 | 0 | 9.2 | 9.2 | 0 | −0.85 | 0.93 | 0.017 | 0.59 | 0.27 |
| Nepal 2009 | 568 | 0 | 7.2 | 7.2 | 0 | −0.76 | 0.91 | 0.034 | 0.75 | −0.14 |
| Nepal 2010 | 569 | 0 | 8.1 | 8.1 | 0 | −0.65 | 0.91 | 0.006 | 0.51 | 0.05 |
| Sudan North Darfur 2006–11 (high quality, high prevalence) | 954 | 2 | 25.5 | 25.2 | 0.3 | −1.37 | 1.02 | 0.131 | 0.26 | −0.07 |
| Sudan South Darfur 2007-9 (high quality, medium prevalence) | 802 | 3 | 19.1 | 19.0 | 0.1 | −1.14 | 1.02 | 0.102 | 0.29 | −0.17 |
| Haiti (Artibonite) 2004–5 (high quality, low prevalence) | 889 | 2 | 5.1 | 5.1 | 0 | −0.25 | 1.04 | 0.817 | 0.27 | −0.02 |
| Somalia 2007(1) (low quality, high prevalence) | 898 | 1 | 22.1 | 22.1 | 0 | −1.03 | 1.29 | <0.001 | 0.27 | 0.31 |
| Somalia 2007(2) (low quality, medium prevalence) | 905 | 0 | 10.3 | 10.2 | 0.1 | −0.40 | 1.29 | <0.001 | 0.15 | 0.13 |
| Somalia 2006 (low quality, low prevalence) | 905 | 14 | 9.3 | 9.1 | 0.2 | −0.37 | 1.23 | 0.005 | 0.30 | 0.19 |

<sup>a</sup>Excludes observations < −4 WHZ or >4 WHZ from observed mean. <sup>b</sup>Observations used in the analysis. <sup>c</sup>Number of observations that were excluded (<−4 WHZ or >4 WHZ from observed mean). <sup>d</sup>GAM is defined as WHZ < −2 or the presence of edema.
the sample size (Table 4). For 8 of the 10 surveys the bias was positive. The bias was the highest relative to the true prevalence of wasting for the 2007 through 2010 Nepal surveys (Table 5).

The precision, represented by the half-width 95% CIs, was superior for the PROBIT method for all the simulation datasets and sample sizes (Table 6). The absolute difference in the CI shows the largest absolute gains in precision for the smaller sample sizes (Figure 1). Within each simulation survey, the ratio of the half-width CI of the standard method to the PROBIT method was relatively constant across all sample sizes for each simulation database (Figure 2). These results are consistent with the theoretical model for precision mentioned above.

Discussion

We have shown that the magnitude and direction of the bias for the PROBIT methodology depended on the simulation survey dataset in contrast to the Dale article which stated that the PROBIT method overestimates GAM and can be corrected with a uniform value. Our bias was also consistently higher than those reported in the Dale article, but this may be due to the fact that they averaged the bias over 560 surveys and the positive and negative values then cancelled each other out. The relative bias was higher for the Nepal simulation datasets, which all had lower SD (<1) and a higher kurtosis than the other six datasets. On the other hand, all three Somalia datasets that were significantly non-normal by the Shapiro-Wilk test showed much lower relative bias. The results of our study are limited by the fact that our analyses used simulated WHZ population data created from sample survey datasets instead of the actual exhaustive population data. We do not know if the true populations would have had distributions closer or farther away from the normal distribution. Also, the influence of measurement error in the field was ignored; this may have caused more bias for the standard prevalence.

Table 4 Average bias for the PROBIT method by simulation survey

| n (Sample Size) | Nepal 2007 | Nepal 2008 | Nepal 2009 | Nepal 2010 | Sudan 2006 | Sudan 2007 | Haiti 2004 | Somalia 2007(1) | Somalia 2007(2) | Somalia 2006 |
|----------------|------------|------------|------------|------------|------------|------------|------------|----------------|----------------|--------------|
| 50             | 1.09       | 1.57       | 1.37       | −1.16      | 1.32       | 0.87       | −0.15      | 0.84           | 0.45           | 0.35         |
| 100            | 0.88       | 1.40       | 1.25       | −1.21      | 1.41       | 0.91       | −0.16      | 0.70           | 0.34           | 0.38         |
| 150            | 0.87       | 1.29       | 1.37       | −1.24      | 1.52       | 1.04       | −0.25      | 0.73           | 0.57           | 0.33         |
| 200            | 0.90       | 1.32       | 1.37       | −1.23      | 1.48       | 0.99       | −0.18      | 0.76           | 0.45           | 0.42         |
| 250            | 0.84       | 1.29       | 1.27       | −1.23      | 1.46       | 1.04       | −0.22      | 0.70           | 0.46           | 0.31         |
| 300            | 0.90       | 1.36       | 1.34       | −1.30      | 1.44       | 1.13       | −0.26      | 0.79           | 0.52           | 0.39         |
| 350            | 0.87       | 1.40       | 1.29       | −1.25      | 1.43       | 1.10       | −0.26      | 0.86           | 0.53           | 0.39         |
| 400            | 0.88       | 1.44       | 1.32       | −1.29      | 1.36       | 0.98       | −0.25      | 0.76           | 0.50           | 0.39         |
| 450            | 0.92       | 1.39       | 1.29       | −1.29      | 1.42       | 1.07       | −0.26      | 0.71           | 0.54           | 0.36         |
| 500            | 0.86       | 1.39       | 1.28       | −1.26      | 1.45       | 1.03       | −0.29      | 0.79           | 0.52           | 0.34         |
method than the PROBIT method. Another limitation is that we ignored the cluster survey design of the non-Nepal surveys when we created a simulated population of WHZ using simple random sampling. Further investigation is needed to determine the behavior of the PROBIT method when applied to cluster surveys. Also, we looked only at wasting, which does not include edema. Looking at GAM in the populations where edema is high and many of the edema cases have WHZ greater than $-2$, would add an additional positive bias, since edema cases are not accounted for directly by WHZ distribution.

**Conclusions**

The results of our study clearly show that the bias from PROBIT method is population dependent and should not be generalized for all populations. In our examples, the PROBIT method consistently outperformed the standard method in terms of precision for all sample

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**Table 5 Relative Bias (bias/true estimate) of PROBIT methodology by simulation survey**

| n (Sample Size) | Nepal 2007 | Nepal 2008 | Nepal 2009 | Nepal 2010 | Sudan 2006 | Sudan 2007 | Haiti 2004 | Somalia 2007(1) | Somalia 2007(2) | Somalia 2006 |
|-----------------|------------|------------|------------|------------|------------|------------|-----------|-----------------|----------------|------------|
| 50              | 0.26       | 0.17       | 0.19       | 0.14       | 0.05       | 0.05       | 0.05      | 0.04            | 0.04           | 0.04        |
| 100             | 0.21       | 0.15       | 0.18       | 0.15       | 0.06       | 0.05       | 0.05      | 0.03            | 0.03           | 0.04        |
| 150             | 0.21       | 0.14       | 0.19       | 0.15       | 0.06       | 0.06       | 0.05      | 0.03            | 0.06           | 0.04        |
| 200             | 0.21       | 0.14       | 0.19       | 0.15       | 0.06       | 0.05       | 0.05      | 0.03            | 0.04           | 0.05        |
| 250             | 0.20       | 0.14       | 0.18       | 0.15       | 0.06       | 0.06       | 0.04      | 0.03            | 0.04           | 0.04        |
| 300             | 0.22       | 0.15       | 0.19       | 0.16       | 0.06       | 0.06       | 0.05      | 0.04            | 0.05           | 0.04        |
| 350             | 0.21       | 0.15       | 0.18       | 0.16       | 0.06       | 0.06       | 0.05      | 0.03            | 0.05           | 0.04        |
| 400             | 0.21       | 0.16       | 0.18       | 0.16       | 0.05       | 0.05       | 0.05      | 0.03            | 0.05           | 0.05        |
| 450             | 0.22       | 0.15       | 0.18       | 0.16       | 0.06       | 0.05       | 0.05      | 0.03            | 0.05           | 0.04        |
| 500             | 0.21       | 0.15       | 0.18       | 0.16       | 0.06       | 0.05       | 0.06      | 0.04            | 0.05           | 0.04        |

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**Table 6 95% Half-Width confidence intervals for the standard and PROBIT method**

| n   | Method | Nepal 2007 | Nepal 2008 | Nepal 2009 | Nepal 2010 | Sudan 2006 | Sudan 2007 | Haiti 2004 | Somalia 2007(1) | Somalia 2007(2) | Somalia 2006 |
|-----|--------|------------|------------|------------|------------|------------|------------|-----------|-----------------|----------------|------------|
| 50  | Standard | 5.4        | 7.9        | 7.0        | 7.7        | 12.1       | 10.9       | 5.9       | 11.5            | 8.6            | 7.9        |
|    | PROBIT | 4.8        | 6.5        | 6.6        | 5.5        | 9.7        | 9.0        | 4.0       | 8.4             | 6.7            | 5.9        |
| 100 | Standard | 3.8        | 5.8        | 5.1        | 5.4        | 8.4        | 7.8        | 4.1       | 8.2             | 6.0            | 5.6        |
|    | PROBIT | 3.3        | 4.6        | 4.8        | 3.8        | 6.8        | 6.3        | 3.0       | 6.0             | 4.7            | 4.1        |
| 150 | Standard | 3.2        | 4.7        | 4.2        | 4.3        | 6.8        | 6.2        | 3.5       | 6.3             | 4.8            | 4.3        |
|    | PROBIT | 2.7        | 3.8        | 3.9        | 3.2        | 5.4        | 5.2        | 2.5       | 4.7             | 3.7            | 3.2        |
| 200 | Standard | 2.7        | 4.1        | 3.4        | 3.8        | 5.9        | 5.4        | 3.0       | 5.6             | 4.4            | 3.9        |
|    | PROBIT | 2.3        | 3.3        | 3.2        | 2.7        | 4.7        | 4.5        | 2.1       | 4.1             | 3.3            | 2.8        |
| 250 | Standard | 2.4        | 3.6        | 3.2        | 3.2        | 5.5        | 4.6        | 2.8       | 5.2             | 3.9            | 3.4        |
|    | PROBIT | 2.1        | 2.9        | 3.0        | 2.5        | 4.4        | 3.9        | 1.9       | 3.9             | 3.0            | 2.5        |
| 300 | Standard | 2.2        | 3.5        | 2.9        | 3.2        | 4.8        | 4.3        | 2.5       | 4.8             | 3.4            | 3.1        |
|    | PROBIT | 1.9        | 2.8        | 2.7        | 2.3        | 3.8        | 3.5        | 1.7       | 3.5             | 2.6            | 2.3        |
| 350 | Standard | 2.0        | 3.1        | 2.7        | 2.8        | 4.5        | 3.9        | 2.3       | 4.2             | 3.2            | 2.9        |
|    | PROBIT | 1.7        | 2.5        | 2.5        | 2.0        | 3.6        | 3.3        | 1.6       | 3.1             | 2.5            | 2.1        |
| 400 | Standard | 2.0        | 3.0        | 2.5        | 2.7        | 4.3        | 3.8        | 2.1       | 3.9             | 3.0            | 2.7        |
|    | PROBIT | 1.7        | 2.3        | 2.4        | 1.9        | 3.3        | 3.2        | 1.5       | 3.0             | 2.4            | 2.0        |
| 450 | Standard | 1.8        | 2.7        | 2.4        | 2.5        | 4.0        | 3.6        | 2.0       | 3.8             | 2.7            | 2.5        |
|    | PROBIT | 1.6        | 2.1        | 2.2        | 1.8        | 3.2        | 3.0        | 1.4       | 2.9             | 2.1            | 1.9        |
| 500 | Standard | 1.8        | 2.6        | 2.2        | 2.3        | 3.8        | 3.5        | 1.9       | 3.5             | 2.7            | 2.5        |
|    | PROBIT | 1.5        | 2.1        | 2.2        | 1.7        | 3.0        | 2.8        | 1.3       | 2.7             | 2.1            | 1.9        |
sizes as opposed to the Dale article which stated the gain in precision is only for small sample sizes. We agree with the Dale article that the PROBIT method is most advantageous for the smaller sample sizes, where the gains in absolute precision are the greatest. However, the ratio of the precision of the standard method to the PROBIT method was shown to be close to constant across sample sizes, consistent with the theoretical model. Further work is needed to explore whether some of the survey data characteristics (e.g., SD, skewness, kurtosis, prevalence, etc.) can

Figure 1 The absolute difference in the 95\% half-width confidence limit between the PROBIT method - standard prevalence method.

Figure 2 The ratio of standard prevalence method 95\% half-width CI to the PROBIT method 95\% half-width CI.
consistently explain the degree and directionality of bias, so caution should be used when applying this method.

Competing interests
Both authors declare that they have no competing interests.

Authors’ contributions
CJB and OOB designed the study, CJB conducted the analysis, and CJB and OOB drafted the manuscript. Both authors read and approved the final manuscript.

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