

RESEARCH PAPER

Weighting National Survey Data in Bangladesh: Why, How and Which Weight ?

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Abstract

Background: Weighting of national survey data enables the sample to be more representative of the target population. Weighting procedure is a thorough exercise and yields several types of weights. However, considerable variation exists among authors on which weight to use leaving the researchers baffled. As a result, survey data are often used by researchers without the weights leading to erroneous conclusions. In addition, despite availability of powerful yet costly statistical software-- researchers from developing countries are mostly unable to use those due to high cost. In this article, we share our experience on weighting for recent national surveys in Bangladesh using Microsoft Excel.

Objectives: Overall objective was to perform sample weighting of a national survey of Bangladesh using Excel. As specific objective, the study was aimed at creating different weighting variables, describe their features and identify the appropriate weight to be used for analysis.

Methods: We generated four types of weights: the base weight calculated from probabilities of selection, and non-response adjusted, population calibration adjusted, and trimmed weights. We compared the distribution of the population by sex and age by unweighted and four types of weighted numbers. Finally, we calculated weighted means, medians, ranges, standard errors, confidence intervals, variances, multiplicative effects and design effects with these four weights. In addition, we compared the weighted prevalence of a key variable of the survey using these four weights.

Results: We compared unweighted distribution with weighted ones and identified that weighting makes the sample distribution to conform to the target population. Among the four calculated weights, the trimmed weight had narrow standard error and variance, and smallest design and multiplicative effects. It yielded an acceptable prevalence and distribution of prevalence of mental disorder.

Conclusion: Among the four weights, we show that the trimmed weight met all parameters of good quality and precision. We performed this complex exercise using Microsoft Excel which is largely available to researchers in Bangladesh. Therefore, we recommend using the trimmed weight for national level surveys in Bangladesh in a similar context.

Keywords: Weighting, Base weight, Population calibration, Trimming

Introduction

Sample survey is one of the most important methods of collecting health data that can draw conclusion on a reference population.¹ However, accurate inference cannot be drawn without treating the sample data.² Weighting corrects the imperfections in the sample that prevents bias and other differences between the

sample and the reference population.³ In complex sample surveys four types of imperfections emerge from unequal probabilities of selections, multistage selection, stratifying sample into the reporting domains, and non-responses.⁴ Ignoring these will lead to incorrect inferences in a survey.

Though sample survey can draw conclusion to a reference population, the results may be influenced by sampling and non-sampling errors.^{1,5} Among the non-sampling errors, non-response – both unit non-response and item non-response – is addressed rigorously through weighting.⁶ Adjustment of the non-sampling error can be different depending on the data collection technique of the survey - digital and paper-

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pencil.⁷ Digital data collection has a well-ordered method to adjust non-sampling error compared to pen-paper based one.⁸ Several recent national level household (HH) surveys in Bangladesh used digital data collection tools.⁹⁻¹¹

In addition, weighting adjusts the weighted sample distribution for key variables of interest (for example, age, race, and sex) to make it conform to a known population distribution.³ Production of design-unbiased estimates of parameters of interest is possible by applying proper weights.¹² Thus weighting procedure is a critical step after the survey data have been collected and all the essential steps of data processing have been completed.¹³ However, there is no universally held protocol for calculating weights. The aim of the weighting procedure is to calculate the 'final weight' starting with base weight, and non-response, population calibration and trimming adjustments.

Testing variability of the calculated non-response rates and weight is an important step of generating acceptable weights.⁹ High variation in weights can lead to some observations having too much importance leading to distortion of results.¹⁴ In addition, if the sampling design is not informative, using the weights should not introduce any significant differences in the estimates.¹² In addition, if the sampling design turns out to be informative, the use of weighted estimators will produce "better" results.¹² Additionally, a trimming procedure can be applied and the process varies between researchers.^{15,16}

Weighting itself to some researchers is like a black box.¹³ Handling different types of weights and which to use sometimes lead researchers confused. In addition, although there are many powerful statistical softwares available for complex sample analysis, yet these are used much less in the financial context of a developing country like Bangladesh. As a result survey data are often used by researchers without the weights leading to erroneous conclusions.¹² Given the influence weights have on survey results, it is important that researchers understand enough about weighting process to be discerning users of the survey data.¹³ In this article we briefly described the weighting process, our approach in identifying which weight to use and explain the reason behind selecting one. So far, there is no scientific article on weighting of national level survey data by researchers from Bangladesh and this article is the first of its kind in the context of performing the exercise using Microsoft Excel.

Materials and Methods

Brief overview of the weighting procedure: A detailed step-by-step procedure of weighting is described elsewhere.¹⁷ Following is a brief description:

1. *Base weight calculation:* This involves the possibility of selection of PSUs (p_1), HH (p_2), sex randomization (p_3) and individuals (p_4) (figure 1).¹⁸

i. *PSU selection probability (p_1):* Selection for PSUs within each of the 16 strata (8 division x 2 residence status) is done.

$$p_1 = \frac{\text{Number of selected PSUs in a strata (31)}}{\text{Total number of PSUs in that strata}}$$

ii. *HH selection probability (p_2):* It is calculated by systematic selection of 18 HHs within each PSU. It is performed in 496 PSUs.

$$p_2 = \frac{\text{Number of selected HHs in a PSU (18)}}{\text{Total number of HHs in that PSU}}$$

iii. *Probability of sex randomization (p_3):* Equal HH sex allocation of the selected 18 HHs are undertaken in each PSU. This yielded a probability of '0.5'. This is applicable for all (8 928) the respondents of the survey.

$$p_3 = \frac{\text{Number of selected sexes (1)}}{\text{Total number of sex strata (2)}}$$

iv. *Individual selection probability (p_4):* The selection probability for one eligible individual among a number/s of eligible HH members is calculated. This is obtained from the survey response data and is applicable to all the respondents of the survey.

$$p_4 = \frac{\text{Number of selected HH memebr (1)}}{\text{Total eligible HH members}}$$

The base weight is calculated as,

$$\text{base weight} = \frac{1}{p_1} \times \frac{1}{p_2} \times \frac{1}{p_3} \times \frac{1}{p_4}$$

2. *Non-response weight:* In this step we estimated the probability of responses from 'disposition codes' (table I). The non-response weight factor is calculated by taking the inverse of the response rate for a subset of the survey and is undertaken at PSU, HH and individual levels.¹⁹

- i. **PSU-level non-response factor:** This is applied for 16 strata (8 division x 2 residence status). It is calculated as,

$$PSU \text{ non-response factor} = \frac{\text{Sum of base weight of eligible PSUs}}{\text{Sum of base weight of completed PSUs}}$$

- ii. **HH non-response factor:** It is calculated within each PSU, so there are 496 adjustment cells. The HH level non-response adjustment is calculated as,

$$HH \text{ non-response factor} = \frac{\text{Sum of base weight of eligible households}}{\text{Sum of base weight of completed households}}$$

- iii. **Person non-response factor:** It is calculated by gender, age group and a core variable of interest calculated in 16 (2x4x2) adjustment cells. The person-level non-response adjustment is,

$$Individual \text{ non-response factor} = \frac{\text{Sum of base weight of eligible households}}{\text{Sum of base weight of completed rosters}}$$

The non-response adjusted base weight is calculated by multiplying the three non-response factors with the base weights successively.

$$\begin{aligned} \text{Non-response adjusted base weight} \\ = \text{base weight} * \text{non-reposnses weights} \\ (\text{PSU} \times \text{HH} \times \text{Individual}) \end{aligned}$$

- 3. **Population calibration:** The goal was to bring weighted sums of the sample data in line with the corresponding age-sex matched counts of target population.^{20,21} Initially projected population is estimated (not described) – if recent population data unavailable – then population calibration factor (r) is calculated.

Calculating post stratification adjustment factor (r)

The population calibration factor is calculated by division, residence, gender and the five age groups resulting in 160 (8 x 2 x 2 x 5) adjustment cells. The post-stratification adjustment is calculated as:

$$\text{population calibration factor} = \frac{\text{projected population in a domain}}{\text{non response adjusted weights in that domain}}$$

Population calibrated weights are calculated by multiplying the non-response adjusted base weight with population calibration factor.

- 4. **Trimming of weight:** We applied this procedure on the population calibrated weight.¹³ Initially we identified the extreme weights and fixed a cut-off value. The weights above the cut-off value were trimmed and equally distributed among the non-trimmed weights repeating this till no weights were above the cut-off point.^{15,16}

We checked all the steps of calculations for the weighting process including the distribution of the weights specially taking notice of the extreme values and back-tracking these for possible errors.

Role of the funding source: No fund was required to undertake the exercise described in the manuscript.

Results

The results shown are extracted from the National Mental Health Survey (NMHS) Bangladesh 2019 where the estimated sample size of 8 928 – aged 18 years and above – was selected in three stages (figure 1).^{11, 22}

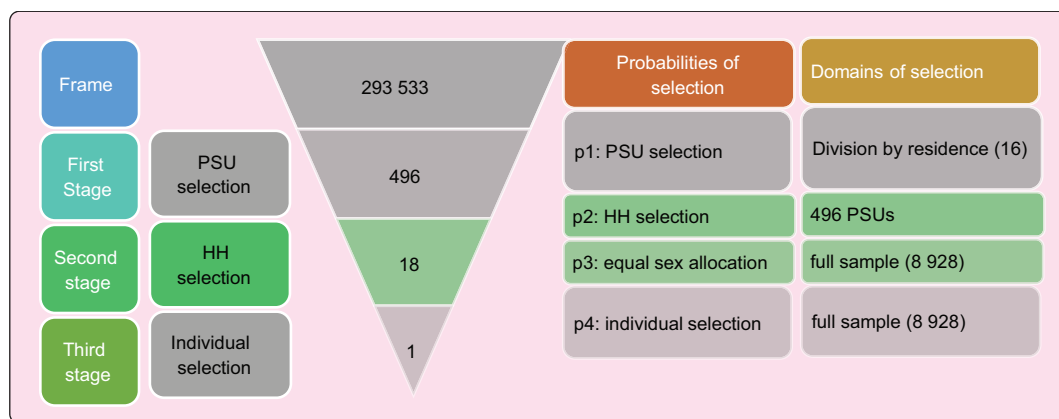


Figure 1: Sampling stages and probabilities of selection of a Survey

The overall response rate of the survey was 90.4% (table I).²⁴ We calculated the four weights using the mathematical formulas mentioned in the method section. We used Microsoft Excel (“Excel”) in Microsoft Office 365 bundle for this exercise.

Table I: Distribution of respondents for household and individual interviews by disposition codes of a Survey.

Status	Number	Percent
<i>A. Household interview</i>		
Roster completed	7320	91.1*
Roster not completed	719	8.9
Total	8039	100.0
<i>B. Individual interview</i>		
Completed	7270	99.3†
Not completed	50	0.7
Total	7320	100.0
Overall response rate	-	90.4‡

* Household response rate (%) = $[7320 \times 100] / [8039] = 91.0\%$

† Individual response rate (%) = $[7270 \times 100] / [7320] = 99.3\%$

‡ Total response rate (%) = $91.0 \times 99.3 / 100 = 90.4\%$

1. **‘Base weight’ calculation:** Probabilities of selection of PSUs, HHs, sex randomization and individual selection probability were taking into consideration. This is applied to 16 strata comprised of eight divisions and two residence strata. This procedure yielded a total base weight value of 79 422 102 (table II).

2. **Non-response factor calculation:**

- i. PSU-level non-response factor: This is also calculated for 16 domains. The value for the PSU non-response is essentially ‘1’ for all the 15 domains except in the one domain where on PSU was dropped. The mean PSU non-response is 1.0008.
- ii. HH non-response factor: This is calculated in all 496 PSUs. The mean PSU non-response is 1.1002.
- iii. Person non-response factor: The mean PSU non-response is 1.1002.

When this base weight is adjusted with the non-response weights, the adjusted base weight stands at 92 569 866 (table II).

Calculating the projected population from census data:

The total projected population calculated for adults aged 18 years or more is: 102 161 911. We accommodated for the change in division number from seven to eight (table II).²⁵

Population weight/ Calibration (r):

This is calculated in 160 domains: eight divisions, two residence strata, two sex strata and five age groups. In each of the domains the sum of projected population in that domain is divided by the non-response adjusted base weights of that domain. The mean ‘r’ was 1.33 (table II).

3. **Calculating population calibration and non-response adjusted weight:**

This weight is the product of base weight; PSU, HH, and individual non-response factors; and population calibration factor. Here calculated adjusted weight was 102 948 678 (table II).

4. **Trimming of weight:** In our exercise, we trimmed the non-response and population calibration adjusted base weight. We identified the median of the non-response adjusted and population calibrated weight to be 9 091.9. All weights above and below the 3.5 times median(15)(16) value of 31 821.7 and was set at that value.^{15,16} We trimmed any weight above 31 821.7 and fixed the weight at that value (table III).

Comparing the calculated weights: A comparison was made between the distribution of the projected population with the unweighted sample to show the differences in distribution by age and residence. (figure 2A and B). It is shown that the unweighted sample distribution is not similar to the population distribution. However, when we make the same comparison with weighted distributions with any of the four calculated weights, it shows that the distribution closely matches with that of population. The best match was achieved by the sample distribution weighted with population calibrated and trimmed weights (figure 2).

All the weights except the trimmed weight show a wide range denoting instability of the calculated weights. Sum of the calculated weights gradually increased from the base weight to the trimmed weights. The population calibrated weights and the trimmed weights thus stands at 100.8% of the projected population (table III). The distribution of the trimmed weight is more centrally oriented as is denoted by the

difference between maximum and minimum, narrower standard error, confidence level than other weights. The multiplicative effect for the trimmed weight is 1.5 and the only weight which is less than 2.⁹

We also checked the effect on the different weights on the prevalence of mental disorders according to the NMHS 2019.¹¹ The unweighted prevalence is 17.3%. Which is very close to the weighted prevalence (15.8%–16.8%). We also calculated the prevalence

in urban-rural and male and female domains and found no notable difference. However, we observe that the prevalence of mental disorders tends to decrease from unweighted to weighted results. However, we think that this difference is negligible. We calculated the design effect of unweighted and weighted calculations. Though it is somewhat increased in the weighted results, we observe the lowest design effect for base weights (1.7) and trimmed weights (1.7) (table IV).

Table II: Calculation of adjusted weights* from base weight.

Sl. No.	Strata code [†]	Base weight [‡]	Non-response PSU [§]	Non-response HH [§]	Non-response Person	Non-response adjusted weight ^Á	Projected population [¶]	Population calibration factor ^{**}	Population calibrated weight ^{††}	Trimmed weight ^{‡‡}
1	10212	4353.4	1.00	1.05	1.05	4808.0	416824.0	0.9155	4401.7	6472.1
2	10213	4353.4	1.00	1.05	1.05	4808.0	344170.0	0.9988	4802.1	6872.4
3	10211	13060.0	1.00	1.05	1.05	14424.0	558175.0	1.2017	17332.9	19403.2
~	~	~	~	~	~	~	~	~	~	~
~	~	~	~	~	~	~	~	~	~	~
8894	30114	17760.7	1.00	1.10	1.21	23636.9	558955.0	1.2515	29582.1	31668.4
8895	30122	35521.4	1.00	1.10	1.21	47273.7	1191581.0	0.7461	35272.9	31821.5
8896	30123	17760.7	1.00	1.10	1.21	23636.9	732745.0	0.4940	11677.0	13763.2
Total		79 422 102.0				92569865.8	102161911.0		102948677.6	102950428.1

* Calculated from non-response weights and population calibration adjusted base weights

[†] Strata code contains divisional (two digits from left), residence (third digit from left), sex (fourth digit from left) and age group (last digit from right) codes

[‡] Calculated by, base weight = $1/p_1 \times 1/p_2 \times 1/p_3 \times 1/p_4$, p_1 = primary sampling unit; p_2 =household; p_3 =sex randomization and p_4 =individual selection probabilities

[§] PSU: primary sampling unit; HH: Household;

^Á Calculated by, Non-response adjusted base weight=base weight x non-responses weights (PSU x HH x Individual)

[¶] Projected population of Bangladesh aged e¹⁸ years is based on Census 2011(25)

^{**} Population calibration factor = (projected population in a domain)/ (non-response adjusted weights in that domain)

^{††} Population calibrated weight= Non-response adjusted weight x Population calibration factor

^{‡‡} Trimmed weight: calculated after trimming any weight of population calibration adjusted weights beyond 3.5 times median weight (31821.53) and set at that level. The additional weights trimmed is then equally distributed among the non-trimmed weights. This is run twice till no weights were more than 3.5 times median weight.

Table III: Comparison of untrimmed versus trimmed weights (n=7270)

Statistic	Untrimmed weights			Trimmed weight [§]
	Base weight [*]	Non-response adjusted weight [†]	Population calibrated weight [‡]	
Mean	10924.6	12733.1	14160.8	14161.0
Median	8081.9	9440.1	9091.9	11178.1
Mode	17741.5	20058.3	23189.2	31821.5
Standard Error	130.4	153.9	186.8	112.6
Standard Deviation	11118.5	13123.6	15928.7	9598.6
Sample Variance	123620412.3	172228764.5	253723472.9	92132725.6
Minimum	594.5	653.4	464.3	2550.5
Maximum	210852.8	259127.8	261512.4	31837.4
Sum	79422102	92569866	102948678	102950428
Percent difference ^Á	77.7	90.6	100.8	100.8
95% confidence level	255.6	301.7	366.2	220.7
Multiplicative effect ^{¶(9)}	2.0	2.1	2.3	1.5

* Calculated by, base weight = $1/p_1 \times 1/p_2 \times 1/p_3 \times 1/p_4$, p_1 = primary sampling unit; p_2 =household; p_3 =sex randomization and p_4 =individual selection probabilities

[†] Calculated by, Non-response adjusted base weight=base weight x non-responses weights (PSUxHHxIndividual)

[‡] Calculated by, multiplying the non-response adjusted base weight with population calibration factor.

[§] All weights above 3.5 times median (31821.53) is set at that value and excess weights are equally distributed among non-trimmed weights and process is repeated till no weight is above the cutoff value.

^Á Percent difference from projected population(25) of 102 161 911 calculated as, (sum of weights = 100)/102161911

[¶] Multiplicative effect = $1 + (\text{sample variance}) / (\text{mean weight})^2$

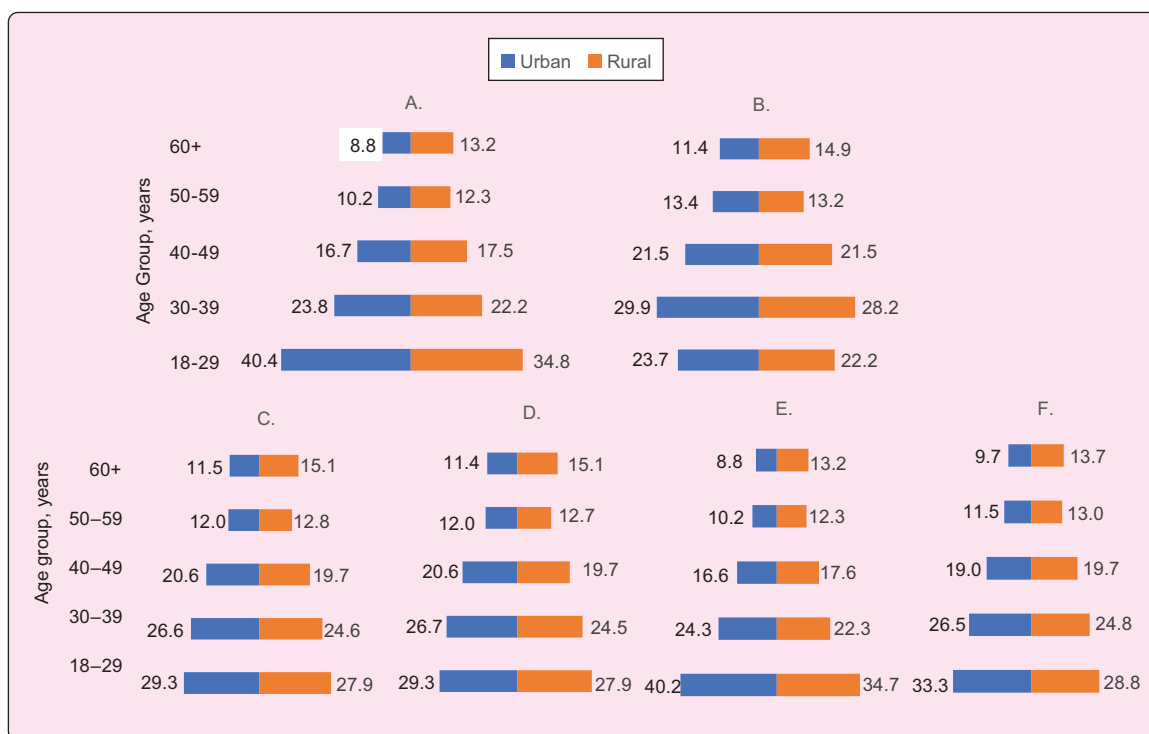


Figure 2: Comparison of population* (A) with unweighted (B) distributions and weighted sample distributions C: base weights, D: non-response adjusted weights, E: population calibrated weights, and F: trimmed weights in percent

* Projected population of Bangladesh aged ≥18 years is based on Census 2011.²⁵

Table IV: Distribution of prevalence* (% , 95% confidence interval) and design effect by four weights (n=7270)

Residence	Unweighted	Weighted			
		Base†	Non-response adjusted‡	Population calibrated§	Trimmed^
Overall	17.0 (16.1–18.0)	16.8 (15.5–18.1)	16.8 (15.4–18.1)	15.8 (14.5–17.1)	16.2 (15.1–17.3)
Urban	16.7 (15.4–18.0)	15.4 (13.3–17.4)	15.3 (13.2–17.4)	14.4 (12.4–16.4)	15.3 (13.7–16.8)
Rural	17.4 (15.9–18.8)	17.2 (15.6–18.7)	17.2 (15.6–18.8)	16.3 (14.7–17.9)	16.6 (15.1–18.0)
Male	15.0 (13.7–16.2)	13.8 (12.2–15.5)	13.7 (12.1–15.4)	12.5 (10.9–14.1)	13.2 (11.9–14.6)
Female	18.9 (17.7–20.2)	19.4 (17.8–21.1)	19.5 (17.8–21.2)	18.8 (17.1–20.6)	18.8 (17.4–20.3)
Design effect¶(4)	1.3	2.3	2.3	2.4	1.7

* Prevalence of mental disorders among aged ≥18 years from National Mental health Survey Bangladesh 2019.¹¹

† Calculated by, base weigh = 1/p1x1/p2x1/p3x1p4, p1= primary sampling unit; p2=household; p3=sex randomization and p4=individual selection probabilities.

‡ Calculated by,

§ Calculated by, multiplying the non-response adjusted base weight with population calibration factor.

^ All weights above 3.5 times median weight is set at that value and the excess weights are equally distributed among the non-trimmed weights and process is repeated till no weight is above the cutoff value.

¶ Design effect=(variance obtained in simple random sampling)/(variance obtained in complex sampling).

Discussion

We calculated four weights: base, non-response adjusted, population calibrated and trimmed weights using Microsoft Excel. We presented here the

weighting process from a recently conducted NMHS 2019 and tested those for quality.^{9,11}

It is claimed that weighting with base weight only is an efficient method as it is a simple one to

construct.^{13,17} It may be completed after the mapping and listing activity before the data collection. It avoids the performing meticulous non-response calculations and the need for population projection estimation and calibration. Thus base weight can be used as the final weight for a survey when response rate is 90% or more.²⁴ Otherwise, calculating a non-response and population calibration adjusted base weight is recommended.⁹ However, we generated all four weights despite survey response rate was acceptable and fresh census data unavailable.

In the NMHS Bangladesh 2019 data were collected through handheld computers and item non-response was absent.⁸ However, the weighting procedure corrected the sample distribution for unit non-response. The compared to the unweighted distribution of sample, the weighted distribution were more reflective of population distribution and size.

Despite the sampling design with equal allocation of PSUs to urban-rural and male-female strata, the calculated weights corrected the sample distribution for variables like sex, residence etc. to make it conform to the population by distribution and size achieving one of the prime objectives of the weighting exercise.^{3,15} The biasness induced by the design effect is also reduced by the small design effect in the weighted results.²⁵ Small design effect will help to estimate a smaller required sample size for future studies which is much needed in a low-resource country.²⁶

In addition, we calculated trimmed weights.¹⁵ Though some authors do not recommend this procedure as it might induce inaccurate results by introducing a small bias.^{14,27} However, it also greatly reduces standard errors.²⁴ The disadvantage of weighting data is reduced precision to some extent.²⁵ Some researchers worry about dealing with highly unequal weights which trimming might address thus improving precision.¹⁵ In our study, the trimmed weight was stable and provided a favorable result as suggested by others.¹⁴

We performed non-response adjustment without taking into account characteristics of each individuals rather than in a subgroup - a weakness noted by some authors.²⁸ We also used a basic calibration procedure to achieve the population adjusted weight for performing the exercise in Microsoft Excel using simple statistical techniques.⁹ Despite recommendation of using expensive statistical

software for weighting of data, we used the easily available and affordable Microsoft Excel for this exercise and generated weights through a simple step-by-step procedure. This has implications in increased applicability of weighting procedure for surveys to generate high-quality results in resource-limited setting like Bangladesh.

We tested these weights for compensation of non-sampling errors, variability and accuracy, and compared with population distribution.^{9,13} It has been argued that even if weights reduce bias, they might largely inflate variance of estimates.²⁹ Though we encountered a little loss of precision overall in the process if base weight is used, this is gradually removed when we use the other weights. The results calculated using the trimmed weight was the most precise. Except for the trimmed weight, other weights had wider values denoting instability. In our data we showed that trimming procedure generated a weight that stroke a good balance between instability and accuracy.³⁰

Conclusion

Weighting compensated for the non-sampling errors and corrected the imperfections in the sample and prevented bias between the sample and the reference population in contrast to the unweighted sample. We found that the trimmed weight was the most acceptable among the four weights. The results generated by using the trimmed weights yields a more nationally representative, precise results and renders it comparable with other national data.

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