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Population versus sampling procedures: implications from epidemiological studies

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ABSTRACT

Since sampling procedures are closely related to scientific validity, it is necessary to understand the influence of sampling procedures on obtained research results to ensure that epidemiological studies provide reliable information for planning actions designed to ensure quality in promoting health. Therefore, we verified whether the results regarding postural habits provided by diverse sampling procedures are consistent with those obtained from an entire population. A data bank obtained from a population epidemiological study involving 1,597 elementary school children from all the schools in the municipality of Teutônia, Rio Grande do Sul, Brazil (N = 11) was used. A question referring to postural habits contained in the Back Pain and Body Posture Evaluation Instrument questionnaire was analyzed. The data from the entire population were analyzed and compared with the results obtained from data collected using four distinct sampling procedures (simple random, stratified, clustered, and intentional sampling). The postural habits data from both the population and the four sampling procedures were analyzed using descriptive statistics and a calculated 95% confidence interval. The stratified sampling procedure, followed by the random and clustered procedures, presented the best distribution of school children, most closely approximating the distribution in the entire population. Therefore, the necessity of research about posture, both in the planning and execution stage, is vital. Researchers must pay attention to factors such as sampling method and utilizing an effective sample size.

KEYWORDS
posture, epidemiology, biostatistics, method, population, sample size

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Introduction

Epidemiological studies are used to monitor the health situation of the population, support planning and financial investments, and assess existing health policies (Christensen, 2007; Hayat, 2013). In short, epidemiological studies describe phenomena or compare the behavior of variables in a population (Gabriel

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& Michaud, 2009). Most of these studies, particularly those related to postural habits, describe phenomena of a certain population based on information obtained from sampling procedures (Kasten, Rosa, Schmit, Noll, & Candotti, 2017; Noordzij et al., 2010). Assessing a sample instead of an entire population provides the following advantages: lower cost, less time required, as well as speed and ease in acquiring and analyzing data (Noordzij et al., 2010). This process is based on the premise that conducting a study with a sample containing a satisfactory quantity of elements is sufficient to produce reliable conclusions regarding an entire population.

The sample size is determined by several factors; therefore, the ideal size should be estimated for each study considering specific features (e.g., objective, the parameter to be estimated, the classification of the variable of interest, the maximum acceptable error, the desired level of confidence, etc.) (Altman, 1980; Clark, Berger, & Mansmann, 2013; Noordzij et al., 2010). It should be noted that even with a scientifically well-defined sample, the results will always be subject to a degree of uncertainty since data provided by a sample may lead to random variation as they only constitute part of the population.

This degree of uncertainty regarding the results is associated with two key aspects: the sample size and the sampling procedure [7,8]. The first aspect may be resolved by using a sample size calculation, which can be used to provide the precise "*N*" for each study. The second aspect is more complex and presents researchers with a number of alternatives including random sample, stratified sample, cluster sample, intentional sample, accidental sample, and so on (Clark et al., 2013; Dupont & Plummer, 1998; Hayat, 2013).

As the sampling procedures are closely related to scientific validity, it is necessary to understand the influence of sampling procedures on obtained research results to ensure that epidemiological studies provide reliable information for planning actions designed to ensure quality in promoting health. Therefore, we verified whether the results regarding postural habits provided by distinct sampling procedures are consistent with those obtained from an entire population.

Methods

The data for this descriptive study originated from the database of a populational epidemiological study involving 1,597 fifth- to eighth-grade elementary school children (aged 11–14 years) from all the schools (N = 11) in the municipality of Teutônia, Rio Grande do Sul, Brazil (Noll, Candotti, Rosa, & Loss, 2016). This study was approved by the Ethics and Research Committee of the Federal University of Rio Grande do Sul (no. 19832) and was in accordance with the Helsinki Declaration. The school children withdraw from the study at will or opt-out of any of the tests. Prior to participation, the children voluntarily provided informed, written consent.

A self-report questionnaire called the Back Pain and Body Posture Evaluation Instrument (BackPEI) was used (Noll, Tarragô Candotti, Vieira, & Fagundes Loss, 2013). For the present study, only behavioral questions that evaluated the body posture of the school children in the following activities were used: preferred sleeping position, sitting position when writing, sitting position on a chair when talking, sitting position when using a computer, position adopted when lifting an object from the ground, and the means and mode of transporting their school backpack.

Data analysis procedures

The data from the entire population were analyzed and then compared with the results from four samples from the same population obtained using probabilistic sampling (simple random, stratified, and cluster samples) and non-probabilistic sampling (intentional sample). To use of intentional samples when extrapolating data for a population is inappropriate; therefore, to simulate this erroneous situation, data from an intentional sample was also analyzed. Figure 1 shows the criteria used in the selection of the members of the population for each of the four sampling procedures included in the present study.

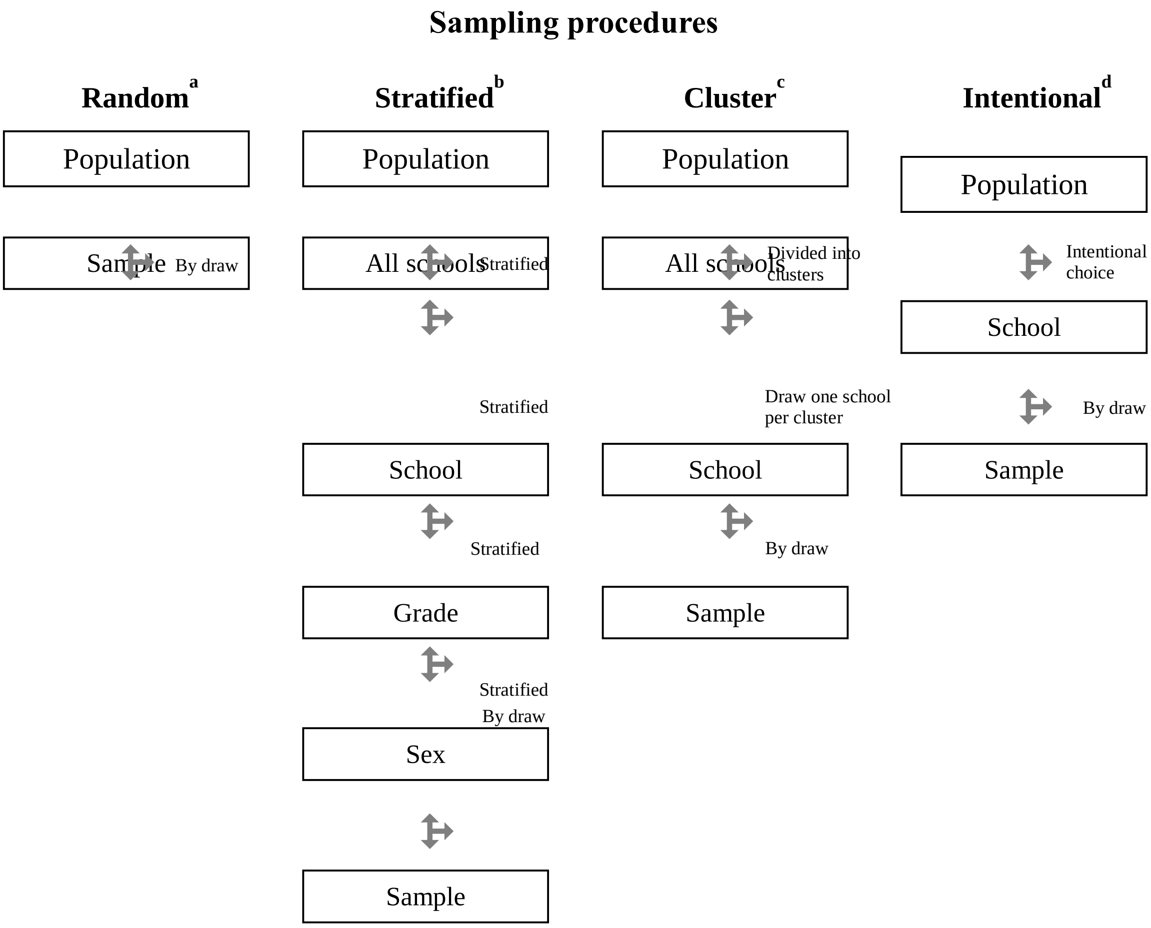

Figure 1. Detailed presentation of the criteria used in the sampling procedure to choose the participants in the random, stratified, cluster, and intentional samples.

[a]Random sample: the sample participants were drawn from a list including all the participants in the population.

[b]Stratified sample: the list including all the participants in the population was stratified according to status (municipal school, state school, or private school), school, grade, and sex; later, the sample members were drawn proportionally from each stratum.

[c]Cluster sampling: the population was divided into clusters (state or private schools) and one school was drawn at random from each cluster after the members of the sample were drawn from each cluster.

[d]Intentional sample: a school was intentionally chosen and the sample members were drawn at random.

In addition to determining in detail the sampling procedure used, the adequate sample size was defined so that the results could be extrapolated to the entire population by means of Equation 1 (based on the proportions of a finite population). The sample size was calculated based on N = 1597, a 95% confidence level, a sampling error of 5%, and an incidence of backpain of 50%. Therefore, based on the insertion of these data in Equation 1, the sample should contain 310 school children.

Equation 1

$$n = \frac{N.z^2.p.q}{E^2(N-1) + z^2.p.q}$$

where:

n – required sample size

N – population size

z – number of standard deviations of the normal distribution

p – prevalence of the studied variable

q – proportion of non-prevalence ($q = 1\text{-}p$) of the studied variable

E – maximum permitted margin of error

Statistical treatment

Descriptive statistics were used to analyze the population, and the sampling procedures concerning each of the behavioral questions included in this study. The results of the entire population were adopted as the "true value" and the results from the sampling procedures were classified as "no difference" or "difference" based on two criteria. Criterion 1 used the 95% confidence interval (95% CI), with the results from the sampling procedures classified as (1) "no difference" (when the confidence interval included the "true value") and (2) "difference" (when the confidence interval did not include the "true value"). Criterion 2, adopted arbitrarily, classified the results from the sampling procedures as (1) "no difference" when the value from the sampling procedure varied by no more than 5% from the "true value" and (2) "difference" when the value from the sampling procedure varied by more than 5% from the "true value."

Results

The random and stratified sampling procedures include the same percentage of schoolchildren as the population regarding sex and school status. Regarding the selection of school children in the cluster sampling procedure, most of percentages differed concerning the population since the confidence interval did not include the "true value" and the percentage differed more than 5% from the "true value." With the intentional sampling procedure, because just one school was chosen, 100% of the school children in this sampling procedure were from the state school (Table 1).

Table 1. Results from the sampling procedures compared to the population concerning the distribution of school children included in the analysis by sex and school status.

Method	Sex	School status Municipal % (95% CI)	State % (95% CI)	Private % (95% CI)
Population (true value)	M (n = 856)	51.9	39.1	9.0
	F (n = 741)	52.8	39.5	7.7
	T (N = 1597)	52.3	39.3	8.4
Random sample	M (n = 171)	50.9 (45.9–55.9)	40.9 (35.9– 45.8)	8.2 (5.4–10.9)
	F (n = 139)	48.2 (43.2–53.2)	41 (36.1–45.9)	10.8 (7.7–13.9)
	T (n = 310)	49.7 (44.7–54.7)	41 (36.1–45.9)	9.4 (6.5–12.3)
Stratified sample	M (n = 165)	52.1 (47.1–57.1)	38.8 (33.9–43.7)	9.1 (6.2–12)
	F (n = 145)	53.8 (48.8–58.8)	38.6 (33.7–43.5)	7.6 (5–10.2)
	T (n = 310)	52.9 (47.9–57.9)	38.7 (33.8–43.6)	8.4 (5.6–11.2)
Cluster sample	M (n = 168)	39.9 (35.0–44.8) [a/b]	44.6 (39.6–49.6) [a/b]	15.5 (11.9–19.1) [a/b]
	F (n = 142)	43 (38.1–47.9) [a/b]	43 (38.1–47.9)	14.4 (10.9–17.9) [a/b]
	T (n = 310)	41.3 (36.4–46.2) [a/b]	43.9 (38.9–48.9)	14.8 (11.3–18.3) [a/b]
Intentional sample	M (n = 159)	–	100 [a/b]	–
	F (n = 151)	–	100 [a/b]	–
	T (n = 310)	–	100 [a/b]	–

[a]Confidence interval did not include the true value. [b]Value from the sampling procedure differed by more than 5% from the true value. M = male; F = female; T = total.

When the distribution of school children in the distinct sampling procedures was analyzed according to sex and age, the stratified sampling procedure presented the results closest to the real distribution of the population, followed by the random and cluster procedures (Table 2). Regarding the students selected using the intentional sampling procedure, several strata differed in percentage from the value of the entire population (Table 2).

Table 2. Results obtained from the sampling procedures compared to the entire population regarding distribution of school children included in the analysis by sex and age.

Method	Sex	Age (years)					
		11 % (95% CI)	12 % (95% CI)	13 % (95% CI)	14 % (95% CI)	15 % (95% CI)	16 % (95% CI)
Population (true value)	M (n = 856)	11.6	22.4	23	23.7	14	5.3
	F (n = 741)	14.4	24.4	24.2	23.2	11.2	2.6
	T (N = 1597)	12.9	23.4	23.5	23.5	12.7	4
Random sample	M (n = 171)	14 (10.5–17.5)	18.7 (14.8–22.6)	17.5 (13.7–21.3) [a/b]	26.3 (21.9–30.7)	15.8 (12.2–19.4)	7.6 (5–10.2)
	F (n = 139)	14.4 (10.9–17.9)	26.6 (22.2–31)	25.2 (20.9–29.5)	22.3 (18.1–26.5)	8.6 (5.8–11.4)	2.9 (1.2–4.6)
	T (n = 310)	14.2 (10.7–17.7)	22.3 (18.1–26.5)	21 (16.9–25.1)	24.5 (20.2–28.8)	12.6 (9.3–15.9)	5.5 (3.2–7.8)
Stratified sample	M (n = 165)	10.9 (7.8–14)	24.8 (20.5–29.1)	21.2 (17.1–25.3)	23.6 (19.4–27.8)	15.2 (11.6–18.8)	4.2 (2.2–6.2)
	F (n = 145)	15.2 (11.6–18.8)	24.8 (20.5–29.1)	21.4 (17.3–25.5)	23.4 (19.2–27.6)	12.4 (9.1–15.7)	2.8 (1.2–4.4)
	T (n = 310)	12.9 (9.5–16.3)	24.8 (20.5–29.1)	21.3 (17.2–25.4)	23.5 (19.3–27.7)	13.9 (10.4–17.4)	3.5 (1.7–5.3)
Cluster sample	M (n = 168)	9.5 (6.6–12.4)	27.4 (22.9–31.9) [a]	21.4 (17.3–25.5)	24.4 (20.1–28.7)	12.5 (9.2–15.8)	4.8 (2.7–6.9)
	F (n = 142)	17.6 (13.8–21.4)	26.1 (21.7–30.5)	24.6 (20.3–28.9)	21.1 (17–25.2)	9.2 (6.3–12.1)	1.4 (0.2–2.6)

	T (n = 310)	13.2 (9.8–26.6)	26.8 (22.4–31.2)	22.9 (18.7–27.1)	22.9 (18.7–27.1)	11 (7.9–14.1)	3.2 (1.4–5)
Intentional sample	M (n = 159)	8.8 (6–11.6)	17.6 (13.8–21.4) [a]	17.6 (13.8–21.4) [a/b]	28.9 (24.4–33.4) [a/b]	17.6 (13.8–21.4)	9.4 (6.5–12.3) [a]
	F (n = 151)	10.6 (7.5–13.7) [a]	23.8 (19.5–28.1)	23.8 (19.5–28.1)	25.2 (20.9–29.5)	11.9 (8.7–15.1)	4.6 (2.5–6.7)
	T (n = 310)	9.7 (6.7–12.7) [a]	20.6 (16.6–24.6)	20.6 (16.6–24.6)	27.1 (22.7–31.5)	14.8 (11.3–18.3)	7.1 (4.5–9.7) [a]

[a]Confidence interval did not include the true value. [b]Value from the sampling procedure differed by more than 5% from the true value. M = male; F = female; T = total.

The stratified sampling procedure presented the results for prevalence of suitable postural habits closest to the true value, followed by the cluster and random sampling procedures (Table 3). The prevalence found with the intentional sampling system differed most concerning the true value when compared to the other sampling procedures (Table 3).

Table 3. Results from the prevalence of suitable postural habits for the entire population and for each of the sampling procedures (for both sexes).

		Suitable posture					
Method	**Sex**	**Sleeping position % (95% CI)**	**Sitting position when writing % (95% CI)**	**Sitting position on a chair when talking % (95% CI)**	**Sitting position when using a computer % (95% CI)**	**Lifting an object from the floor % (95% CI)**	**Use of backpack to carry school material % (95% CI)**
Population (True value)	M (n = 856)	66.2	14	16.3	20.6	6.3	93.8
	F (n = 741)	65.5	15.4	8.8	21.3	9.5	90.6
	T (N = 1597)	65.8	14.7	12.8	20.9	7.8	92.3
Random sample	M (n = 171)	61.4 (56.5–66.3)	14.6 (11.1–18.1)	13.5 (10.1–16.9)	24.1 (19.8–28.4)	11.7 (8.5–14.9) [a/b]	94.1 (91.7– 96.5)
	F (n = 139)	64 (59.2–68.8)	15.8 (12.2–19.4)	10.1 (7.1–13.1)	15.8 (12.2–19.4) [a/b]	5.8 (3.5–8.1) [a]	90.6 (87.7–93.5)

	T (n = 310)	62.6 (57.8–67.4)	15.2 (11.6–18.8)	12 (8.8–15.2)	20.4 (16.4–24.4)	9.1 (6.2–12)	92.6 (90–95.2)
Stratified sample	M (n = 165)	67.9 (63.2–72.6)	15.8 (12.2–19.4)	18.8 (14.9–22.7)	20.7 (16.6–24.8)	6.1 (3.7–8.5)	95.2 (93.1–97.3)
	F (n = 145)	68 (63.3–72.7)	17.9 (14.1–21.7)	9.7 (6.7–12.7)	23.6 (19.4–27.8)	10.4 (7.3–13.5)	88.3 (85.1–91.5)
	T (n = 310)	68 (63.3–72.7)	16.8 (13.1–20.5)	14.5 (11–18)	22.1 (18–26.2)	8.1 (5.4–10.8)	91.9 (89.2–94.6)
Cluster sample	M (n = 168)	68.9 (64.3–73.5)	11.9 (8.7–15.1)	16.3 (12.6–20)	20.4 (16.4–24.4)	5.4 (3.1–7.7)	95.2 (93.1–97.3)
	F (n = 142)	66.2 (61.5–70.9)	14.1 (10.6–17.6)	7 (4.4–9.6)	19.1 (15.2–23)	7.8 (5.1–10.5)	93.7 (91.3–96.1) [a]
	T (n = 310)	67.7 (63–72.4)	12.9 (9.5–16.3)	12 (8.8–15.2)	19.8 (15.8–23.8)	6.5 (4–9)	94.5 (92.2–96.8)
Intentional sample	M (n = 159)	70.3 (65.7–74.9)	11.3 (8.1–14.5)	17 (13.2–20.8)	24.7 (20.4–29)	7.6 (5–10.2)	96.2 (94.3–98.1) [a]
	F (n = 151)	56.7 (51.7–61.7) [a/b]	14.6 (11.1–18.1)	7.3 (4.7–9.9)	16.7 (13–20.4) [a]	10.1 (7.1–13.1)	94.7 (92–96.6) [a]
	T (n = 310)	63.7 (58.9–68.5)	12.9 (9.5–16.3)	12.3 (9–15.6)	20.8 (16.7–24.9)	8.8 (6–11.6)	95.5 (93.4–97.6) [a]

[a]Confidence interval did not include the true value. [b]Value from the sampling procedure differed by more than 5% from the true value. M = male; F = female; T = total.

Discussion

Our results indicated that the stratified sampling procedure presented the results closest to the true value, followed by the cluster and random sampling procedures; however, the intentional sampling system presented diverse prevalence results concerning the true value. The specialized literature indicates that all of these probabilistic sampling procedures (random, stratified, and cluster) can be used when the objective is to infer the data for an entire population

(Hayat, 2013; Noordzij et al., 2010). However, these probabilistic sampling procedures are known to present distinct characteristics, including the need to list and individually identify each of the participants in an entire population in the case of random and stratified sampling as well as the need for secondary characteristics of the population to permit stratification. These features, as well as the human, financial, and time resources available to conduct research, particularly that of an epidemiological nature, influence the researcher when choosing the most suitable procedure for studies regarding problems related to body posture.

Our results demonstrated that, for the evaluation of postural habits, the stratified sampling system presented the distribution of the school children closest to the distribution of the entire population, followed by the random and cluster procedures. Random sampling procedure has been understood to comprise the greatest degree of scientific rigor because its main characteristic is the guaranty that each participant within the population has the same possibility of being selected to be part of the sample. From a statistical point of view, this means that a characteristic, relation, or difference found in a sample will probably be present in the population from where the sample was selected. However, according to Snedecor and Cochran (Snedecor & Cochran, 1967), for heterogeneous groups, where diversity is found between sexes, ages, and regions of the planet (as was the case in the evaluation of postural habits in school children), it is vital to use the stratified sampling procedure because the use of homogeneous strata leads to greater precision in estimating the characteristics of an entire population. This corroborates our findings of since this method allows for greater representativeness and thus reduces the probability of sample error.

The current findings may be extrapolated to other areas of epidemiological investigation since ignoring the traditional statistical analyses of sample design (based on the assumptions of simple random sampling) may produce errors regarding frequency, mean estimations, and respective variance. Such errors can, in turn, compromise the results, the testing of hypotheses, and the research conclusions. Moreover, the use of statistical inference is not recommended in non-probabilistic sampling procedures as it impedes the extrapolation of the results to the entire population.

In summary, our findings indicate that stratified sampling procedure presented the distribution of school children, which best reflected that of the true population, both for the selection of participants and the description of school children's postural habits. Given that epidemiological research has gained visibility in recent years and is a vital tool for monitoring the health situation of the population, supporting planning and financial investments and assessing the effectiveness of existing health policies, it is essential that great methodological rigor is applied in sampling procedures. The current results can aid researchers in their decision-making processes.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Matias Noll: literature search, study design, data collection, data analysis, data interpretation, and writing the article.

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