A119 Comparison of Frequentist Methods for Estimating the Total Weight of Consignments of Drugs

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After attending this presentation, attendees will understand the problematic behavior of some ways that have been suggested to estimate total drug weight of consignments based on a subsample.

This presentation will impact the forensic science community by showing that suggested confidence intervals of total drug weight of consignments based on a subsample are basically unreliable.

Suppose a consignment of n packages suspected of containing illicit drugs is seized, of which it is considered too time-consuming to individually determine the individual drug bearing weights $x_1,...,x_n$. Instead, a sub-sample of m packages is taken, without replacement. Given the sample, several authors have commented on how to obtain confidence bounds for the total drug weight $w = x_1+...+x_n$ of the whole consignment. These bounds turn out to be problematic from a practical point of view.

The analyses are usually based on the assumption that the consignment is interpreted as a population with a fraction p of the packages containing drugs, and if so, the drug weights are normally distributed.

Complicating factors in the statistical analysis of the set-up are that:

1. Sampling takes place without replacement, whereas m/n may be relatively large, which reduces uncertainty, and

2. The probability distribution of total drug weights per package is a mixture of a point-mass at zero and a normal distribution.

The first of these leads to the introduction of the so-called finite population correction in limits of confidence intervals, and the second leads to separate estimating procedures for the “success rate” (fraction of non-zeroes) and the normal weight distribution of drug bearing packages.

Indeed, let the mean and standard deviation of the whole subsample, including zeroes, be defined as X_m and S_m. Moreover, let the fraction of observed *non-zero* elements in the sub-sample be $P_m = K_m/m$, and sample mean and standard deviation of the non-zero elements X^*_m and S^*_m. The obvious point estimator of the total drug weight is $nX_m = nP_mX^*_m$. In [Tzidony, Ravreby, 1992], the statistical behavior of X^*_m is studied, assuming that the fraction of non-zeros P_m in the subsample is equal to that over the whole consignment (p). On this basis, confidence intervals for the total drug weight of the consignment are obtained of the form (*) $nX_m - w \le t_{m-1,1-\alpha} \times Fpc \times (n/\sqrt{m}) \times S^*_m$ where the constant $t_{m-1,1-\alpha}$ depends on the degrees of freedom $m-1$ and the desired percentage of confidence (1-α)×100%.

It was recently observed in [Stoel, Bolck, 2009] that the standard deviation used was only over the (non-zero) drug containing units, so that in (*), the terms $t_{m-1,1-\alpha}$ and $(n/\sqrt{m})$ should be replaced by $t_{Km-1,1-\alpha}$ and $(n/\sqrt{K_m})$. They give new intervals. The above is an improvement but adds the conceptual problem that degrees of freedom appear which are random, next to the fact that the random behavior of P_m is still not taken into account. An alternative is to ignore the possible zeroes, and use the canonical inequality of the form

(*) $nX_m - w'' t_{m-1,1-\alpha} \times Fpc \times (n/) \times S^*$

This certainly has the advantage of simplicity. Knowledge about the statistical model, which separates success rate, mean drug weight and standard deviation, is thus ignored. However, the estimation of two parameters, each with its own measurement error, is avoided. Moreover, this approach does not use the assumption that $P_m = p$, which leads to underestimation of the variance involved. The current study shows

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that the classical confidence intervals are basically unreliable, since they are based on an underestimation of the variation of the random variables involved. In a simulation experiment where 90% of the scores were non-zero, the 95% confidence interval based on (*) turned out to be correct in 35% of the cases.

Two alternatives to (*) are presented that do yield asymptotically correct results, among which the canonical one described in (**). These alternative intervals are still not reliable for small subsamples though. The reason for this is the inherent multimodal behavior of the sample mean. There seems to be no obvious way to fix this.

Drug Sampling, Forensic Statistics, Finite Population

