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Response to editorial by R. Kordi et al.

Misplaced decimal places

The authors of the editorial on *Troublesome decimals* (Kordi et al., 2011) have provided a rationale for setting the decimal places of a reported statistic on the basis of the limit of its precision. For example, in the case of means the authors recommended one more decimal place than was measured on each datum, on the grounds that the mean has more precision than a single datum. The authors then suggested reporting the standard deviation (SD) with either the same precision as the mean or with one more decimal place. In our view, their approach is wrong: the key principle in reporting summary statistics clearly to the reader should be *minimum adequate* accuracy, not *maximum available* accuracy. When this principle is applied, a simple two-digits rule emerges: the SD is rounded to two significant digits, and the mean is then matched to the decimal places of the SD. The same principle applies to confidence limits and the effect statistic they accompany: expressed in ± form, the confidence limits are rounded to two digits, then the effect statistic is matched to the decimal places of the confidence limits. In this letter we provide examples and justification for this principle, and we discuss some minor exceptions. Most of the assertions can be found in a recent article on the use of statistics in sports medicine and science (Hopkins et al., 2009).

In the following examples, the means all have the same true value to any number of decimal places, but they are rounded differently to match the deliberately different SD:

8.567 ± 0.071
8.57 ± 0.71
8.6 ± 7.1
9 ± 71
10 ± 710
0 ± 7100

Notice that the notion of meaningful digits extends into powers of 10 on either side of the decimal point, depending on the magnitude of the SD; for example, it is correct to write 64 200 ± 3400, but it is wrong to write 64 180 ± 3420, 64 182 ± 3419, 64 182.4 ± 3419.1, and, of course, 64 000 ± 3000.

There are two stages to the justification of the two-digits principle. First, to see why a statistic such as the mean needs neither more nor less accuracy than the statistic representing its variability or uncertainty, consider one of the above examples, 8.57 ± 0.71. The mean and the SD convey the notion that the original numbers vary typically from the mean by an amount equal to the SD. Stating the mean as 8.6 would therefore not make full use of the precision of the variability to convey how much larger or smaller the numbers are typically, and stating it as 8.573 would provide more precision than was available from the variability.

Now, to see why the SD needs only two significant digits, there are two considerations. First, the minimum number of digits should always be presented, because it is easier for readers to perceive the magnitudes of statistics when there are fewer digits. Second, use of two digits implies an error of between 1 part in 198 (± 0.5 in 99, when the two digits are 99) and 1 part in 20 (± 0.5 in 10, when the two digits are 10). Is an error of at most 1 part in 20 acceptable in a statistic that already represents variability or uncertainty? In our experience the answer is generally yes, and there is also a justification based on the smallest important difference between means. The SD is used to gauge magnitudes of differences between means, which is why it is important to show the SD and not the standard error of the mean. The widely accepted default smallest important difference between means is 0.20 of the between-subject SD; therefore an error of 1 part in 20 in the SD is 0.05 SD, which is obviously a trivial error. Nevertheless, 0.05 could add to a similar error in another mean and on rare occasions make a trivial difference substantial, or vice versa, Thus, SDs with their first two meaningful digits between 10 and 20 could sometimes be reported with three digits to ensure that the means are also reported with precision that eliminates additional error when comparing group means from different studies.

An argument based on smallest important magnitudes leads to the same two-digits rule for percentages and correlations. When percentages represent frequent events or classifications, the smallest important difference between groups is 10%. Specifying a percentage between 10% and 99% without a decimal place therefore represents an error of ± 0.5%, which is negligible compared with this smallest difference. When percentages are small (<10%), they usually represent proportions of uncommon events or classifications, and for comparisons of such proportions a ratio of 1.10 is considered the smallest important value. Percentages with one decimal place therefore have adequate accuracy for values >2.0%, but for values between 1.0% and 2.0%, an extra decimal place could be justified in some circumstances. Correlations similarly need at most two significant digits, on the grounds that the smallest correlation is 0.10. Examples: 0.97, 0.52, 0.13, 0.02.

The two-digits rule is also appropriate for confidence limits expressed in ± form. If the confidence limits are to be expressed in the interval form (lower limit to upper limit), precision needs to be established using the ± form, then converting the limits to an interval.

Hopkins et al. (2009) were sketchy about what to do when the measure of variability is an SD or confidence limits expressed in times/divide form (×/÷ followed by a number representing a factor). Such measures arise from back-transformation after analysis of log-transformed variables, and their use is becoming common. Here two digits are also appropriate for the kind of large variability that should be shown as a factor, such as ×/÷4.3, but when the variability is less than a factor of two, the factor variability needs to be ×/÷1.73, ×/÷1.21, and so on. When the factor is <1.10, which means a variability of <10%, an extra decimal is necessary: ×/÷1.073. However, factor variability this small is better presented as percent variability, and then the extra digit is automatically included: ±7.3%. Two meaningful digits are also needed for the mean that goes with the factor SD or confidence limits – do not attempt to match the digits or decimals of the mean to those of the measure of variability. Specify factor effects such as risk, odds, and hazard ratios in exactly the same manner as a factor SD: two meaningful digits when the value is 2.0 or more, otherwise two decimal places. Finally, the only advice we offer on presentation of *P*-values is to avoid them in favor of confidence limits.

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