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Mathematics of Experimentation (Additional File)

Worked Example of Accuracy and Precision

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A medical student (she just started her clerkship in pediatrics) and a professional anthropometrist, both took MUAC (mid-upper-arm circumference) of right arm of a 7-year-old girl. The data are given in Table 1. By computing accuracy and precision, identify medical student/anthropometrist (measurer M_1 or M_2) — reference value of MUAC is 16.5 cm.

Table 1. Measured MUAC values of a 7-*year*-old girl

MUAC (cm)	*1st*	*2nd*	*3rd*	*4th*	*5th*
Measurer M_1	16.4	16.3	16.7	16.8	17.1
Measurer M_2	16.5	16.6	16.4	16.6	16.4

Accuracies (A) and precisions (P) of measurers M_1 and M_2 are computed in Tables 2*a*, *b*, respectively.

Measurer M_1**:** $\overline{O} = \frac{1}{N}\sum_{i=1}^{N} O_{\mathrm{i}} = \frac{83.3}{5} = 16.66\,cm \bullet \overline{|O|} = \frac{83.3}{5} = 16.66\,cm$

$$D = \sum_{i=1}^{N} \frac{|O_{\mathrm{i}} - \overline{O}|}{N-1} = \frac{1.24}{4} = 0.31 \;\; cm \bullet D_{\mathrm{R}} = \sum_{i=1}^{N} \frac{|O_{\mathrm{i}} - R|}{N-1} = \frac{1.4}{4} = 0.35 \;\; cm$$

$$A = 100\left[1 - \frac{D_{\mathrm{R}}}{D_{\mathrm{R}} + \overline{|O|}}\right] = 97.942386832\% \bullet P = 100\left[1 - \frac{D}{D + \overline{|O|}}\right] = 98.173246907\%$$

Measurer M_2**:** $\overline{O} = \frac{1}{N}\sum_{i=1}^{N} O_{\mathrm{i}} = \frac{82.5}{5} = 16.5\,cm \bullet \overline{|O|} = \frac{82.5}{5} = 16.5\,cm$

$$D = \sum_{i=1}^{N} \frac{|O_{\mathrm{i}} - \overline{O}|}{N-1} = \frac{0.4}{4} = 0.1 \;\; cm \bullet D_{\mathrm{R}} = \sum_{i=1}^{N} \frac{|O_{\mathrm{i}} - R|}{N-1} = \frac{0.4}{4} = 0.1 \;\; cm$$

$$A = 100\left[1 - \frac{D_{\mathrm{R}}}{D_{\mathrm{R}} + \overline{|O|}}\right] = 99.397590362\% \bullet P = 100\left[1 - \frac{D}{D + \overline{|O|}}\right] = 99.397590362\%$$

A comparative statement is prepared, which shows that measurer M_2 has not only *higher precision* — indicator of

Table 2*a*. Accuracy and precision computation of measurer M_1 (reference value, R = 16.5 *cm*)

i	$O_{\mathrm{i}}\,(cm)$	$\|O_{\mathrm{i}}\|\,(cm)$	$(O_{\mathrm{i}} - \overline{O})\,(cm)$	$\|O_{\mathrm{i}} - \overline{O}\|\,(cm)$	$(O_{\mathrm{i}} - R)\,(cm)$	$\|O_{\mathrm{i}} - R\|\,(cm)$
1	16.4	16.4	–0.26	0.26	–0.1	0.1
2	16.3	16.3	–0.36	0.36	–0.2	0.2
3	16.7	16.7	0.04	0.04	0.2	0.2
4	16.8	16.8	0.14	0.14	0.3	0.3
5	17.1	17.1	0.44	0.44	0.6	0.6
$\sum$	83.3	83.3		1.24		1.4

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Fig. 1.Measuring MUAC of a 7-*year*-old girl

good work habits (Figure 1), 99.397590362% as compared to 98.173246907% (measurer M_1), but also *higher accuracy* — indicator of accessibility to good instruments, 99.397590362% as compared to 97.942386832% (measurer M_1). According to these results (Table 3), measurer M_2 seems to be *professional anthropometrist*, whereas measurer M_1 looks like *medical student*. In case, the professional anthropometrist forgot his glasses on the day of measurement, his precision should have been higher, but accuracy might have dropped.

Table 2*b*. Accuracy and precision computation of measurer M_2 (reference value, R = 16.5 *cm*)

i	O_i (*cm*)	$\lvert O_i \rvert$ (*cm*)	$(O_i - \overline{O})$ (*cm*)	$\lvert O_i - \overline{O} \rvert$ (*cm*)	$(O_i - R)$ (*cm*)	$\lvert O_i - R \rvert$ (*cm*)
1	16.5	16.5	0.0	0.0	–0.1	0.1
2	16.6	16.6	0.1	0.1	–0.2	0.2
3	16.4	16.4	–0.1	0.1	0.2	0.2
4	16.6	16.6	0.1	0.1	0.3	0.3
5	16.4	16.4	–0.1	0.1	0.6	0.6
$\sum$	82.5	82.5		0.4		0.4

Please note that mean deviation (D) is used instead of standard deviation (σ) as the data are not normally distributed (number of observations being only 5).

Table 3. Accuracies and precisions of measurers M_1 and M_2

	Accuracy	*Precision*
Measurer M_1	97.942386832 %	98.173246907 %
Measurer M_2	99.397590362 %	99.397590362 %

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Prof. Dr. Muhammed Rafi and Prof. Dr. Razi Hussain Memorial Lecture: Mathematics of Experimentation
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