

Comparing methods of measurement: why plotting difference against standard method is misleading

J Martin Bland, Douglas G Altman

Summary

When comparing a new method of measurement with a standard method, one of the things we want to know is whether the difference between the measurements by the two methods is related to the magnitude of the measurement. A plot of the difference against the standard measurement is sometimes suggested, but this will always appear to show a relationship between difference and magnitude when there is none. A plot of the difference against the average of the standard and new measurements is unlikely to mislead in this way. We show this theoretically and illustrated by a practical example.

Lancet 1995; **346**: 1085-87.

Introduction

In earlier papers [1,2] we discussed the analysis of agreement between methods of clinical measurement. We had two issues in mind: to demonstrate that the analyses then in general use were incorrect and misleading, and to recommend a more appropriate method. We saw the aim of such studies as to determine whether two methods agreed sufficiently well for them to be used interchangeably. This led us to suggest that the analysis should be based on the differences between measurements on the same subject by the two methods. The mean difference would be the estimated bias, the systematic difference between methods, and the SD of the differences would measure random fluctuations around this mean. We recommended 95% limits of agreement, mean difference plus or minus 2 (more precisely, 1.96) SDs, which would tell us how far apart measurements by the two methods were likely to be for most individuals.

Figure 1 shows a typical data set, the measurement of systolic blood pressure by a test method, finger pressure, and a standard method, arm blood pressure. This is a random subsample of 200 observations from a larger data set. [3, 4] The sub-sample was drawn to avoid cluttered graphs. The mean difference, finger minus arm, is 4.3 mm Hg and the SD is 14.6 mm Hg. Hence the lower 95% limit is $4.3 - 1.96 \times 14.6 = -24$ mm Hg and the upper 95% limit is $4.3 + 1.96 \times 14.6 = 33$ mm Hg. Thus we estimate that for 95% of subjects the finger measurement will be between 24 mm Hg below the arm measurement and 33 mm Hg above it.

For the mean and SD of the differences to be meaningful estimates we must assume that they are reasonably constant throughout the range of measurement. We suggested checking this assumption graphically. [1, 2] The usual plot, method one versus method two, is inefficient because the

points tend to be clustered along the line of equality (figure 1), especially if the two methods give closely related measurements. We therefore proposed that the difference be plotted against the average of the measurements by the two methods (figure 2).

In figure 2 we have also added the 95% limits of agreement and the regression line of difference on average. The main departure from assumptions we were expecting was an increase in variability, shown by an increase in the scatter of the differences, as the magnitude of the measurement increased. There may also be a trend in the bias, a tendency for the mean difference to rise or fall with increasing magnitude. Either would show that the methods did not agree equally through the range. In figure 2, for example, there is an increase in bias with magnitude, shown by the positive slope of the regression line. Such deviations from assumptions can often be dealt with by a suitable transformation, usually logarithmic. [2] In particular, this approach will be effective if the differences are proportional to the magnitude of the measurement.

The 95% limits of agreement approach has been widely adopted and the *Lancet* paper [2] widely cited. [5] However, it is sometimes argued that when one method may be regarded as a 'gold standard', it is presumably more accurate than the other method and so we should plot the difference against the gold standard. [6,7] We think that this idea is misguided and is likely to lead to misinterpretation. Here we will show why, and that the plot of difference against average is almost always preferable.

Plotting difference against average

We denote our standard measurement by S , the new or test measurement by T , their variances by σ_S^2 and σ_T^2 , and their correlation by ρ . If the study includes a wide range of measurements, and unless the two methods of

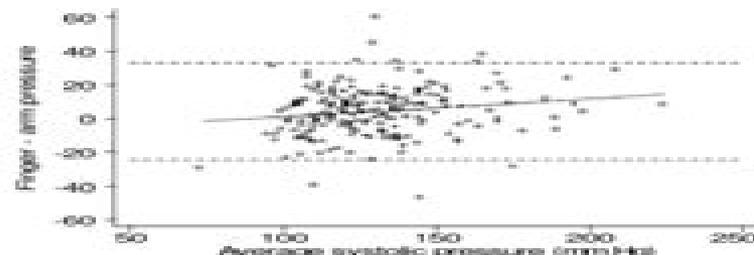


Figure 1. Test and standard measurements, with line of equality

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Evidence-Based Diagnosis Thomas B. Newman, Michael A. Kohn, 2020-06-25 Medicine is becoming increasingly reliant on diagnostic prognostic and screening tests for the successful treatment of patients With new tests being developed all the time a more informed understanding of the benefits and drawbacks of these tests is crucial Providing readers with the tools needed to evaluate and interpret these tests numerous real world examples demonstrate the practical application and relevance of the material The mathematics involved are rigorously explained using simple and informative language Topics covered include the diagnostic process reliability and accuracy of tests and quantifying treatment benefits using randomized trials amongst others Engaging illustrations act as visual representations of the concepts discussed in the book complementing the textual explanation Based on decades of experience teaching in a clinical research training program this fully updated second edition is an essential guide for anyone looking to select develop or market medical tests *Medical Principles and Practice*, 2005 *Veterinary Clinical Pathology*, 2006 [Challenges in Sun Protection](#) Christian, Surber, Uli, Osterwalder, 2021-10-25 In the early 20th century tanned skin was associated with good health However people began to protect themselves against potential overexposure to avoid sunburns Around 1945 the first sunscreen products became available In the years to follow a vast number of different sunscreen filters and frameworks regulating filter substances and preparations and methods characterizing sunscreen products were developed The perception regarding the tasks of sunscreen products changed several times initially it was promoted as a lifestyle product then as a skin cancer preventive means and more recently also for anti aging Different purposes and the widespread use of these products have led to myriad studies and a wealth of information In this volume the editors present a current collection of information analyzing and discussing issues related to sunscreen products and their use These include challenges regarding the ideal sunscreen product including filter selection and formulation issues measurement methods performance characterization safety and regulatory issues Further papers address topics related to the use of sunscreen products in everyday life in vulnerable

cohorts and outdoor workers Controversial topics such as environmental effects of sunscreen products and the risks and benefits of UV radiation in the context of skin cancer vitamin D and cardiovascular and metabolic health are also covered

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The novel begins with Richard Papen, a bright but troubled young man, arriving at Hampden College. Richard is immediately drawn to the group of students who call themselves the Classics Club. The club is led by Henry Winter, a brilliant and charismatic young man. Henry is obsessed with Greek mythology and philosophy, and he quickly draws Richard into his world. The other members of the Classics Club are equally as fascinating. Bunny Corcoran is a wealthy and spoiled young man who is always looking for a good time. Charles Tavis is a quiet and reserved young man who is deeply in love with Henry. Camilla Macaulay is a beautiful and intelligent young woman who is drawn to the power and danger of the Classics Club. The students are all deeply in love with Morrow, and they are willing to do anything to please him. Morrow is a complex and mysterious figure, and he seems to be manipulating the students for his own purposes. As the students become more involved with Morrow, they begin to commit increasingly dangerous acts.

The Secret History is a brilliant and gripping novel that will keep you speculating until the very end. The novel is a warning tale about the dangers of obsession and the power of evil.

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