## Public Health England

Protecting and improving the nation's health

**Technical Guide**

# Funnel Plots

## What is a Funnel Plot?

A funnel plot is a type of chart in which an indicator is plotted on the y-axis against the denominator (or sample size) of that indicator on the x-axis. As the sample size increases, the control limits narrow, giving a characteristic funnel shape (Figure 1).

The funnel plot is a useful display method when denominator sizes vary and identification of statistically significant outliers is important, especially when many values are to be plotted on a single graph.
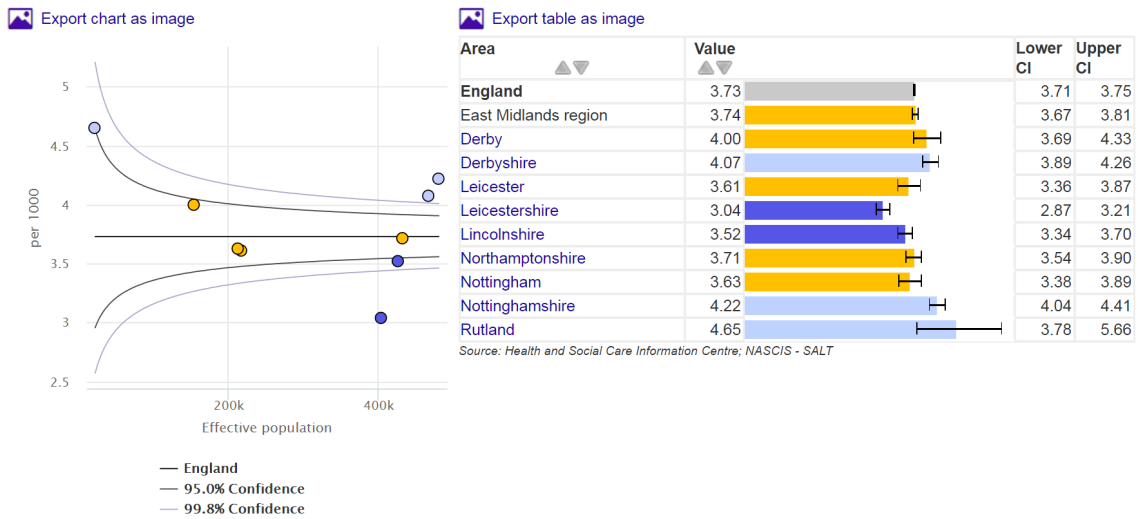
## Interpretation

The control limits or 'funnels' represent the bounds of statistical confidence around the average value. Specifically, this means that any observation plotted within the funnel limits will have a confidence interval which includes the average value: such variation within the funnel limits would be expected even in a controlled system (ie a system where the only difference between observations is expected random variation). Conversely, the confidence interval of any observation plotted outside the funnel limits would not include the average value, and may therefore indicate unexpected deviation from the norm and warrant further investigation. However, even within expected random variation, 2 out of every 1,000 observations are likely to lie outside the 3 standard deviation funnel and 5 out of every 100 observations are likely to lie outside the 2 standard deviation funnel, and this should be taken into consideration when interpreting funnel plots.

## Funnel Plots in Fingertips

Funnel plots are available in Fingertips[1] for some indicators under the Compare Areas tab (Figure 1). Select the areas of interest in the Fingertips header and then hover over the funnel plot points to see which areas they represent from the table on the right.

**Figure 1 – Example of a Fingertips Funnel Plot**

**Adults (18 to 64) with learning disability getting long term support from Local Authorities**  2014/15    Crude rate - per 1000



Export chart as image

Export table as image

| Area | Value | Lower CI | Upper CI |
|------|-------|----------|----------|
| **England** | 3.73 | 3.71 | 3.75 |
| East Midlands region | 3.74 | 3.67 | 3.81 |
| Derby | 4.00 | 3.69 | 4.33 |
| Derbyshire | 4.07 | 3.89 | 4.26 |
| Leicester | 3.61 | 3.36 | 3.87 |
| Leicestershire | 3.04 | 2.87 | 3.21 |
| Lincolnshire | 3.52 | 3.34 | 3.70 |
| Northamptonshire | 3.71 | 3.54 | 3.90 |
| Nottingham | 3.63 | 3.38 | 3.89 |
| Nottinghamshire | 4.22 | 4.04 | 4.41 |
| Rutland | 4.65 | 3.78 | 5.66 |

*Source: Health and Social Care Information Centre; NASCIS - SALT*

— England
— 95.0% Confidence
— 99.8% Confidence

# Public Health England Funnel Plot Tools

## Accessing the Tools

Excel tools that facilitate the creation of funnel plots are available on the Fingertips Technical Guidance site. These can be accessed via the following link:
https://fingertips.phe.org.uk/profile/guidance

The appropriate tool must be selected based on the statistic being input (proportion, rate (including directly standardised rate), or ratio of observed to expected counts (including indirectly standardised ratio). This ensures that the data input template is set up to receive the available data and that the correct methods and confidence intervals are applied. Use the guide (Figure 2) on the following page to determine which tool is appropriate for your data.

## Statistical Methods

The funnel limits for proportions are calculated using the Wilson Score method for binomially distributed variates. The funnel limits for rates, indirectly standardised ratios and counts are calculated using exact Poisson distribution probabilities. The methodology used to plot the funnel lines in the funnel plot tools are defined in Appendix A.

# Further Reading

The funnel plot is an example of a statistical process control chart. Further information on statistical process control is available in Technical Briefing 2: Statistical process control methods in public health intelligence,[2] published by APHO in 2009 and available on the Fingertips Technical Guidance site.

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[2] https://fingertips.phe.org.uk/profile/guidance/APHO Tech Briefing 2 SPC Methods.pdf

**Figure 2 – Selecting the Appropriate Funnel Plot Tool**

# Proportions

## When should this tool be used?

When there is a fixed denominator population and a subset of this population that meet a certain condition. Numerators must fall between zero and the denominator value, giving proportions between 0 and 1 (0% and 100%)

## Notes

If the data are rates (and can theoretically therefore give values greater than 1 (or 100%)) then use the Rates tool

# Rates

## When should this tool be used?

When the numerator is a count of events over time and the denominator is a related population (or person-years if the count covers multiple years)

## Notes

Suitable for Crude and Directly Standardised Rates

# Ratios

## When should this tool be used?

When there is an observed number of events (at least zero and not constrained to an upper limit) relative to an expected number of events within a population (eg indirectly standardised ratios or SMRs)

## Notes

Two display options are offered:
1) When the observed count = expected the ratio is shown as 100% (eg SMRs)
2) When the observed count = expected the ratio is shown as zero (ie negative values represent observed count < expected and vice versa)

## PHE Technical Guides

This document forms part of a suite of PHE technical guides that are available on the Fingertips website: https://fingertips.phe.org.uk/profile/guidance

## Appendix A:
## Methodology for plotting the funnel lines in the Excel funnel plot tool charts

The funnel lines on the Excel funnel plot tool charts are plotted as a series of 100 points joined as a line graph. The 100 points are selected such that there are many points plotted where the x-axis value is small and the funnel slope is rapidly changing, and fewer points plotted where the x-axis value is large and the funnel slope is relatively constant. This ensures a smooth line when the points are joined.

## Proportions

Funnel points are plotted for each of 100 denominator values selected. For each denominator value $(n)$, the position of each funnel point is determined by applying the inverse of the Wilson Score confidence interval method (with confidence level $1 - \alpha$) to the denominator assuming a reference proportion $(x_{ref})$ equal to the overall average as shown by the equation below:

$$FP_{1-\alpha} = \frac{8x_{ref}\left(\frac{n}{z^2} + 1\right) \pm \sqrt{\left(8x_{ref}\left(\frac{n}{z^2} + 1\right)\right)^2 - 64x_{ref}\left(\frac{1}{z^2} + \frac{1}{n}\right)\left(n\left(x_{ref}\left(\frac{n}{z^2} + 2\right) - 1\right) + z^2(x_{ref} - 1)\right)}}{8n\left(\frac{1}{z^2} + \frac{1}{n}\right)}$$

Where $z$ is the cumulative inverse of the standard normal distribution for $p = (1 - \alpha)/2$.

## Rates

Funnel points are plotted for each of 100 event counts selected. For each event count $(O)$, a funnel point is plotted against an x-axis population $(n)$ equal to the exact Poisson distribution confidence limit for that event count assuming a reference rate $(x_{ref})$ equal to the overall average, and a y-axis rate $(r)$ equal to the rate resulting from this count and population.

## Ratios

Funnel points are plotted for each of 100 observed event counts selected.  For each observed event count ($O_{obs}$), a funnel point is plotted against an x-axis expected event count ($O_{exp}$) equal to the exact Poisson distribution confidence limit for that observed event count.  The y-axis ratio to plot against ($r$) is equal to the ratio resulting from these observed and expected counts using a zero-based ($r_0$) or 100-based ($r_{100}$) average.