**1. Effect Size and Outcome Frequency**

* **Rare outcomes** (e.g., disease incidence <1%) often require very large relative changes before they appear as a measurable effect. For example, reducing incidence from 0.5% to 0.25% is a **50% relative risk reduction**, but the absolute risk difference is only 0.25%. That small absolute difference makes it harder to detect statistically, even though the relative effect is large.
* **Common outcomes** make even small relative changes detectable because the absolute differences are larger. For example, reducing prevalence from 40% to 35% is only a 12.5% relative reduction, but the 5% absolute difference is more visible in the data.

**👉 In practice: the rarer the outcome, the harder it is to detect an effect, even if the effect size (in relative terms) is large.**

**2. Power and Outcome Frequency**

* **Power** depends on both sample size and how many outcome events occur.
  + With **rare outcomes**, you have fewer “events” → larger variance → lower power.
  + With **common outcomes**, you get more events → narrower confidence intervals → higher power.
* In logistic regression or survival models, the rule of thumb is that you need a certain number of outcome events per predictor (often 10–20). If outcomes are rare, you can’t reliably estimate effects, and power drops sharply.
* In **interrupted time series (ITS)** or other designs, if the outcome rate is very low, random fluctuation can overwhelm the signal, making slope or level changes look unstable.

**3. Interaction Between Effect Size and Frequency**

* **High frequency + small effect size** → still detectable, because enough events accumulate.
* **Low frequency + large effect size** → may still lack power, because the event counts are too few.
* **Low frequency + small effect size** → almost impossible to detect without very large samples or long follow-up.

✅ **Key takeaway**:

* Higher outcome frequency improves power by reducing variance and widening detectable effect sizes.
* Lower outcome frequency reduces power, even if the relative effect size is large, because absolute changes are small and event counts are sparse.
* Designing studies with rare outcomes usually requires larger sample sizes, longer follow-up, or alternative outcomes (composite endpoints, proxies) to achieve sufficient power.