



APPLICATION OF THE PARETO PRINCIPLE TO RECREATIONAL DIVING DEATHS

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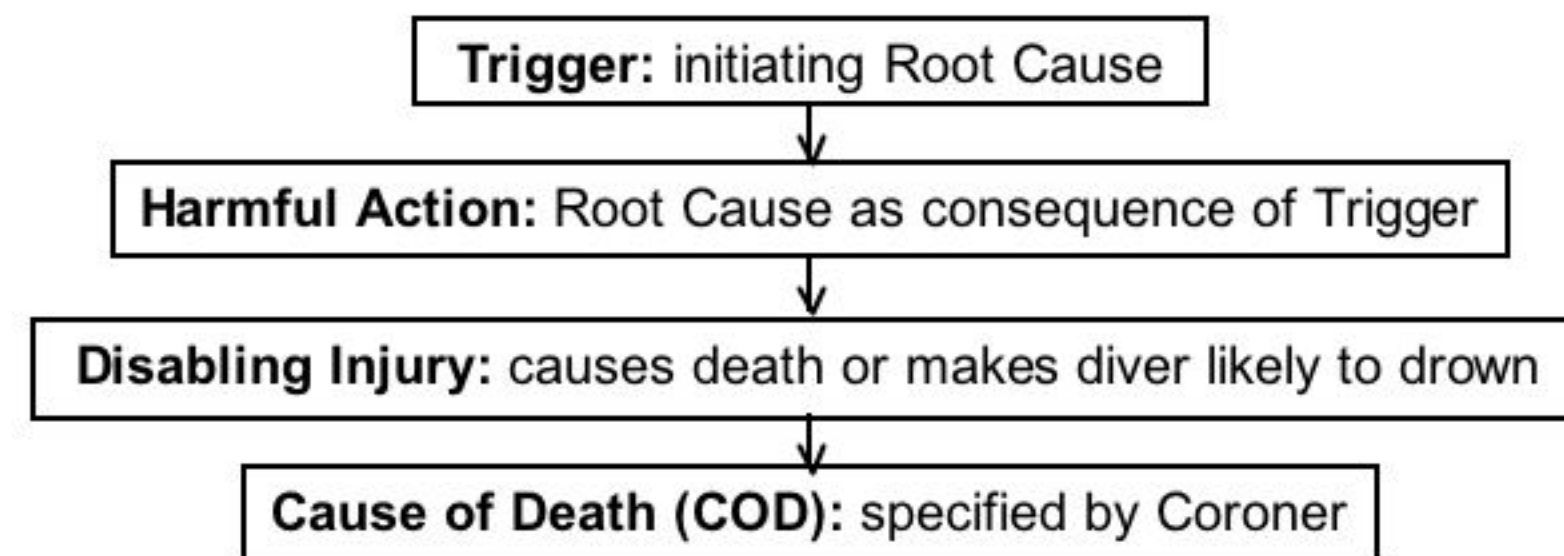


INTRODUCTION

- ❖ The Pareto principle is a quality assurance technique based on the observation that most failures result from a few vital causes (1).
 - ❖ Eliminating the vital causes reduces the risk of failure.
- ❖ Intrinsic factors (e.g., health) may also influence risk.
- ❖ We investigated causes and intrinsic factors associated with 947 open-circuit diving deaths from 1992-2003.

METHODS

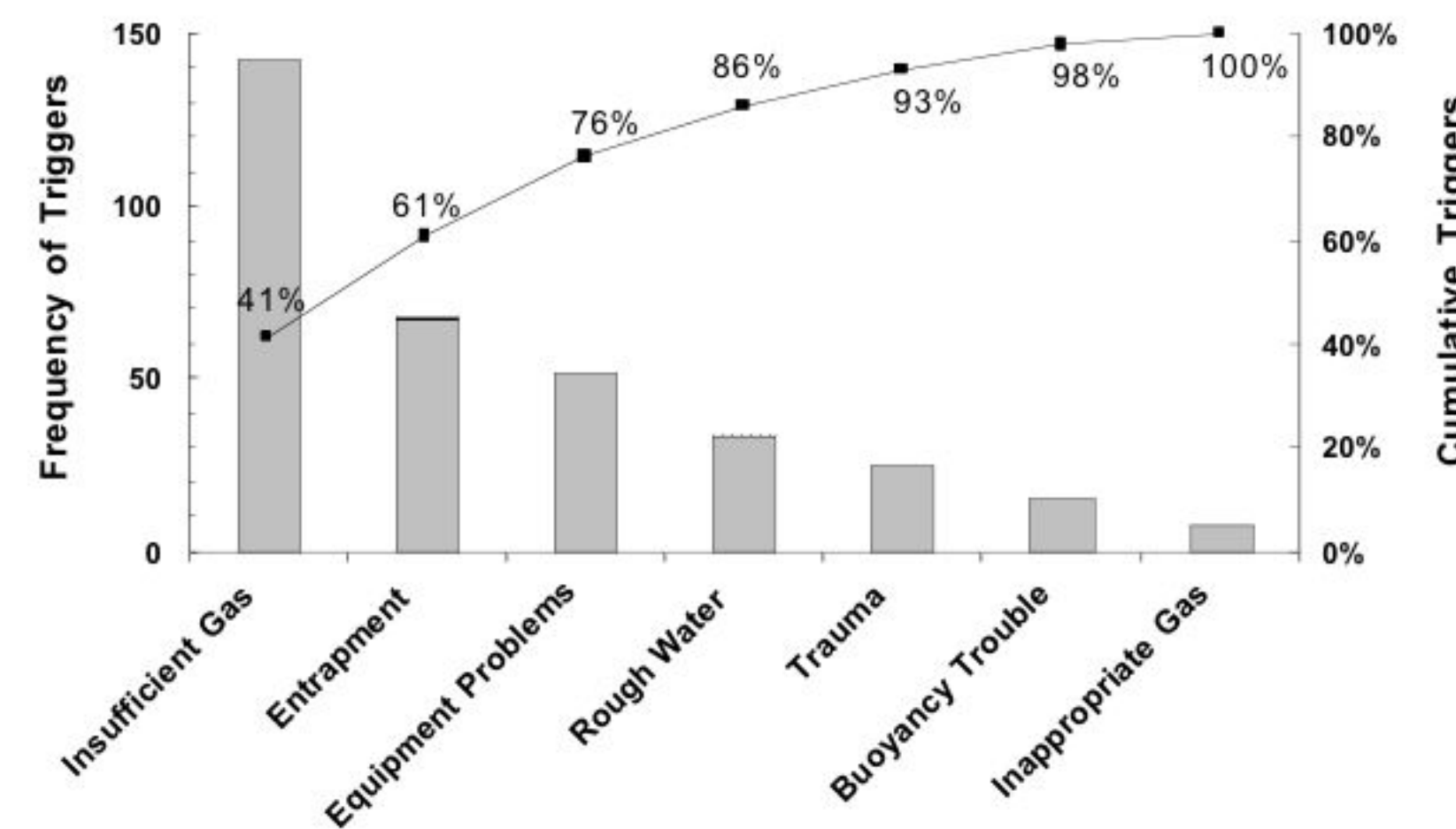
- ❖ We modified Root Cause Analysis (RCA; 2) for diving fatalities as shown in the sequence below.
 - ❖ Root causes are observable adverse events for which safety guidelines might be recommended.



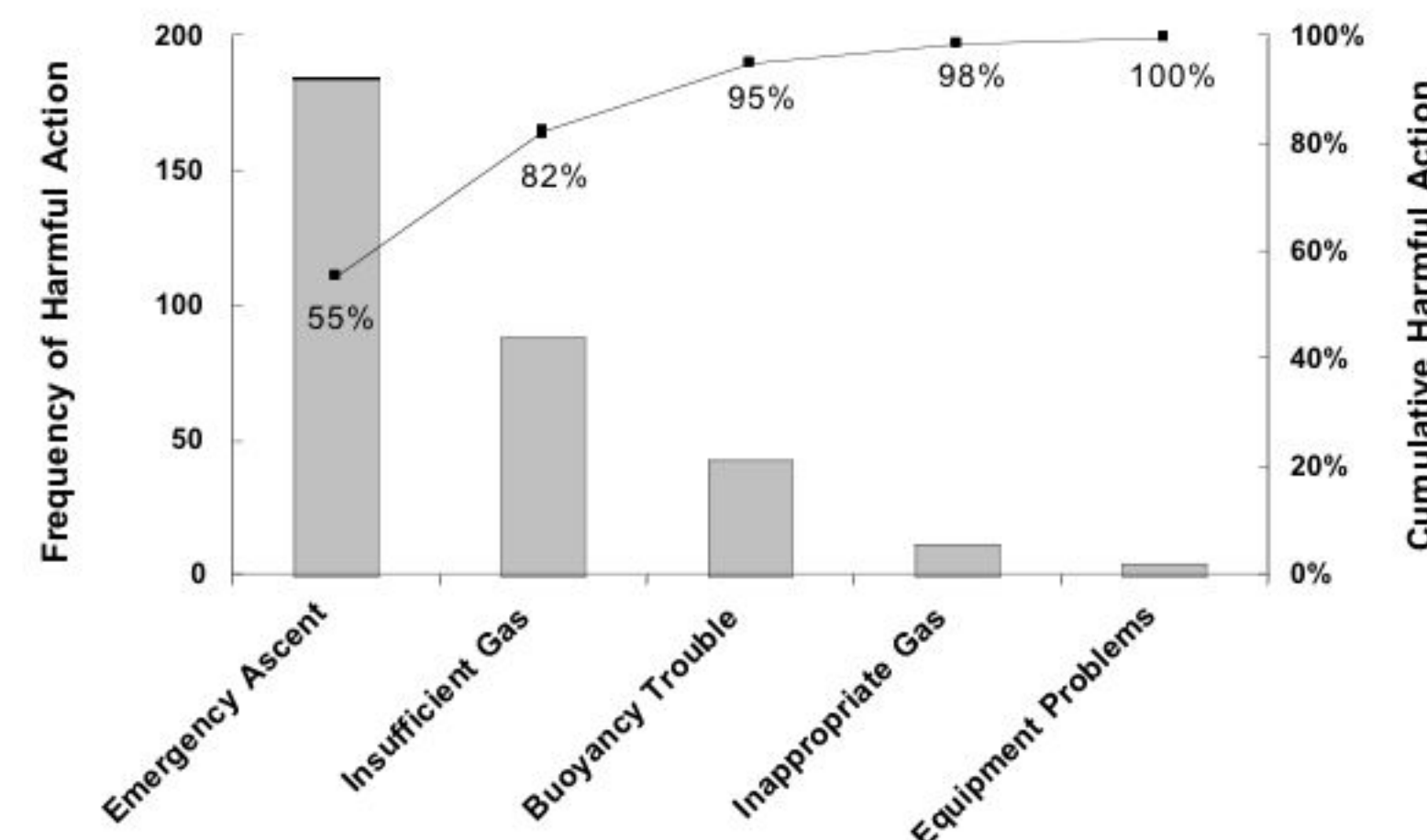
- ❖ Disabling Injury was more important to understanding fatality risks than was COD since divers incapable of self-rescue often drowned.
- ❖ Statistical associations of root causes with each Disabling Injury (as opposed to all others) were tested using logistic regression with $p \leq 0.05$ and odds ratio (OR) > 2 .
- ❖ Intrinsic factors were not included in RCA and were also tested for association with Disabling Injury.
 - ❖ Intrinsic factors involved health, certification, experience, dress, buddy system, diving activity, and breathing gas.

RESULTS

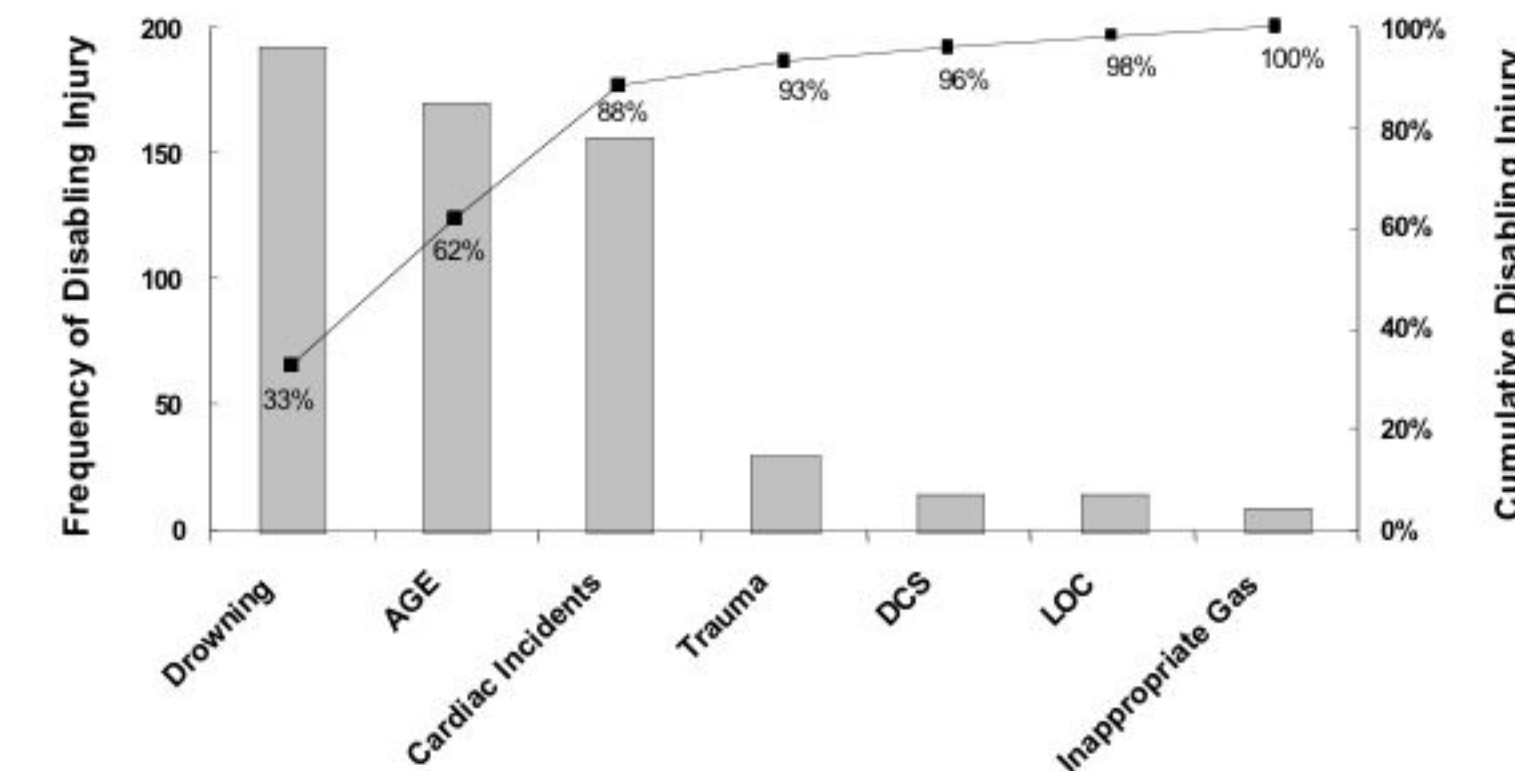
- ❖ Triggers (see below) for 86% of deaths included insufficient gas (41%), entrapment (20%), equipment problems (15%), and rough water (10%).



- ❖ Harmful Actions (see below) for 95% of deaths included emergency ascent (55%), insufficient gas (27%), and buoyancy trouble (13%).



- ❖ There were 3 major Disabling Injuries (see below) – Drowning (33%), Arterial Gas Embolism (AGE; 29%), and Cardiac Incidents (26%) – and 4 minor Disabling Injuries – Trauma (5%), DCS (2.5%), unexplained Loss of Consciousness (LOC; 2.5%), and Inappropriate Gas (2%).



- ❖ Drowning, AGE, and Cardiac Incidents had characteristically different Triggers, Harmful Actions, and statistical associations.

❖ Drowning:

- ❖ Triggers: entrapment (40%), insufficient gas (32%), equipment trouble (15%), and rough water (11%).
- ❖ Harmful Actions: insufficient gas (62%), buoyancy trouble (17%), emergency ascent (13%), and trauma (5%)
- ❖ Associations: entrapment (OR ≥ 30), insufficient gas (OR=16), equipment trouble (OR=4.5), rough water (OR=2), drysuit (OR=4.1), and being female (OR=2.1)

❖ AGE

- ❖ Triggers: insufficient gas (63%), equipment trouble (17%), and entrapment (9%).
- ❖ Harmful Actions: emergency ascent (96%).
- ❖ Associations: emergency ascent (OR ≥ 30) and depth less than 80 fsw (OR=2).

❖ Cardiac Incidents

- ❖ Triggers and Harmful Actions were rare but about 60% of decedents indicated dyspnea, fatigue, distress, chest pain, or not feeling well.
- ❖ Associations: cardiovascular disease (OR ≥ 30) and age greater than 40 (OR=6.4).

DISCUSSION

- ❖ For greatest reduction in Disabling Injuries due to Drowning or AGE, the most important safety guidelines might be those that would minimize insufficient gas, entrapment, emergency ascent, and equipment problems.
- ❖ Pre-dive evaluation of divers with risk factors for cardiovascular disease might reduce the occurrence of Cardiac Incidents.
- ❖ Study limitations included missing data, single reviewer bias, ascertainment bias, missing or inadequate post-mortem examination, and lack of a safe diver control population.

CONCLUSIONS

- ❖ Drowning, AGE, and Cardiac Incidents were the most frequent Disabling Injuries associated with diving death.
- ❖ The Pareto principle, Root Cause Analysis, and regression analysis may contribute to incremental improvement of diving safety guidelines, but additional information and independent verification are needed to overcome study limitations.

REFERENCES

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- Rooney J, Vanden Heuvel L. Root cause analysis for beginners. Quality Progress. 2004; July:45-53.