# Dose dependency with Electro Physical Agents: Both the Arndt Schulz Law and the Goldilocks Principle provide an explanatory model

**Tim Watson,** Allied Health Professions and Midwifery, University of Hertfordshire, Hatfield, United Kingdom (t.watson@herts.ac.uk)
**Ah-Cheng GOH,** Department of Physical Therapy, Shinshu University,Matsumoto, Japan (gohac@shinshu-u.ac.jp)

## Issue:

Electro physical agents (EPA's) have an evidenced role as a component of physical therapy practice, but the published evidence clearly identifies a dose dependent response for optimal outcome.

## Models:

The Arndt-Schulz Law has been widely employed to describe a theoretical construct model to rationalise dose dependency when EPA's are employed (Fig 1).

The Goldilocks Principle (children's story) has similarly been used (Figs 2 and 3) in multiple disciplines including Business Management and Planetary Science and is an alternative model which can be employed in this context.

## Dose Responses with Electro Physical Agents:

There is strong published evidence from all Electro Physical Agents (EPA's) evaluated that demonstrates a DOSE DEPENDENCE in the lab & clinical environments. The critical parameters vary with the energy type being delivered (electrical, thermal, mechanical) and include: FREQUENCY; INTENSITY; POWER; POWER DENSITY; TOTAL ENERGY; ENERGY DENSITY combined with TREATMENT DURATION AND TREATMENT FREQUENCY.

A substantial proportion of quality dose-response studies with electro physical agents are derived from animal based research but have potential to transfer to human dosimetry research. A stronger understanding of dose responses with EPA's could lead to focussed dosimetry research which will in turn, serve to underpin clinical practice.

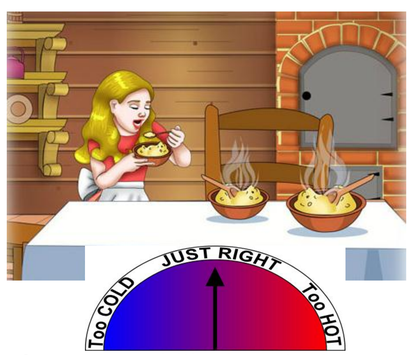


**Figure 2**: Goldilocks Principle as a children's story (Courtesy www.childsfunspot.com)

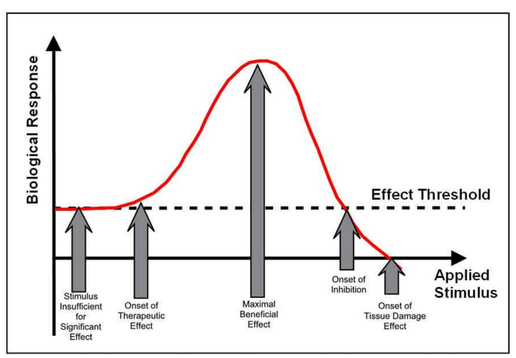


**Figure 1**: Arndt Schulz Law applied with EPA's (after Watson (2010))

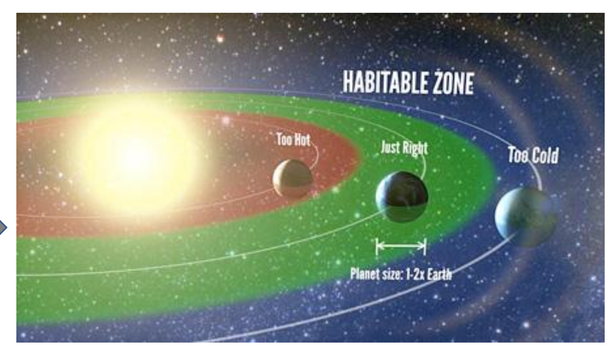


**Figure 3**: Goldilocks Principle applied in Planetary Science (Courtesy Erik Petigura/UC Berkeley)

## Example 1 : Laser

Numerous papers relating to LASER THERAPY demonstrate a clear dose response. Tumilty et al (2010) conducted a systematic review and meta-analysis for the use of laser in Tendinopathy. The overall results were conflicting but when they specifically evaluated the research outcomes in relation to the treatment doses employed, it was concluded that in the studies with positive results employed 'doses' which were consistent with the identified dose window.

TABLE 6. EFFECTIVE PARAMETERS

| Injury site | Number of studies | Parameters | World association for laser therapy | Bjordal et al. 2001 |
|---|---|---|---|---|
| Epicondylitis | 6 | 904 nm 1064 nm 60 mW/cm² 1.8–3.5 J/cm² | 780–860 nm: 4 J 904 nm: 1 J < 100 mW/cm² | 830 nm; 5–100 mW/cm² 0.7–7 J/cm² 904 nm; 2–100 mW/cm² 0.3–3 J/cm² |
| Rotator cuff | 3 | 820 nm 904 nm 320 mW/cm² 19 J/cm² | 780–860 nm: 9 J 904 nm: 3 J | 830 nm; 30–600 mW/cm² 4.2–42 J/cm² 904 nm; 12–600 mW/cm² 0.4–4 J/cm² |
| Achilles | 2 | 820 nm 904 nm 20–60 mW/cm² 1.8–3.6 J/cm² | 780–860 nm: 8 J 904 nm: 2 J < 100 mW/cm² | 830 nm; 5–100 mW/cm² 0.7–7 J/cm² 904 nm; 2–100 mW/cm² 0.3–3 J/cm² |
| Wrist | 1 | 830 nm 32 mW/cm² 4 J/cm² | 780–860 nm: 8 J 904 nm: 2 J | No guideline |

## Example 2 : TENS

Hughes et al (2013) demonstrated a clear effect of the current magnitude required when using TENS at different stimulation frequencies (2, 30 and 80Hz) and at different anatomical locations. The 'current window' (elsewhere called the intensity window) clearly varied by location and frequency employed. Other researchers have demonstrated strong TENS related window effects (e.g. Johnson 2014 a, b)

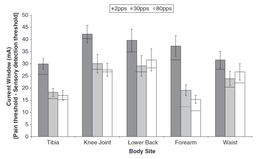


FIGURE 3. Mean ± SEM transcutaneous electrical nerve stimulation current amplitude windows calculated as pain threshold relative to sensory detection threshold (mA) for different body sites and frequencies. Dashed line indicates strong nonpainful intensity. pps indicates pulses per second.

## Example 3 : Shockwave

Zhang and colleagues set out to evaluate the energy density and number of shock required for an optimal response to SHOCKWAVE (in cell culture). Both energy density (mJ/mm²) and shock number demonstrated a clear curve response which mirrors both Arndt Schulz and Goldilocks models.

Clinically, authors have demonstrated dose dependent responses. Iopollo et al (2012) illustrated dose related effects in their clinical trial and Speed (2014) makes specific reference to dose magnitude effects in her recent review

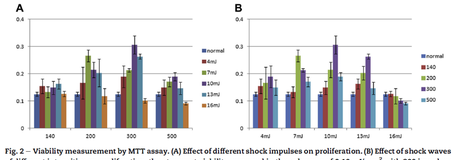


Fig. 2— Viability measurement by MTT assay. (A) Effect of different shock impulses on proliferation. (B) Effect of shock waves of different intensities on proliferation, the strongest viability appeared in the subgroup of 0.10 mJ/mm² with 300 impulses ($P \leq 0.05$). (Color version of figure is available online.)

## Example 4 : RF / Shortwave

Al Mandeel and Watson (2010) demonstrated the magnitude of physiological responses to PULSED SHORTWAVE THERAPY were dose dependent. This was transferred to a clinical study (in press) which reflected the same profile. In the results extracted below, the effect of PULSED SHORTWAVE on local blood flow varies before-during-after treatment, but also varies with the magnitude of the applied energy. These results are reflected in current RADIO FREQUENCY research (Kumaran and Watson (2015).

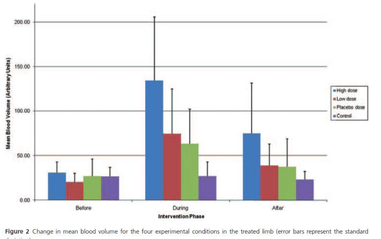


Figure 2 Change in mean blood volume for the four experimental conditions in the treated limb (error bars represent the standard deviation)

**Conclusion:** Both the Arndt Schulz Law and the Goldilocks Principle can be usefully employed to describe the response of a biological system to an externally applied energy. Both have the potential to provide a model which results in a more easily identified optimal delivery (or dose) when using electro physical agents in practice, education or research. Future research considering dose dependency is considered essential in order to refine the currently dosimetry models which are often generated retrospectively.

References :

Al-Mandeel and Watson (2010) The thermal and nonthermal effects of high and low doses of pulsed short wave therapy (PSWT). Physiother Res Int 15(4): 199-211
Hughes et al. (2013) An investigation into the magnitude of the current window and perception of transcutaneous electrical nerve stimulation (TENS) sensation at various frequencies and body sites in healthy human participants. Clin J Pain 29(2): 146-153
Ioppolo et al. (2012) Extracorporeal Shock-Wave Therapy for Supraspinatus Calcifying Tendinitis: A Randomized Clinical Trial Comparing Two Different Energy Levels. Phys Ther 92(11): 1376-1385
Johnson (2014a) Transcutaneous electrical nerve stimulation: review of effectiveness. Nurs Stand 28(40): 44-53
Johnson (2014b) Transcutaneous Electrical Nerve Stimulation (TENS): Research to support clinical practice. Oxford University Press
Kumaran and Watson (2015) Capacitive resistive monopolar radiofrequency (CRMF) therapy at 448 Khz: localized application significantly enhances and sustains skin physiological responses (WCPT A-613-0000-02940)
Speed (2014) A systematic review of shockwave therapies in soft tissue conditions: focusing on the evidence. Br J Sports Med 48(21): 1538-1542
Tumilty et al. (2010) Low level laser treatment of tendinopathy: a systematic review with meta-analysis. Photomed Laser Surg 28(1): 3-16
Watson (2010) Key concepts with electrophysical agents. Physical Therapy Reviews 15(4): 351-359.
Zhang et al. (2014) The dose–effect relationship in extracorporeal shock wave therapy: the optimal parameter for extracorporeal shock wave therapy. Journal of Surgical Research 186(1): 484-492