Requirements for benchmarking the ergonomics of PPE systems

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INTRO

- **prEN 17558:2020** *Ergonomics of PPE ensembles* suggests wear trials for assessing the performance of PPE systems against non-restrictive clothing as benchmark.
- Requires specification of '**non-appreciable difference**', e.g. <20% employed as default benchmark value
- How to **establish empirically based benchmark** criteria?
  - Study case: **increased metabolic rate** contributing to the **thermal burden of PPE use**[1)]

DATA FROM LUCY DORMAN'S PHD WORK[2,3)]

- **Metabolic rate (M)** recorded from six persons (3f, 3m) comparing **14 PPE ensembles** against repeatedly tested (8 times) sports clothing as benchmark control
- Activities: **Rest**; **Treadmill** walking (5 km/h, 4 min); **Step-Test** (100 steps/ 4 min, 20 cm); obstacle **circuit** incl. load lifting and carriage (6 min, pace-controlled)

ANALYSIS

- Mixed model ANOVA for repeated measurements[4)]
  1. **M with control clothing** for separate activities.
  2. **%Change in M (ΔM) with PPE** compared to control
  3. Model simulating the **influence of ΔM due to PPE** on **productivity loss** (**PL**)[5,6)] for different levels of activity[7)] (M = 200–600 W) and heat stress (WBGT = 26–32 °C)[8)]

RESULTS & DISCUSSION

1. 15–18% total **variance** & within-subject **correlation** of 0.4–0.6 yield input needed for **sample size** calculation[9)]
2. PPE with **large significant effects** of 10–12% ΔM would **pass the default** benchmark (20%). Non-significant difference to control linked with lower ΔM (6–8%).
3. 20% ΔM associated with 9% increase in simulated PL, far beyond yearly changes in industrial productivity[10)]; lower ΔM (5–10%) increased PL by only 2–4%.

CONCLUSION

- Our data and supplemental modelling advocate for a benchmark criterion ΔM 6–10% thus **challenging a standard default** of 20%.
- Preferably, **benchmarks** for testing the **ergonomics of PPE systems** should be based on **empirical studies**.

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Use **empirical data** to establish **benchmark criteria** in **standards** for **testing** the **ergonomics of PPE systems.**

1 Metabolic Rate (M) with sports clothing

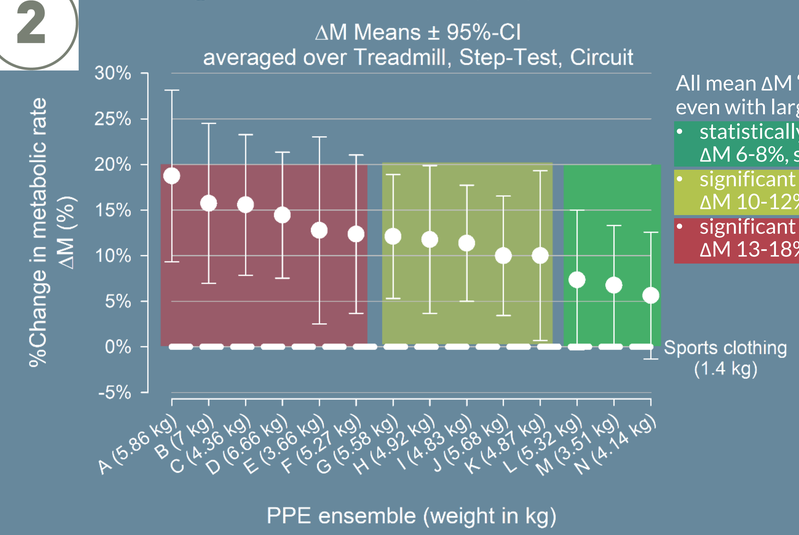
measurements with individual means ± SD

Summary Statistics

	mean(W)	SE(W)	ICC	CV_{within}	CV_{total}
Rest	*118*	*6*	*0.55*	*11%*	*17%*
Treadmill	*326*	*20*	*0.61*	*11%*	*18%*
Step-Test	*413*	*19*	*0.49*	*11%*	*15%*
Circuit	*412*	*21*	*0.40*	*14%*	*18%*

SE standard error
ICC within-subject intra-class correlation
CV coefficients of variation for within-subject and total variance

2 Change in Metabolic Rate (ΔM) with PPE ensembles relative to sports clothing



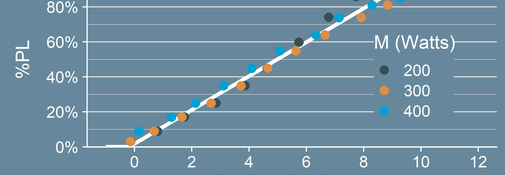
All mean ΔM 'tolerable' as per default 20% benchmark, even with large effect size ES = ΔM / CV_{total}[9,11)]

- statistically non-significant to control ΔM 6-8%, small to moderate ES (0.3–0.4)
- significant increase, but tolerable upper CI<20% ΔM 10-12%, moderate to large ES (0.6–0.7)
- significant increase, non-tolerable upper CI>20% ΔM 13-18%, large to very large ES (0.8–1.1)

3 Model of heat related productivity loss for physical work

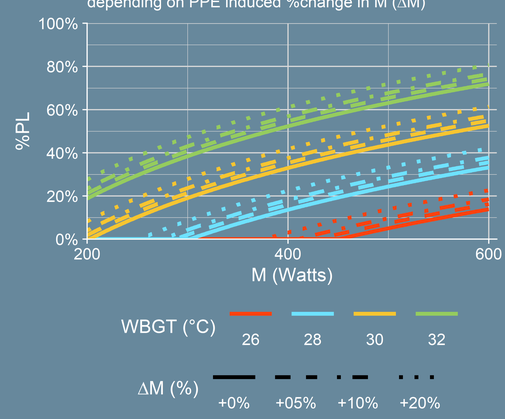
(A) Percentage Productivity Loss (%PL)

$$\%PL = \mathbf{max}\{0, \mathbf{min}[90, 1.77 + 9.68\times(WBGT - WBGT_{lim})]\}$$

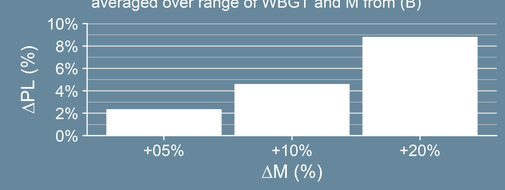


with $WBGT_{lim} = 56.7 - \log_{10}(M)$

(B) %PL vs Metabolic Rate (M) and WBGT depending on PPE induced %change in M (ΔM)



(C) Change in %PL (ΔPL) depending on PPE induced %change in M (ΔM) averaged over range of WBGT and M from (B)



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