Infographic. Cooling strategies to attenuate PPE-induced heat strain during the COVID-19 pandemic

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COVID-19 healthcare personnel (HCP) use personal protective equipment (PPE; ie, isolation gowns, eye protection, facemasks and respirators) to safely perform their medical duties. However, PPE creates a microenvironment around the skin due to a higher thermal resistance and lower water vapour permeability of the materials being used compared with the normal clothing ensemble of HCP.[1] Consequently, heat loss capacity via the skin surface is greatly reduced. The metabolic energy expenditure from regular working activities could, therefore, not be completely lost to the surrounding environment, leading to heat strain, thermal discomfort, excessive sweating, faster dehydration and an increased cardiovascular strain. To accommodate heat loss, blood redistribution from central organs and skeletal muscle to the skin occurs, which will further exacerbate the physiological strain, ultimately leading to shorter work tolerance times and a reduced physical and cognitive performance.[1 2] The most common recommendation for working in PPE is to adjust the work/rest schedule and incorporate more and longer breaks in order to alleviate heat strain. However, this recommendation is not always feasible in clinical settings as hospitals are often understaffed during the COVID-19 pandemic.

Physiologists evaluated many heat stress mitigation measures to improve athlete and military performance in challenging ambient conditions.[3 4] Cooling interventions are known to improve exercise performance, decrease heat stress and enhance post-exercise recovery.[5] Translating these concepts and solutions to medical science may attenuate heat stress and improve occupational performance for COVID-19 HCP. Similar knowledge transfer has previously been applied to minimise heat stress and extend work tolerance times in other occupational workers wearing protective clothing.[6] Indeed, a previous study demonstrated that that cooling devices worn under PPE can decrease the physiological and subjective strain in a simulated hot and humid laboratory environment.[7]

Cooling for HCP can be applied prior to (precooling), during (percooling) and after (postcooling) working activities with PPE (figure 1), but it is important to note that there is less evidence for the benefits of postcooling compared with precooling and percooling. Precooling and postcooling strategies can be applied at home, during work breaks or on arrival at the hospital, while percooling strategies should be worn underneath PPE during the work shift. Ideally, a combination of precooling, percooling and postcooling strategies would be used to accumulate the beneficial effects of cooling on work tolerance time and physiological strain.

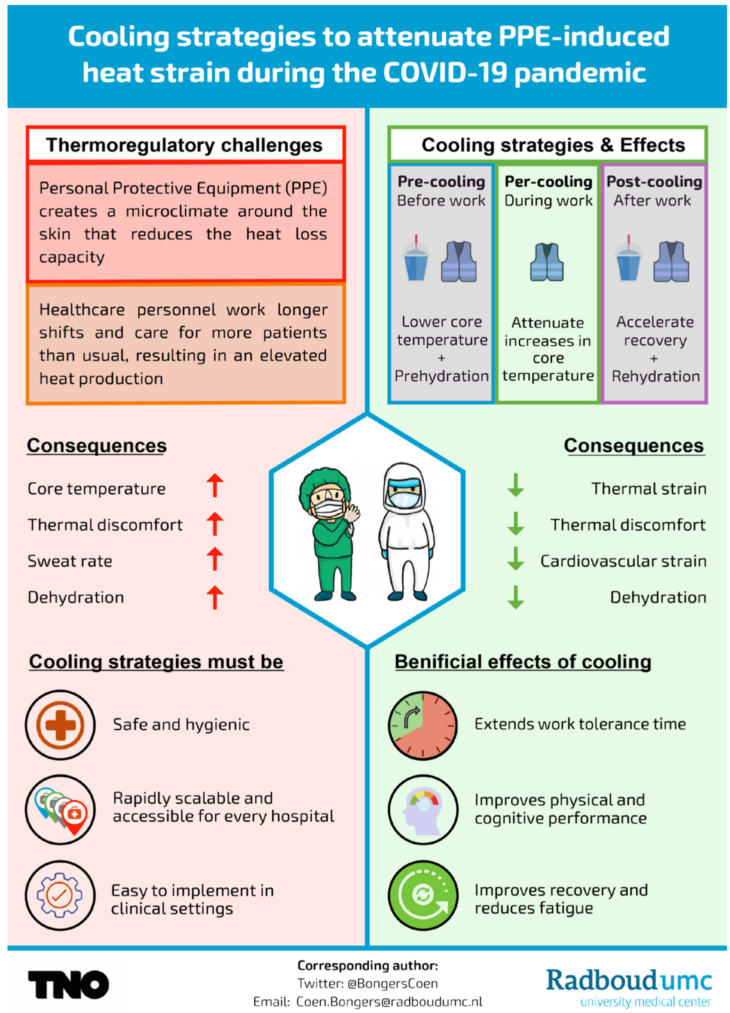

Figure 1 Infographic.

Practical considerations should be taken into account while introducing cooling strategies to HCP. For instance, cooling interventions must be safe and hygienic (eg, prevention of contamination), easy applicable (eg, limited extra weight, no restrictions during work), rapidly scalable and compliable to clinical regulations. Examples of cooling strategies that could be used in clinical settings are cold water/ice slurry ingestion (precooling and postcooling) and cooling vests (precooling, percooling and postcooling). Dependent on the setting (intensive care unit vs ward), PPE wear time, physical duties (nurse vs physician) and personal preferences, the type, frequency and severity of cooling interventions can be further optimised. In this way, cooling solutions may contribute to alleviate PPE-induced heat stress for HCP during the COVID-19 pandemic.

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Correction notice This article has been corrected since it published Online First. The funding and twitter statements have been corrected.

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REFERENCES

1 McLellan TM, Daanen HAM, Cheung SS. Encapsulated environment. *Compr Physiol* 2013;3:1363–91.
2 Holmér I. Protective clothing and heat stress. *Ergonomics* 1995;38:166–82.
3 Bongers CCWG, Thijssen DHJ, Veltmeijer MTW, *et al*. Precooling and percooling (cooling during exercise) both improve performance in the heat: a meta-analytical review. *Br J Sports Med* 2015;49:377–84.
4 Shapiro Y, Pandolf KB, Sawka MN, *et al*. Auxiliary cooling: comparison of air-cooled vs. water-cooled vests in hot-dry and hot-wet environments. *Aviat Space Environ Med* 1982;53:785–9.
5 Bongers CCWG, Hopman MTE, Eijsvogels TMH. Cooling interventions for athletes: an overview of effectiveness, physiological mechanisms, and practical considerations. *Temperature* 2017;4:60–78.
6 Chan APC, Song W, Yang Y. Meta-Analysis of the effects of microclimate cooling systems on human performance under thermal stressful environments: potential applications to occupational workers. *J Therm Biol* 2015;49-50:16–32.
7 Quinn T, Kim J-H, Strauch A, *et al*. Physiological evaluation of cooling devices in conjunction with personal protective ensembles recommended for use in West Africa. *Disaster Med Public Health Prep* 2017;11:573–9.