Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Exercising and face masks: An important hypothesis buried in a selective review

Several things surprised us about Chandrasekaran and Fernandes' hypothesis that "exercise with facemask" may cause "hypercapnic hypoxia, potentially increasing acidic environment, cardiac overload, anaerobic metabolism and renal overload" [1].

First, in the 'Highlights' section, the authors describe their paper as a "study [which] demonstrates potential complications associated with facemasks during exercise". Yet the ideas presented in the paper are almost entirely speculative. Whilst we agree that there is a hypothesis which needs testing, it should have been presented in a more balanced and circumspect way.

Second, the authors' literature review was incomplete. To support their claim that the evidence on wearing of face masks in public places is "debatable" in the context of COVID-19 prevention, they cite only one paper (a peer-reviewed narrative review which actually argues that the evidence for masking is strong [2]). They fail to cite several additional peer-reviewed narrative reviews, systematic reviews and meta-analyses, all of which provide powerful syntheses of evidence in favour of masking in public places, especially reviews of fluid dynamic studies of droplet and aerosol transmission [3–5]. They also fail to cite a systematic review on the "harms" of face mask use, which looked for *but did not find* any harms caused by the wearing of face masks and coverings in community settings [6]. They do not mention two recent, well-conducted modelling studies, based on real-world data, which both demonstrated a highly statistically significant benefit from community masking [7,8].

Third, the authors incorrectly state that the World Health Organisation does not recommend masking of asymptomatic individuals in public places. Their paper was submitted on 8th June 2020. On 5th June 2020, the WHO issued the following statement: "WHO has updated its guidance to advise that to prevent COVID-19 transmission effectively in areas of community transmission, governments should encourage the general public to wear masks in specific situations and settings as part of a comprehensive approach to suppress SARS-CoV-2 transmission" (page 6) [9]. They also fail to note that the US Centers for Disease Control and Prevention [10], Public Health England [11], and at least 200 countries around the world [12] now require masking in some public places.

Fourth, they misrepresent our paper which argued for use of the precautionary principle (masks are unlikely to do harm but could give great benefit, so it is ethical to act without waiting for definitive evidence) [13]. They describe this paper as "morally exploiting" community members. This language is offensive, unscholarly and appears to illustrate that the authors have either not read our paper or are wilfully seeking to distort its message.

Fifth, the authors seriously misrepresent the recommended scenario of how an individual would go about exercising with a face covering. No reputable sports medicine guidance is suggesting wearing a tightly-fitting filtering facepiece respirator (FFR). On the contrary, and acknowledging that no consensus guidelines exist, we recommend that athletes should exercise in a fabric face mask (mainly to protect others, and especially indoors), unless they exercise alone or in an elite athlete "performance bubble" where athletes, support staff and opponents adhere to strict measures to reduce the risk of viral transmission during training and competition [14]. In suggesting a tight-fitting FFR, the authors are thus setting up a straw man.

Sixth, even assuming that the hypothesis relating to tightly-fitting FFRs during exercise is worth testing, the authors selectively report the results of a study by Roberge et al to support their statement "Exercising with customised tight facemasks induces a hypercapnic hypoxia environment" [15]. In that study, ten healthy healthcare workers each performed multiple treadmill walking sessions at 1.7 miles/h and at 2.5 miles/h while wearing a FFR with exhalation valve, FFR without exhalation valve, and without FFR. Roberge et al concluded no significant differences in the physiological variables when comparing controls to all FFR models. The finding of transient hypercapnia in two of the ten participants during exercise does not constitute firm evidence of a "hypercapnic environment".

Notably, the findings of that tiny study published in 2010 have yet to be replicated. Roberge's own team published a larger study of exercising with FFRs in 2013 (with 20 participants, 10 of whom appear to be the same as those in their previous study), and concluded that physiological changes "are relatively small and should generally be well tolerated by healthy persons" [16]. Chandrasekaran and Fernandes do not mention another study by Roberge et al of exercising with surgical masks, which did not demonstrate clinically significant changes in oxygen or carbon dioxide saturation [17], nor do they mention another study by different authors which also showed that surgical masks did not cause hypoxia in exercising subjects [18]. A small study published recently showed no significant differences in either oxygen or carbon dioxide saturation in exercising men when surgical or FFR masks were worn compared to no masks, though it did suggest greater respiratory effort and a possible effect on performance with FFRs [19].

Given that the authors present no definitive evidence that exercising even with a tight-fitting FFR leads to either hypoxia or hypercapnia, their arguments about the risks of "respiratory alkalosis, increased lactate levels and early fatigue", not to mention downregulation of immune response, increased cardiac overload, compromised renal function and reduce cerebral perfusion are entirely speculative, backed up by irrelevant references or none. Their depiction of a hypoxia-induced dramatic reduction in hemoglobin saturation in their Figure 2 is frankly misleading.

Seventh, the section "Can facemasks increase the risk of coronavirus?" includes no peer-reviewed scientific references; it is a quote from a newspaper article.

In amongst these authors' partisan claims that facemasks worn by community members are harmful (as noted above, there is considerable evidence that they are beneficial [2–5,7,8]), there is an important hypothesis. All the studies published to date on face masks and face

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coverings, which produced broadly reassuring findings, have tested them in conditions of low to moderate exercise. It is plausible that an athlete who is exercising intensively for a prolonged period, especially if wearing an overly tight face covering, could be at risk of physiologically significant hypercapnia and hypoxia. This hypothesis needs to be urgently tested, and we are preparing to conduct such a study. It should have been presented more dispassionately and with full acknowledgement of the now well-documented benefits of masking in preventing transmission of COVID-19.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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