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# Impact of global warming on weight in patients with heart failure during the 2019 heatwave in France

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## Abstract

Heatwaves affect human health and should be more and more frequent because of global warming and could lead to increase mortality in general population, especially regarding cardiovascular mortality. During the summer 2019, Europe experienced a strong episode of heatwave. Telemonitoring of patients with heart failure (HF) provide an elegant tool to monitor closely the weights, and we assumed to be able to assess our hypothesis through a nationwide telemonitoring system. Here, we hypothesize that (i) there will be a change in patients' weight during the heatwave and (ii) that the telemonitoring would enable us to follow these changes. The change in weight would be a surrogate for clinical worsening (with or without decompensated HF). Briefly, 1420 patients with a median age of 73.0 years and mean weight of 78.1 kg have been included in this analysis. The relationship between temperature and weight is very strong ( $P < 10^{-7}$ ). The magnitude of the effect seems clinically relevant with a variation of 1.5 kg during a short period. This could expose patients to increased symptoms, HF decompensations, and poor outcomes. These results suggest a new way to implement weight telemonitoring in HF. This suggests also a direct impact of global warming on Human health, with acute episodes that are expected to occur more often, threatening patients with chronic diseases, especially patients with heart failure. In clinical practice, this urges to take into consideration the episodes of extreme heatwave and suggest that we have already useful tools including telemonitoring available in frail patients.

**Keywords** Clinical research; Heart failure; Ethics; Heatwaves; Telemonitoring

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## Introduction

Heatwaves affect human health and will occur more and more frequently with global warming. During the summer of 2019, Europe experienced a strong heatwave episode, and June 2019 was acknowledged as the hottest month ever recorded worldwide.<sup>1</sup> France was one of the most affected countries.<sup>2</sup>

Heatwaves could lead to increased mortality in the general population, especially cardiovascular mortality.<sup>3</sup> A meta-analysis of 54 studies from 20 countries suggested a significant association between heatwaves and cardiovascular mortality [risk estimate (RE) 1.149; 95% confidence interval

(CI) 1.090, 1.210].<sup>4</sup> The magnitude of this association varied across countries and studies but seemed to be more robust in specific subgroups, especially in patients with heart failure (HF). Considering the high heterogeneity detected between studies and limited investigations into subpopulations, the authors advocated for more research to provide a clearer picture of how heatwaves affect cardiovascular diseases in different settings.

We hypothesized that the body weight of patients with HF could change under the pressure of a heatwave, which could be a reason for acute decompensation or treatment side effects. The change in weight could be a surrogate for clinical worsening (with or without decompensated

HF). Telemonitoring is an elegant tool for closely monitoring weight in patients with HF, and we assumed we could assess our hypothesis through a nationwide telemonitoring system.

## Methods

We collected and analysed the data from patients followed in the telemonitoring system managed by CDM e-Health, an Air Liquide Healthcare affiliate, between 1 June 2019 and 30 September 2019 to accurately catch the two heatwaves at the end of June and end of July.

The inclusion criteria were defined previously by the French health authorities<sup>5</sup>: patients with chronic HF hospitalized for acute HF in the previous month (independent from the cause of HF or other characteristics) and patients hospitalized in the past year with either clinical NYHA Class II or more or increased natriuretic peptide (BNP > 100 ng/L or NT-proBNP > 1000 ng/L). The exclusion criteria were inability to use the telemonitoring system, haemodialysis, liver insufficiency, life expectancy <1 year for a reason other than HF, poor adherence to other therapies, refusal of the therapeutic program, or no home.

Weights were obtained in routine practice; some patients provided daily measurements as requested, but others were less regular. Daily temperatures (at noon) were obtained using the closest weather station from the residence of each patient within the SYNOP data. Patient weight and daily temperature were analysed using restricted cubic splines and presented as continuous variables.

All patients were followed in the same manner, including daily weight monitoring using on-line scales, self-monitoring, and symptom reporting via a device. Weight remains the cornerstone of telemonitoring in patients with HF, because it is related to congestion. Here, other parameters based on self-reported symptoms are taken into consideration in the algorithm. Input from patients was remotely manipulated during working hours 5 days per week. An alert was generated in case of weight gain of  $\geq 3$  kg over 2 days or  $\geq 2$  kg over 5 days, or in case of at least three symptoms worsening (nocturnal dyspnoea, orthopnoea, cough, oedema, or fatigue) on the same day or worsening of at least two symptoms on 3 consecutive days.

Patient weight, daily temperature, and daily temperature  $-2$  days were analysed using a linear mixed-effects model for repeated measures in which patients were considered the random variable. Cardiac alerts were analysed using a generalized (logistic) mixed model.

All analyses were conducted by the Medical Statistical Department of Montpellier University Hospital using statistical software R (Version 4.0.3). A two-sided  $P$ -value < 0.05 was considered significant.

## Results

A total of 1420 patients (28% female) from 68 counties (representing more than 71% of the French territory), with a median age of 73.0 years and mean weight of 78.1 kg, were included in this analysis. Pairs of data were included in the analysis when both their weight and the temperature where the patient lives were available ( $n = 770$ ). Thus, a total of 55 952 data points were included.

Temperatures during the duration of the study are presented in *Figure 1A* and weights in *Figure 1B*. The relationship between temperature and weight was very strong ( $P < 10^{-7}$ ; *Figure 1*). As expected, there was a strong relationship between patient weight and the probability of an alert (from clinical evaluation,  $P < 10^{-16}$ ). Interestingly, gender was not associated with the occurrence of alerts, but age was; older patients presented with significantly more alerts. In contrast, no direct significant relationship was found between temperature and the occurrence of an alert, which suggests a different impact of temperature increase on weight variations leading to alerts and a mediation effect between alerts and temperature via weight. Daily temperature  $-2$  days was significantly related to alerts ( $P = 0.002$ ). Several latency times have been tested. The best adjustment was obtained with a delay of 2 days. There was no clear threshold between temperature and weight. The link between temperature at day D and weight at day D + 2 is presented in *Figure 2*.

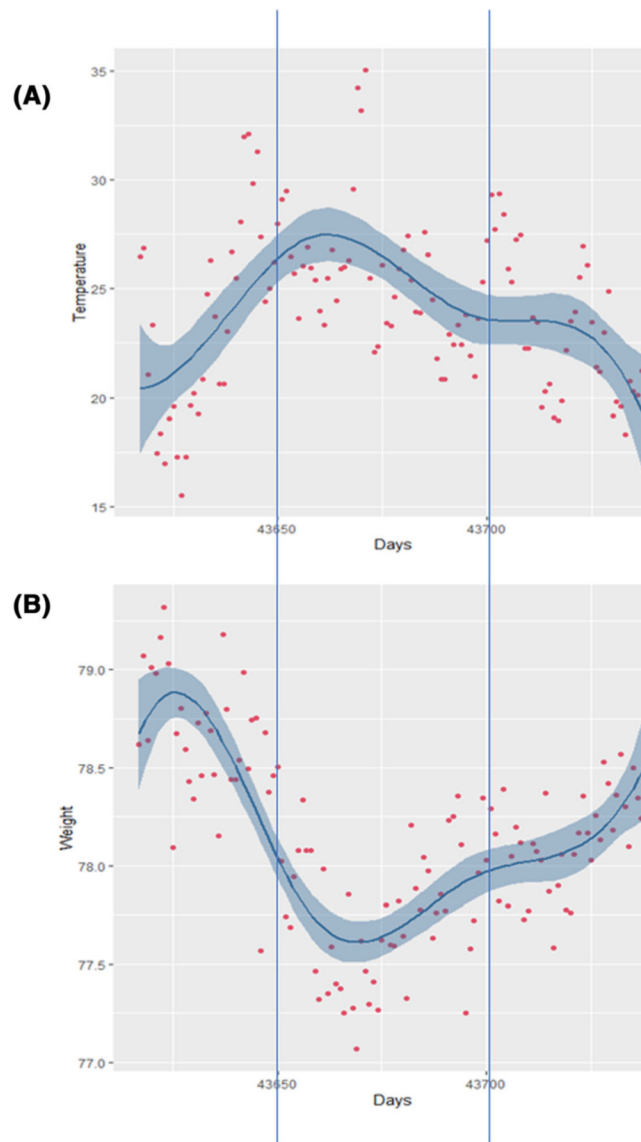
## Discussion

Here, we report a strict relationship between temperature and body weight in patients with HF in a nationwide observational study for the first time.

France was one of the countries most affected by the heatwave, with much of the country exceeding 32°C (90°F) on 26 June. However, the situation was heterogeneous throughout the country, with an Orange Alert issued by Meteo France for much of the country, excluding Brittany and the northern departments, and four southern departments put on Red Alert, including our centres.

Because of a similar experience in 2003 that led to more than 15 000 deaths in France, the authorities were proactive in helping the population with rapid deployment of protective measures, especially for the older and vulnerable populations, including patients with HF: Public cooling rooms were opened, parks and pools extended operating hours, and museums with air conditioning allowed free entry, among other measures. Despite these actions, patients with HF present strong variations in weight that seem clinically relevant. For a mean weight of 78 kg, we notice a variation of 1.5 kg in a short period of time. The variations follow time strictly.

**Figure 1** (A) Temperatures (°C) registered locally, between 1 June 2019 and 30 September 2019. (B) Weight (kg) measured daily for 1420 patients during the same period.



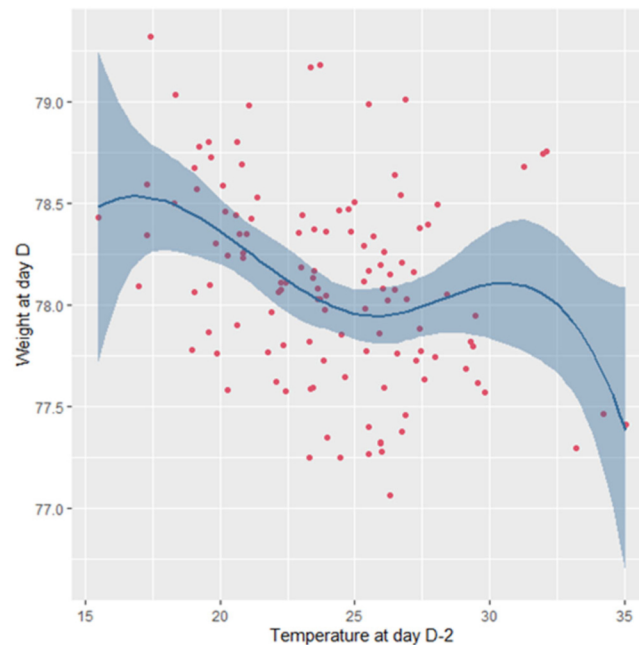
The telemonitoring system implemented by CDM e-Health was developed at a national level. In France, its use has been proactively encouraged by health authorities through national experimentation that started before the COVID pandemic and was encouraged even more since the pandemic. In the recent ESC guidelines, non-invasive telemonitoring is recommended for Class IIb, Level B, in order to reduce the risk of recurrent cardiovascular and HF hospitalizations and cardiovascular deaths.<sup>6</sup> Avoiding contacts and the risk of infection have been suggested, especially during pandemic conditions, but it could also provide unexpected data as demonstrated here. Furthermore, we could probably investigate some new topics and pave the way for innovative use of

these systems. It is all the more likely as the system used here is relatively simple and robust and mainly based on self-reported symptoms and a connected balance to provide daily weight measurements.

## Limitations

There are several limitations to this study. First, this is an observational study. Data obtained by the nationwide telemonitoring system were analysed in order to investigate our hypothesis, but the system was not designed for this pur-

**Figure 2** Pairs of data are included in the analysis when both the weight and the temperature where the patient lives were available ( $n = 770$ ). 55 952 data have been included. The relationship between temperature and weight is very strong as presented in the figure,  $P < 10^{-7}$ .



pose. Second, all inclusion and exclusion criteria were supposed to be respected by the physicians, so we assume that a large majority of patients presented with severe HF, but there is no way to confirm this. Third, we do not have detailed clinical characteristics of the population, especially the cause of HF or the drugs received, including diuretics. Importantly, we can only suggest a mediation effect between temperatures and alarms. Even if a time-related relationship is established, it would be of interest to analyse in detail the alerts, main components, and relationship to weight. This should be taken into consideration in the further versions of the telemonitoring systems. Importantly, a 'mediation effect' means that several days are needed for weight changes, with clinical outcomes several days later, limiting the interest in clinical practice, as weight changes are often late signs of cardiac decompensation and subject to many influencing factors. However, most of the telemonitoring approaches in use worldwide are based on weight variations, sometimes in combination with more sensitive systems, such as telemonitoring of pulmonary artery pressures, which is not currently reimbursed in France. Finally, as the system had not been designed for this purpose, we cannot exclude that some alerts could have been triggered during heatwaves by symptoms (fatigue) rather than an increase in weight (fatigue linked to decreased weight). Thus, adaptive algorithms are needed during telemonitoring of weight. It would be logical to propose algorithms that integrate some environmental parameters, including daily temperatures, but also pollution or acute situations

(e.g. natural disasters, war, and strong strikes). Such changes should be investigated in dedicated studies.

## Conclusion

We reported a strict relationship between temperature and body weight in patients with HF for the first time in a nationwide observational study. The magnitude of the effect seems to be clinically relevant, with a variation of 1.5 kg over a short period. This could expose patients to increased symptoms, HF decompensation, and poor outcomes. These results suggest a new way to implement weight telemonitoring in HF, such as paving the way for semiautomatic adaptations of the doses of diuretics. Last but not least, this suggests a direct impact of global warming on human health, with acute episodes that are expected to occur more often threatening patients with chronic diseases, especially the more fragile populations. Our duty is to prepare.

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## Conflict of interest

None declared.

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