https://doi.org/10.35627/2219-5238/2025-33-6-34-39
Оригинальная исследовательская статья

Analysis of Drug Sales in Pharmacies to Determine the Effects of Heat Waves on Chronic Diseases in Istanbul

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Summary

Introduction: Heat waves (HWs) are one of the most important atmospheric events that negatively affect human health. Studies show that HWs trigger many diseases causing an increase in hospital admissions, ambulance calls, and emergency department visits during HW periods.

Objective: To analyze changes in drug sales in pharmacies during HW periods in order to determine human health effects of HWs and to establish the most affected chronic diseases based on calculated sales growth.

Materials and methods: For this study, drug sales data were obtained from eight pharmacies located in different districts of Istanbul and classified according to the indications they contained. Meteorological data were obtained from the Istanbul Meteorological Directorate. HWs are defined as temperatures at a threshold of 90 % of daily maximum temperatures lasting for at least 3 or more consecutive days. Using this definition, it was determined that a 14-day HW occurred in Istanbul on July 12–26, 2023. In the analysis, pharmaceutical sales data between the 12th and 26th days of each month, April, May, and June, were used as a reference. Risk ratios were found by comparing the drug sales rate in the HW period with those in the reference periods. The significance values were calculated using the logarithmic Z test.

Results: During the heat wave, the sales of eye drops increased by 104 %, cardiovascular and blood pressure medicines by 38 %, psychology and depression medicines by 37 %, respiratory and chest disease medicines by 17 %, and antihistamines by 12 %.

Conclusions: The findings demonstrate that high temperatures triggered eye, chronic heart, psychological, and chronic respiratory allergic diseases, as shown by increased sales of drugs used to treat these conditions. The results of the study will guide future preventions to be taken against HWs.

Keywords: heat waves, drugs, pharmacy, chronic heart diseases, psychological diseases, respiratory diseases, eye diseases.

Cite as: Öztürk Y. Examination of drug sales in pharmacies to determine the effects of heat waves on chronic diseases in Istanbul. *Zdorov'e Naseleniya i Sreda Obitaniya*. 2025;33(6):34–39. (In English) doi: 10.35627/2219-5238/2025-33-6-34-39

Анализ аптечных продаж лекарственных препаратов для определения влияния волн тепла на хронические заболевания в Стамбуле

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Резюме

Введение. Волны тепла (ВТ) являются одним из важнейших атмосферных явлений, оказывающих негативное влияние на здоровье человека. Исследования показывают, что ВТ вызывают множество заболеваний и, как следствие, ведут к увеличению числа госпитализаций, вызовов скорой помощи и посещений отделений неотложной помощи в периоды ВТ.

Цель исследования: проанализировать изменения в объёмах аптечных продаж лекарственных препаратов в периоды волн тепла с целью установления их влияния на здоровье человека и выявить хронические заболевания, на которые ВТ оказывают наибольшее воздействие, на основе расчетного роста продаж.

Материалы и методы. Для этого исследования были получены данные о продажах лекарственных средств, классифицированных в соответствии с содержащимися в них показаниями, из восьми аптек, расположенных в разных районах Стамбула. Метеорологические данные были получены от Стамбульского метеорологического управления. Волнами тепла считаются температуры атмосферного воздуха, достигающие 90 % от максимальных суточных температур, сохраняющиеся в течение трех и более последовательных дней. Согласно этому определению, с 12 по 26 июля 2023 года в Стамбуле наблюдалась 14-дневная волна тепла. В ходе анализа для сравнения использовались данные о продажах фармацевтических препаратов с 12-го по 26-е число каждого месяца, а именно: апреля, мая и июня. Относительные риски были рассчитаны путем сравнения показателей продаж лекарственных средств в период волны тепла с контрольными показателями. Значения статистической значимости были рассчитаны с использованием логарифмического Z-теста.

Результаты. В период волны тепла продажи глазных капель выросли на 104 %, препаратов для лечения сердечно-сосудистых заболеваний и гипертонии – на 38 %, психических расстройств и депрессии – на 37 %, болезней органов дыхания – на 17 % и антигистаминных препаратов – на 12 %.

Выводы. Результаты показывают, что высокие температуры вызывают болезни глаз и сердца, психические расстройства и респираторные аллергии, о чем свидетельствует рост продаж лекарственных средств, используемых для лечения этих состояний. Результаты исследования будут определять меры, которые должны быть приняты против волн тепла в будущем.

Ключевые слова: волны тепла, лекарственные препараты, аптека, болезни сердца, психические расстройства, болезни органов дыхания, болезни глаз.

Для цитирования: Озтюрк Ю. Анализ аптечных продаж лекарственных препаратов для определения влияния волн тепла на хронические заболевания в Стамбуле // Здоровье населения и среда обитания. 2025. Т. 33. № 6. С. 34–39. doi: 10.35627/2219-5238/2025-33-6-34-39

https://doi.org/10.35627/2219-5238/2025-33-6-34-39
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1. Introduction

Recent studies show that heat waves (HWs) negatively affect human health [1, 2, 3]. Studies investigating the relationship between HWs and health show an increase in mortality [4]. In 2003, it was found that 70,000 extra deaths occurred across the continent due to HW in Europe [5]. It was determined that 14,800 extra deaths occurred only in France due to the HW [6]. A study conducted in Istanbul found that 419 extra deaths occurred in HW between 2013 and 2017 [7]. In 2016, 29 extra deaths occurred in HWs in Izmir [8]. A study conducted in Fethiye, Türkiye, determined that 22 extra deaths occurred due to HW [9].

Studies to determine the human health impacts of HWs have examined increases in hospital admissions [10], emergency room admissions [11], and ambulance calls [12] in addition to deaths. A 2006 study of the human health impacts of a HW in California found approximately 16,166 additional emergency room visits and 1,600 additional hospitalizations [13]. A study in Italy found that a one-day increase in HW duration resulted in a 16 % increase in hospital admissions [14]. A 2011 study in Sydney, Australia, found a 2 % increase in emergency room admissions, a 14 % increase in ambulance calls, and a 13 % increase in mortality rates due to HW [15]. A study conducted in Perth, Australia, determined a 4.4 % increase in total emergency room visits during HW periods [16]. A study conducted in the USA found a 3 % increase in hospital admissions during HW periods [17]. A study conducted in Korea found a 4 % increase in hospitalizations due to high temperatures during HW periods [18].

Studies have shown that HW triggers some chronic diseases [19]. In a study conducted in the USA, it was determined that HWs trigger heart diseases [20]. It has been determined that increases in cardiovascular and blood pressure diseases [21], chest and respiratory diseases [22], and psychological and mental diseases [23] occur during high-temperature periods. In a study conducted in Edirne, Türkiye, it was determined that there was a 36 % increase in cardiology outpatient clinics, a 24 % increase in neurology outpatient clinics, and a 17 % increase in pulmonology outpatient clinics during the HW period [24].

Examining the studies in the literature, the effects of HW on human health have generally been studied with data from hospitals. However, a study investigating which diseases are more affected by heat waves by examining the changes in drug sales during heat wave periods has not yet been conducted. Therefore, it was deemed appropriate to conduct this study.

This study aims to reveal the effects of HWs on human health in Istanbul. For this purpose, the study tried to determine which diseases are more affected by HWs by examining the changes in drug sales in pharmacies during HW periods compared to reference periods. The results obtained from this study will be helpful for future studies on protection against high temperatures.

2. Materials and Methods

2.1. Study Area

Istanbul is located between 280°' and 290° east longitude and 410°' and 400°' north latitude in the Marmara Region. It has a height of 40 m above sea level and a surface area of 5.196 km^2, with a population of 15,000,000 people. It has a transitional climate between the Black Sea and Mediterranean climates. The hottest month in the region is August, with an average of 29.6 °C. The coldest month is January, with an average of 4.1 °C.

2.2. Pharmaceutical Data

Pharmacy data was collected from six pharmacies in different districts of Istanbul. These data cover 14 days of pharmaceutical sales between the 12th and 26th of each month between April and July 2023. Since pharmacies in Türkiye are closed on Sundays, data for this day is not available. In the analyses, medicines are grouped according to the indications for which they contain. Accordingly, drugs are grouped as painkillers, antihistamine drugs, antibiotics, eye drops, cardiovascular and blood pressure drugs, fungicides, stomach drugs, psychological and antidepressant drugs, respiratory and lung diseases drugs.

2.3. Meteorological Data

Meteorological data was obtained from the Fethiye General Directorate of Meteorology Branch. The meteorological data includes the daily maximum temperature data of Istanbul for 2023.

2.4. Definition of Heat Waves

Since everyone accepts no common definition of HW, many definitions have been used in the studies [25]. In these definitions, daily maximum [26], minimum [27] and average temperatures [28]; relative values such as 90 %, 95 % [29] or fixed thresholds such as 30 °C, 35 °C [30] and consecutive temperatures such as two days, three days, or four days [31] were used. This study defines HW as temperatures that persist for at least three consecutive days or more at 90 % as a threshold value, using daily maximum temperatures. With this definition, the HW that lasted 14 days between July 12 and 26 in Istanbul in 2023 was detected. April, May, and June were selected as the reference period for the analysis. The days between the 12th and 26th of each month in the reference period were used as reference days in the analysis.

2.5. Statistical Analysis

The Microsoft Office Excel (Microsoft Corporation, Redmond, WA, USA) was used for statistical analysis. Increases in pharmaceutical sales during the HW periods were calculated using equations 1 and 2 below. Risk ratios (RR) and their significance were calculated using equation 3 below. A 95 % confidence interval was also calculated. For statistical significance, the p-value < 0.05 was accepted. Natural logarithmic Z tests were used to compare drug sales rates in the HW period with those in the reference periods [24]. The Z test was calculated using equation 6 below, and the p-value was calculated using equation 7 below.

$$DR_{(HeatWave)} = \frac{Number\ of\ Drugs\ Heatwave\ Period}{Population \cdot Number\ of\ Days\ Heatwave\ Periods} \quad (1)$$

$$DR_{(Referance\ Period)} = \frac{Number\ of\ The\ Drugs\ Referaence\ Period}{Population \cdot Number\ of\ Days\ Referaence\ Periods} \quad (2)$$

$$RR = \frac{DR_{(HeatWave)}}{DR_{(Referance\ Period)}} \quad (3)$$

https://doi.org/10.35627/2219-5238/2025-33-6-34-39
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$$var(DR_{Heatwave}) = \sqrt{\frac{Numbers\ of\ Drugs\ Heatwave\ Period}{Population \cdot Number\ of\ Days\ Heatwave\ Periods}} \quad (4)$$

$$var(DR_{Referance\ Period}) = \sqrt{\frac{Numbers\ of\ Drugs\ Referance\ Period}{(Population \cdot Number\ of\ Days\ Referance\ Periods)^2}} \quad (5)$$

$$Z = \frac{\ln(DR_{heat\ wave}) - \ln(DR_{referance\ period})}{\sqrt{\frac{var(DRheat\ wave)}{(DR_{heat\ wave})^2} + \frac{var(DRreferance\ period)}{(DR_{referance\ period})^2}}} \quad (6)$$

$$P\ Value = 2x(1\text{-}Normdist(Z,avarage;\ standard\ deviation;cumulative)) \quad (7)$$

Where $DR_{heatwave}$ represents the drug sales rate in the HW period and $DR_{referaence\ period}$ represents the drug sales rates in the reference periods.

3. Results

Table 1 presents meteorological data for Istanbul. Accordingly, the highest daily temperature was 37.7 °C in July, and the lowest was 9.3 °C in April. When drug sales were analyzed by month, the highest number of sales occurred in June, with 8,627 items.

Table 2 presents information on drug sales grouped by active ingredient. This table shows the RR and confidence intervals calculated by comparing the amounts of medicines sold during the HW period with those sold during the reference months. Accordingly, the RR indicating the increase in eye drops sales during the HW period was calculated as 2.04 (95 % CI: 1.56–2.67, $p < 0.05$). The RR indicating the increase in sales of cardiovascular and blood pressure medicines was 1.38 (95 % CI: 1.32–1.46, $p < 0.05$), while the RR indicating the increase in sales of psychology and depression medicines was 1.37 (95 % CI: 1.26–1.50, $p < 0.05$), RR 1.17 (95 % CI: 1.03–1.33, $p < 0.05$) indicating an increase in sales of medicines for respiratory diseases and RR 1.12 (95 % CI: 1.02–1.22, $p < 0.05$) indicating an increase in sales of medicines for allergies.

There was a decrease in the sales of antibiotics and painkillers during the HW period. Accordingly, the RR indicating the decrease in antibiotic sales was 0.82 (95 % CI: 0.77–0.87, $p < 0.05$), and the RR indicating the decrease in painkiller sales was 0.850 (95 % CI: 0.81–0.89, $p < 0.05$). Increases in the sales of medicines used for fungal and stomach diseases were not statistically significant.

4. Discussion and Conclusions

The study found a 108 % increase in the sale of eye drops during the HW period. One of the reasons for this increase is thought to be that the eyes are exposed to more sunlight due to the decrease in cloud cover in the sky during HW periods. Studies have shown that cloud cover decreases during HW periods [32]. Due to this decrease, more sunlight comes to the earth's surface, and the earth is exposed to more light [26]. As

Table 1. **Descriptive data for Istanbul**

Таблица 1. **Описательные данные по Стамбулу**

	April / Апрель	May / Май	June / Июнь	July / Июль
Maximum temperatures / Максимальные температуры (°C)	23.8	28.8	32.0	37.7
Minimum temperatures / Минимальные температуры (°C)	9.3	13.9	21.2	28.2
Average insolation duration (hours) / Средняя продолжительность инсоляции (в часах)	5.9	7.4	8.7	9.5
Total drug sales (quantity) (between 12–26 of each month) / Общий количественный объем продаж лекарственных препаратов (с 12 по 26 число каждого месяца)	7,723	7,200	8,627	8,014

Table 2. **Changes in pharmaceutical sales during heat waves**

Таблица 2. **Изменения в продажах фармацевтических препаратов в периоды аномальной жары**

Medicines / Лекарственные препараты	Medicine sales during HW / Объем продаж препаратов в период волны тепла	Total medicine sales in the reference period / Общий объем продаж препаратов в периоды сравнения	RR (95 % CI) / ОР (95 % ДИ)	Confidence interval / Доверительный интервал		*p*
Eye drops / Глазные капли	87	142.0	2.04	1.56	2.67	0.000
Heart and blood pressure / Препараты для лечения сердечно-сосудистых заболеваний и гипертонии	2174	5235.0	1.38	1.32	1.46	0.000
Psychology and depression / Препараты для лечения психических расстройств и депрессии	711	1724.0	1.37	1.26	1.50	0.000
Respiratory / Препараты для лечения болезней органов дыхания	324	923.0	1.17	1.03	1.33	0.015
Antibiotics / Антибиотики	1326	4865	0.82	0.77	0.87	0.000
Allergy / Средства от аллергии	611	2009	1.12	1.02	1.22	0.016
Analgesic / Анальгетики	2743	9695.0	0.85	0.81	0.89	0.000
Fungal diseases / Противогрибковые препараты	406	1158	1.05	0.94	1.18	0.381
Gastrointestinal diseases / Препараты для лечения желудочно-кишечного тракта	634	1753	1.08	0.99	1.19	0.078

https://doi.org/10.35627/2219-5238/2025-33-6-34-39
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a result, eyes are thought to be negatively affected. Additionally, studies show that heat waves increase air pollution [33]. Therefore, it may cause an increase in eye infections during HW periods. A study conducted in Spain determined an increase in eye diseases during HWs [34]. In another study, deterioration of the retina of the eye was observed at high temperatures [35]. The results of these studies are consistent with the findings described. The increase in eye drop sales during the heatwave HW period show that high temperatures contribute to a rise in eye diseases.

The results demonstrated a 38 % increase in sales of chronic heart and blood pressure medications during the HW. The studies investigating the relationship between temperature and health show that chronic heart diseases are among the diseases most affected by high temperatures [36]. It has also been determined that there is an increase in deaths due to heart diseases during HW periods [37]. A study determined a 36 % increase in the patient density of the cardiology outpatient clinic due to high temperatures [24]. Considering these studies conducted in many parts of the world, one may conclude that HW triggers heart disease. Therefore, the increase in cardiovascular and blood pressure medications during heatwave periods matches the findings of studies conducted in this field.

It was determined that there was a 33 % increase in sales of mental health medications during the HW period. The increase in the number of psychology patient applications in hospitals during HW periods is thought to have caused an increase in drug sales. Previous studies have shown that while there is an increase in psychology outpatient clinic visits during HW periods [38] there is an increase in suicide cases, bipolar disorder diseases, and dementia. [39]. The increase in these diseases during the HW period is thought to increase the sales of drugs used to treat these conditions.

The study revealed a 20 % increase in sales of medicines for respiratory diseases and a 10 % increase in those of antihistamines. This result coincides with the results of previous studies. One study determined that the number of respiratory patients admitted to the hospital increased during the HW period [40]. Another study showed an increase in respiratory and allergic diseases due to air pollution during the HW period [22]. A study investigating the effects of global warming on allergies determined that air pollution increased due to the warming of the atmosphere, resulting in an increase in allergy rates [41]. It is thought that the increases in respiratory diseases during the HW period also led to an increase in the sales of drugs used to treat these diseases. Therefore, the results of the study overlap with the results of those studies.

During the HW, sales of antibiotics used to treat infectious diseases decreased by 18 %. This result coincides with the study conducted in Singapore, which showed a 13 % reduction in dengue fever infectious disease during HWs [42]. This study determined that high temperatures reduced the reproduction of mosquitoes and consequently decreased infectious disease spread by mosquito bites. A study conducted in Australia determined a 19 % decrease in hospital admissions due to Campylobacter infectious disease during the HW period [43].

Acknowledgement: The author would like to thank eight pharmacy owners from Istanbul for providing pharmaceutical sales data.

Благодарность: автор хотел бы поблагодарить восемь владельцев стамбульских аптек за предоставление данных о продажах фармацевтической продукции.

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https://doi.org/10.35627/2219-5238/2025-33-6-34-39
Original Research Article

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Author contribution: The author confirms sole responsibility for the study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

Compliance with ethical standards: Not applicable.

Funding: This research received no external funding.

Conflict of interest: The author has no conflicts of interest to declare.

Received: February 19, 2025 / Accepted: June 10, 2025 / Published: June 30, 2025

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Соблюдение этических стандартов: данное исследование не требует представления заключения комитета по биомедицинской этике или иных документов.

Финансирование: исследование проведено без спонсорской поддержки.

Конфликт интересов: автор декларирует отсутствие явных и потенциальных конфликтов интересов в связи с публикацией данной статьи.

Статья получена: 19.02.25 / Принята к публикации: 10.06.25 / Опубликована: 30.06.25