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Research article

HIGH AMBIENT TEMPERATURES AND MENTAL HEALTH: RISKS, METHODS AND RESULTS

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This work is an analytical review. Initial research data have been taken from original studies published in peer-reviewed scientific journals in 2014–2024. The following search terms were used when searching for English language sources in PubMed database: (mental health OR mental disorders OR mental illness OR suicide) AND (high ambient temperatures OR heat stress OR hot weather OR heat waves). Russian language sources were sought in eLibrary using the following keywords: mental health; mental disorders; mental diseases; suicide; high ambient temperatures; heat waves; global warming.

The review has established the following. Effects produced by high ambient temperatures on mental health have only recently become a separate research topic within a broader context of 'Climate Change and Population Health' studies or, as the WHO terminology puts it, 'Population Health under Changing Climate'. In contrast to five previous reports, the Sixth Assessment Report of the Intergovernmental Panel on Climate Change contains a bigger section on impacts exerted by climate on mental health. Scientific evidence suggests with high confidence that exposure to high ambient temperatures and heat waves causes mental disorders. These disorders include anxiety, depression, acute post-traumatic stress, suicidal behavior, and use of psychoactive substances; they are diagnosed as both mild disorders and severe cases that require hospital admission. Effects of heat stress on human psyche are caused by complex interactions between physiological and psychological factors. The human body tries to maintain the thermal balance and this induces a whole cascade of physiological reactions, ranging from increased heart rate to dehydration. Physiological strain undermines mental health and causes sleep disorders, irritability, mental fatigue and cognitive disorders.

Keywords: *climate change, heat waves, high ambient temperatures, heat stress, mental health, risk factors.*

Heat waves are the periods that create significant discomfort for humans and are statistically associated with drastic mood swings, aggression and anxiety, especially among people with low socioeconomic status [1, 2]. This has even made researchers suggest a new concept, heat-related violence [3]. Moreover, the American Psychological Association has reported that a relative increase in mortality during heat waves has been thrice as high among patients with mental disorders compared to healthy people [4]. Also, suicide rates have been reported to rise during heat waves [5] and in early summer when weather typically gets hot [6]. The frequency of emergency ambulance dispatches due to suicidal behavior grew by more than four times in Shenzhen, China, during heat waves lasting for 3 or more days (RR = 4.53, 95 % CI: 1.23–16.68) [7]. In contrast to five previous reports, the Sixth Assessment Report of the Intergovernmental Panel on Climate Change[1] contains a bigger section on climate change impacts on mental health. Mental disorders have been established in people exposed to dangerous meteorological events such as floods, typhoons, storms or droughts in many countries across the globe. The same happens during fires or other emergencies.

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[1] Climate Change 2022: Impacts, Adaption and Vulnerability. Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In: H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf [et al.] eds. Cambridge, UK; New York, NY, USA, Cambridge University Press Publ., 2022, 3056 p. DOI: 10.1017/9781009325844

This review focuses on methods for investigating effects of climate change on mental health in greater detail in comparison with our previous reviews of health effects of climate change. This subject is still new for Russian researchers.

Materials and methods. This work is an analytical review. Initial research data have been taken from the original studies published in peer-reviewed scientific journals in 2014–2024. Several criteria were used in selection of relevant sources. Original studies had to contain the following:

1) quantitative data on temperature stress during a hot season during the study period or definition of heat waves since different authors tend to use different definitions;

2) descriptions of analyzed samples (the number of subjects and reference to a city or a country); we also considered meta-analyses, which generalized the results reported in several local studies in order to identify health effect modifiers;

3) a formulated statistical hypothesis and description of statistical methods used to test it. We took both direct epidemiological studies that involved establishing numerical relationships between a dose and a level of effects produced on mental health and the results obtained by survey data analysis, for example, about the number of complaints about certain symptoms. The studies of the first type were given priority in selection for review.

The following search terms were used when searching for English language sources in PubMed database: (mental health OR mental disorders OR mental illness OR suicide) AND (high ambient temperatures OR heat stress OR hot weather OR heat waves). Russian language sources were sought in eLibrary using the following keywords: mental health; mental disorders; mental diseases; suicide; high ambient temperatures; heat waves; global warming. References in publications, which were found using the above mentioned keywords, were analyzed by hand to search for additional relevant articles.

Main results. An original epidemiological study conducted in Odessa and the Odessa region is among the first Russian publications on the subject. It covered 11,200 suicides during the period between 2000 and 2016 [8]. The results of this study revealed seasonality in suicidal behavior as the number of suicides grew in May when daylight hours became progressively longer (the linear correlation coefficient was $r = 0.97$ at the significance level $p < 0.001$). A relationship was also established between suicide rates and high ambient temperatures since the typical seasonal spring-summer temperature rise was the most pronounced in May. Another study analyzed a relationship between frequency of suicides and geliogeophysical and technogenic factors in three cities located in the Murmansk region, that is, in high latitudes. The three cities were Monchegorsk, located near a nickel smelter, Apatity and Kirovsk, the cities famous for mineral fertilizer factories. Suicide frequency was higher in Monchegorsk, a city exposed to emissions from Severonikel Plant. Possible health effects of solar activity cycles tend to be more intensive in high latitudes [9]. A scoping review [10] of effects of high ambient temperatures on suicide rates worldwide reported that the results of multiple studies suggested the relation between suicide rates and high ambient temperatures.

Neurophysiological pathways of heat stress. When explaining possible pathways that could explain increase in hospital admissions for mental disorders during hot periods, researchers often turn to brain biochemistry. Heat stress induces an increase in plasma serotonin, which inhibits the production of dopamine (DA), a neurotransmitter that appears to influence brain functioning in complex task performance [11]. High ambient temperatures also affect the production of serotonin in platelets, which is associated with such diseases as schizophrenia and depression [12]. Overheating of neuron tissue can induce changes in temperature-sensitive processes in the brain, for example, synapse conductivity, cerebral circulation, production and metabolism of the most important neuromediators (catecholamine, noradrenaline, and gamma-aminobutyric acid), which affect the symptoms of schizophrenia and other mental disorders [13]. Overheating of the brain impairs the blood-brain barrier permeability, which can result in brain edema and functional disorders in the brain. Patients with schizophrenia reportedly have difficulties with thermal regulation [14]. High temperature inhibits the production of L-Tryptophan, a serotonin precursor; low concentrations of L-tryptophan in plasma are associated with major depression disorders [15].

Declining cognitive functions under high ambient temperatures can also be a pathway, since such patients may fail to perceive how hazardous heat is and to take relevant safety precautions. Similarly, patients with dementia should also be at higher risk since they may fail to take relevant protective actions during extreme heat. The increased level of physical discomfort that they experience under such weather can exacerbate dementia symptoms and lead to excitation [16]. Psychoactive drugs can reduce the body ability to perform thermal regulation. Strong heat stress can induce mental confusion and declining cognitive abilities in patients with schizophrenia [17].

High ambient temperatures as a risk factor affecting mental health. Epidemiological studies of the effects of high ambient temperatures on mental health can be divided into two uneven groups according to the procedure of selection of an exposure variable: (1) describing continuous relationship between a selected health outcome and variations in ambient temperature and (2) examining effects produced by heat waves as a discrete weather phenomenon when a binary heat wave indicator is used as an exposure. Most of studies belong to the first type. Thus, a systematic review [18] of literature indexed in databases such as PubMed, Embase, Scopus, Web of Science and PsycINFO, identified 44 studies describing continuous temperature relationships and only 12 studies that focused on heat waves. Accordingly, the results reported in the first-type studies are usually given as an increase in morbidity / mortality per specified change in temperature within the given percentile range, or per each 1 °C increase in temperature. However, if a temperature averaged over several days before the effect ($T_{0\text{-}n}$) is taken as an exposure variable, then the model measures the effects of stress accumulated over $n + 1$ day (the day when the effect started is considered the zero one). As we shall see, the results of studies that concentrate on the relationship between the effect and ambient temperature are most frequently reported exactly for such averaged temperatures. If the results are reported for extreme ambient temperatures $T_{0\text{-}n}$ at the 95-th percentile or higher, then we actually speak about effects produced by heat waves. The second-type studies usually report increases in morbidity / mortality during heat waves in comparison with the remaining days or with specifically selected control days.

Let us first consider several examples of studies that focus on continuous relationships between mental health measures and ambient temperatures with emphasis on age-related differences. In the next section, we will consider the effects produced by discrete heat waves. During extreme heat, there was a growth in mental disorder hospitalizations and especially an apparent rise in levels of transient mental disorders in Hong Kong [19] and Shanghai [20]. Long-term exposure to heat in two Canadian provinces, Alberta and Ontario [21] led to increased number of emergency department visits for mental and behavioral disorders including such diagnoses as dementia, neurotic disorders, schizophrenia and personality behavior disorders.

In Hong Kong, Poisson Generalized Additive Model (GAM) was used to study the relationship between daily hospital admissions for mental disorders and a daily set of meteorological parameters including average daily ambient temperature. Overall, 44,600 hospital admissions were analyzed, which were registered in 2002–2011. To describe a smooth relationship between the number of hospital admissions and ambient temperatures, the Distributed Lagged Non-linear Model (DLNM) was used to account for the potential lagged effects. In the core model, the daily counts of mental-disorder admissions were regressed against the long-term trend (day of study), seasonal trend, holiday effect, day-of-week effect, and also levels of ambient air pollution, which at present is considered a conventional 'good practice' in such studies. Cumulative relative risks (*RR*) were estimated for the interquartile range of temperatures, that is, a relative growth in hospital admissions, which corresponded to an increase in ambient temperature between the 25th percentile (19.4 °C) and the 75th percentile (28 °C). The estimated *RR* = 1.09 (95 % CI: 1.03–1.15) for all age groups, but it reached 1.20 (95 % CI:

1.09–1.31) for elderly patients aged over 75 years. This indicates that the older age group is highly susceptible. At the same time, no risks were established for children younger than 15 years. The highest risks were established for transient organic psychotic conditions (transient disorders)[2], ICD-9 code 293, RR = 1.51 (95 % CI: 1.00–2.27), and recurrent affective psychoses, ICD-9 code 296, RR = 1.34 (95 % CI: 1.05–1.71). The authors of this study believe that higher relative risks found for the older age-group might be associated with a higher prevalence of cognitive problems among the older population. Previous studies have reported negative associations between temperature and cognitive function among Japanese [22] and Americans [23]. In Hong Kong, a U-shaped association was found between temperature and dementia admissions, that is, risks of dementia increased under high ambient temperatures [19].

In Shanghai, a quasi-Poisson generalized additive model (GAM) combined with a distributed lag non-linear model (DLNM) was used to analyze the lag-exposure-response relationship between daily mean temperature, relative humidity and hospital admissions for mental disorders. First, the distributed lags were up to 21 days; however, it was shown that lags up to 7 days would be quite sufficient since after day 7 a cumulative effect loses its statistical significance [20]. The model also considered an apparent relationship between hospital admissions and a calendar period (adjusted for a day-of-week, seasonal and long-term trends) and ambient air pollution with PM_{10}, SO_2 and NO_2. Overall, 94,000 hospital admissions during 2008–2015 were analyzed and a relative increase in hospital admissions was calculated, which corresponded to a temperature rise from its median value (18.3 °C) up to 99th percentile (33.1 °C). The maximum effect was reached at a lag of 0–1, that is, for the sum of temperatures on a hospital admission day and the previous day. The respective risk for all age groups was RR = 1.27 (95 % CI: 1.07–1.49). Obviously, this risk is much higher than in Hong Kong since it corresponds to the temperature rise up to the 99th percentile and not the 75th one. However, the authors report a respective result for the 75th percentile (24.5 °C), RR = 1.08 (95 % CI: 1.00–1.17), and it is almost the same as the result reported for Hong Kong. The authors of the study conducted in Shanghai report that this level of risk is mostly reached due to age groups ≥45 years since for this group RR = 1.32 (95 % CI: 1.08–1.62). The effect lost any significance for the age group 0–44 years and amounted to RR = 1.10 (95 % CI: 0.89–1.36); that is, ambient temperatures had practically no effect on hospital admissions.

The effects of high ambient temperatures on mental health have been observed not only in Asia but also in the Western hemisphere. Thus, a strong association was found in Toronto, Canada, between mean daily temperature at 28 °C and hospital admissions for all mental disorders and specifically for schizophrenia, mood, and neurotic disorders [24]. This temperature in Toronto corresponds to the 99th percentile of average daily temperature distribution. The ambient temperature that corresponded to the 50th percentile was taken as a reference one. The association was the strongest for the regressor T_{0-4}, that is, on the fifth day of continuous exposure to extreme heat. Relative risk for hospital admissions for all mental and behavioral disorders at T_{0-4} = 28 °C was equal to 1.29 (95 % CI: 1.09–1.53).

In the USA, a relationship was found between a rise in average monthly ambient temperatures and a growing number of complaints about mental disorders (depression, stress, and emotional disorders), which a respondent had for the last 30 days prior to the day of a survey. Overall, 2 million people took part in the survey all over the country [25]. The maximum daily temperature averaged over the same period (T_{30}) was taken as an exposure variable. To simplify the design of this study a bit, we can say that all cities in the USA were divided into five groups with the 5 °C differences in this variable: the first (reference) group with 10 °C < T_{30} < 15 °C; the second group with 15 °C < T_{30} < 20 °C and so on, to the last group with T_{30} ≥ 30 °C. The number of complaints in the last but one group with 25 °C < T_{30} < 30 °C was higher by 0.7 %

[2] Similar to transient disorders of cerebral circulation.

than that in the reference group, and the number of complaints in the last group was 1.3 % higher than that in the reference group. Therefore, empirical evidence suggested the effect of rising average monthly temperatures on the prevalence of mental symptoms.

We have already mentioned this Canadian study [21], which used a case-crossover design in contrast to time series analysis. Let us look at it in greater detail. Specifically, each day with an emergency department (ED) visit was compared to several control periods for the same patient when he/she did not visit the ED. In this Canadian study, the control periods were selected as the same days on the different weeks during the same month. For instance, if an ED visit for mental and behavioral disorders occurred on the first Monday of January 2020, the control periods would be identified as those other Mondays during January 2020. Only the first ED visit during the respective month was considered. This study design was less prone to bias from effects of a day-of-week and a month-of-year and also accounted for individual-level confounders (e.g. smoking status) since 'the case controlled itself'. A case and its control would differ from each other by only weather and environmental conditions in a place where a patient lived, for example, levels of ambient air pollution. Conditioned logistic regression was applied to investigate influence exerted by these variables in 'case – control' pairs. A distributed lag non-linear model (DLNM) was used because it described lagged exposures to environmental factors that accumulated over several days. The greatest temperature effect would be reached when considering the lags between 0 and 5 days ($T_{0\text{-}5}$), that is, heat stress accumulated over five days prior to a hospital visit. Overall, the sample included almost 10 million (!) ED visits for mental and behavioral disorders over the period 2004–2020 in Alberta and Ontario provinces. An average daily temperature and humidity were retrieved from the Daymet North American Meteorological Database using a 1 km × 1 km grid approximating the coordinates of the zip code of a patient's place of residence. In this study, the authors calculated odds ratios (*OR*) of emergency department visits at the 97.5th percentile of average daily temperature distribution in reference to the 'optimal' temperature under which the number of ED visits was the lowest in a given administrative region. This optimal temperature was within the range between the 5th and 95th percentiles and was established by visual examination of the graph of the relationship between ambient temperature and the number of ED visits. ORs were calculated separately for each region and then the average weighted value was determined using meta-analysis. These values are presented in Table 1 for specific diagnoses and age groups. The greatest heat effects were found in the age group of 30–49 years; the lowest, in the age group ≤ 18 years. The highest risk among all analyzed diagnoses was established for substance use disorders.

Effects of heat waves. Medical visits for mental disorders were studied using 'case-crossover' method in Jinan, China (population is 6.8 million) during the four strongest heat waves in the summer of 2010 [26]. That summer was extremely hot; four heat waves were registered and lasted for 4, 3, 4 and 3 days, respectively. Each visit to a doctor during a heat wave was considered a 'case'; control days

Table 1

Odds ratio (*OR*) for visits to the emergency department during extreme heat and under optimal ambient temperature in Canada [21]

Analyzed group	*OR*	95 % CI
Any mental disorder, any age	1.15*	1.12–1.17
Age of 30–49 years	1.18*	1.15–1.22
Age ≤ 18 years	0.97	0.91–1.02
Substance use disorders	1.29*	1.24–1.33
Schizophrenia	1.15*	1.10–1.20
Neurotic disorders	1.15*	1.12–1.19
Dementia	1.16*	1.07–1.25

Note: * risk is significant at 95 % level, $p < 0.05$.

were selected on the same days-of-week one, two and three weeks prior to a heat wave as well as one, two and three weeks after it (provided that those control days themselves did not fall within a heat wave period). This study design is called ‘symmetric bidirectional’. This method is quite useful for examining short-term exposures when a time gap between an ED visit and a control day is longer than a typical period of exposure to an analyzed environmental factor; in this case, duration of a heat wave.

A heat wave was defined as uninterrupted sequence of three or more days when the maximum daily temperature was above 35 °C. Odds ratio of seeing a doctor for all mental and behavioral disorders (ICD-10 codes F00–F99) during a heat wave and on control days was calculated considering a possible time lag between 0 and 5 days from heat exposure to visiting a doctor. The largest odds ratios (ORs) during the heat waves for daily hospital visits for mental illness were 2.231 (95 % confidence interval (CI): 1.436–3.466) at a 3-day lag, 2.836 (95 % CI: 1.776–4.525) at a 2-day lag, 3.178 (95 % CI: 1.995–5.064) at a 3-day lag, and 2.988 (95 % CI: 2.158–4.140) at a 2-day lag for the first, second, third, and fourth heat waves, respectively.

Further results were obtained for a sample of all four heat waves taken together, and control days – the remaining days between June 01 and August 31. Odds ratios of hospitalization during heat waves (taking into account the abovementioned lags) and during the control period differed significantly depending on the following effect modifiers: age, place of residence, occupation, and marital status. Since these individual characteristics were not always available for the outpatients, modification of effects produced by heat was investigated only for the hospitalized patients.

Odds ratio for hospitalization during heat waves against the control period was three times higher for old people ≥ 65 years than that in the age group ≤ 64 years (*OR* = 3.034, 95 % CI: 1.802–5.139). The risk of heat waves on mental illness in urban areas was more serious than that in the rural or suburban areas (*OR* = 1.523, 95 % CI: 1.120–2.074). Outdoor workers (*OR* = 1.714, 95 % CI: 1.198–2.398) and singles (*OR* = 1.709, 95 % CI: 1.233–2.349) were more likely to suffer from mental illness during the heat wave periods.

As for specific diagnoses, the greatest effects of heat waves on hospitalization were found for schizophrenia, classification disorders, and delusional disorders (ICD-10 codes F20–F29), mood disorders (F30–F39) and especially for neurological, stress-related and physical disorders (F40–F49). The chances of hospitalizations due to the last group of diagnoses were almost five times higher during the heat waves than those in the control period.

The effects produced by heat waves lasting three days and longer on mortality and morbidity (judged as the number of hospital admissions) for various causes were examined in the Greater Metropolitan Sydney Region (5 million people). Among them, all mental disorders and some specific diseases were investigated including schizophrenia, dementia, and substance use disorders [27]. The analyzed data covered warm seasons (spring and summer) over the period between 1997 and 2010. The authors used the ‘case – crossover’ method. ‘Cases’ were represented by both separate days of moderate heat ($T \geq 95^{th}$ percentile of average daily temperature distribution over a warm half of year) or strong heat ($T \geq 99^{th}$ percentile), and ‘three-day severe heat events’. Three-day severe heat events were selected using a temperature averaged over a hospitalization day and two previous days (T_{0-2}) with the same threshold values of the percentiles. These selection criteria on average give 9 waves of moderate heat and 2 waves of strong heat per year. Just as in previously mentioned studies, control days were the same days-of-week within the same months as hot days. The authors reported a rather weak relationship between the number of hospitalizations and hot weather (Table 2).

Obviously, the effects on the old age group are not always stronger. Table 2 provides the results for single hot days with the zero lag between temperature and hospitalization. However, intensity of the effect may grow if we consider lags of several days; in this study, lags of up to three days were considered. The same concerns heat waves. We can take a lag of 1–3,

Table 2

Odds ratio *OR* (95 % CI) of hospitalization for mental disorders on hot and control days in Sydney [27]

Age group	Single hot days, lag 0		Three-day heat events, lag 0–2	
	Moderate heat	Severe heat	Moderate heat	Severe heat
Thresholds	$T_0 \geq 95$ %	$T_0 \geq 99$ %	$T_{0\text{-}2} \geq 95$ %	$T_{0\text{-}2} \geq 99$ %
Any age	1.01 (0.98–1.04)	1.08 (0.97–1.20)	1.03* (1.00–1.05)	1.05 (0.99–1.10)
Age ≥ 65	1.03 (0.96–1.09)	0.94 (0.81–1.09)	1.09* (1.02–1.16)	1.05 (0.91–1.20)

Note: *$p < 0.05$.

2–4 days etc. instead of 0–2 days; however, such lags were not investigated in this study. For example, when investigating specific diagnoses, the authors found that the maximum effect for hospitalizations for mood disorders was reached at a 1-day lag after the days of moderate heat, *OR* = 1.06 (95 % CI: 1.00–1.12). The greatest absolute effects were established for substance use disorders, *OR* = 1.08 (95 % CI: 0.97–1.20) and for hospitalizations for dementia, *OR* = 1.14 (0.99–1.31).

This Australian study has an obvious drawback since it did not consider the duration of heat waves. In this respect, we should mention a study conducted in Vietnam with its focus on effects produced on hospital admissions for mental disorders by heat waves of different duration [28]. Overall, the authors analyzed 21,443 hospital admissions to the Hanoi Mental Hospital in 2008–2012. In this study, the authors defined extreme heatwaves using consecutive days of a temperature higher than normal skin temperature (above 34 °C). Therefore, they used the threshold of 35 °C for the maximum daily temperature T_{max}, which corresponded to the 90th percentile of its year-round distribution.

Binary indicators $T_{0\text{-}2} \geq 35$ °C or $T_{0\text{-}6} \geq 35$ °C were used to identify days with accumulated heat stress. The authors interpret such ‘cases’ as the effects produced by heat waves not shorter than 3 days or not shorter than 7 days. Note that this approach is different from a conventional one, when all days during an interrupted heat wave are considered “cases”. Thus, the condition $T_{0\text{-}2} \geq 35$ °C means that only the last day is the indicator for a three-day heat wave; or, the three last days are indicators for a five-day heat wave; etc. Thus, the effects of accumulated heat stress are investigated. In this study, over five years, 175 single days were observed with the maximum temperature above 35 °C. Of those events, 61 included at least three consecutive days with such conditions, and ten events of these included at least seven consecutive days with such temperatures. Increases in hospital admissions were estimated exactly for these samples in comparison with the remaining days within the analyzed period.

A negative binomial model adjusted for a day-of-week, seasonality and long-term trend was used for regression of hospital admissions against the binary ambient temperature indicator. Such a model is used for overdispersed dependent variable, when its distribution is considerably different from Poisson’s. Table 3 provides data on estimated relative risks of hospital admissions for all mental disorders, specific diagnoses and susceptible population groups.

Obviously, among specific diagnoses, the highest risks were found for organic disorders and specifically for the codes F04–F06 (organic amnesic syndrome, delirium and other mental disorders due to brain damage) as well as for mental retardation. The authors mention such effect modifiers as place of residence (higher risks were established for rural population) and older age. For example, risks of heat waves were found to be twice as high for people aged ≥ 61 years against those established for all age groups.

Meta-analysis of risks established in local studies. Many local studies have been conducted recently. Subsequent meta-analysis of obtained local-specific results is used to study possible causes for their heterogeneity; that is, to investigate possible effect modifiers. Let us consider a systematic review [18], which used meta-analysis of random effects of both high ambient temperatures and heat waves.

Table 3

Relative risks of single days and heat waves, *RR* (95 % CI) for hospital admissions for mental disorders in Hanoi [28]

Analyzed group	Single days	3-day waves	7-day waves
Any mental disorder (F00–F99)	1.04 (0.95–1.13)	1.15* (1.005–1.31)	1.36* (1–1.90)
Rural population (any diagnosis)	N/A	1.26* (1.04–1.52)	1.69* (1.08–2.64)
Age ≥ 61 years (any diagnosis)	N/A	1.31 (0.8–2.15)	3.2* (1.63–6.29)
Organic, including symptomatic, mental disorders (F00–F09)	1.21 (0.95–1.54)	1.37 (0.97–1.95)	**3.62* (1.76–7.42)**
Organic amnesic syndrome, delirium and other mental disorders due to brain damage (F04–F06)	1.31 (0.94–1.82)	**1.52* (1–2.40)**	**4.76* (1.74–13.18)**
Mental retardation (F70–F79)	1.14 (0.83–1.55)	**1.68* (1.08–2.62)**	2.3 (0.8–6.88)

Note: *$p < 0.05$.

A relative increase in the effect size per 1 °C was selected as a quantitative measure in meta-analysis of studies of high ambient temperatures. Therefore, when analyzing the studies reporting a relative risk between the two percentiles of temperature distribution, it was necessary to know the absolute temperature range in °C, for which this relative risk was established, and to calculate the natural logarithm *ln*(*RR*), assuming there was a log-linear relationship between a risk and temperature within the given range [29]. Regarding high temperatures, the meta-analysis of 15 studies investigating *mortality* for all mental disorders established a pooled growth in the effect by 2.2 % for each 1 °C increase in temperature, *RR* of 1.022 (95 % CI: 1.015–1.029); the effect was approximately 1.5 times stronger among people older than 65 years compared to those younger than 65 years. Accordingly, relative risks of mortality for each 1 °C increase were *RR* (≥ 65) = 1.025 (95 % CI: 1.015–1.035) and *RR* (< 65) = 1.017 (95 % CI: 1.005–1.028). As for specific causes, the greatest mortality risk was attributed to substance-related mental disorders (*RR* = 1.046; 95 % CI: 0.991–1.101), followed by organic mental disorders (*RR* = 1.033; 95 % CI: 1.020–1.046).

The meta-analysis of 21 studies with their focus on morbidity (hospital admissions or emergency department visits for any mental disorder) estimated a pooled effect as a 0.9 % increase for each 1 °C increase in temperature, *RR* = 1.009 (95 % CI: 1.007–1.015). The authors reported a very narrow confidence interval for this estimate ($p < 0.001$) unlike to the typical results reported in individual local studies, which were covered by the review. An advantage of meta-analysis is an increase in statistical significance of pooled effect estimates since the more precise is individual risk estimate, the higher relative weight it gains in calculation of the pooled effect estimate. A relative increase in morbidity per 1 °C was twice as high for the elderly people relative to the middle-aged ones: respectively, *RR* (≥ 65) = 1.010 (95 % CI: 1.005–1.015), and *RR* (< 65) = 1.005 (95 % CI: 1.003–1.006). Therefore, elderly people are considered the most susceptible population group in this study. When examining specific mental diagnoses, the authors found the greatest effects on morbidity per each 1 °C increase in temperature for mood disorders, *RR* = 1.011 (95 % CI: 1.003–1.018); organic mental disorders, *RR* = 1.008 (95 % CI: 1.001–1.015); schizophrenia, *RR* = 1.007 (95 % CI: 1.002–1.011); neurotic and anxiety disorders, *RR* = 1.007 (95 % CI: 1.001–1.013).

Large number of local studies that estimated the effects of high ambient temperatures on mental health allowed the authors of the review [18] to analyze such effect modifiers as climate and income per capita. Five climatic zones were included in the study (following the Koppen – Geiger climate classification); among them, the highest risks of high ambient temperatures were established in tropical and subtropical climate; the lowest, in continental climate. Just as expected, countries with higher incomes per capita on average had lower risks than middle-income countries.

The authors of the review [18] also made an effort to adjust the obtained pooled risk estimates allowing for publication bias, when only selected results or the highest risks are reported. Special methods are available for such adjustment including funnel plots or trim-and-fill technique. The adjusted effect estimates turned out to be slightly lower but still significant. Thus, an adjusted effect on mortality for each 1 °C increase in temperature was RR = 1.014 (95 % CI: 1.011–1.017); and the effect on morbidity was RR = 1.007 (95 % CI: 1.004–1.010).

Meta-analysis of results reported in the studies of heat waves is possible only for those studies where authors use similar definitions of heat waves when selecting a temperature measure (average daily or maximum temperatures), threshold temperature percentiles and wave duration. Therefore, only those studies were included in the meta-analysis, which used average daily temperatures as the exposure metric, a heat threshold temperature was selected at the 95th percentile, and all heat waves longer than 3 days were considered. The analysis of nine such studies with their focus on *morbidity* found a relatively low total risk during heat waves, RR = 1.064 (95 % CI: 1.006–1.123). Only five studies were included in the meta-analysis of effects produced by heat waves on mortality; however, the pooled risk turned out to be statistically insignificant and the authors did not report it.

High ambient temperatures and workers' mental state. The WHO pays special attention to workers' mental health at the workplace. As estimated by this organization, 15 % of working age population has mental disorders and this leads to a tremendous loss of 12 billion workdays every year; this corresponds to annual economic loss of 1 trillion USD[3]. Several reports on this topic have been published in Russian by the WHO and its Regional Office for Europe; they cover prevention of mental diseases, guidelines on mental health protection at workplace[4] and other relevant topics. Risks for mental health increase in heating microclimate, both at a workplace and at home. A study of effects produced by heat on mental health in Jinan, China [26] established a considerable rise in odds ratio of hospital admissions for mental disorders for outdoor workers relative to those who worked indoors during a heat wave. Some indirect evidence of it can be found in another study conducted in Peru [30]. On average, each additional outdoor work hour per day (under approximately 28 °C) increased the mean number of mental disorder symptoms by 13 % (95 % CI: 1–25 %). Resting in a shaded place during a break decreased frequency of these symptoms by 27 % (95 % CI: 0–47 %). Therefore, it is extremely important to have optimal work and rest regimes in hot weather in Russia just like in many southern countries.

A survey was conducted in a large cohort of Thai workers (more than 40 thousand people). It revealed a significant relationship between workers who often suffer from heat stress at workplace and those who complain about psychological distress [31]. The respondents gave their own estimates of psychological distress by answering three questions concerning anxiety symptoms: 'in the past 4 weeks, how often did you feel (1) nervous, (2) restless or fidgety, or (3) felt so tired everything was an effort?' Having summed up the answers, the researchers identified those who suffered from psychological distress and those who did not have any complaints. Logistic regression was used to calculate odds ratio of getting psychological distress for workers exposed to heat stress at their workplaces in comparison with unexposed ones. Naturally, more workers complained of poor mental state among those exposed to heat stress. A risk of getting psychological distress due to exposure to heat stress at workplace grew with workers' age. Very interesting results were obtained for such effect modifiers as work in office / physical work, work in urban area / work in rural area (Table 4). The variable 'office / physical

[3] Mental health at work. *WHO*, 2024. Available at: https://www.who.int/news-room/fact-sheets/detail/mental-health-at-work (November 11, 2024).

[4] WHO Guidelines on mental health at work: Executive summary. Geneva, WHO, 2022, 14 p. Available at: https://iris.who.int/bitstream/handle/10665/363156/9789240057760-eng.pdf (November 11, 2024).

Table 4

Influence of age, job type and area on the statistical relationship between heat stress at workplace and psychological distress [31]

Age group, type and area of work	The number of respondents exposed to heat stress, *N*	Odds ratio of getting psychological distress, *OR* (95 % CI)
Age of 15–29 years	3906	1.80** (1.62–2.01)
Age of 30–44 years	3234	1.86** (1.62–2.14)
Age ≥ 45 years	336	2.35* (1.42–3.88)
Bangkok/office	251	2.62** (1.84–3.74)
Bangkok/physical	58	1.10 (0.36–3.38)
Urban/office	945	2.04** (1.62–2.56)
Urban/physical	150	1.41 (0.75–2.65)
Rural/office	1142	2.35** (1.90–2.90)
Rural/physical	212	2.49** (1.50–4.11)

Note: $*p < 0.05$; $**p < 0.01$.

work' differently affected this risk in urban and rural areas. Thus, a considerably higher risk of getting psychological distress under exposure to heat stress was identified for office workers in urban areas whereas this risk was higher for those involved in physical work in rural areas.

The effects of heat on construction workers were examined in Texas, USA [32], where 100 workers took part in a survey. The responses revealed that excessive heat affected workers mentally (difficulty concentrating, lack of focus, irritability, and frequent mood swings). Significant increases in frequency of these symptoms were established using the non-parametric Kruskal – Wallis test for outdoor workers compared to those who worked indoors.

A similar survey was conducted in Japan [33] among 115 construction and 204 traffic control workers who also had to work outdoors in hot weather. The survey revealed that construction workers subjectively suffered more from heat than traffic control workers. In particular, in hot weather, construction workers more frequently suffered from such mental symptoms as sleep disorders, overall fatigue, tiredness, irritability and impatience.

Sixteen traffic police workers were interviewed in Ahmadabad, India. They had to perform their work duties outdoors in summer and were exposed to high ambient temperatures ranging between 32 and 37 °C [34]. Sixty-nine percent of the respondents complained about loss of work capacity due to heat exposure; 56 % complained about loss of coordination; 38 % reported increased irritability and anxiety. Traffic police officers, just like couriers, communal service workers and other outdoor workers, are examples of professional groups with high occupational health risks in terms of effects produced by heat on mental health.

The WHO Policy Brief on mental disorders under climate change[5] postulates that climate change aggravates many social and environmental risk factors for mental health and psychosocial problems. This may lead to emotional stress, new developing mental impairments and deterioration of medical condition for people who already have such disorders. Therefore, considering climate-related health risks, special attention should be paid to mental health issues and provision of relevant psychosocial support.

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[5] Corvalan C., Gray B., Villalobos C., Sena A., Hanna F., Campbell-Lendrum D. Mental Health and Climate Change: Policy Brief. Geneva, WHO, 2022, 16 p. Available at: https://iris.who.int/bitstream/handle/10665/354104/9789240045125-eng.pdf?sequence=1 (November 12, 2024).

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