sustainability

MDPI

Article

How to Create Healthy, Stress-Resilient Post-Pandemic Cities

Magdalena Wdowicka [1,*], Lidia Mierzejewska [1], Marta Szejnfeld [1], Bogusz Modrzewski [1], Kamila Sikorska-Podyma [1], Adam Wronkowski [1] and Ewa Lechowska [2]

[1] Department of Spatial Planning and Urban Design, Faculty of Human Geography and Planning, Adam Mickiewicz University, 61-680 Poznan, Poland; lidia.mierzejewska@amu.edu.pl (L.M.); marta.szejnfeld@amu.edu.pl (M.S.); b.modrzewski@amu.edu.pl (B.M.); kamila.sikorska-podyma@amu.edu.pl (K.S.-P.); adam.wronkowski@amu.edu.pl (A.W.)

[2] Department of Investment and Real Estate, Faculty of Economics and Sociology, University of Lodz, 90-255 Lodz, Poland; ewa.lechowska@eksoc.uni.lodz.pl

* Correspondence: magdalena.wdowicka@amu.edu.pl

Abstract: This article analyzes the correlation between the city size, population density and character of three Polish cities and the following aspects: (1) inhabitants' subjective stress level and its change during the COVID-19 pandemic, (2) sources and effects of their stress during the pandemic, (3) ways of reducing stress by residents and the role of greenery in this respect and (4) directions of changes in the structure of post-pandemic cities desired by their residents. The main research method was geo-surveys, the results of which were developed using statistical analysis and GIS methods. On the basis of the constructed scale, respondents subjectively assessed the level of experienced stress and its change during the COVID-19 pandemic. The research shows that none of the considered features of cities (including size measured by the number of inhabitants) are related to the level of pandemic stress of their inhabitants. All of them, on the other hand, are correlated with the directions of urban spatial development desired by the residents, conducive to stress reduction. Furthermore, the size of the city and its character affect the subjectively perceived change in stress levels during the pandemic (compared to the stress level before pandemic). Some of the effects of pandemic stress and ways of reducing it depend on the character of the city. The stress experienced by the inhabitants is the lowest in cities with the largest share of green areas in the spatial structure (especially with forest complexes and naturally shaped areas of river valleys), where an effective system of greenery has been adopted (the Howard's garden city model), and at the same time with dominant single-family housing. The research results were used to indicate new directions for shaping post-pandemic cities that are more resistant to stress and thus healthier for their residents.

Keywords: city; stress-resilient city; healthy city; COVID-19; urban stress; stress causes; stress effects; urban greenery; biophilic design; urban spatial structure

Citation: Wdowicka, M.; Mierzejewska, L.; Szejnfeld, M.; Modrzewski, B.; Sikorska-Podyma, K.; Wronkowski, A.; Lechowska, E. How to Create Healthy, Stress-Resilient Post-Pandemic Cities. *Sustainability* **2024**, *16*, 3644. https://doi.org/10.3390/su16093644

Academic Editors: Felicia Di Liddo, Pierluigi Morano, Francesco Tajani and Paola Amoruso

Received: 26 March 2024
Revised: 22 April 2024
Accepted: 24 April 2024
Published: 26 April 2024

1. Introduction

The observed global trend towards the intensification of urbanization processes and living an urban lifestyle has positive but also negative consequences. On one hand, it has contributed to an improvement in urban sanitation and infrastructure over the last several decades, which have resulted in a better quality of life, particularly in comparison to the 19th-century cities of the industrial age that offered poor sanitary conditions and therefore bred numerous epidemics (the plague, tuberculosis, influenza, etc.) [1,2]. As a result, being at the same time environments full of informative and situational stimulants, cities began to be perceived as fields of professional and personal opportunities. On the other hand, however, cities are dynamic, unpredictable and stress inducing places, full of inequalities, exacerbating the health condition of residents [3–5].

The literature on stress in cities, its causes, effects, and ways of relieving it, is not very extensive [6–9]. Furthermore, cities vary to a significant degree. Their different features,

mainly their size measured by the number of inhabitants, decide about both development potential and the problems and challenges they face. Studies reflecting on the correlation between residents' stress and the size of an inhabited center are scarce. The issue is tackled in the research by Adli [7] and—in relation to pandemic stress—in the article by Zahangir and Rokonuzzaman [10]. Unexplored problems that need to be examined more thoroughly are those of whether the size of a city during the pandemic had an effect on: (1) the stress level of residents, (2) causes of this stress, (3) its effects, (4) ways of reducing it and (5) the role of the spatial structure, including greenery, in its reduction. These are the issues addressed in this publication. Filling the identified research gaps will make it possible to acquire new knowledge that is needed for developing the concept of a healthy, stress-resilient, livable city.

It has been assumed, in line with Lalonde's report of 1974 prepared for WHO, that health is not only the lack of an objectively identified disease or infirmity but the entirety of physical, mental and social wellbeing [11,12]. Therefore, health is understood as freedom from distress and degradation, freedom to act and maintain autonomy in time, and stress resilience [11,13]. In this context, health is not only a biological concept but also a psychological and social one, dependent on four determinants: (1) lifestyle, that is the total of personal pro-health choices (53%), (2) the impact of physical and social environments (21%), (3) biology and genetics (16%) and, only 10% is dependent on, (4) the quality and access to formal healthcare, including pharmacology [14].

It is worth emphasizing that compliance with "healthy lifestyle" recommendations does not automatically guarantee mental health, since psychological wellbeing relies heavily on many different factors, an important role being played by a living environment and conditions of social functioning of an individual. This, in turn, depends on a properly planned and developed spatiofunctional structure of a city [15].

The primary objective of the study is to indicate new directions for developing healthy, stress-resilient, post-pandemic cities. Consequently, the research examined the correlation between the city size, population density, its character (resulting from, e.g., the spatiofunctional structure and access to greenery) and the pandemic stress experienced by residents.

The main aim of the study is accomplished by answering the question of whether the following aspects depended on the city size, its population density and the city character during the COVID-19 pandemic:

(1) Inhabitants' stress level and its change;
(2) Sources and effects of this stress;
(3) Ways of reducing stress by inhabitants and the role of greenery in this respect;
(4) Directions of changes in the structure of post-pandemic cities desired by residents.

The focus is also on increasing and decreasing the impacts of spatial structure elements of cities of different sizes on the stress of urban dwellers during the pandemic. We assume that the larger the city, the more densely populated and more densely developed and therefore the higher the pandemic stress level; the same is true for the role of greenery in stress reduction. The answers to the posed research questions rest on the results of the geo-survey conducted. In-depth research was carried out in two Polish cities and one town that were different in size and situated in the Poznań agglomeration area—Poznań, Swarzędz and Puszczykowo.

The results achieved during the research may serve to prepare conceptions of healthy, stress-resilient cities, referring to their size, population density and character. Detection of these dependencies will allow indicating directions for desirable changes that are universal for cities and specific for a given group of urban centers.

The research, the results of which are shown in this publication, relates to the need pronounced in the literature concerning the institution of a new scientific discipline combining the issues of city planning and public health [16,17], allowing for neurology. The discipline is identified as neuroarchitecture, neurourbanism or neurogeography. Its research field should embrace the influence of urban structure elements on the state of the human nervous system (the correlation between urban living and mental disorders), allowing

for the conception of the stressed urban brain, which is significant in the face of a still growing urban population [18]. It also fills the gap in the subject of better understanding the interactions between the mental health of residents and the availability and quality of green areas [19].

2. Theoretical Background

The search for the characteristics of healthy, stress-resilient, post-pandemic cities requires prior identification of sources of stress in cities, what shapes the level of this stress, as well as the role played by the COVID-19 pandemic and its accompanying countermeasures (restrictions, lockdowns) in this regard. Due to the harmfulness of stress for residents and its negative impact on public health, it is also important to point out the elements of urban development that help residents reduce their stress, which are urban green areas (UGI).

2.1. Stress in the City

The residents' stress may have different origins. Among them, one can distinguish the following sources: (1) economic, such as lack of a sense of financial stability, fear of shortages of resources in case of crisis, fear of losing a job, (2) social, consisting of social deprivation/discrimination, lack of a sense of security, helplessness, aggression, social threats, unpredictable environments, social isolation, chaos, communication stress, etc., and (3) environmental, such as noise, congestion, housing type and quality, insufficient personal space, disruption to chronobiological rhythm or a low air quality [9,18].

Stress, in the face of civilizational changes and violent occurrences with unpredictable results, may significantly affect the wellbeing of urban residents, including affecting their health [11,20,21]. The long-term deprivation of wellbeing elements that are essential to the proper biological, economic and social functioning of human beings may lead to psychosomatic diseases resulting from prolonged stress. Long-term social stress seems to be particularly disadvantageous and, to a much greater extent than environmental stressors, may contribute to epigenetic disorders, a greater risk of neurodegenerative diseases, accelerated aging, schizophrenia (the risk is twice as high as in rural areas), anxiety, fear and depression [7,9].

2.2. The Stress Level and the Size of the City

Health disorders caused by stress are observed in urban environments rather than in rural ones [6,22]. Moreover, unfavorable stress effects correlate with the demographic or socioeconomic features of urban dwellers to a small degree, yet they intensify with the size of the inhabited city [6,7,23,24]. Furthermore, the urban environment is characterized by a reduced neural ability to cope with stress [7,25] accompanied by the shortage of a restorative environment conducive to a quick post-stress regeneration [19].

Since the urban population is expected to double over the next 30 years, there is a legitimate concern that urban stress will intensify [19]. Therefore, what is needed are further, in-depth studies on urban stress factors and their effects, as well as mental stress factors (anxiety, depression and substance use), in relation to city sizes [26], and building resilience to them. Stress-caused mental diseases, next to obesity and a decline in physical activity, are recognized as one of the main challenges for 21st-century cities [27]. It is also not without significance that stress results in the deterioration of urban dwellers' health, which contributes to increasing healthcare costs.

2.3. Stress in the City during the COVID-19 Pandemic

Cities as environments for numerous social contacts were particularly vulnerable to the quick transmission of the virus, which in the initial phase of the pandemic spread much faster in larger centers [5]. The research conducted in the United Kingdom shows that the pandemic was perceived at its onset as a strong stressor by 75% of those surveyed, 49% of them suffered aggravated symptoms of adaptation disorders, including 26% of those with depression symptoms [28]. Comparative studies in Bangladesh and Chittagong revealed

that a significant proportion of the infected respondents experienced depression, anxiety and stress symptoms, with their greatest intensification in larger cities [10].

According to WHO [29], in the first year of the pandemic there was an increase in anxiety and depression by 25%, and the reasons behind this deterioration turned out to be social isolation, loneliness, fear of losing economic safety and also concerns about one's health and personal life and those close to them [29]. The research carried out in Portugal [30] confirmed these results, indicating that women and persons with previously diagnosed mental illnesses were more exposed to an increase in psychopathological symptoms. Moreover, pandemic stress effects may also include a significant rise in restlessness, lack of motivation, too little exercise, irritability, sadness and depression, social withdrawal and also an increase in medication and alcohol abuse [31]. The health deterioration of urban dwellers caused by pandemic stress necessitates searching for ways to improve their health situation and building stress resilience.

2.4. The Role of Greenery in Relieving Stress during COVID-19

In the history of civilization, the natural environment has been recognized many times as an important factor in relieving stress [27,32]. It has been proven that access to high-quality parks and open public spaces positively affects health, including mental health, and is related to pro-health behavior; it is conducive to heightened physical activity and social contacts [33]. The greater number of hours spent by urban residents among greenery correlates with a higher degree of declared mental health [34].

A special role for urban greenery in relieving stress was also identified during the COVID-19 pandemic, although natural areas were also subject to restrictions as potential places of virus spread [35]. The research conducted during the pandemic among the residents of Madrid, revealed that most of them advocated for open access to urban greenery for reasons of health, mental health in particular [31]. A greater number of visits to urban green areas was recorded in numerous cities [35,36], which made it possible for residents to maintain an active lifestyle (despite the requirements of social distancing), reduce addiction to electronic devices, reduce the stress of those confined to the indoor environment [37] and mitigate exposure to tension at home and allowed social cohesion [38]. Overall, it improved physical, mental and emotional health [39]. Greenery was also frequently used by parents to organize time for their children when schools were closed [35]. What was especially recognized during the pandemic was the significance of large urban parks [38].

The research results provided indicate the need to verify and update post-pandemic urban policies on developing public health in cities towards preventive solutions (strengthening stress resilience) that are next to intervention (institutional) measures [40,41]. There is an ever-greater need for rethinking the approach to the design, construction and exploitation of cities to make them healthier for inhabitants, which will require reorganization of their spatial structure [42,43]. The transformations should be oriented to an improvement in the availability of green areas to residents and, in consequence, increase their stress resilience. The application of biophilic design is one of the ways to achieve the vision of such a city.

Biophilic design is based, among other things, on environmental psychology theories—stress recovery theory [44] and attention restoration theory [45]. These theories show the need for modification and redesigning of the urban environment to enhance residents' wellbeing through improving their contact with nature. On a planning scale, the biophilic city [46] is both biodiverse and involves the process of learning and evolving towards better access to a psychophysically restorative environment. Thus, it fulfils the requirements of a self-healing city to some extent [47]. Also, in the conception of a biophilic city, the function of the psychophysical restoration of city dwellers is attributed to urban greenery areas, which are treated as restorative environments [48,49].

3. Research Area

The geo-survey was conducted in three urban areas (two cities and one town) located in the Poznań agglomeration, namely in Poznań, Swarzędz and Puszczykowo (Figure 1). The most important criteria for the choice of the areas of study included: (1) the size of the unit, measured by the number of inhabitants, (2) population density and (3) the character of the city. The term "character of the city" is understood primarily as its functional and spatial structure, which has a most significant impact on the uniqueness of settlement units, as well as the dominant (economic) function of the center. In the context of the conducted research, within the functional and spatial structure, the most important elements include: residential development areas—their distribution, size, density (intensive—multi-family, extensive—single-family), type (single- and multi-family) and green areas—their system/layout in the city plan, location, size and type (including arranged and undeveloped areas). An additional selection criterion was also the location of the city in the agglomeration, as well as its administrative rank.

Figure 1. The situation of the investigated areas against the country, Greater Poland Voivodeship and Poznań County.

Poznań is one of the largest cities in the country in terms of population number—545.07 thousand (fifth in Poland)—and area—262 km^2/26,191 ha (ninth in Poland) [50]. As a regional metropolis, it performs a role at the center of the Poznań agglomeration as the scientific, trade, industrial and cultural hub of the region and is home to voivodeship and county authorities. Poznań is diversified with respect to housing estates; its spatiofunctional structure rests on the ring and radial system of greenery, following the conception of a "compact city" (Figure 6). The green areas overall occupy more than 30% of its total area [50].

Swarzędz is a medium-sized city with respect to its population number (28.98 thousand) [50], situated in the immediate neighborhood of the core metropolis (about 10 km east of the Poznań center). It performs the function of the administrative center of the urban–rural commune of Swarzędz (the largest and most densely populated commune of Poznań County). The city itself is also very densely populated, which places it in fifth

position in the country—3521.4 persons/km^2 in 2021 [50]. Swarzędz is a recognized center in the field of furniture manufacturing (predominant activity: services and production) and does not have any clear spatiofunctional structure, with a small proportion of green areas in a dispersed, pointed pattern.

Puszczykowo is a small town with a population of 9.41 thousand [50]. It is located near Poznań (about 12 km south) in its impact zone and mainly performs the function of a so-called dormitory (residential) district for the central city. The town also fulfils a tourist function because of its situation in the immediate vicinity of Wielkopolski National Park, which surrounds the city. Puszczykowo is designed according to Howard's idea of "garden cities", and almost half of its area is covered by forest land, which is mostly protected by law. The most important features of all three centers are compared in Table 1.

Table 1. The comparison of the cities under research [50].

Typical Feature	Poznań	Puszczykowo	Swarzędz
area (ha)	26.191	1.639	823
population number (thou.)	545.07	9.41	28.98
population density (pers./km^2)	2081.1	574.0	3521.4
housing resources			
number of housing units	292.187	3.159	11.130
number of persons per housing unit	1.87	2.98	2.60
usable space of apartment (m^2)	63.2	127.2	75.8
usable space per person (m^2)	33.9	42.7	29.1
character of buildings	high intensity of multi-family housing and service development in the center, single-family housing development on the peripheries	Dominance of single-family housing	high proportion of single-family housing development, multi-family housing on the peripheries in northern and southern parts of the city
green areas			
area (ha)	5820.28	798.66	60.26
share % urban green areas * and forests	22.22	48.73	7.20
system/greenery pattern in urban structure	ring and radial system (five wedges and central ring—city parks: plants)	linear and ring system, Howard's city garden idea	pointed, dispersed system, concentrated mainly in north part
green area per resident (ha)	0.01	0.08	0.002

* urban greenery consists of parks (walking and leisure), inner green squares, housing estate green areas, street greenery, cemeteries and forests.

The distribution of green areas in the investigated cities and their "embedding" in greenery is shown in Figure 6.

4. Research Methodology

4.1. Geo-Survey

This work is based on research that has drawn mainly on primary data from Internet surveys using computer-assisted web interviewing. Use was made of a geo-survey, a tool that is based on geoinformation systems [51,52]. As a research instrument, a geo-survey is the combination of an Internet survey and a map, making it possible for respondents to plot vector geographic structures on the interactive digital map and answer questions

related to that [53]. Owing to this fact, it is possible to recognize the characteristics of a local space based on the knowledge, experience and opinions of the residents or users of the analyzed area [54–56]. The geo-survey was widely distributed among the residents of the three centers. The link to the tool was shared by the official websites and social media (Facebook, Twitter (X), Instagram) of the municipal offices of the surveyed cities, the Faculty of Human Geography and Spatial Planning of the Adam Mickiewicz University and through the project website.

The geo-survey research consisted of 25 questions, 3 of them being interactive maps. The remaining questions were closed-ended in character (e.g., questions on a scale of 0–10, multiple choice and yes/no questions). The results presented in the article refer to nine geo-survey questions, two of which took the form of an interactive map on which respondents marked stressful and stress-reducing places. In addition to the possibility of marking specific places on maps, the questionnaire questions concerned the level of stress during COVID-19, the change in stress levels as a result of the COVID-19 pandemic, the perceived effects of stress, stressful and stress-reducing elements and desired changes in the structure of post-pandemic cities conducive to stress reduction. The perceived, subjective level of stress was assessed by the respondents using a scale of 0–10 (0—no stress; 10—very high level of stress). The perceived subjective change in stress level as a result of the pandemic compared to the pre-pandemic time was determined by the answers "increased", "did not change" or "decreased". The obtained results were subjected to statistical analysis. The aim was to determine what percentage of respondents indicated an increase, decrease or maintenance of the level of stress experienced during the pandemic compared to the period preceding the pandemic.

The detailed content/text of the questionnaire questions and answer choices is set out in Supplementary Materials. The geo-survey was carried out between July 2022 and March 2023 (the geo-survey was available for completion for a total of 9 months). It should be noted that during the 9-month study period, the pandemic situation in Poland began to stabilize (vaccinations were available and restrictions were gradually lifted). Therefore, the duration of the study had no impact on the results obtained. This is unequivocally confirmed by the results of statistical analyses indicating that there is no relationship between the time of completing the survey and the level of stress of the residents (augmented Dickey–Fuller test: Dickey-Fuller = −10,139, Lag order = 10, p-value = 0.01, Phillips–Perron unit root test: Dickey–Fuller Z(alpha) = −1115.3, Truncation lag parameter = 7, p-value = 0.01, Mann–Kendall test: bump = −0.00183, 2-sided p-value = 0.92811)

A deliberate selection of a sample was used, including the inhabitants of Poznań, Swarzędz and Puszczykowo. Only adults could complete the survey. The research included 1558 respondents overall (933 from Poznań—59.88% of the total; 454 from Swarzędz—29.14%; and 171 from Puszczykowo—10.98%). All participants who completed the geo-survey were qualified for the survey and their answers were included in the data analysis process. In total, the research in all the analyzed centers comprised 68.49% women, 29.46% men and 2.05% individuals who identified as neither. The largest number of participants was between 36 and 60 years of age (38.83%), followed by those 18–25 years old (32.41%) and those between the ages of 26 and 35 (24.52%). Respondents between 61 and 70 years of age accounted for 3.4% of the total and those over 70 years of age only 0.83% of the people interviewed. The majority of the respondents (57.96%) had university education; their detailed feature structure can be found in Table 2.

In order to present the results of the research on the spatial distribution of places relieving and increasing COVID-19 pandemic-related stress on maps, use was made of the point signature method. Each point corresponds to one answer given by the respondents in the geo-survey. The points were retrieved from geographic coordinates in the WGS84 pattern. The persons participating in the geo-survey research were asked to identify sites that reduce or exacerbate their stress level (up to a maximum of five places each) by marking those places on the OpenStreetMap. To present the results in this article, use was made of data on the administrative borders of the investigated cities/town: Poznań, Swarzędz and

Puszczykowo and data on the distribution of greenery, waters and development retrieved from open spatial database (OpenStreetMap).

Table 2. Respondents' structure in the survey.

Variable	TOTAL		Poznań (n = 933)		Puszczykowo (n = 171)		Swarzędz (n = 454)	
	n	%	n	%	n	%	n	%
Age of respondents								
18–25	505	32.41	386	41.4	20	11.7	99	21.8
26–35	382	24.52	216	23.2	34	19.9	132	29.1
36–60	605	38.83	306	32.8	96	56.1	203	44.7
61–70	53	3.40	20	2.1	18	10.5	15	3.3
over 70	13	0.83	5	0.5	3	1.8	5	1.1
Gender								
Other	32	2.05	27	2.9	1	0.6	4	0.9
Woman	1067	68.49	634	68	115	67.3	318	70
Men	459	29.46	272	29.2	55	32.2	132	29.1
Education								
Elementary	41	2.63	10	1.1	12	7	19	4.2
Secondary	541	34.72	320	34.3	33	19.3	188	41.4
University	903	57.96	575	61.6	117	68.4	211	46.5
Vocational	73	4.69	28	3	9	5.3	36	7.9
Occupational activity								
Pensioner	66	4.24	22	2.4	16	9.4	28	6.2
Unemployed	66	4.24	27	2.9	7	4.1	32	7
Private sector employee	472	30.30	250	26.8	45	26.3	177	39
Public sector employee	418	26.83	246	26.4	43	25.1	129	28.4
Entrepreneur	142	9.11	68	7.3	40	23.4	34	7.5
Student	394	25.29	320	34.3	20	11.7	54	11.9

4.2. Statistical Methods

In the statistical analyses conducted, the city was expressed as an ordinal variable, determining the city size by the population number (thus the cities were ranked: 1—Puszczykowo, 2—Swarzędz, 3—Poznań), an interval variable (population density) and also as a nominal variable (name of the city), allowing for a city's unique character (Table 1). To establish correlations between the size, population density, character of a city and the variables studied such as the pandemic-induced stress level, its changes, ways of reducing urban dwellers' stress during the pandemic and resident-desired directions for the city development conducive to the alleviation of their stress level, use was made of such statistical measures as the Pearson contingency coefficient C, Cramer coefficient V, a chi-squared test for pairs of nominal or nominal and ordinal variables, Spearman's correlation coefficient and Pearson correlation coefficient r for pairs of variables in ordinal or interval scales. The analysis allows for significance levels with the following values: 0.1 (*), 0.05 (**) and 0.01 (***). It needs to be emphasized that the values of the Pearson coefficient r should be treated with caution as they are extremely sensitive to outliers, that is, unusual, infrequent observations, and it concerns only a linear correlation. Moreover, correlation coefficients do not take into account a dependent and an independent variable. They only show the

consistency in the direction of change of the expected value of the variables under study. On the other hand, contingency coefficients are measures of curvilinear correlation and do not indicate the direction of the correlation.

5. Results

5.1. Stress Level during the Pandemic

The results of the geo-survey conducted in three Polish cities: Poznań, Puszczykowo and Swarzędz confirm that the cities' inhabitants are highly exposed to stress. During the COVID-19 pandemic, the residents assessed their stress on a scale from 0 to 10 (0—no stress, 10—the highest level) on average at the level of 5.51. While 5.50% of the respondents did not feel stress at all, 7.30% of them experienced it at the highest level (Table 3).

Table 3. Stress level experienced by urban residents during the COVID-19 pandemic.

Stress Level Experienced \ City/Town	Total	Poznań	Puszczykowo	Swarzędz
lack of stress (% respondents)	5.5	5.3	5.5	5.8
highest stress level (% respondents)	7.3	7.5	6.8	7.2
mean stress level (on a scale 0–10)	5.51	5.53	5.30	5.56

The highest mean stress level during the pandemic was experienced by the residents of Poznań and Swarzędz (5.5), whereas a slightly lower mean level was recorded among Puszczykowo town dwellers (5.3). Consequently, the primary data analysis might suggest that there is some correlation between the size of a city and the level of the pandemic stress experienced. However, in the course of the statistical analyses conducted, no linear correlation was found between the size of the city, its population density and its character and the pandemic-induced stress level.

5.2. Changes in the Stress Level Resulting from the COVID-19 Pandemic

As a result of the pandemic, 39.1% of the residents experienced an increase in stress, 29.3% did not notice any changes in the stress level and 31.6% of the respondents stated that stress in the pandemic period decreased (Figure 2). Mostly, Poznań and Swarzędz residents suffered from an increase in stress levels (40.7% and 37.9%, respectively). In Puszczykowo, the lowest increase in pandemic-induced stress level and the related restrictions was observed. Such a distribution of responses may suggest a certain relationship between a stress level change and the city size, yet this was not statistically proven (Table 4). What was recorded, however, was a statistically significant correlation between a stress level change and the unique character of a city (Table 1). Poznań, the most populated city, saw the highest increase in stress levels during the pandemic (Figure 2).

Table 4. Correlation between the size of the city, its density and its character and the stress level, including its change.

Stress	Unique Character of City			City Size (Population Number)		Population Density	
	Pearson C	Cramer V	chi2	Spearman	Pearson r	Spearman	Pearson r
Stress level	0.09193	0.06528	10.21	0.01835	0.01871	0.01887	0.02347
Change in stress level	0.1027	0.07298	12.76 **	0.0007554	0.003482	0.02814	0.03005

Asterisks indicate appropriate significance levels: 0.05 (**).

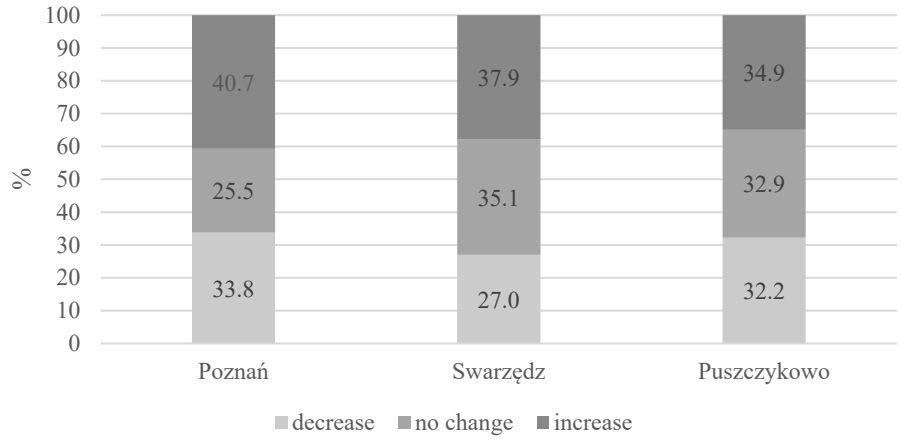

Figure 2. Change in the stress level in cities as a result of the COVID-19 pandemic.

5.3. Stress Sources during the COVID-19 Pandemic

It should be noticed that the most stressful factor for residents during the COVID-19 pandemic turned out to be not the virus itself but the series of restrictions introduced as a consequence of it in the city space. The presence of the virus caused residents stress at the level of 5.23 on average (on the scale from 0—no stress to 10—the highest level), while it was experienced much more strongly in relation to a fear of rising prices (7.84), difficulties with access to healthcare facilities (7.43), introduced limitations to mobility and leaving places of residence (6.97), a fear of losing income (6.56), uncertainty as to changes within the pandemic restrictions (6.29) and travel difficulties (6.17) (Table 5).

Table 5. Mean level of experienced stress in the analyzed cities during the COVID-19 pandemic in relation to stressors.

City/Town / Stressor	Mean Level of Experienced Stress (on Scale from 0—No Stress to 10—Highest Level)			
	Total	**Poznań**	**Puszczykowo**	**Swarzędz**
Presence of COVID-19 virus	5.23	5.21	5.44	5.17
Uncertainty as to changes in restrictions	6.29	6.26	6.35	6.30
Fear of losing jobs	5.94	5.84	5.61	6.29
Fear of losing part of income	6.56	6.40	6.35	6.94
Fear of rising prices	7.84	7.77	7.35	8.16
Fear of provision of childcare	2.88	2.30	3.23	3.86
Fear of quarantine	5.37	5.35	5.34	5.41
Fear of change to remote working	3.11	3.09	3.00	3.17
Fear of ensuring remote working/learning conditions for household members	3.49	3.18	3.03	4.28
Fear of using public transport	4.53	4.51	4.49	4.60
Closure of sports clubs	3.69	3.55	3.74	3.39
Closure of catering facilities	4.39	4.44	3.82	4.53
Closure of cultural and recreation facilities	4.45	4.55	4.29	4.34

Table 5. *Cont.*

City/Town / Stressor	Mean Level of Experienced Stress (on Scale from 0—No Stress to 10—Highest Level)			
	Total	**Poznań**	**Puszczykowo**	**Swarzędz**
Limitations to leaving places of residence and mobility	6.97	6.94	6.84	7.06
Difficulties with access to healthcare facilities	7.43	7.33	7.48	7.61
Need to wear masks	5.06	4.68	5.05	5.80
Fear of others' not abiding by restrictions	5.67	5.86	5.25	5.50
Difficulties with travel	6.17	6.21	6.28	6.04

On the other hand, the least stress during the pandemic was felt in relation to the provision of childcare in the event of the closure of kindergartens and nurseries (mean 2.88) and the probability of remote work (mean 3.11).

The influence of individual stressors on the residents of the investigated cities was diverse; however, most of the stressors under analysis were felt by the Swarzędz respondents. The residents of this city, compared to those from the remaining examined centers, were especially vulnerable to stress related to the fear of rising prices, losing jobs and income, difficulties with access to healthcare facilities and limitations to leaving places of residence. By contrast, the closure of cultural and entertainment facilities was significantly more stressful to the inhabitants of Poznań than those of Swarzędz or Puszczykowo. The limitations to travel, on the other hand, were found to be most stressful by the residents of Puszczykowo. What seems to be interesting is the fact that the presence of the COVID-19 virus was distressing at the lowest mean level for the residents of Swarzędz (5.17)—a city with the highest population density—whereas it was at the highest level for the respondents from the smallest of the investigated centers, Puszczykowo (5.44). The residents of Poznań felt virus-presence-related stress on average at the level of 5.21.

For some urban stressors, statistically significant correlations with the city population density level were detected (Table 6). The residents' concerns grow with an increase in population density and are related to the fear of losing one's job or that of other close persons, losing part of their income, rising prices, no possibility of taking care of children in the event of closing nurseries/schools/preschools, ensuring remote working/learning conditions for all members of a household (computer devices, space), fear of closing catering facilities and the need to wear protective masks.

Table 6. Correlation between population density and selected urban stressors during the pandemic.

Urban Stressors	Population Density	
	Spearman	**Pearson r**
Fear of losing one's job or that of other close persons	0.07782 ***	0.07199 **
Fear of losing part of income	0.08699 ***	0.0758 ***
Fear of rising prices	0.1104 ***	0.1094 ***
Fear of ensuring childcare provision in event of closing nurseries/schools/preschools	0.1195 ***	0.1058 ***
Fear of ensuring remote working/learning conditions for household members	0.1335 ***	0.1354 ***
Closing catering facilities	0.0505 *	0.0571 **
Need to wear protective masks	0.111 ***	0.1025 ***

Asterisks indicate appropriate significance levels: 0.1 (*), 0.05 (**), 0.01 (***).

5.4. Effects of Stress

The residents of the analyzed cities indicated primarily the psychophysical aspects of their health deterioration as consequences of the experienced pandemic-related stress. Those were: impairment and a general reluctance to act (69.4%), problems with concentration and remembering (63.1%), sleeping disorders (51.3%), escalating family conflicts (40.5%), anxiety attacks (36.3%) and compulsive eating (31.8%) (Figure 3). They also included, but to a lesser extent, conflicts at work (23.2%), conflicts between neighbors (11.4%) and a lack of appetite (20.7%). Among the other consequences of long-term, chronic stress, the residents of the investigated cities mentioned most often: headaches, depression states, apathy and a general deterioration of their mental state.

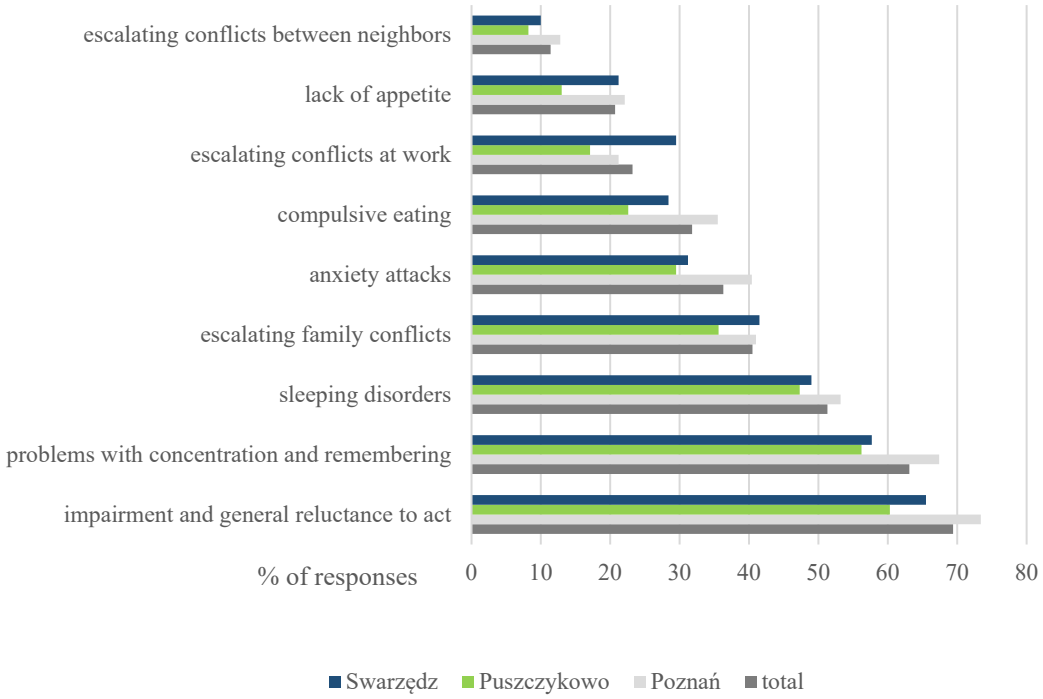

Figure 3. Effects of stress experienced by the residents of the investigated cities during the COVID-19 pandemic.

What should be noted is a significant difference regarding the stress effects experienced by the residents of the individual cities. The most negative results of stress by far were felt by the inhabitants of Poznań (the largest of the analyzed cities), as opposed to Puszczykowo (the smallest of the investigated centers, created on the basis of Howard's garden city urban concept), which had the least adverse effects. Residents of Poznań indicated more frequently than the residents of the other cities a general impairment and reluctance to act (73.4% of the respondents) and problems with concentration and remembering (67.4%). Moreover, they experienced anxiety attacks and the need to eat compulsively much more often.

The prevalence of pandemic-related stress effects, such as conflicts at work and lack of appetite, does not vary greatly depending on the size of the city. Therefore, it can be observed that there is a certain relationship between the size of the city and some effects of pandemic stress, though this has not been statistically proven. In other words, certain stress effects occur more frequently in larger cities. (Figure 4).

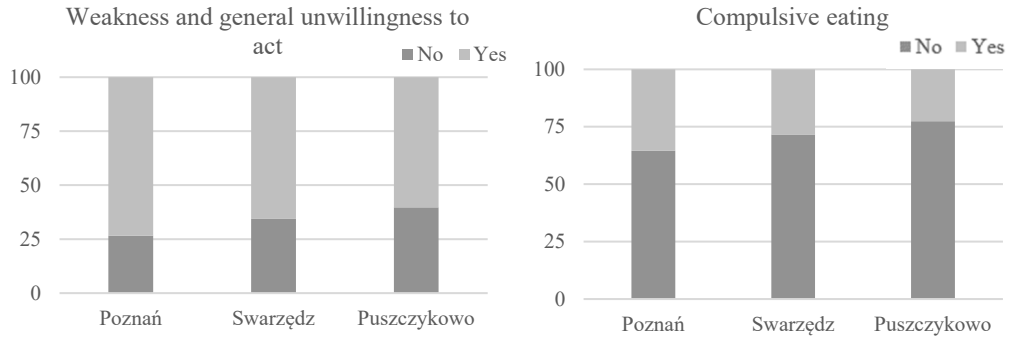

Figure 4. Selected effects of stress correlating with the size of the city.

When analyzing the effects of stress on the characteristics of a city, the strongest correlation was observed between the character of the city and feelings of weakness and general reluctance to act, as well as problems with concentration and memory. Additionally, a clear relationship exists between the character of the city and stress-related effects such as increased conflicts at work, anxiety attacks and compulsive eating. The weakest correlation is observed with loss of appetite (Table 7).

Table 7. The unique character of the city and the effects of stress on the inhabitants of the studied cities.

Effects of Stress	Pearson C	Cramer V	chi2
Weakness and general reluctance to act	0.1064	0.107	13.71 ***
Concentration/memory problems	0.1038	0.1044	13.05 ***
Anxiety attacks	0.09979	0.1003	12.05 ***
Lack of appetite	0.0712	0.07138	6.104 **
Compulsive eating	0.09942	0.09992	11.96 ***
Increasing conflicts at work	0.1021	0.1027	12.63 ***

Asterisks indicate appropriate significance levels: 0.05 (**), 0.01 (***).

5.5. Ways of Reducing Stress

What especially helped to relieve the stress level during the pandemic was contact with nature, i.e., spending time surrounded by greenery (92.4% of indications), the view of greenery/nature itself (90.8%), outdoor physical activity (87.2%) or gardening work and plant care (65.7%). In addition, direct contact with close ones (83.9%) and with pets (70.6%) was a strong support. A significant proportion of the respondents coped also with stress by devoting themselves to their hobby (77%) and watching movies (76.9%) (cf. Figure 5).

The significant importance of greenery was indicated mainly by the residents of Poznań. Over 94% of the respondents coped with stress better while out in nature or looking at greenery (92.1%). Furthermore, for the majority of the participants from Poznań that were interviewed, compared to those from Puszczykowo or Swarzędz, the important stress relieving factors were contact with the close ones (85.3%), hobbies (80.8%) and watching movies (78.8%). In comparison to the other investigated places, the respondents from Puszczykowo paid much more attention to outdoor activity (88.4%) and plant care (71.2%). On the other hand, the Swarzędz respondents coped with stress better through contact with pets (71.6%).

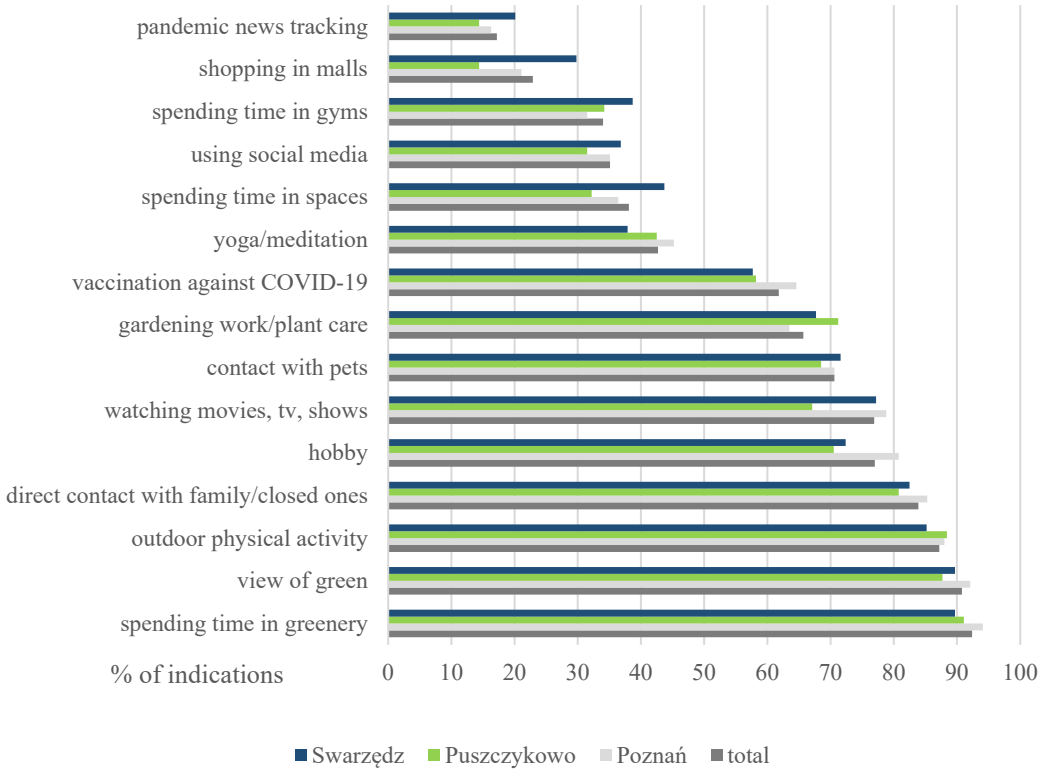

Figure 5. Factors relieving the stress level of the urban residents during the COVID-19 pandemic.

It has been observed that some methods of reducing inhabitants' stress in the investigated cities during the pandemic depended on the character of a city and were related to their different spatiofunctional structures. They included spending time surrounded by greenery (in parks, gardens and green squares), in public places (among people) and shopping in malls or shopping centers (Table 8). The last two were most often indicated by Swarzędz residents and the least often by the inhabitants of Puszczykowo. Poznań dwellers most preferred spending time in the green to relieve stress, as opposed to Swarzędz inhabitants who chose this type of stress reduction the least frequently.

Table 8. Correlation between the character of the city and the ways of reducing the inhabitants' stress.

Ways of Stress Reduction	chi-Square Test
Spending time in green spaces (parks, gardens, green squares)	6.899 **
Taking up/continuing hobby activities (manual works, etc.)	13.37 ***
Watching movies, TV series, programs, etc.	9.253 ***
Spending time in public places (among people)	7.879 **
Doing shopping	17.02 ***

Asterisks indicate appropriate significance levels: 0.05 (**), 0.01 (***).

The surveyed residents clearly indicated that green and recreational areas had an impact on reducing their stress levels. In Swarzędz, these types of places played a diminished role in alleviating stress during the pandemic because of their scarcity, whereas in Poznań, a city with landscaped green spaces, their role was the largest.

With regard to the role of greenery in managing stress levels, some statistically significant correlations were observed. They relate to the character of the city and its population density and not its size or population number (Table 7). With an increase in population density, the influence of greenery (as one of the city structure elements) on reducing the level of stress experienced by the inhabitants rises.

5.6. Desirable Directions for Transforming Urban Spatial Structure

What especially helped to relieve stress levels during the pandemic was contact with nature. Among the necessary changes in urban spatial structure towards creating a resident-friendly living environment that would improve the health condition and relieve stress, the respondents mainly indicated the need to increase the share of greenery at the expense of built-up areas. As was previously mentioned, this is the very contact with nature that was perceived as the most important element for relieving stress during the pandemic by the residents. On a scale from 0 to 10 (0—development of built-up areas to 10—development of greenery) the mean indication of the residents was 8.78. The respondents from Poznań and Swarzędz were those who attached much significance to such a trend in urban spatial structure. However, a large proportion of the residents emphasized the creation of unmanaged green areas—biodiverse complexes as close to natural ones as possible (on a scale from 0—unmanaged greenery to 10—managed green areas, the mean indication in the analyzed cities was 4.27). It was particularly important to the inhabitants of Puszczykowo (mean 3.91), probably in relation to the conscious choice of the place of residence in the immediate vicinity of Wielkopolski National Park, and for the residents of Poznań (mean 4.13). The creation of unmanaged greenery was less important for the inhabitants of Swarzędz (the mean 4.81), for whom it is somewhat less significant whether managed or unmanaged greenery should be created in the city.

The statistical analyses indicate the correlation between the proportion of the responses related to the directions for urban development conducive to stress reduction and the character of the city, its size and population density (Table 9). Poznań dwellers perceive the need for development of greenery in the city as most important, in contrast to the inhabitants of Puszczykowo. The more densely populated the city, the greater the need of the residents for the development of green areas.

Table 9. Correlation between the character, size and population density of the city and resident-desired directions for urban development towards a stress-reducing city.

Resident-Desired Directions for Urban Development during Pandemic	City Character	City Size (Population Number)		Population Density	
	Test chi^2	Spearman	Pearson r	Spearman	Pearson r
Built-up areas vs. greenery (parks, boulevards)	46.39 ***	0.106 ***	0.139 ***	0.1348 ***	0.1112 ***
Unmanaged greenery (forests, meadows, boulevards) vs. landscaped greenery (parks, green squares)	59.78 ***	−0.02817	−0.01832	0.06939 *	0.08646 **

Asterisks indicate appropriate significance levels: 0.1 (*), 0.05 (**), 0.01 (***).

Given the type of greenery needed to reduce the pandemic-induced stress level in cities (landscaped or unmanaged green), the residents' opinions differ and depend statistically on the city character and its population density (Table 8). There is no connection here with the size of the city. In Puszczykowo, one may notice a greater need for planning unmanaged greenery in the form of forests, meadows and walking routes than for landscaped greenery arranged into parks or green squares. This was true in Poznań as well, yet the proportion of the responses was lower. In Swarzędz, however, the residents see the role of both landscaped and unmanaged greenery in stress-level regulation. The distribution of the responses here is relatively equal. If the city is more densely populated, landscaped greenery is a more desirable direction than natural greenery in terms of urban development.

5.7. Stress-Exacerbating and Stress-Reducing Impact of Urban Spatial Structure Elements on City Dwellers

The results of the research clearly indicate the existence of a close relationship between particular types of urban areas and stress levels. In all three investigated cities, the residents'

stress was intensified in closed spaces (regardless of the type and function of the building) and reduced in open spaces. In spatial terms, the distribution of stress-inducing places indicated by the respondents is clearly visible in urbanized spaces. While in Poznań and Puszczykowo they concentrate in specific sites (stations, shopping malls, main squares), they are widely dispersed in Swarzędz, which is related to a chaotic form and structure of the city.

On the other hand, the spatial analysis of the distribution of stress-reducing sites evidently reflects the structure and greenery patterns in the investigated cities. What is noticeable is the correlation of the investigated places not only with green spaces but also with water. The wedges of greenery are especially important for the inhabitants of Poznań: north–south related to the Warta River and east–west associated with the valley of the Bogdanka and Cybina rivers and the lakes formed in those valleys. Urban parks were also indicated as important places for helping to reduce stress. Puszczykowo dwellers pointed mainly to the national park areas surrounding and cutting into urban development and the recreation and sports areas designated in the central part of the town. The residents of Swarzędz, because of a low share of green areas both within the city and the whole commune, indicated mainly places around Lake Swarzędzkie (Figure 6).

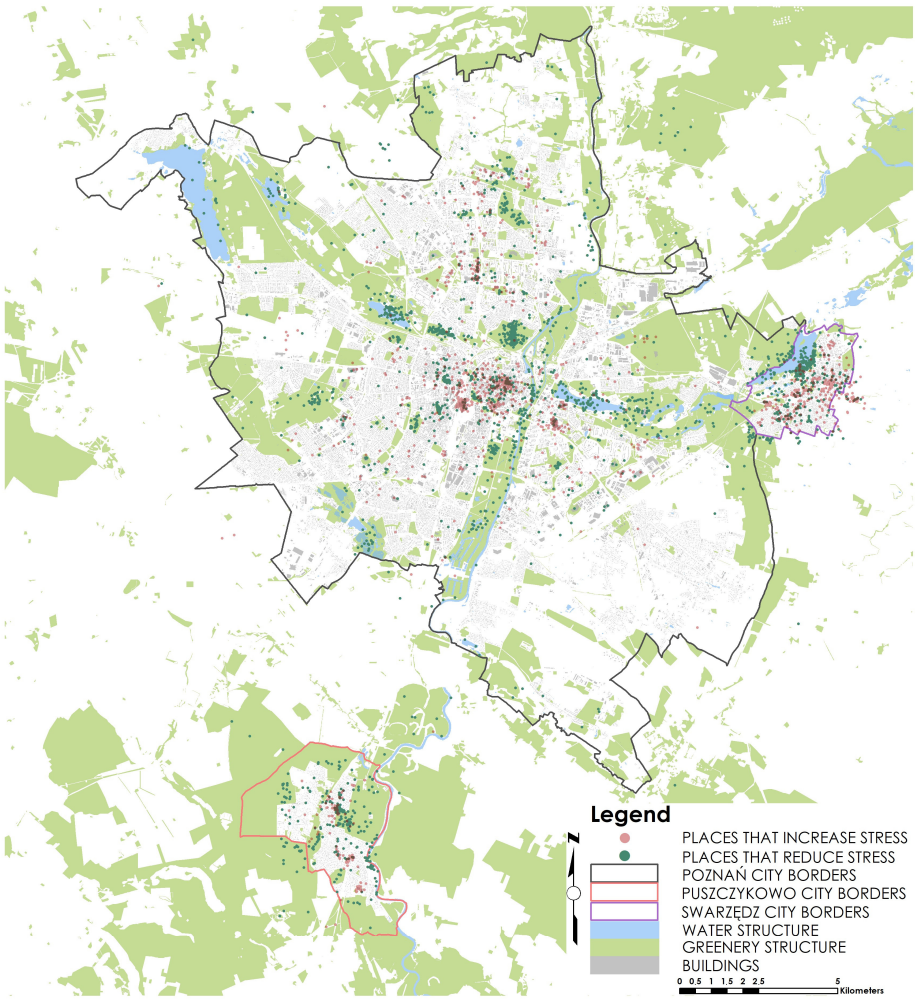

Figure 6. Spatial distribution of places reducing and increasing stress during the COVID-19 pandemic (total for Poznań, Puszczykowo and Swarzędz).

To sum up, the research conducted shows that the character of the city (the result of its spatiofunctional structure, including its share of greenery) and its population density were more important for regulating the residents' stress levels during the pandemic and for

ways of stress reduction (including the role of greenery) than the city size itself expressed by the population number (Table 10).

Table 10. Correlations between the variables studied.

Variables	Stress Level	Change in Stress Level	Ways of Reducing Stress during the Pandemic	Desirable Directions for Stress-Resilient City Development in Residents' Opinions		
				Total	Development of Greenery at Expense of Built-Up Areas	Types of Greenery Needed in a Stress-Resilient City (Landscaped/Unmanaged)
City size	−	−/+	ND	++	+	−
City character	−	+	+	+++	+	+
Population density	−	−	ND	+	+	+

Characters in the table: − no statistically significant correlation; + statistically significant correlation identified; −/+ no statistically significant correlation with a noticeable relation after primary data analysis; ND = no data. Gradation of statistically significant correlation: + occurs; ++ occurs to a greater degree; +++ occurs to the greatest degree.

The character of the city is also related to the particular ways of reducing urban dwellers' stress during the pandemic.

In the resident-desired directions for the development of a stress-resilient city, one can observe the greatest relationship with a specific character of a city, resulting from, e.g., its different spatiofunctional structure. The city size is also significant, but to a lesser extent. The population density of a center plays the smallest role in this respect.

6. Discussion of the Results

We all live in a world full of stress. The literature analysis shows that stress concerns primarily urban residents [6,22] and its level increased during the COVID-19 pandemic, which is indicated in the results of the research conducted in the initial period of this health crisis [29,30]. Such a conclusion has been confirmed by the research results demonstrated in this article. Although our study was carried out in the final phase of the pandemic, it shows that the stress level declared by the respondents was above average, and almost 40% of the surveyed were still experiencing a marked increase in pandemic-related stress. It may mean that urban residents are subject to long-term, harmful stress, adversely affecting their wellbeing and, consequently, also their health [11,20,21], particularly their mental health [10,27–29,31].

There is a common view in the literature that residents' stress levels grow with the size of a city [6,7,23], also during the pandemic [10,24]. The statistical analyses carried out in this research do not confirm such a thesis. A linear correlation between the city size, its population density and character and the pandemic-induced stress level has not been identified. The analysis of the primary data distribution shows, however, some correlation with the size of a city regarding stress level change, especially its increase. The greater the city, the larger the increase in the pandemic-induced stress level.

The research results presented in this publication confirm that the restrictions introduced during the pandemic were more stressful for urban residents than the virus itself [9,30]. The fear of isolation/quarantine, however, did not rank as high as in the work of Sebastião et al. [30]. The sources of pandemic-related stress in the investigated cities generally include those recognized by WHO [29]. However, the residents of Swarzędz, more than the inhabitants of the remaining cities, experienced economic stress (fear of rising prices, losing jobs and income), which referred to the sources of stress mentioned in the works by Pykett et al. [18] and Mierzejewska et al. [9], and also stress related to more difficult access to healthcare and restrictions to leaving their places of residence. For Poznań, it was the closure of cultural and entertainment facilities, and for Puszczykowo,

stress related to travel limitations. Thus, the sources are of different character in cities of different sizes.

The consequences of pandemic-related stress for the health of the residents living in the investigated cities are similar to those presented in the literature [29,31] and concern primarily a lack of motivation to act, sleeping disorders, anxiety attacks and also, but to a smaller degree, depression. We confirm the unfavorable effects of pandemic-related stress, mainly in terms of mental health. Owing to the fact that the respondents felt the need to eat compulsively more often than they had an appetite, it may result in the problem of obesity in the future, which has already been recognized by Ward Thompson, albeit not in the context of the pandemic [27]. Our research indicates that the impact of stress is influenced by the nature of the city.

In terms of health, a vital role during the pandemic was played by the stress reduction methods adopted by the inhabitants. The results obtained confirm the observations made in the literature [31,35,38], that greenery was an important factor contributing to relieving stress (spending time in green areas, looking at greenery, plant care, gardening work, etc.). Not without significance was also contact with the close ones or even with strangers in public places, which may prove that isolation is an important stress-inducing factor [9,29].

The stress-relieving role of greenery points to the legitimacy of the transformations of urban spatial structures towards expanding a restorative environment conducive to quick post-stress regeneration [19], thus increasing the natural ability of those structures to cope with stress, which is indicated by Kondo et al. [15], Lederbogen et al. [25] and Adli [7]. The basic trends preferred by the inhabitants of the cities in question regarding changes in this structure concern increasing the share of greenery in the city and, in this respect, the results obtained show the correlation with the size (the greatest need was expressed by Poznanians as opposed to the residents of Puszczykowo). There is no such correlation with regard to the preference between unmanaged and managed greenery (unmanaged green areas are valued most by the residents of Puszczykowo and then by Poznanians).

The obtained research results indicate that it is justified to use the experience of the COVID-19 pandemic in shaping healthy, stress-resilient, post-pandemic cities. At the same time, they point to the need to develop new models of city management during pandemic crises that will be conducive to reducing residents' stress and improving public health. The COVID-19 pandemic has demonstrated the ineffectiveness of conventional, generally used models and methods of urban governance and urban policy in dealing with the consequences of the pandemic [57–60]. It has led to a resurgence of state and state authority intervention in infection control, public health and social and economic support [61]. Decisions concerning cities were usually made at a higher level than the local level, which meant that they were not adapted to local conditions. The decisions were taken mainly after consultation with experts in the field of epidemiology and did not take into account feedback from residents regarding the scope and effects of restrictions and lockdowns. This often led to excessive actions, intensifying the stress of city residents with all its negative consequences. The new model of urban governance should combine the principles of good urban governance with the advantages of participatory, expert, smart and multi-level management models, including adaptive management [62,63]. Such a model should, above all, take greater account of feedback from city dwellers on the scope and effects of the measures taken, as well as the expansion of the group of experts, including mental health specialists. One of the most important objectives of such management should be to improve the health of city residents, including their mental health, and to create conditions that support the resilience of cities and their inhabitants to stress.

7. Conclusions

The research conducted negatively verifies the hypothesis whereby urban dwellers' stress increases with the city size. What was observed, however, was the correlation between the size of a city and the directions for its development conducive to stress reduction. The strongest need for the development of greenery was demonstrated by

Poznań residents. On the other hand, the responses of the inhabitants of Puszczykowo, a town with the largest share of green areas in its total area, indicate the most modest need in this regard of all the analyzed urban units.

The obtained results have proved that the character of a city affects a number of issues related to pandemic stress and the methods for its reduction. First, a statistically significant correlation with a change in the stress level was noted. The smallest increase in the pandemic-induced stress level was observed in Puszczykowo, whereas the largest was in Poznań. Second, the relationship between the character of a city and the ways of stress reduction was noted. It concerns, in particular, the stress-reducing effect of greenery. Third, the statistical analyses showed a correlation between the character of a city and certain effects of stress, such as weakness, reluctance to act, problems with concentration and memory, increased conflicts at work, anxiety attacks and compulsive eating. Additionally, there was a correlation between urban development that promotes stress and the character of a city. The respondents from Puszczykowo pointed to a greater need for planning unmanaged green areas, while in Swarzędz, the relevant responses concerned both landscaped and unmanaged greenery.

What is also worth paying attention to is the relationship between the population density and (1) the sources of stress, (2) the stress-reducing role of greenery and (3) the urban development directions conducive to stress reduction. The respondents' concerns related to losing one's job or that of close persons, rising prices, no possibility of ensuring childcare provision or remote working/learning conditions for all members of a household, the need to wear protective masks and closure of catering facilities are stronger with an increase in the population density of the city that they live in. The influence of greenery on the reduction of stress experienced by the residents grows with an increase in urban population density as well. The latter is also related to the need for greenery development in the city the respondents live in.

While taking into account the key role of greenery strongly emphasized by the respondents in the reducing stress of urban dwellers, what is reasonable and even necessary is the reconstruction of the urban spatiofunctional structure not only of the cities themselves but also of the entire agglomeration towards: (1) increasing the area of greenery in cities, especially natural, unmanaged greenery, which would provide a high level of biodiversity, according to the new trends in urban development planning adopted in numerous strategic documents [64–66], (2) increasing access to green areas by striving for a polycentric network of publicly accessible local green areas, especially in compact multi-family housing developments (without home gardens), as well as workplaces, by creating both larger green areas and their smaller enclaves, etc. (so-called "pocket parks"), small squares, green roofs (buildings, bus shelters and other facilities, etc.) and walls (building facades) or floors (roundabouts, grassy tracks and others), (3) designs based on nature resources (nature-based solutions), in particular the preservation and use of potential areas related to the occurrence of natural river valleys, numerous surface waters, wetlands, forests and meadows, old-growth forests, agricultural areas or existing recreation areas near public facilities (especially schools or kindergartens), (4) planning public spaces in a way that ensures free movement of pedestrians, i.e., more land-intensive public spaces and (5) the use of a planning authority (strategies/master plans) to create local urban planning regulations increasing the urban green factor (minimum share of biologically active area, maximum share of impermeable area, share of tall greenery, minimum number of trees, etc.).

In order to maintain a high level of biodiversity in cities, it is necessary to maintain ecological corridors combining urban greenery with the larger green complexes (forests) occurring in suburban zones, ensuring the biodiversity of fauna and flora (plot-to-plot approach) through the use of green and blue corridors, including greenery accompanying railway lines, roads or riverbanks. Furthermore, it is important to consciously and purposefully select plants in cities, not merely adjusted to the existing climate conditions but also affecting nervous and immunological systems in the right way (by secreting biologically active substances). The introduction of such solutions into urban space has an unques-

tionable, medically documented influence on raising the level of city residents' health by reducing stress, supporting post-stress regeneration and building resilience to the potential stressors encountered in urban space.

The research results indicate a possible wide application of biophilic design principles, which concern expanding local greenery networks and thus making it possible for inhabitants to have greater and more comfortable access to green areas. The application of biophilic design also involves proposals for new ways of using the already existing greenery and the improvement of local soundscaping, which may generally affect an increase in the perception of residents' wellbeing [43,67–70]. The proposed direction for transforming the spatiofunctional structure of cities into more stress-resilient centers fits in with a biophilic design trend, which emphasizes the need to modify and redesign an urban environment towards enhancing the wellbeing of inhabitants by improving their contact with nature.

Owing to the fact that the studies were limited in terms of the spatial scope to three cities of different sizes situated within one agglomeration, the conclusions should be generalized cautiously. A similar investigation would be a valuable development, embracing residents of more cities, also in other countries, which could additionally show the influence of cultural differences or lifestyles on the issue in question. The future research may allow for cities more distant from the regional core and also compare the results obtained for urban units with those for rural areas. One should also consider the limitations of the method selected and the technique of collecting data. The research covers only a portion of the cities' populations, which may affect the results achieved. The respondents' structure reveals the shortage of those over sixty years of age, which may result from the limited possibilities of using electronic devices and the Internet.

However, the investigation provides valuable results pointing to the sources of urban residents' stress, the consequences of pandemic stress for the inhabitants' health and also methods of stress reduction, among which greenery plays a huge role. The results contribute significantly to a discussion on the social implications of the pandemic and make it possible to recognize trends towards building healthy, stress-resilient cities. They also have, next to a cognitive value, an applicable dimension and should be a statement inspiring further research and discourse on the subject.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16093644/s1, Table S1. Content and characteristics of geo-survey questions.

Author Contributions: Conceptualization: M.W. and L.M.; methodology: M.S. and E.L.; statistical analysis: E.L.; formal analysis: M.W. and L.M.; investigation: M.W., L.M., M.S., B.M., K.S.-P., A.W. and E.L.; resources: M.S., K.S.-P. and E.L.; writing manuscript: M.W., L.M., M.S., B.M., K.S.-P., A.W. and E.L.; visualization: M.S. and K.S.-P.; supervision: M.W. and L.M.; project administration: L.M.; funding acquisition: L.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded in whole by the National Science Centre, Poland (no. 2021/41/B/HS4/02471). For the purpose of Open Access, the author has applied a CC-BY public copyright license to any Author Accepted Manuscript (AAM) version arising from this submission.

Institutional Review Board Statement: The conducted geo-survey research was approved by the Ethics Committee for Research Involving Human Participants at the Adam Mickiewicz University in Poznań (Resolution No. 18/2021/2022, 16 May 2022) for scientific research conducted with human participation.

Informed Consent Statement: Patient consent was waived due to the inability to identify the individual patients involved in the study.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Voigtländer, N.; Voth, J. *The Three Horsemen of Riches: Plague, War and Urbanization in Early Modern Europe*; Economics Working Papers 1115; Department of Economics and Business, Universitat Pompeu Fabra: Barcelona, Spain, 2008; pp. 1–50. Available online: https://repositori.upf.edu/bitstream/handle/10230/778/1115.pdf;jsessionid=38F73A26C9C15DF4CB7A899EB71FDD9E?sequence=1 (accessed on 15 April 2024).
2. Engelmann, L.; Henderson, J.; Lynteris, C. *Plague and the City*, 1st ed.; Routledge: London, UK, 2018; pp. 1–186. [CrossRef]
3. Yates, D. The stress of city life. *Nat. Rev. Neurosci.* **2011**, *12*, 430, 498–501. [CrossRef] [PubMed]
4. Abbott, A. Stress and the city: Urban decay. *Nature* **2012**, *490*, 162–164. [CrossRef] [PubMed]
5. Stier, A.J.; Berman, M.G.; Bettencourt, L.M.A. Early pandemic COVID-19 case growth rates increase with city size. *Urban Sustain.* **2021**, *1*, 31. [CrossRef]
6. Ellison, C.W.; Maynard, E.S. *Healing for the City: Counseling in the Urban Setting*; WiPF and STOCK: Eugene, OR, USA, 1992; pp. 1–336.
7. Adli, M. Urban Stress and Mental Health. Cities, Health and Well-Being, Hong Kong. 2011. Available online: https://lsecities.net/wp-content/uploads/2011/11/2011_chw_4030_Adli.pdf (accessed on 12 April 2024).
8. Steinheuser, V.; Ackermann, K.; Schönfeld, P.; Schwabe, L. Stress and the City: Impact of Urban Upbringing on the (re)Activity of the Hypothalamus-Pituitary-Adrenal Axis. *Psychosom. Med.* **2014**, *76*, 678–685. [CrossRef]
9. Mierzejewska, L.; Sikorska-Podyma, K.; Szejnfeld, M.; Wdowicka, M.; Modrzewski, B.; Lechowska, E. The Role of Greenery in Stress Reduction among City Residents during the COVID-19 Pandemic. *Int. J. Environ. Res. Public Health* **2023**, *20*, 5832. [CrossRef] [PubMed]
10. Zahangir, M.S.; Rokonuzzaman, M. Depression, anxiety and stress among people infected with COVID-19 in Dhaka and Chittagong cities. *Heliyon* **2022**, *8*, 10415. [CrossRef] [PubMed] [PubMed Central]
11. World Health Organization. *Constitution of the World Health Organization*; World Health Organization: New York, NY, USA, 1947.
12. World Health Organization. *Health in the Green Economy: Health Co-Benefits of Climate Change Mitigation—Housing Sector*; World Health Organization: Geneva, Switzerland, 2011. Available online: https://www.who.int/publications/i/item/ (accessed on 29 September 2022).
13. Tzoulas, K.; Korpela, K.; Venn, S.; Yli-Pelkonen, V.; Kaźmierczak, A.; Niemela, J.; James, P. Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landsc. Urban Plan.* **2007**, *81*, 167–178. [CrossRef]
14. Lalonde, M. *A New Perspective on the Health of Canadians: A Working Document*; Department of National Health and Welfare, Minister of Supply and Services Canada: Ottawa, ON, Canada, 1974. Available online: http://www.phac-aspc.gc.ca/ph-sp/pdf/perspect-eng.pdf (accessed on 6 April 2020).
15. Kondo, M.C.; Fluehr, J.M.; McKeon, T.; Branas, C.C. Urban Green Space and Its Impact on Human Health. *Int. J. Environ. Res. Public Health* **2018**, *15*, 445. [CrossRef] [PubMed]
16. Freestone, R.; Wheeler, A. Integrating Health into Town Planning: A History. In *The Routledge Handbook of Planning for Health and Well-Being*; Barton, H., Thompson, S., Burgess, S., Grant, M., Eds.; Routledge: Oxford, UK, 2015; pp. 17–36.
17. Giles-Corti, B.; Vernez-Moudon, A.; Reis, R.; Turrell, G.; Dannenberg, A.L.; Badland, H.; Foster, S.; Lowe, M.; Sallis, J.F.; Stevenson, M.; et al. City planning and population health: A global challenge. *Lancet* **2016**, *388*, 2912–2924. [CrossRef]
18. Pykett, J.; Osborne, T.; Resch, B. From Urban Stress to Neurourbanism: How Should We Research City Well-Being. *Ann. Am. Assoc. Geogr.* **2020**, *110*, 1936–1951. [CrossRef]
19. Hedblom, M.; Gunnarsson, B.; Iravani, B. Reduction of physiological stress by urban green space in a multisensory virtual experiment. *Sci. Rep.* **2019**, *9*, 10113. [CrossRef] [PubMed]
20. Sfeatcu, R.; Cernuşcă-Miţariu, M.; Ionescu, C.; Mihai, R.; Cernuşcă-Miţariu, S.; Coldea, L.; Bota, G.; Burcea, C.C. The concept of wellbeing in relation to health and quality of life. *Eur. J. Sci. Theol.* **2014**, *10*, 123–128. Available online: https://www.researchgate.net/publication/298026525_The_concept_of_wellbeing_in_relation_to_health_and_quality_of_life (accessed on 14 April 2024).
21. Holt-White, E.; De Gennaro, A.; Anders, J.; Cullinane, C.; Early, E.; Montacute, R.; Shao, X.; Yarde, J. Mental Health and Wellbeing. COSMO COVID Social Mobility & Opportunities Study. 2022. Available online: https://cosmostudy.uk/publication_pdfs/mental-health-and-wellbeing.pdf (accessed on 15 April 2024).
22. Peen, J.; Schoevers, R.A.; Beekman, A.T.; Dekker, J. The current status of urban–rural differences in psychiatric disorders. *Acta Psychiatr. Scand.* **2010**, *121*, 84–93.
23. Kiani, R.; Tyrer, F.; Hodgson, A.; Berkin, N.; Bhaumik, S. Urban-rural differences in the nature and prevalence of mental ill-health in adults with intellectual disabilities. *J. Intellect. Disabil. Res.* **2013**, *57*, 119–127. [CrossRef] [PubMed]
24. Frisenstam, K.L.; van den Bosch, M.; Chen, Y.; Friberg, P.; Osika, W. Swedish Children, Adolescents, and Young Adults Living in Rural and Urban Areas: An Internet-Based Survey. *JMIR Public Health Surveill.* **2017**, *3*, e9. [CrossRef] [PubMed]
25. Lederbogen, F.; Kirsch, P.; Haddad, L.; Streit, F.; Tost, H.; Schuch, P.; Wüst, S. City living and urban upbringing affect neural social stress processing in humans. *Nature* **2011**, *474*, 498–501.

26. Komiti, A.; Murray, G.; Hodgins, G.; Fraser, C.; Judd, F.K.; Jackson, H.J. High prevalence disorders in urban and rural communities. *Aust. N. Z. J. Psychiatry* **2002**, *36*, 104–113. [CrossRef] [PubMed]
27. Ward Thompson, C. Linking landscape and health: The recurring theme. *Landsc. Urban Plan.* **2011**, *99*, 187–195. [CrossRef]
28. Dragan, M.; Grajewski, P.; Shevlin, M. Adjustment disorder, traumatic stress, depression and anxiety in Poland during an early phase of the COVID-19 pandemic. *Eur. J. Psychotraumatol.* **2021**, *12*, 1860356. [CrossRef]
29. World Health Organization. 2022. Available online: https://www.who.int/news/item/02-03-2022-covid-19-pandemic-triggers-25-increase-in-prevalence-of-anxiety-and-depression-worldwide (accessed on 10 April 2024).
30. Sebastião, R.; Dias Neto, D.; Costa, V. Understanding Differential Stress and Mental Health Reactions to COVID-19-Related Events. *Int. J. Environ. Res. Public Health* **2023**, *20*, 5819. [CrossRef]
31. Maury-Mora, M.; Gómez-Villarino, M.T.; Varela-Martínez, C. Urban green spaces and stress during COVID-19 lockdown: A case study for the city of Madrid. *Urban For. Urban Green.* **2022**, *69*, 127492. [CrossRef] [PubMed]
32. Kuo, M. How might contact with nature promote human health? Promising mechanisms and a possible central pathway. *Front. Psychol.* **2015**, *6*, 1093. [CrossRef] [PubMed]
33. Alderton, A.; Davern, M.; Nitvimol, K.; Butterworth, L.; Higgs, C.; Ryan, E.; Badland, H. What is the meaning of urban liveability for a city in a low-to-middle-income country? Contextualising liveability for Bangkok, Thailand. *Glob. Health* **2019**, *15*, 51. [CrossRef] [PubMed]
34. Van den Berg, M.; Van Poppel, M.; Van Kamp, I.; Andrusaityte, S.; Balseviciene, B.; Cirach, M.; Danileviciute, A.; Ellis, N.; Hurst, G.; Masterson, D.; et al. Visiting green space is associated with mental health and vitality: A cross-sectional study in four european cities. *Health Place* **2016**, *38*, 8–15. [CrossRef] [PubMed]
35. Volenec, Z.M.; Abraham, J.O.; Becker, A.D.; Dobson, A.P. Public parks and the pandemic: How park usage has been affected by COVID-19 policies. *PLoS ONE* **2021**, *16*, e0251799. [CrossRef]
36. Lu, Y.; Zhao, J.; Wu, X.; Ming Lo, S. Escaping to nature during a pandemic: A natural experiment in Asian cities during the COVID-19 pandemic with big social media data. *Sci. Total Environ.* **2021**, *777*, 46092. [CrossRef]
37. Stieger, S.; Aichinger, I.; Swami, V. The impact of nature exposure on body image and happiness: An experience sampling study. *Int. J. Environ. Health Res.* **2021**, *32*, 870–884. [CrossRef]
38. Morse, J.W.; Gladkikh, T.M.; Hackenburg, D.M.; Gould, R.K. COVID-19 and human-nature relationships: Vermonters' activities in nature and associated nonmaterial values during the pandemic. *PLoS ONE* **2020**, *15*, e0243697. [CrossRef] [PubMed]
39. Campbell, L.; Svendsen, E.; Landau, L.; Johnson, M.; Plitt, S. Quarantine Fatigue and the Power of Activating Public Lands as Social Infrastructure. 2020. Available online: https://www.thenatureofcities.com/2020/12/20/quarantine-fatigue-and-the-power-of-activating-public-lands-as-social-infrastructure/ (accessed on 14 April 2024).
40. World Health Organization. Building Health Systems Resilience for Universal Health Coverage and Health Security during the COVID-19 Pandemic and Beyond: WHO Position Paper. Geneva: World Health Organization. 2021. Available online: https://www.who.int/publications/i/item/WHO-UHL-PHC-SP-2021.01 (accessed on 15 April 2024).
41. UN Habitat. Envisioning the Future of Cities. World Cities Report 2022. 2022. Available online: https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf (accessed on 14 April 2024).
42. Kaal, H. A Conceptual History of Livability. *City* **2011**, *15*, 532–547. [CrossRef]
43. Tennakoon, T.M.M.P.; Kulatunga, U. Understanding liveability: Related concepts and definitions. In Proceedings of the 8th World Construction Symposium, Colombo, Sri Lanka, 8–10 November 2019; pp. 578–587. [CrossRef]
44. Ulrich, R.S. Aesthetic and affective response to natural environment. In *Human Behavior and the Environment*; Altman, I., Wohlwill, J.F., Eds.; Plenum Press: New York, NY, USA, 1983; pp. 85–125. [CrossRef]
45. Kaplan, R.; Kaplan, S. *The Experience of Nature: A Psychological Perspective*; Cambridge University Press: Cambridge, UK, 1989; pp. 1–168. Available online: https://www.hse.ru/data/2019/03/04/1196348207/[Rachel_Kaplan,_Stephen_Kaplan]_The_Experience_of_(b-ok.xyz).pdf (accessed on 15 April 2024).
46. Beatley, T. *Biophilic Cities. Integrating Nature into Urban Design and Planning*; Island Press: Washington, DC, USA, 2011.
47. Alexander, C.; Neis, H.; Anninou, A.; King, I. *A New Theory of Urban Design*; Oxford University Press: New York, NY, USA, 1987.
48. Hartig, T.; Mitchell, R.; de Vries, S.; Frumkin, H. Nature and health. *Annu. Rev. Public Health* **2014**, *35*, 207–228. [CrossRef]
49. Hartig, T.; Mang, M.; Evans, G.W. Restorative Effects of Natural Environment Experiences. *Environ. Behav.* **2016**, *23*, 3–26. [CrossRef]
50. Statistics Poland. Statistical Information (Annual), Warsaw, Poland. 2022. Available online: https://stat.gov.pl/obszary-tematyczne/ludnosc/ludnosc/powierzchnia-i-ludnosc-w-przekroju-terytorialnym-w-2021-roku,7,18.html# (accessed on 10 January 2024).
51. Jankowski, P.; Czepkiewicz, M.; Młodkowski, M.; Zwoliński, Z. Geo-questionnaire: A method and tool for public preference elicitation in land use planning. *Trans. GIS* **2016**, *20*, 903–924. [CrossRef]
52. Bąkowska, E.; Kaczmarek, T.; Mikuła, Ł. Wykorzystanie geoankiety jako narzędzia konsultacji społecznych w procesie planowania przestrzennego w aglomeracji poznańskiej. (The use of geo-questionnaire as a public consultation tool in the process or urban planning in Poznań Agglomeration). *Roczniki Geomatyki* **2017**, *15*, 147–158. Available online: https://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-86bda447-dc79-416e-afbf-f2c43056716c (accessed on 14 April 2024).

53. Jankowski, P.; Kaczmarek, T.; Zwoliński, Z.; Bąkowska-Waldmann, E.; Brudka, C.; Czepkiewicz, M.; Młodkowski, M. *Zastosowanie Aplikacji Geoankiety i Geodyskusji w Partycypacyjnym Planowaniu Przestrzennym: Dobre Praktyki*; Application of geo-Survey and Geo-Discussion in Participatory Spatial Planning; Bogucki Wydawnictwo Naukowe: Poznan, Poland, 2018.
54. Kahila, M.; Kyttä, M. SoftGIS as a Bridge-Builder in Collaborative Urban Planning. In *Planning Support Systems Best Practice and New Methods*; Geertman, S., Stillwell, J., Eds.; The GeoJournal Library; Springer: Dordrecht, The Netherlands, 2009; pp. 389–411. [CrossRef]
55. Bugs, G.; Granell, C.; Fonts, O.; Huerta, J.; Painho, M. An assessment of Public Participation GIS and Web 2.0 technologies in urban planning practice in Canela, Brazil. *Cities* **2010**, *27*, 172–181. [CrossRef]
56. Kyttä, M.; Broberg, A.; Tzoulas, T.; Snabb, K. Towards contextually sensitive urban densification: Location-based softGIS knowledge revealing perceived residential environmental quality. *Landsc. Urban Plan.* **2013**, *113*, 30–46. [CrossRef]
57. Clark, L. *Innovation in a Time of Crisis*; Harvard Business Publishing: Brighton, MA, USA, 2020. Available online: https://www.harvardbusiness.org/innovation-in-a-time-of-crisis/ (accessed on 14 April 2024).
58. Cave, B.; Kim, J.; Viliani, F.; Harris, P. Applying an Equity Lens to Urban Policy Measures for COVID-19 in Four Cities. *Cities Health* **2020**, *5*, S66–S70. [CrossRef]
59. Alqutob, R.; Al Nsour, M.; Tarawneh, M.R.; Ajlouni, M.; Khader, Y.; Aqel, I.; Kharabsheh, S.; Obeidat, N. COVID-19 Crisis in Jordan: Response, Scenarios, Strategies, and Recommendations. *JMIR Public Health Surveill.* **2020**, *6*, e19332. [CrossRef] [PubMed]
60. Śleszyński, P.; Khavarian-Garmsir, A.R.; Nowak, M.; Legutko-Kobus, P.; Abadi, M.H.H.; Nasiri, N.A. COVID-19 Spatial Policy: A Comparative Review of Urban Policies in the European Union and the Middle East. *Sustainability* **2023**, *15*, 2286.
61. McGuirk, P.M. Global urbanism: Urban governance innovation in/for a world of cities. In *Thinking Global Urbanism: Essays on the City and Its Future*; Lacione, M., McFarlane, C., Eds.; Routledge: London, UK; New York, NY, USA, 2021.
62. Folke, C.; Hahn, T.; Olsson, P.; Norberg, J. Adaptive governance of social-ecological systems. *Annu. Rev. Environ. Resour.* **2005**, *30*, 441–473. [CrossRef]
63. Folke, C. Social–ecological systems and adaptive governance of the commons. *Ecol. Res.* **2007**, *22*, 14–15. [CrossRef]
64. The New Leipzig Charter. The Transformative Power of Cities for the Common Good. Federal Ministry of the Interior, Building and Community. 2020. Available online: https://ec.europa.eu/regional_policy/whats-new/newsroom/12-08-2020-new-leipzig-charter-the-transformative-power-of-cities-for-the-common-good_en (accessed on 14 April 2024).
65. The European Green Deal. European Commission. 2019. Available online: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (accessed on 14 April 2024).
66. European Union Biodiversity Strategy 2030. European Commission. 2020. Available online: https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en (accessed on 14 April 2024).
67. Surico, J. Need More Outdoor Public Space? Maybe Cities Already Have It. CityLab. Available online: https://www.bloomberg.com/news/articles/2020-05-06/5-ways-cities-can-make-more-public-space-fast (accessed on 14 April 2024).
68. To, W.M.; Chung, A.W.L.; Vong, I.; Ip, A. Opportunities for Soundscape Appraisal in Asia. In Proceedings of the Euronoise 2018, Crete, Greece, 27–31 May 2018. Available online: https://www.researchgate.net/publication/326044280_Opportunities_for_soundscape_appraisal_in_Asia (accessed on 14 April 2024).
69. Romanowska, M. Urban soundscape preferences in relations to the function of a place: Case studies in Warsaw. *Misc. Geogr. Reg. Stud. Dev.* **2018**, *22*, 237–242. [CrossRef]
70. Sasanpour, F. Livable city one step towards sustainable development. *J. Contemp. Urban Aff.* **2017**, *1*, 13–17. [CrossRef]