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The challenges posed by climate change to successful ageing

Ever since the 2003 heat wave that caused 70,000 heat deaths [23], the dramatic consequences of climate change and rising temperatures in Europe have become an intensively researched topic [10]. During heat waves, the older urban adult population is at highest risk [22]. Due to climate change, heat waves are expected to increase in number, intensity and duration [13] alongside a concurrent rise in the older adult population living in cities. Climate change significantly endangers the chances of successful ageing in urban areas, and this issue will become even more important in the near future.

Successful ageing in stressful environments

The concept of successful ageing refers to a multidimensional state of well-being, encompassing the absence of disease and disability, the maintenance of high physical and cognitive functioning, and engagement in social and productive activities [25]. Ageing can be perceived as an environmental process in the sense that it is shaped by the mutual interaction of individuals and groups and their environment(s) [28]. Powell Lawton's *Press-Competence Model* assumes that people are more dependent upon their environments the less resources they have at their disposal [19]. As people lose health and mobility resources with age, the 'environmental press', such as the balance between environmental demands and personal resources, increases and endangers successful ageing. To give an example, heat—as an environmental stressor—might lead to the withdrawal of persons with health restrictions from the outdoor environment, thus limiting the possibilities for social engagement. In a meta-study, Lui et al. [20] identified four dimensions within the age-friendly city discourse: physical (i.e. barriers) versus social (i.e. neighbourhood networks) 'infrastructure' and top-down versus bottom-up governance. In a narrower sense, however, environmental factors, such as climate, air quality or noise are often neglected in gerontological research despite the fact that older adults are particularly vulnerable towards these environmental stressors. Most frequently, environmental resources and stressors are unequally distributed among socio-economic variables [24]. In the course of ageing, human bodies become more susceptible to environmental stressors. Older persons have, over the course of their life, accumulated environmental contaminants and basically carry a history of environmental exposures within their bodies: a bodily memory of the environmental (in-)justice they have experienced throughout their lifetime [9]. It is thus crucial to acknowledge not only the unequal distribution of competences and personal resources, but also that of environmental resources and stressors in environmental gerontology.

One environmental stressor of particular relevance today is rising temperatures. High temperatures affect the living conditions of people especially in urban areas. This is due to the urban heat island effect that causes higher air temperatures in cities than in surrounding rural environments [21].

Several studies have documented the dramatic consequences of heat waves. For example, the heat wave in 2003 resulted in 70,000 deaths in Europe [23], 15,000 of those in France in August alone [12]. In the USA, an average of 400 deaths per year are classified as heat deaths [6]. The number of heat-related deaths is probably much higher, given that in many cases heat is not recognised as the fatal cause.

Among the urban population, certain groups are at higher risk than others, such as older adults, urban poor and individuals with chronic health conditions [22]. The morbidity and mortality rates among older adults increase in the course of, and following, heat waves [10, 11]. The reasons for the increased risks encountered by older adults are, amongst others, that their thermoregulation differs from younger people and that they have decreased resistance to external impacts, such as high temperatures [17]. Furthermore, pre-existing conditions of, e.g. the cardiovascular system and kidneys [14], or mental disorders like dementia aggravate the vulnerability of older adults [4].

The issue of urban heat islands affecting older adults will become even more

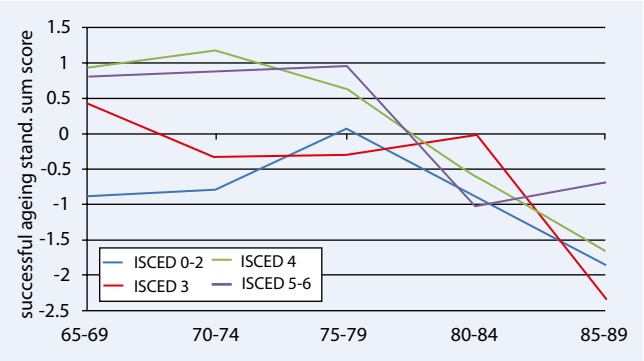

Fig. 1 ◀ Successful ageing according to age and education (measured by ISCED levels, see footnote 3)

important in the near future. Due to climate change, a further increase of heat waves in number, intensity and duration is predicted for the 21st century [13]. Furthermore, cities have a large and growing older adult population, a large number of whom live in poor housing conditions. However, little is known about the behavioural responses of older adults to higher temperatures. A comprehensive understanding of their individual adaption strategies is crucial in the process of adjusting to climate change. Three main research questions arise:

1. Does climate change endanger the chances of successful ageing in urban areas?
2. How do age, social inequalities and the living environment intersect with environmental stressors such as heat in affecting successful ageing in urban areas?
3. Which heat adaption strategies do older adults deploy and to what extent can they mediate heat stress in an effort to increase the chances of successful ageing under the conditions of climate change?

Ageing and climate change: the STOPHOT project

Objectives

The 3-year STOPHOT project aims to improve the chances of successful ageing in urban areas by reducing the vulnerability of older adults above the age of 65 years and living in cities (Vienna) in terms of urban heat. This study appears to be the first investigation in Austria to establish a comprehensive knowledge base on heat perception, awareness of heat risks and adaptive behaviours among older adults. The project follows a mixed-methods approach, combining both qualitative (i.e. stakeholder interviews, stakeholder workshops) and quantitative (aggregate data analysis, surveys) methods. The results of the quantitative surveys carried out in the project provide the database for this article.

Methods

After extensive pre-tests, a quantitative survey was carried out between September and November 2011 among older adults living in private homes and residents of retirement and care homes. The STOPHOT sample included individuals living in both heat islands (49.8%) and green areas (50.2%) to examine whether heat endangers the chances of successful ageing in urban areas. Four study areas within and outside of urban heat islands were identified. This selection was based on spatial analyses using criteria such as the temperature of radiation from surfaces during a hot midsummer day in the evening in August 2001,[1] the amount of green space, socio-economic data (age, education, housing conditions), as well as the locations of retirement and care homes. Study area 1 has a high quantity of green space and is economically prosperous, study area 2 has a low quantity of green space and is economically rich, study area 3 has a high quantity of green space and is economically poor and study area 4 has a low quantity of green space and is economically poor. Study areas 2 and 4 are within the urban heat islands.

On the basis of random selection within these areas, the target and control groups were interrogated via anonymous telephone interviews using computer-assisted telephone interviews (CATI). Face-to-face interviews (CAPI) were conducted with older adults living in retirement and care homes run by the "Vienna Pensioner Residences Fund". The sample consisted of 401 older adults (age >65 years) living in private homes, 200 older adults living in retirement and care homes and 300 younger persons (18–55 years) to control for age as a major independent variable. The present study focuses on the group of older adults living in private homes. The average age of this group was 74.1 years; 65.6% of the respondents were female.

The standardised questionnaire covered four main thematic areas: (1) heat perception and heat stress, (2) heat adaption, (3) health status and (4) social and socio-economic variables. Perceived heat stress was measured with the question "How do you feel during a heat wave?" with 11 items (4-level Likert Scale), of which three indicated positive somatic effects (active, energetic, happy) and eight negative effects (faint, anxiety, headache, dizziness, breathing problems, exhaustion, sleeping problems, fatigue). Heat adaption was measured with the question "What do you do when you are hot?" with 16 dichotomous (yes/no) adaption items and the question "What do you prefer to do when it is hot?" with three possible answers: (a) stay indoors, (b) go outdoors and (c) depart for my second residence. Health variables included the SF-8 battery[2] and a six-item activities of daily living (ADL) measure, including the ability to take a bath or shower, get dressed, take the stairs, go for a walk, go shopping and autonomously walk longer distances. In addition to socio-economic variables (i.e., educational attainment, available income), social contacts (with relatives, friends and neighbours) as well as social activities (sports, informal and formal volunteering, religious activities and participation in seniors' organisations)

[1] The basis for the identification of the urban heat islands was a thermal map of Vienna showing the temperature differences in the city.

[2] http://www.sf-36.org/tools/sf8.shtml.

were collected. The interviews with older adults living in private homes lasted on average more than 30 min. No information about response rates was collected. For each study area, 100 questionnaires were collected.

New variables were constructed for data analysis. Following Rowe and Kahn's definition, the concept of successful ageing was measured relying on three dimensions, i.e. subjective health status, physical functionality (measured by ADL) and social activities [25]. Based on the (standardised) variables of the three dimensions, we developed a successful ageing sum score as a dependent variable. The score ranged from −3 to +3, with higher values indicating better health, functionality and more social activities. The 'risk group' was defined as people who fall in the highest quarter of mentioned heat-induced conditions.[3] Beyond bivariate correlations, data analysis methods comprised analyses of variances (ANOVA) and linear regression models.

Finally, survey results were discussed with stakeholders of the city administration, non-governmental organisations (NGOs) and organisations representing older adults, and adaption measures were jointly developed (see section on 'Practical conclusions').

Results

Successful ageing

The successful ageing sum score varied significantly according to age class ($F=2.09$, $p<0.01$), education[4] ($F=5.41$, $p<0.01$), available income ($F=2.97$, $p<0.01$), former occupational status ($F=2.65$, $p<0.05$) and socio-economic structure of the res-

[3] Based on the items: fainting, anxiety, headache, dizziness, breathing problems, exhaustion, sleeping problems, fatigue.

[4] Educational attainment was categorised in reference to the UNESCO's International Standardised Classification of Education (ISCED), 1997 version, ranging from level 0 to 6. Level 0 indicates pre-primary education as highest educational attainment, level 1 indicates primary education, level 2 lower secondary education, level 3 upper secondary education, level 4 post-secondary, non-tertiary education, level 5 first stage of tertiary education and level 6 second stage of tertiary education.

Abstract · Zusammenfassung

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The challenges posed by climate change to successful ageing

Abstract

Ever since the 2003 heat wave that caused 70,000 heat deaths, the dramatic consequences of climate change and rising temperatures in Europe have become an intensively researched topic. During heat waves, the older urban adult population is at highest risk. The STOPHOT project is the first investigation in Austria to establish a comprehensive knowledge base on heat perception, awareness of heat risks and adaptive/coping behaviours among older adults. The main research questions include: (1) Does climate change endanger the chances of successful ageing in urban areas? (2) How do age, social inequalities and the living environment intersect with environmental stressors in affecting successful ageing? (3) Which heat adaption strategies do older adults deploy and to what extent can they mediate heat stress in an effort to increase chances of successful ageing under the conditions of climate change?

The results indicate that climate change and rising temperatures are in fact one important determinant of whether and how an older person can maintain well-being in later life. Older adults (>65 years) with a low socioeconomic status and poor health conditions, who tend to be socially isolated, are most at risk. However, no 'heat island effect' of the residential environment could be found. How much a person suffers from heat stress is highly dependent on the adaption strategies deployed. Adaption strategies of older urban residents mostly centred on body-related measures, such as drinking more or wearing lighter clothes, and indoor-centred measures, particularly avoiding the outdoors.

Keywords

Successful ageing · Environmental gerontology · Climate change · Urban heat islands · Adaption strategies

Durch den Klimawandel gestellte Herausforderungen an ein erfolgreiches Altern

Zusammenfassung

Seit der Hitzewelle 2003, die 70.000 Todesfälle verursachte, sind die drastischen Folgen des Klimawandels und steigender Temperaturen in Europa zu einem intensiv erforschten Thema geworden. Bei Hitzewellen besteht ein sehr hohes Risiko für die städtische Population älterer Erwachsener. Das STOPHOT-Projekt ist die erste Untersuchung in Österreich, die sich mit der Erstellung einer umfassenden Wissensdatenbank zur Hitzewahrnehmung, zum Bewusstsein hinsichtlich der Risiken von Hitze und zu Anpassungs-/Bewältigungsstrategien von älteren Erwachsenen befasst. Zu den wesentlichen Fragen dieser Untersuchung gehören: (1) Gefährdet der Klimawandel die Chancen auf ein erfolgreiches Altern im städtischen Umfeld? (2) Wie wirken Alter, soziale Ungleichheit und Lebensumfeld sich zusammen mit Umweltstressoren auf erfolgreiches Altern aus? (3) Welche Anpassungsstrategien an Hitze wenden ältere Erwachsene an, und bis zu welchem Ausmaß können sie Stress durch Hitze in einen Versuch umsetzen, die Chance auf erfolgreiches Altern unter den Bedingungen des Klimawandels zu erhöhen? Die Ergebnisse zeigen, dass Klimawandel und steigende Temperaturen tatsächlich eine bedeutende Determinante darstellen, ob und wie das Wohlergehen einer älteren Person auch im höheren Alter fortbestehen kann. Ältere Erwachsene (>65 Jahre) mit niedrigem sozioökonomischem Status und schlechtem Gesundheitszustand sowie der Tendenz zur sozialen Isolation haben das höchste Risiko. Es war jedoch kein „Hitzeinseleffekt" des Wohnumfelds festzustellen. Wie sehr jemand unter Hitzestress leidet, hängt in hohem Maße von den eingesetzten Anpassungsstrategien ab. Die Anpassungsstrategien älterer Stadtbewohner konzentrierten sich zumeist auf den Körper, d. h. mehr Trinken und leichtere Bekleidung, sowie auf den Aufenthalt in Innenräumen, insbesondere die Vermeidung des Aufenthalts im Freien.

Schlüsselwörter

Erfolgreiches Altern · Ökologische Gerontologie · Klimawandel · Städtische Hitzeinseln · Anpassungsstrategien

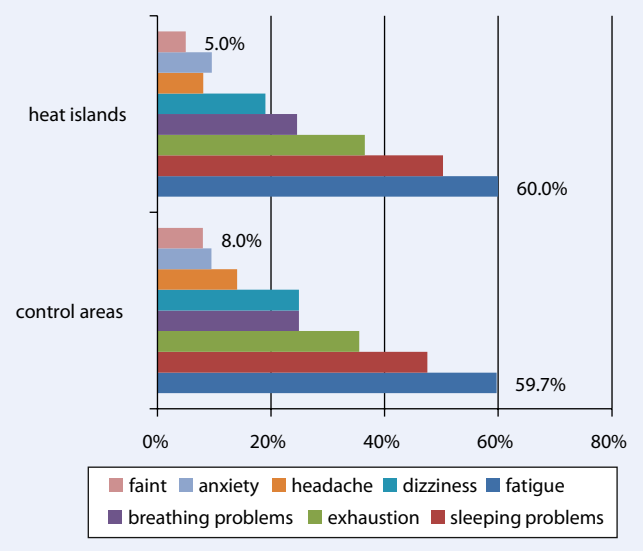

Fig. 2 ◀ Heat-induced effects according to residential area

idential area (F=7.65, p<0.01) (**Fig. 1**). Results show that the younger, the higher the educational status, income, occupational status (white-collar versus blue-collar) and the more privileged the socio-economic structure of the residential area, the better the chances of ageing successfully. No gender differences could be found.

Heat-induced conditions and coping strategies

Heat primarily affected older adults' energy balance—commonly reported heat impacts on physical well-being included fatigue and sleeping problems (**Fig. 2**). Older adults (>65 years) suffered more severely from heat stress than the younger control group (18–55 years, p<0.01). Living in a heat island, however, had no direct effect on successful ageing and no effect on the number of heat-induced conditions.

The risk group comprises older adults (65 years and older) with a low socio-economic status and poor health condition, who tend to be socially isolated. Respondents living in heat islands mentioned an average of 3.1 heat-induced conditions, while respondents living in green areas mentioned 2.8 on average (p>0.05).

Based on the reported adaption measures, three different strategies were identified: body-related strategies (i.e. increasing liquid intake, taking cold showers), indoor strategies (i.e. primarily staying at home, closing the curtains) and outdoor strategies (i.e. going outside, going swimming)[5] (**Tab. 1**). The majority reduced their activity levels and stayed in their apartments when it was hot. They perceived their homes to be cooler than the outdoors.

Living in a heat island did not affect the type of coping strategies deployed. Perceived heat stress, on the other hand, correlated with coping strategies. Correlations were strongest between heat stress and indoor coping strategies (r_P =0.36; p<0.01). More indoor adaption measures correlated with an increase in heat-induced conditions, whereas outdoor strategies correlated negatively with heat stress (r_P =−0.16; p<0.01). There was no significant correlation with bodily measures.

Predicting successful ageing

Three dimensions of determinants of successful ageing were included in a multivariate linear regression model: (a) socio-demographic characteristics, such as age and gender, (b) characteristics of the social situation, such as education, available income, former occupational status and socio-economic structure of the living area and (c) factors related to urban heat, such as living in an area with a low quantity of green spaces, perceived heat stress and heat adaption behaviour.

The first model comprising age and gender explained 5% of the variance of the successful ageing sum score, social characteristics explained another 6% and climate change-related factors explained 11% of the variance. The final regression model explained about 20% of the variance (**Tab. 2**). Climate change-related factors, such as heat-induced conditions and heat adaption strategies, explained as much of the variance of successful ageing as socio-demographic and socio-economic factors. Heat-induced conditions (heat stress; Beta =−0.28), age (Beta =−0.19) and heat-related outdoor coping strategies (Beta =+0.17) had the strongest effects on successful ageing.

The age effect remained relatively stable across the models, as calendar age was shown to be significantly correlated with successful ageing (health status and functionality in particular). Due to the narrow focus of the study, various support factors that could control for the age effect, such as social support, loneliness or self-efficacy, could not be controlled for.

Discussion

This study assumed that climate change endangers the chances of successful ageing in urban areas, particularly in heat islands. Age, social inequalities and the living environment were assumed to intersect with environmental stressors, shaping the modes in which successful ageing can take place. Finally, the study assumed that older adults' heat adaption strategies could play a crucial role in mediating the negative effects of climate change.

The results indicate that temperature is one important determinant of well-being in later life. To what extent a person suffers from heat stress is attributed to successful ageing. If heat waves and hot periods increase in the future, this threat to

[5] Three summarising scores were constructed to resemble heat-coping strategies, depending on whether coping activities mainly involved the indoors, the outdoors or the body. Indoor measures [9]: close curtains, close windows during daytime, sleep, move little outdoors, turn the air-conditioner on, turn the fan on, stay in cooler rooms indoors, conduct activities early or late in the day, stay indoors; outdoor measures [3]: go swimming, go to cooler places outdoors, go outdoors; body measures [5]: wear lighter clothes, increase liquid intake, eat more soup/drink mineral water, take a cold shower, rinse forearms with cold water.

Tab. 1 Heat adaption strategies among older persons (>65 years) living at home

Strategy	Measure	65+ living at home (%)
Body-related	Wear lighter clothes	99.3
	Drink sufficient amounts	90.2
	Eat soup/drink mineral water	76.2
	Cold water on forearms	75.6
	Cold shower	56.7
Indoor	Draw curtains	88.2
	Close windows by day	79.5
	Activities early/late	85.7
	Stay indoors	65.5
	Move little outdoors	63.5
	Go to cooler rooms indoors	63.5
	Turn fan on	40
	Sleep	35.5
	Turn air-conditioner on	11.6
Outdoor	Go to cooler places outdoors	54.4
	Go swimming	51.9
	Go outdoors	21.3
N	401	

Tab. 2 Successful ageing (standardised sum score) by socio-economic and heat-related variables—linear regression, beta-values

Independent variable	Model 1	Model 2	Model 3
Age	−0.24[c]	−0.24[c]	−0.19[c]
Gender (female)	−0.04	+0.02	0.00
Education		+0.1[a]	+0.05
Former occupation		+0.07	+0.08
Available income		+0.11[b]	+0.00
Social status of the living area (low)		−0.1[b]	+0.09[a]
Heat island			−0.08
Heat stress			−0.28[c]
Indoor coping			+0.02
Outdoor coping			+0.17[c]
Body coping			+0.04[a]
Adjusted R^2	0.05[c]	0.1[c]	0.2[c]
N	401	401	401

[a]p<0.10; [b]p<0.05; [c]p<0.01.

older adults' well-being—and, in further consequence—morbidity and mortality may become even more severe.

Initially the study assumed that whether an older person lives in a heat island increases the degree of heat stress, which in turn gives rise to different coping strategies that are more or less effective in terms of support or hindrance for (of) successful ageing. Yet living in a heat island had neither a direct effect on the amount of heat-induced conditions, nor did it affect the coping strategies deployed or chances of successful ageing in general.

How much a person suffers from heat stress is, however, highly dependent on the adaption strategies deployed. Adaption strategies of older urban residents mostly centred upon body-related measures, such as drinking more or wearing lighter clothes, and indoor-centred measures, particularly avoiding the outdoors. A small percentage integrated the outdoor environment into their own 'heat response plans'. Despite frequent uses of these strategies, we failed to find a correlation between body-centred measures and heat stress, while we indeed found a positive correlation between indoor strategies and heat stress (i.e., the more indoor strategies are deployed, the worse the conditions). As the survey design is not longitudinal, we cannot speak of causality. Moreover, we cannot know how the heat-induced conditions of respondents would be without these measures being deployed.

Two explanatory scenarios are possible: (a) older adults suffering most from heat stress deploy more sophisticated (i.e. indoor) adaption strategies, while those more resistant to high temperatures continue their usual outdoor life or (b) indoor strategies are counter-productive in regard to heat stress and outdoor strategies are recommendable. If the latter scenario is accurate, however, the question remains as to why older adults do not make use of outdoor strategies as much as indoor strategies to overcome heat stress?

A study by Kalkstein and Sheridan indicated that only half of people adapt their behaviour in response to heat warnings [16]. Particularly the most vulnerable populations, including low-income households, the homeless and older adults do not adapt [29]. Possible explanations are that today's "older adults" (>65 years) do not identify with being "old" and thus might not believe themselves to be in danger of higher temperatures [1], or that they would not register the heat due to intake of medications [26]. In the STOPHOT study, however, most respondents reported suffering from heat stress and deploying a wide range of adaption measures. We can thus assume that they were aware of heat threats and attempted to adapt accordingly.

Apart from the lack of heat awareness, there might be factors that prevent older adults from going outside to cooler places when it is hot. Such factors could be personal or environmental (i.e., reduced mobility without barrier-free infrastructure in the neighbourhood), and often they are both. Health problems and frailty can turn any attempt to leave the home into a challenge. Seemingly small tasks, such as changing clothes, getting downstairs or opening heavy doors can be exhausting—especially under hot temperatures—and might lead to avoidance of going outside [26].

The amount and quality of cooler places, particularly green spaces, are supposed to be a pull-factor for going outside among older adults. However, we did not identify a correlation between the amount of green spaces in the immediate residential surroundings and outdoor measures deployed. This could be due to various factors: First, access to cooler outdoor places might be limited because of physical barriers and lack of transportation or because they are highly exposed to the sun. Second, green spaces might not be (perceived as) cooler than the apartment. In the

Tab. 3 Practical conclusions

	Description of measures
Information	Increased information and awareness-raising efforts on the impacts of heat waves targeting risk groups; inclusion of relatives, friends, neighbours to better assist the elderly during heat waves; increased communication of proper behaviour during heat waves and information about cool spaces (indoor/outdoor) to be visited during off-heat day times
Green spaces	Provision of safe and attractive green spaces with shading from trees, benches, elderly-friendly offers such as guided leisure activities
Access to cool areas	More elderly-friendly corridors to public green spaces, e.g. shaded trails through green inner yards and resting sites with benches in shadowy places
Cool city	Increasing the green infrastructure of cities: more in- and outdoor cooling rooms; more cooperation between urban planners and seniors clubs

STOPHOT study, respondents perceived their home to be cooler than the outdoors—but several studies indicated that larger parks and green spaces with trees can be cooler in the daytime [5]. Third, the quality of green spaces is influential on older adults' outdoor behaviour. The pleasantness of open spaces and lack of nuisance may encourage older adults to engage in outdoor activities [2, 27]. Fourth, security is an issue—in Sampson et al.'s research, the risk of crime was reported to be a constraint to going to a cooler place or even opening the windows at night [18].

Apart from these aspects, the results are also limited. Despite the body of literature, no heat island effect on the behaviours and perceptions of the respondents could be detected in the STOPHOT data. This may be attributed either to a gap between objective and subjective health conditions or to a flawed selection of heat islands versus green areas, as no reliable micro-level data have as yet been accumulated for average temperatures and other micro-climatic conditions in Vienna.

The significant correlation between heat stress and successful ageing may also be a tautological artefact due to the operationalisation of successful ageing. The concept of successful ageing still lacks a consensual definition in both operationalisation and derivation, while empirical applications of the successful ageing concept often emphasise an absence of disabilities [7, 15]. This has been criticised as excessively limiting the percentage of the population ageing successfully [15]. A focus on disease prevalence underemphasises adaption processes that are crucial in understanding well-being in later life [3, 15]. In the STOPHOT study, this emphasis on physiological health may have led to a tautological correlation between heat stress, defined as health conditions under high temperatures, and successful ageing, defined as subjective health, functionality and social activities. Those enjoying lesser health resources are naturally more vulnerable to environmental stressors and thus more likely to suffer from heat stress. Similarly, functionality—measured by ADL–could create such a tautology with indoor and outdoor adaption measures. There is a strong demand for longitudinal studies to precisely distinguish between the conditions and the outcomes of adaption processes to environmental stressors.

Practical conclusions

So far, only few measures that can make the heat more bearable for elderly in Vienna have been implemented. These measures have mainly been realised for public buildings and public (green) spaces and include measures such as greening of roofs/facades/courtyards and the planting and preservation of trees. Furthermore, the city of Vienna provides a heat wave warning system for the population, although a special heat action plan does not exist.

Measures already implemented especially for the elderly are rare, e.g. a list of recommendations regarding proper behaviour during heat has already been distributed to elderly who live alone in private homes. In some retirement homes first measures have been implemented such as the provision of drinking fountains in common areas, diet food on hot days, apartments with heat protection and announcements providing information about heat waves. However, legal requirements for retirement homes are lacking.

Within this project, possible measures to reduce the vulnerability of the elderly have been discussed with stakeholders of the city of Vienna; some of the first recommendations for urban planning are listed in the practical conclusions ◘ **Tab. 3**.

This project initiated discussions among stakeholders. The implementation and realisation of the recommended measures will be negotiated within the city administration and between the various stakeholders. In the ongoing research project "Urban Heat Islands—Strategy Plan Vienna" (e.g. [8]) the acceptance, feasibility and costs of measures etc. will be assessed with stakeholders and experts. At the end of the STOPHOT project a manual with results and recommendations will be developed and should assist stakeholders in their implementation efforts.

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Compliance with ethical guidelines

Conflict of interest. A. Wanka, A. Arnberger, B. Allex, R. Eder, H.-P. Hutter, and P. Wallner state that there are no conflicts of interest.

The accompanying manuscript does not include studies on humans or animals.

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