Final report

30 May 2025

The Research Council of Finland decided to fund as part of the Academy Programme Climate Change and Health (CLIHE) the research consortium Climate change and Health: Adapting to Mental, Physical and Societal challenges (CHAMPS) for the years of 2020 to 2023. Because the government of Finland implemented stringent COVID-19 epidemic policies which delayed the start of work for the research consortium, the period of usage of budgeted finances was lengthened to end on 31 December 2024.

The CHAMPS comprised five partners including the Finnish Institute for Health and Welfare, Finnish Meteorological Institute, Finnish Environment Institute, University of Helsinki, and University of Eastern Finland. The Finnish Institute for Health and Welfare was the coordinating body, and the Finnish Meteorological Institute was responsible for the public relationships. The principal investigators of this research consortium were Timo Partonen, Reija Ruuhela, Timothy R. Carter, Marko Elovainio and Marianna Virtanen, respectively.

Introduction

The CHAMPS aimed at studying the impacts of climate change on health focusing on three distinct yet connected topics. The first relates to mental health impacts associated with seasonal variation in daylight intensity (solar radiation) and the modifying effects of cloudiness, snow cover and other weather variables. The second concerns health impacts of thermal (both heat and cold) stress and the influence of social vulnerability and exposure of the population on the severity of impacts. The third considers the implications of these impacts for occupational health and work productivity, social inequalities and economic costs.

Objectives

The overall objectives of the CHAMPS, which focuses on Finland both nationally and for the city of Helsinki, were fourfold as follows.

1. To investigate relationships between weather variables and observed mental, behavioural and physical health effects, to test potential mediators, and to describe the spatial and temporal distributions of these effects.

2. To identify differential patterns of exposure and vulnerability among populations affected by the weather events, and attempt to relate these to information on demographic, socioeconomic, occupational and pre-existing health status.

3. To project future health impacts and costs, applying causal relationships established for present-day climate under a range of climate change, socioeconomic and adaptation scenarios.

4. To work with stakeholders to identify appropriate adaptation pathways for ameliorating future health risks attributable to changing climate in the context of broader policy goals.

Research questions

Further, the specific research questions in CHAMPS relating to the above objectives were presented.

1. What mechanisms explain the observed association between lack of solar radiation during winter periods and mental health of the Finnish general population? How are impacts affected seasonally by the amount and spectrum of solar radiation? Does thermal stress also play a role? How is the association between solar radiation and mental health reflected in an increased risk of sickness absence, hospitalisation, psychotropic medication or suicides?

2. To what extent does heat and cold stress contribute to sickness absence and mortality? What are the patterns and costs of sickness absence, ambulance call outs, healthcare and medication attributable to climate factors under the present climate? How do social vulnerability factors explain variations in health risks related to heat and cold stress? What kind of social disadvantages are the most important in this context?

3. Based on the findings above, how will those health risks change temporally and spatially for scale-specific indicators in Finland and in Helsinki over the near-term (2030s) and longer-term (2060s and beyond) under different climate change and socio-economic scenarios?

4. Which adaptation pathways would be potentially most effective for reducing adverse health impacts over the near-term and longer-term future?

To this end, the research work in CHAMPS produced data which were translated into deliverables in form of scientific publications. Here, we present the key findings from studies we conducted for the research consortium.

Scenarios

Over the past 15 years, the climate change research community has developed a scenario framework, the so-called Shared Socioeconomic Pathway–Representative Concentration Pathway (SSP–RCP) framework, combining alternative futures of climate and society to facilitate integrated research and consistent assessment to inform policy [**6**, **21**]. It is used to explore how the future may evolve under a range of alternative conditions, or how desirable outcomes might be achieved and undesirable outcomes avoided. However, current climate risk assessments primarily rely on static indicators or linear extrapolations, which do not fully capture dynamic socio-economic drivers like urbanization, aging, and income distribution with more qualitative variables relating to vulnerability. Projections of climate and non-climate impact drivers can increase confidence in anticipating future risk and better underpin adaptation policies [**22**]. An approach that combines model-based impact response surfaces with probabilistic projections of climate change and population to estimate the likelihood of exceeding pre-specified thresholds of impact is of relevance for policy making by addressing the relative sensitivity of impacts to key climate and socio-economic drivers [**8**, **12**].

The groundwork for applying these socioeconomic scenarios for healthcare and social welfare in Finland was initiated in the research project Pathways linking uncertainties in model projections of climate and its effects (PLUMES) which was funded by the Research Council of Finland [**9**]. Next, these scenarios were presented for discussion at the scientific conference Preparing for the future: analysing and identifying responses to societal challenges using scenarios and other tools for future scanning, as hosted by the research programmes of the Strategic Research Council [**19**]. Further, a virtual programme-wide workshop on Scenarios for Climate Change and Health Analysis in Finland was held on 16 December 2020 in the context of the Academy Programme Climate Change and Health (CLIHE). There is a report of this workshop at the website of Finnish Environment Institute [**7**].

Its purpose was (1) to exchange information between consortium projects in CLIHE on scenario planning and anticipated needs, (2) to explore opportunities for collaboration and exchange of data and scenarios, and (3) to discuss possible co-ordination in the use of a shared scenario framework and common choice of core scenarios to support research in CLIHE. The workshop was attended by about 30 participants from a cross-section of CLIHE projects. It included introductory presentations on the National Adaptation Plan for Health and Social Welfare and on the framing of scenarios for climate change analysis as well as presentations on data and scenario needs in seven of the CLIHE projects: ALL-IMPRESS, CHAMPS, Diseases-on-Wings, ECOCIDE, HEATCLIM, HERCULES and VECLIMIT. Three break-out groups were held to articulate and discuss aspects of (1) socioeconomic scenarios, (2) climate and related scenarios, and (3) scenario combinations.

Currently, national socioeconomic pathways are available for the agriculture and food and social welfare and health sectors based on the global shared socioeconomic pathways. Co-creation of regional, system-level Shared Socioeconomic Pathway based scenarios and narratives is in its early stages [**32**]. To inform about the science-based actions and support adaptation planning for healthcare and social welfare in Finland, national socioeconomic narratives for future healthcare and social welfare in Finland are under review [**47**]. These four alternative narratives are based on the global shared socio-economic pathways, and this work has been presented at scientific conferences in Helsinki, Finland (2020), Laxenburg, Austria (2022), and Montréal, Canada (2023).

Projections

In the Arctic, climate warming causes permafrost thawing that has significant effects on ecosystems and the human infrastructure. Examples of the many consequences of permafrost thaw in the Arctic permafrost region were provided [**20**]. Furthermore, measurements of solar ultraviolet radiation from January to June 2020 at ten Arctic and subarctic locations were compared with historical observations [**4**]. The ultraviolet index data showed large anomalies, occurring mostly between early March and mid-April 2020 and exceeding measurements of preceding years by up to 140% for several days. Historical mean values were surpassed by more than six standard deviations at several locations in the Arctic. Next, ultraviolet time series based on satellite retrievals were validated against ground-based measurements to form a unique 30-year long global dataset to be used for multiple ultraviolet impact studies all over the globe [**18**]. Finally, simulations following the RCP 6.0 climate scenario for the period 1960–2100 demonstrated that ultraviolet-B (i.e., wavelengths of 280–320 nm) irradiance will decrease by 8.2%±3.8% at latitudes poleward of 55°N from 2050 to 2100 [**10**]. The key findings were that measurements and the model simulations agreed rather well, giving support to the simulations of the future scenarios.

Climate scenarios for Finland were updated to correspond the shared socioeconomic pathway greenhouse gas scenarios, considering nearly 30 global climate models that participated in Phase 6 of the Coupled Model Intercomparison Project (CMIP6) [**27**]. The shared socioeconomic pathways and CMIP6 global climate models had also been used by the Intergovernmental Panel on Climate Change (IPCC) in composing the Sixth Assessment Report as of 2021. Projections were provided for three future 30-year periods and all four shared socioeconomic pathway scenarios from which enough global climate model data were available. According to these projections, warming is likely to be stronger in winter than in summer, the precipitation totals are likely to increase, even though in southern Finland in summer, the mean change appears to be negligibly small, and solar radiation

presumably slightly increases in summer and decreases in winter. Further, utilising bias-corrected daily-mean temperature data, the occurrence and severity of heatwaves in Finland were assessed, demonstrating that, at the 2.0°C global warming level, heatwaves above 20°C are experienced in southern Finland nearly every year and in the majority of northern Lapland approximately every second year [28]. Furthermore, in northern Europe, the average annual number of heatwave days is projected to become three to fourfold [29], and future temperature-related mortality in various climate change and adaptation scenarios in Finland was calculated [51].

Cohort-based studies

In three studies, data from the prospective Young Finns Study were used to evaluate associations of long-term natural light exposure with psychological outcomes among Finnish adults. For these studies, daily meteorological data on natural light (global solar radiation in MJ/m^2) obtained from the Finnish Meteorological Institute were linked to the residential information on each day prior to the outcome assessment, and average daily exposure to natural light was calculated for different exposure lengths. Three psychological outcome categories (i.e., sleep, depressive symptoms and cognitive function) were evaluated in separate studies. Data on sleep and depressive symptoms were self-reported, whereas cognitive function was assessed using the Cambridge Neuropsychological Test Automated Battery.

In the first study comprising 1962 Finnish adults [11], participants exposed to more natural light in their residential neighbourhood reported more sleep problems, shorter sleep duration and they had a diurnal preference towards later hours than participants residing in neighbourhoods with less natural light. These associations were observed only with exposure times of ≥ 1 year, and they were robust to adjustment for individual-level as well as neighbourhood-level socioeconomic characteristics, health behaviours and season. In dynamic clustering analyses, participants exposed to a relatively slowly increasing light exposure pattern preceding the sleep measurements had less overall sleep problems than participants exposed to a recently declining light exposure or a recently increasing light exposure pattern.

The second study [15] was focused on the symptom-specific associations of natural light exposure with depressive symptoms. In a cohort comprising 1845 Finnish adults, natural light exposure over 1 year prior to the depressive symptoms assessment was not associated with the total number of depressive symptoms. However, in symptom-specific analyses, participants exposed to higher levels of solar insolation in their residential neighbourhood were less likely to report suicidal thought, and more likely to report changes in appetite, changes in sleep, and feelings of worthlessness/guilt after adjusting for individual- and neighbourhood-level confounders.

In the third study among 1838 Finnish adults [16], greater long-term exposure to natural light at exposure lengths of ≥1 year was associated with better global cognitive function. The associations of natural light with cognitive function were domain-specific; greater residential natural exposure was associated with better performance in cognitive tasks requiring visual memory, new learning and sustained attention, while no association with spatial working memory and an inverse association with reaction time performance was observed. The associations were small in magnitude, but robust to adjustment for individual-level and neighbourhood-level confounders.

Next, to focus on the associations of wintertime natural light exposure with psychological outcomes, three collaborative studies were conducted.

In the first study among 15,619 Swedish adults, data from the Swedish Longitudinal Occupational Surveys of Health administered by Statistics Sweden were used to estimate impacts of wintertime natural light exposure on depressive symptoms and sleep problems [**24**]. For this study, daily meteorological data on natural light (global solar radiation in MJ/m^2) obtained from the Swedish Meteorological and Hydrological Institute were linked to the residential information on each day prior to the outcome assessment, and average daily exposure to natural light was calculated for different exposure lengths. Solar radiation data were based on validated 11 km × 11 km gridded daily solar radiation data interpolated from measured values (in W/m^2 converted into MJ/m^2) in the observation stations. Data on sleep and depressive symptoms were self-reported. One unit increase in the 4-month averaged global radiation was associated with significantly reduced odds for depressive symptoms, and this finding was confirmed using 4-month cumulative exposure. Further, individuals reporting the daily exposure to daylight of 1 hour or longer during winter months were significantly less likely to report depressive symptoms compared to time when their daily exposure was less than 1 hour.

In the second study among 14,237 Swedish adults, data from the Swedish Longitudinal Occupational Surveys of Health administered by Statistics Sweden were used to estimate impacts of wintertime natural light exposure on symptoms of anxiety [**50**]. For this study, daily meteorological data on natural light (global solar radiation in MJ/m^2) obtained from the Swedish Meteorological and Hydrological Institute were linked to the residential information on each day prior to the outcome assessment, and average daily exposure to natural light was calculated for different exposure lengths. Solar radiation data were based on validated 11 km × 11 km gridded daily solar radiation data interpolated from measured values (in W/m^2 converted into MJ/m^2) in the observation stations. Data on anxiety were self-reported. There was no association of 3-month average solar radiation, precipitation nor snow on the ground (reflecting light) with symptoms of anxiety.

In the third study comprising 251,268 Finnish adults, data from the Finnish public sector study were used to analyse the influence of natural light exposure on psychotropic medication purchases [**25**]. For this study, daily meteorological data on natural light (global solar radiation in kJ/m^2) obtained from the Finnish Meteorological Institute were linked to the residential information on each day prior to the outcome assessment, and average daily exposure to natural light was calculated for different exposure lengths. Solar radiation data were based on validated 10 km × 10 km gridded daily solar radiation data interpolated from measured values in the observation stations. Using personal identification numbers, individuals were linked with medication purchases from the Finnish Prescription Register maintained by the Social Insurance Institution of Finland. A washout period of six months with no purchases was applied to each purchase. There was no association of an increase in the 4-week average of solar radiation by standard deviation (585 kJ/m^2) or high (≥2000 kJ/m^2) vs. low (<500 kJ/m^2) exposure nor precipitation with usage of any psychotropic medication or antidepressants in specific.

Finally, to enlarge the scope of slowly emerging impacts of climate change on psychological outcomes, two collaborative studies were conducted.

In the first of these studies, data from the Environment and Health survey as of 2023 for the Nudging for climate: Using behavioral sciences for steering communities to reduce greenhouse gas emissions and fortify carbon sinks (CLIMATE-NUDGE) consortium of the Research Programme Climate change and humans (CLIMATE) of the Strategic Research Council were used to estimate associations of climate worry, societal and individual efficacy-based climate hope as well as pro-environmental behaviour as coping strategies in climate worry with psychological outcomes among 5701 adults living in the 10 biggest cities in Finland [49]. Data on depressive symptoms and anxiety were self-reported. Climate worry was significantly associated with symptoms of both depression and anxiety. Individual efficacy-based climate hope moderated the association of pro-environmental behaviour with both psychological outcomes in a way that among individuals with higher levels of pro-environmental behaviour engagement, those having higher levels of individual efficacy-based hope had significantly lower odds for symptoms compared with those having lower levels of hope.

The second study comprising 99 reindeer herders living in the northern-most region of Finland was focused on perception on health-related impacts of seasonal variation in solar radiation and ultraviolet exposure [45]. In connection with the project Biocultural adaptation at the changing Arctic (2023–2026), a survey among reindeer herders was conducted with questions on their seasonal variation in mood and behaviour, sun-related behaviour and awareness of ultraviolet radiation induced health hazards. These data were compared with nationwide readouts from the population-based surveys of the Healthy Finland 2023 survey (n=4486) as well as the most recent survey (n=1003) commissioned by the Radiation and Nuclear Safety Authority as of 2022. Eight percent of reindeer herders suffered from seasonal affective disorder and 13% from its subsyndromal form, being more frequent than in the reference survey. The awareness of solar ultraviolet radiation as a health hazard and the use of the ultraviolet index as a source of information for sun protection were less frequent than in the reference survey, although wearing long-sleeved clothing, hats and sunglasses to protect themselves was more common among the reindeer herders.

Healthcare registry-based studies

In two studies, associations of climatic exposures in childhood with later risk of psychiatric diagnoses were assessed with the usage of Finnish nationwide register data.

In the first of these studies [14], we estimated associations of childhood exposure to global solar radiation and ambient temperature with subsequent risk of schizophrenia. The study population comprised 372,494 Finnish persons born in Finland between 1990–1995. For each we calculated the average daily exposure to global solar radiation and ambient temperature from birth to the 10th birthday. The study population was followed from age 10 until the first schizophrenia diagnosis, death, emigration or December 31, 2017, and hazard ratios for the risk of schizophrenia were estimated using Cox regression. Compared to the lowest quintile of global solar radiation or ambient temperature, growing up in the second highest quintile was associated with greater risk of schizophrenia. These hazard ratios were attenuated after adjustment for parental mental disorder, parental education, parental income, area-level socioeconomic characteristics and urbanicity. Continuous linear terms evaluated in secondary models suggested a greater risk of schizophrenia at greater childhood exposure to global radiation and ambient temperature, but these associations did not remain in fully adjusted models. In conclusion, there was no consistent evidence that cumulative

exposure to sunlight and ambient temperature in childhood is associated with the risk of developing schizophrenia.

In the second of these studies [17], we elaborated the abovementioned analysis to look at associations of childhood ambient temperature exposure with a wider array of psychiatric diagnoses. The study population comprised 578,067 Finnish people born in Finland between 1990–1999 for whom we calculated the average daily ambient temperature exposure from birth to the 10th birthday. The cohort was followed from age 10 to the diagnosis of a psychiatric disorder, death, emigration or December 31, 2019. The temperature exposure was fitted as a penalized spline to evaluate nonlinearity. Growing up in residential neighbourhoods exposed to higher temperatures was monotonically associated with a greater subsequent risk a psychiatric disorder after adjusting for parental mental disorder, parental education, parental income, area-level socioeconomic characteristics and urbanicity. In disorder-specific analyses, the associations were evident especially for mood disorders and anxiety disorders, and to a lesser extent for non-organic sleep disorders and substance use disorders.

Further, in three studies, associations of temperature exposures in specific with current risks of acute hospital visits and mortality were assessed with the usage of Finnish nationwide register data.

In the first study [2], all acute hospital visits and all-cause mortality were evaluated using data on the use of specialized healthcare administered by the Finnish Institute for Health and Welfare, and the individual basic information (FOLK) and causes of death administered by Statistics Finland, together with the daily weather data from May to September of 1998 to 2017. Municipal-level daily counts on health-related outcomes, and the daily weather parameters were aggregated to the municipality-month level to form a panel dataset. For each additional day per month in the highest temperature bin, there was a relative increase in the number of acute hospital visits by 1.4 percent for individuals aged less than 65 years and by 0.9 percent for those aged 85 years or older. Among the latter, there was also an increase in mortality of up to 2.2 percent for each additional day per month in the highest temperature bin of more than 25°C. The analysis of cause-specific visits for those aged 75 years or older demonstrated that these extra visits were due to acute respiratory diseases, acute neurocognitive disorders, or acute mental disorders. Taking the healthcare use history into account it was discovered that the highest temperatures were associated with a clear increase in the number of acute hospital visits as well as excess deaths in individuals with dementia, but not in those with mental disorder.

In the subsequent two studies, the focus of analysis was on the impacts of hot weather conditions in the metropolitan area of Finland and on the city of Helsinki in particular. Dependence of the daily risk of deaths on the daily mean temperature for 2000–2018 was modelled using the distributed lag nonlinear model and applied for deaths attributable to four heatwaves in the city of Helsinki and the surrounding hospital district (excluding Helsinki) during the study period, i.e., 2003, 2010, 2014 and 2018 [31]. The mortality rates attributable to these heatwaves were about 2.5-fold higher in Helsinki than in its surroundings. Furthermore, two hot days of the 2018 and 2019 heatwave events, i.e., 2 August 2018 and 28 July 2019, in the Helsinki metropolitan area were analysed as case studies by using the MetCoOp Ensemble Prediction System gridded data, which is an hourly weather forecast product based on HARMONIE-AROME, covering the Nordic Region at a 2.5-km horizontal resolution, and coupled to a SURFEX land surface model including information on surface physiographic

characteristics such as land use, vegetation types, and urban morphology [40]. It was learned that exposure to heat stress tended to fluctuate substantially due to the large-scale weather pattern and local factors such as the urban heat island effect, type of built environment, and impact of the sea.

Furthermore, in a series of five studies, the timing of sickness absence and hospitalisations due to mental disorders as well as deaths from suicide were analysed in relation, first, to season and second, to exposure to solar radiation in a season.

All 978,079 psychiatric hospital admissions during 1987–2017 in Finland were utilised for the smoothed time-series of adjusted ratio of observed to expected daily counts to study seasonal variation and the admission rates by photoperiods [36]. The daily counts of all admissions were standardized into an index by dividing them by the annual daily averages, reflecting the activity of psychiatric hospital admissions within a year and enabling adjustment for the administrative fluctuation in admissions, such as weekend or holiday season effects. Admissions for unipolar depressive episodes dropped in summer but peaked at the end of the rapidly decreasing and increasing photoperiod, as did admissions for bipolar depressive and mixed episodes, whereas manic episodes peaked in summer and were at their minimum in winter. Admissions for schizophrenia were higher than expected from summer to early autumn and lower than expected in other seasons.

Next, 636,543 diagnosis-specific psychiatric sickness absence episodes during 2006–2017 in Finland were analysed [39]. There was a substantial seasonal variation in sickness absence due to common mental disorders as well as bipolar disorder, with peaks in episodes of depressive, anxiety and sleep disorders towards the end of the year and a peak in manic episodes starting in spring.

A key study where the focus of assessment was changed from seasonal pattern to exposure impact, using the case-crossover design with conditional logistic regression by photoperiod, demonstrated associations of the place of residence linked exposure to solar radiation, temperature and precipitation with 438,773 sickness absence episodes due to mental disorder from 2007 to 2019 [48]. Dark, cold and rainy autumns and winters, rainy springs, and rapidly increasing exposures to solar radiation and higher temperatures in springtime appeared to trigger sickness absence episodes due to common mental disorders. Higher exposure to solar radiation in autumn was associated with lower odds for sickness absence due to depressive episodes and anxiety disorders, whereas the odds for sickness absence due to depressive episodes, eating disorders and insomnia were higher in spring with an increasing exposure to solar radiation. Higher temperatures in autumn were associated with lower odds for sickness absence due to depressive disorders, anxiety disorders and insomnia, whereas higher temperatures in spring were associated with higher odds for sickness absence due to all mental disorders under study. Higher precipitation was associated with higher odds for sickness absence due to depressive disorder and insomnia in all seasons as well as due to anxiety disorders in winter and spring, and due to bipolar depressive episodes in spring. Here, on the one hand, a novel finding was that manic episodes leading to sickness absence tended to emerge in spring after exposure to increasing temperatures while exposure to solar radiation or precipitation had no influence. On the other hand, higher exposure to solar radiation in autumn was associated with lower odds for sickness absence due to bipolar depressive episodes while exposure to temperature or precipitation had no influence.

To demarcate the threshold values which make a difference, in another key study [52], associations of the place of residence linked exposure to solar radiation and temperature with sickness absence

episodes due to mental disorders in Finland were calculated with distributed lag non-linear analysis. Sickness absence episodes formed a non-linear relationship with temperature and solar radiation. In general, cold temperatures and dark days were associated with an increased risk of sickness absence due to mental disorders, whereas the risk started to decrease when the temperature reached +10°C and above. Intriguingly, the non-linear relationship appeared to depend on latitude. The threshold for sickness absence among people living in the northern Finland was below 7000 kJ/m² for solar radiation and below -20°C to -29°C for temperature, whereas among people living in the southern Finland, the corresponding thresholds were 11,000 kJ/m² to 13,000 kJ/m² and -10°C to -15°C.

Finally, associations of solar global radiation and its ultraviolet wavelengths in specific with deaths from suicide in southern Finland from March to June of 1979–2019 were calculated with distributed lag non-linear analysis [**46**]. Increases in daily and sub-daily solar global and ultraviolet radiation in spring increased the relative risk of suicide, the risk remaining elevated for up to four days after the exposure.

In addition, as the area of Finland will warm up along climate change, ticks are expected to expand into new areas, thereby increasing human exposure to ticks as well as tick-borne diseases. Some of these diseases such as Lyme borreliosis which is a predominant vector-borne disease in Europe lead to depressive episodes where antidepressant medication might be needed. Thus, to have a current situation analysis and the reference value, the individual prescriptions for antidepressant medication before and after the diagnosis of borreliosis infection were analysed by the registry linkage of the database for medication purchases from the Finnish Prescription Register maintained by the Social Insurance Institution of Finland with the statistical database for the National Infectious Diseases Register administered by the Finnish Institute for Health and Welfare [**53**]. By using the propensity score matching it was shown that people who had an inpatient or outpatient hospital admission due to Lyme borreliosis were more likely to initiate antidepressant medication after the diagnosis of infection than their control group. No difference between the cases and their controls was observed before the cases got the diagnosis of Lyme borreliosis. Of the sociodemographic factors, unemployment was associated with the increased odds for Lyme borreliosis, but the association with antidepressant use was similar among the employed and the unemployed. No other interactions with the sociodemographic factors were observed, suggesting that the association of Lyme borreliosis with antidepressant initiation was similar in all sociodemographic groups.

Data and policy brief

The work by CHAMPS was intended to inform, guide and support the efforts of decision-makers and stakeholders. Therefore, publications were also delivered in form of data brief as well as policy brief.

As there is a gap in the knowledge concerning the long-term and gradual impacts of climate change on mental health, a discussion paper [**5**] was published to summarise the expected impacts of the ongoing climate change on mental health in Finland, to open the discussion concerning mental health on the actions and concrete measures we need for mitigation and adaptation to the ongoing climate change in Finland, and to provide nine science-based recommendations for implementation in the integrated services for social affairs and health in Finland. Further, another discussion paper [**1**] was focused on the evidence basis for identifying groups of people of a population which are likely to be most vulnerable under extreme heatwaves due to the climate change. Furthermore, a data brief [**13**] released recommendations for heat adaptation, including (1) national-level mapping

of competences and educational programmes for social care and healthcare professionals to prepare them against increasing climate change risks, e.g., from heatwaves, (2) digital tool to share the daily bulletin and the recommendations with the citizens, e.g., mobile phone application, and (3) sustainable cooling strategies during heatwaves for the buildings where healthcare and social care services are administered.

To review what is known and what is predicted as impacts of climate change on physical activity, nutrition, and sleep behaviours, with a particular focus on scenarios and projections relevant to people living in northern Europe, a scoping review was conducted [43]. The focus was on impacts which would emerge gradually due to incremental changes in ambient temperature and solar radiation, not to include impacts which would emerge from extreme weather events or the awareness of climate change. Data on climate change impacts on nutrition and sleep were found sparse, those on physical activity heterogeneous. Furthermore, as the Finnish Meteorological Institute has been providing a weather service for pedestrians since 2004, evaluation of the effectiveness of this service in prevention of slip and fall injuries was evaluated using the data from the Finnish Workers' Compensation Center for 2005–2022 as well as the daily warnings about slippery sidewalks from the institutional archives for 2011–2022 [34].

Lessons learned from the COVID-19 pandemic might inform climate change policy as well [26, 37]. This information may also help in societal and ecological resilience building, for which scenario tools and social simulation techniques are useful to support stakeholder preparedness and contingency planning. These tools need to be deployed widely to foster system-wide risk management strategies.

To increase awareness as well as to inform the domestic decision-makers and stakeholders, some documents were published in Finnish as well [3, 30, 38, 41, 42, 44].

Recommendations

To capture a comprehensive view on mental, physical and societal challenges, climate change impact studies and the adaptation plans in high latitude areas should take future changes not only in daily temperature but also in incident solar radiation into account [33]. Up to date, rapid increases in temperature and precipitation have received a lot of attention in climate change adaptation studies, leaving changes in solar radiation rather unexplored. However, seasonal variation in natural light is an essential characteristic of the climate in high latitude areas, and global warming is expected to lead to significant changes in solar radiation.

To assess future exposure and vulnerability to future climate hazards and inform science-based policy assessments, guidelines for the development of socioeconomic indicators were published [23]. This methodology combines single-indicator and index-based approaches, emphasizing participatory methods to define indicators that capture complex, context-specific vulnerabilities. Emphasis was placed on addressing non-climatic factors in climate resilience planning, with the goal of ultimately enhancing human well-being by providing future-generation oriented climate risk assessments for Europe. The application of Shared Socioeconomic Pathway based vulnerability projections maintains coherence across scales yet allows tailoring at the appropriate scale with an efficient use of resources through effective participatory processes.

To advance integration of climate, environment and health services which is needed to address growing health-related risks from climate change, a strategy comprising of a set of good practices

was published as a joint action of World Health Organization and World Meteorological Organization [35]. By having a member in the task force group, CHAMPS contributed to this strategy.

Key achievements

The key achievements of CHAMPS are the following:

1. Work on the climate change scenarios and projections delivered by the Finnish Meteorological Institute and the Finnish Environment Institute provided a solid basis for work on the mapping of heat-related risks as well as health-related impacts of solar radiation in Finland being linked to the residential information and based on validated 10 km × 10 km gridded daily data interpolated from measured values in the weather observation stations. This result was significant from the perspective of the reusability and applicability of the data and methods.

2. Work on the mapping of heat-related risks in the metropolitan area of Finland was conducted in the context of collaboration with the metropolitan authority and different divisions of the city of Helsinki. In collaboration with CHAMPS partners who supplied data as well as collaborating partners elsewhere in Europe, indicators of exposure and vulnerability were mapped using datasets of socioeconomic and health indicators at postal code resolution as of 2000–2017, focusing on health visits and demographic indicators. For the climate hazard, surface temperatures over Helsinki during heatwave conditions were derived from Landsat-8 images held at the Finnish Environment Institute. Values of selected indicators have also been projected into the future using an expert elicitation process. The work with the city and metropolitan area of Helsinki was strongly participatory. This result was significant from the perspective of societal impact and/or relevance.

3. Work on the assessment of impacts of solar radiation on mental health was cutting-edge by its findings. Sickness absence episodes due to common mental disorders were influenced by exposures to meteorological conditions. Darker and colder days in autumn and winter were associated not only with hospitalization, but also with sickness absence due to depressive disorders as well as anxiety disorders among the working population. This work paves the way for quantifying the projected needs for care and their costs as induced by the changing climate in Finland. The work with the universities of Helsinki and Eastern Finland was highly collaborative. This result was significant from the perspective of scientific novelty.

Communication with society

Researchers of CHAMPS were actively taking part in communication themselves via the institutional social media channels (#ClimateHealthChamps) as well as with professionals of the mass-media in form of interviews.

Each CHAMPS consortium partner contributed by giving a lecture on climate change from their perspective to the series of symposia in the curriculum (T-XB20221 Hiilikasasymposiumit, 1 ECTS) co-created with and organised by the University of the Arts Helsinki (Uniarts Helsinki) in the spring term of 2022. This informative input was intended to stimulate the studies and work of the students. The name of the symposia was a reference to and a symbol of the coal pile of Hanasaari coal-fired power plant which was visible from the windows of the main lecture hall of the university.

Stakeholder engagement included a series of four seminars w/o workshops (A to D) as co-created with the Climate Unit in the Urban Environment Division of the city of Helsinki, with the aim to discuss about the risks of climate change as they may affect different target groups responsible for city design, planning, care, and safety aspects.

A. 10 May 2023 seminar with workshop on the theme Health impacts of heat stress and preparedness to heat waves in changing climate.

B. 7 September 2023 seminar on the theme Climate change and health, generic to all the staff working in the healthcare and social welfare as well as rescue services.

C. 27 October 2023 seminar with workshop on the theme How to create healthy urban environment in changing climate.

D. 4 October 2024 seminar on the theme Impact of light on health and wellbeing and lighting of buildings, with the scope including the staff, patients and clients of the city of Helsinki, and how to take lighting design into account for planning of spaces and functions under the changing light due to climate change in the surroundings.

Conclusion

In summary, of the work for the research consortium CHAMPS, 43 scientific reports have been published thus far, in addition to which 7 manuscripts of scientific reports have been submitted and 3 reports are under preparation to be submitted for publication, totalling 53 scientific publications as listed below.

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52. Virtanen M, Haga L, Ruuhela R, Hakulinen C, Elovainio M, Partonen T. Ambient temperature, solar radiation and sickness absence due to mental disorders in Finland: a distributed lag non-linear regional analysis. (to be submitted)
53. Virtanen M, Ruuhela R, Elovainio M, Honkalampi K, Partonen T. Antidepressant medication before and after a Lyme Borreliosis infection: a register-based study. (to be submitted)

Enclosures

Enclosure 1: The final report in the form of the PowerPoint Presentation as delivered in the Climate Change and Health Academy Programme Final Seminar on 14 December 2023.