Study on Intervention Effect of Heat-related Health Risk Early Warning Digital Technology for School-age Children

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1. Research Background and Rationale

Against the backdrop of global warming, high-temperature heatwave events occur frequently. School-age children are a high-risk group for neurocognitive impairment associated with high-temperature exposure due to their immature thermoregulation and heat adaptation abilities. Numerous studies have confirmed that high-temperature exposure not only affects children's physical health but also significantly impairs central nervous system development, leading to reduced cognitive flexibility, inattention, and other problems, severely affecting children's neurocognitive development. This has become an urgent public health issue.

Digital health technologies can provide a novel intervention pathway for protecting children's neurocognitive function through precise early warning and efficient collaboration. However, current relevant studies mostly focus on the impact of high temperature on children's physical health, and research on digital interventions for high temperature-induced neurocognitive impairment is scarce. No efficient health intervention model covering both school and home—the two main living and learning scenarios for children—has been established, making it difficult to meet the needs for protecting children's neurocognitive health in the context of climate change.

Therefore, this study intends to conduct a school-home collaborative digital early warning intervention based on high-temperature health risk early warning technology, focusing on evaluating its protective effect on the neurocognitive function of school-age children, while taking into account secondary outcomes such as physical health, mental health, and knowledge-attitude-practice (KAP). It aims to provide scientific evidence and practical solutions for safeguarding children's neurocognitive development and addressing high temperature-related health risks.

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2. Research Objectives

To evaluate the protective effect of high-temperature health risk early warning digital technology on the neurocognitive function of school-age children through a cluster randomized controlled trial. Meanwhile, to observe its auxiliary protective effects on children's blood pressure, cardiopulmonary function, body composition, mental health, high-temperature health KAP, diseases and accidental injuries, etc. Ultimately, to form a scientific, replicable and scalable digital protection model for children's high-temperature health risk early warning, providing high-quality evidence-based support and public health practice strategies for addressing climate change-related high-temperature health risks and protecting children's neurocognitive development.

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3. Study Design

3.1 Study Design Description

This pilot study is conducted in Beijing, selecting 6 primary schools as research sites. A

stratified cluster randomized controlled design is adopted, with schools as the unit of randomization. Eligible primary schools are randomly assigned to the intervention group and the control group, with 3 schools in each group.

A total of 5 Wisconsin Card Sorting Tests (WCST), 2 health examinations, 2 children's high-temperature protection themed drawing activities, and 5 mini-program questionnaire surveys will be conducted in this study.

The intervention group receives a digital intervention of high-temperature health risk early warning. The research team relies on a WeChat mini-program to release corresponding high-temperature health risk level information, health tips, protection science popularization information and other early warning content when the high-temperature health risk level reaches yellow, orange or red, and simultaneously pushes them to head teachers and parents.

The monitoring and survey schedule for the intervention group during the study period is as follows: at baseline and endpoint, unified offline WCST and health examination will be conducted for children once each, accompanied by one online mini-program questionnaire survey each time. One children's high-temperature protection themed drawing activity will be organized at baseline and at the end of the 3rd month after intervention, and the works will be uploaded to the mini-program for check-in. At the end of the 1st, 2nd and 3rd months after intervention, one online follow-up questionnaire and WCST will be completed each month, together with check-in. Meanwhile, blood pressure will be monitored once a week, and daily blood pressure monitoring and check-in will be implemented after each high-temperature health risk early warning release. In addition, after the release of high-temperature health risk early warnings, the intervention group is required to complete check-in for reading and transmitting early warning information, health tips and protection science popularization content, as well as online mini-program surveys on children's awareness of high-temperature health risk early warning information and short-term behavioral patterns. The above WCST and questionnaire surveys are completed by children with parental assistance; blood pressure monitoring and check-in are the responsibility of head teachers during non-summer vacations and parents during summer vacations.

The control group does not receive high-temperature health risk early warning intervention and only completes the corresponding WCST, health examinations, questionnaire surveys and blood pressure monitoring.

3.2 Primary and Secondary Outcomes

3.2.1 Primary Outcome

The primary outcome is the comprehensive total score of children's executive function constructed based on the Wisconsin Card Sorting Test (WCST) at 2.5 months of intervention.

Based on the original WCST indicators, including Total Trials/ Trials to Complete First Category (TC), Categories Completed (CC), Percentage of Conceptual Level Responses (CLR), Total Errors (TE), Non-Perseverative Errors (NPE), Perseverative Responses (PR), Perseverative Errors (PE), Failure to Maintain Set (FM), the TOPSIS entropy weight method is used to homogenize, normalize and weight-fit the above multiple WCST sub-indicators to synthesize the comprehensive total score of WCST executive function at 2.5 months of

intervention, which serves as the core primary outcome indicator for evaluating intervention effect.

The above single WCST indicators (TC, CC, CLR, TE, NPE, PR, PE, FM) are evaluated at 2.5 months of intervention, serving as the internal constituent dimensions of executive function, and incorporated into the primary outcome system for subsequent stratified analysis and separate statistical analysis of each dimension.

3.2.2 Secondary Outcomes

All secondary outcomes are evaluated uniformly at 2.5 months of intervention.

1. Cardiovascular indicators: Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Heart Rate;

2. Pulmonary function indicators: FEV1, FVC, PEF, FEF25-75%, FeNO50, FeNO200, CaNO, FeCO;

3. Body composition: Body fat percentage, total body water, inorganic salts, basal metabolic rate, body weight;

4. Children's KAP: Children's high-temperature health KAP score, children's high-temperature health cognition and protection behavior drawing score, short-term behavioral pattern score;

5. Children's mental health indicators: SAS Anxiety Scale, CDI Children's Depression Scale score;

6. Children's respiratory symptoms indicators: SGRQ scale score;

7. Absenteeism days during the study period;

8. Academic performance;

9. Diseases and accidental injuries during the study period: Occurrence frequency of heat-related illnesses (heat stroke, heat cramp, heat exhaustion, heatstroke, heat discomfort, etc.); occurrence frequency of gastrointestinal diseases (infectious diarrhea, dysentery); occurrence frequency of respiratory diseases; occurrence frequency of allergies (skin allergy, respiratory allergy, etc.); occurrence frequency of children's accidental injuries;

10. Check-in rate: Check-in rate of early warning information received by the intervention group.

3.3 Study Population

The study is conducted in urban Beijing, selecting 6 primary schools meeting the inclusion criteria. All included primary schools have basically consistent environmental conditions, and one intact fourth-grade class is randomly selected from each school to participate in the study, with a total of 200 participants. The specific inclusion and exclusion criteria are as follows:

School inclusion criteria:

① Willingness to undertake the project;

② Supportive conditions in terms of school, classrooms and teaching staff;

③ High cooperation from the school and teachers;
④ Class size ≥35 students;
⑤ All participating classes are equipped with air conditioners.

Participant inclusion criteria:
① Fourth-grade primary school students (9–11 years old), regardless of gender;
② Voluntary participation of parents and students, high compliance, and signed informed consent;
③ One adult family member must have a mobile device with internet access;
④ Good health status (e.g., no history of major diseases or mental illness);
⑤ Local permanent residents (residence ≥6 months).

Participant exclusion criteria:
① Participants unable or refusing to undergo examinations;
② Primary school students receiving psychological/psychiatric treatment that may confound results;
③ Already participating in other interventional clinical studies that may affect outcome assessment;
④ Other situations deemed unsuitable for participation by the researcher (e.g., cognitive impairment preventing understanding and/or compliance with study procedures and/or follow-up). Meeting any one of the above exclusion criteria leads to exclusion.

Rationale for age range:
① Physiological development: Children in this age group have immature thermoregulation and heat adaptation abilities, with rapid central nervous system development, making them a high-risk critical period for high-temperature exposure-induced neurocognitive impairment, highly matching the core study outcomes;
② Cognition and compliance: Children aged 9–11 can independently complete WCST, questionnaire filling and health monitoring, with better compliance and data reliability than younger children, and fewer confounding factors than adolescent children;
③ Study homogeneity: Fixing on fourth grade unifies academic pressure, campus environment and daily routine, reducing inter-group confounding and improving internal validity of results;
④ Sample representativeness: Focusing on fourth-grade students in urban primary schools in Beijing, the sample has concentrated characteristics and balanced baseline, suitable for precise intervention and effect evaluation.

3.4 Randomization

This is a stratified cluster randomized controlled trial, with primary schools as the cluster randomization unit. Six eligible primary schools in Beijing are included, stratified by geographical location, and randomly assigned to the intervention group (3 schools) and control group (3 schools) at a 1:1 ratio. The random allocation sequence is uniformly generated by professional statisticians not involved in on-site investigation and data collection using statistical software, and the grouping sequence is kept strictly confidential throughout the process. Both groups conduct the study simultaneously. To control inter-group

intervention contamination, the straight-line map distance between all intervention and control group schools is no less than 2 kilometers to reduce the risk of cross-group student overlap and intervention information cross-transmission. Due to the obvious mini-program scenario-based and check-in operational characteristics of the high-temperature health risk early warning digital health intervention model, it is difficult to blind participants and school implementers. However, WCST administrators, physical examiners, questionnaire outcome assessors and statistical analysts only know the study code and are not informed of specific groups, minimizing measurement and reporting bias to the greatest extent.

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4. Known and Potential Risks and Benefits to Participants

4.1 Risks

There are no risky examination items in this study. All medical examinations are performed by qualified medical staff without special medical examination items. All participants follow the principles of informed consent and voluntariness, and the survey starts only after obtaining participants' consent and signed informed consent. The surveys used in the study do not involve sensitive information of respondents. Investigators have received strict training and keep the information provided by respondents confidential. The mini-program used in the intervention group may cause slight operational inconvenience, and trainers will provide training and consulting support to assist in solving problems.

4.2 Benefits

For follow-up participants: Honor certificates issued by UNICEF; free health monitoring, improved high-temperature protection KAP, reduced heat-related health risks; feedback on health examination results and corresponding health guidance.

Social benefits: After the survey, data analysis reports will be compiled to evaluate the effect of high-temperature health risk early warning in improving children's health. An innovative digital intervention model for children's high-temperature health risk early warning will be explored to develop effective protection strategies. The research results will not only directly benefit participating children but also provide key scientific evidence for the country to formulate relevant public health policies.

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5. Intervention

5.1 Intervention Group

The intervention group adopts a digital early warning intervention for children's high-temperature health risks. During the intervention period, when the high-temperature health risk level reaches yellow, orange or red, corresponding high-temperature health risk level information, health tips and protection science popularization information are released to

parents and head teachers via a WeChat mini-program; parents or teachers transmit the above early warning information to children in the intervention group.

During non-summer vacations, Beijing's high-temperature health risk early warning information is pushed to head teachers and parents via the WeChat mini-program; during summer vacations, precise early warning information based on children's actual location is pushed to parents. All recipients are required to promptly convey the information to children after receiving it. The WeChat mini-program is equipped with information reading and check-in functions to monitor users' information reading and transmission behaviors. The research team can remind parents or teachers to complete reading and information transmission check-in to ensure compliance.

5.2 Control Group

The control group does not receive any mini-program-based digital high-temperature health risk early warning intervention.

5.3 Discontinuation or Adjustment Criteria

Participants participate in this study entirely voluntarily and may withdraw at any time without affecting their rights and interests.

5.4 Strategies to Improve Compliance

1. Special training: Provide unified training for school staff, parents and children in relevant positions, clarify intervention processes, mini-program operation specifications and responsibilities of each subject, ensure that participants master core intervention requirements, and only those who pass the assessment after training can participate in the study.

2. Enhanced feedback and supervision: Arrange full-time staff to regularly check compliance data in the mini-program background, including early warning reading rate, check-in completion rate, etc., provide one-on-one reminders to participants with low compliance, analyze reasons for non-compliance and provide targeted guidance, and solve operational problems in a timely manner.

3. Incentive mechanism: Provide appropriate incentives for children and parents who complete intervention requirements and have good compliance, and regularly report compliance status of classes and individuals to enhance participation enthusiasm and improve overall compliance.

4. Communication channel: Establish a special communication group, arrange special personnel to answer questions, respond to various problems encountered by participants during the intervention in a timely manner, collect feedback and optimize the intervention process to ensure smooth progress of the intervention.

5.5 Permitted and Prohibited Interventions

Permitted: Daily teaching, routine campus management, normal family lifestyle;
Prohibited: The control group receiving any form of special high-temperature health

intervention or using similar early warning tools.

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6. Study Procedures

6.1 Recruitment

Recruitment is conducted in intact classes. Informed consent forms are distributed, and participants are included after signed by parents/children, screened according to inclusion and exclusion criteria.

6.2 Data Collection

Study Stage	Baseline	Month 1	Month 2	Month 3	Endpoint
Study Method	Questionnaire & Health Examination (Offline)	Questionnaire (Online Mini-Program)	Questionnaire (Online Mini-Program)	Questionnaire (Online Mini-Program)	Questionnaire & Health Examination (Offline)
Informed Consent	√				
Personal & Family Information Survey	√				
Follow-up Questionnaire Survey[a]	√	√	√	√	√
Wisconsin Card Sorting Test (WCST)	√	√	√	√	√
Health Examination[b]	√				√
High-Temperature Protection Themed Drawing	√			√	

Follow-up High-Temperature Health Warning Questionnaire[c]		Conducted with actual high-temperature health risk warnings (Intervention Group)	Conducted with actual high-temperature health risk warnings (Intervention Group)	Conducted with actual high-temperature health risk warnings (Intervention Group)	
Mini-Program Check-in[d]		Conducted with actual high-temperature health risk warnings (Intervention Group)	Conducted with actual high-temperature health risk warnings (Intervention Group)	Conducted with actual high-temperature health risk warnings (Intervention Group)	
Health Monitoring[e]		Blood pressure once weekly, daily during high-temperature health warnings	Blood pressure once weekly, daily during high-temperature health warnings	Blood pressure once weekly, daily during high-temperature health warnings	
Adverse Events[f]	√	√	√	√	√

a Follow-up Questionnaire Survey: High-temperature health KAP questionnaire, mental health questionnaire (SAS Anxiety Scale, CDI Children's Depression Scale), respiratory function-related scale (SGRQ), children's accidental injury survey, disease outcome questionnaire;

b Health Examination: Blood pressure, heart rate, pulmonary function, body composition analysis;

c Follow-up High-Temperature Health Warning Questionnaire: Survey on children's awareness of high-temperature health forecast information, short-term behavioral patterns;

d Mini-Program Check-in: Reading check-in of early warning information received by the intervention group;

e Health Monitoring: Blood pressure;

f Adverse Events or Serious Adverse Events: Any harmful, unexpected medical event occurring during the study period.

6.3 Questionnaires and Measurements

6.3.1 WCST

The standardized Wisconsin Card Sorting Test (WCST) is used to assess children's executive function. The test is operated by full-time staff who have received unified systematic training and passed the assessment, following the standardized test process throughout to ensure the objectivity and accuracy of measurement results.

Measurement indicators mainly include Total Trials/ Trials to Complete First Category (TC), Categories Completed (CC), Percentage of Conceptual Level Responses (CLR), Total Errors (TE), Non-Perseverative Errors (NPE), Perseverative Responses (PR), Perseverative Errors (PE), Failure to Maintain Set (FM). Based on the above indicators, the total WCST executive function score is calculated.

Measurements are conducted 5 times at baseline, during intervention and at endpoint in strict accordance with the study design. After the test, staff check test records promptly, accurately enter various indicator data into the study database, and review data of children with abnormal test results (e.g., 0 categories completed, excessively high error rate) combined with their status during the test. Data are archived after confirmation as the core basis for subsequent statistical analysis.

6.3.2 Health Indicators Measurement

All participants undergo one health examination at baseline and endpoint respectively, including blood pressure, heart rate, pulmonary function, body composition, etc. On this basis, all participants are required to conduct additional self-monitoring of cardiovascular indicators during the intervention period, with a routine frequency of once weekly, adjusted to daily during heatwaves.

6.3.2.1 Cardiovascular Indicators

Standardized sphygmomanometers are used for measurement. Blood pressure is measured following standard procedures: participants rest quietly for 5 minutes, then measurements are taken in sitting position using self-monitoring electronic sphygmomanometers, and heart rate data are obtained simultaneously. Measurement results are uploaded to the mini-program.

6.3.2.2 Pulmonary Function

Standardized spirometers are used for measurement, operated by staff who have received unified training and passed the assessment, in strict accordance with instrument operating procedures. Before measurement, children are instructed on operation methods, key points for cooperation and precautions, and guided to complete standardized inhalation and exhalation actions to ensure accurate measurement data. Measurement indicators include Forced Expiratory Volume in 1 Second (FEV1), Forced Vital Capacity (FVC), Peak Expiratory Flow (PEF), Forced Expiratory Flow between 25% and 75% of FVC (FEF25–75%), Fractional Exhaled Nitric Oxide at 50 mL/s (FeNO50), Fractional Exhaled Nitric Oxide at 200 mL/s (FeNO200), Alveolar Nitric Oxide (CaNO), Exhaled Carbon Monoxide (FeCO). Each indicator is measured 3 times, and the best value is recorded. Abnormal measurement results are reviewed promptly with reasons recorded. Measurement time points are consistent with health indicators measurement, and children's physical status during measurement is recorded

simultaneously.

6.3.2.3 Body Composition

Inbody body composition analyzers are used for measurement. Before measurement, children are required to remove metal accessories and heavy clothing, stand barefoot on designated areas of the instrument, keep upright and relaxed to ensure full contact between measurement electrodes and skin. Measurement indicators include body fat percentage, total body water, inorganic salts, basal metabolic rate, body weight. The instrument automatically generates a body composition analysis report after measurement, and staff check report information and accurately enter data into the study database. Measurement time points are consistent with health indicators measurement, and secondary measurements are conducted for abnormal data to ensure authenticity and reliability.

6.3.3 Questionnaire on Basic Information of Children and Families

All parents complete the questionnaire on basic information of children and families at baseline, including family basic conditions, children's basic conditions, children's living habits, etc.

6.3.4 Comprehensive Questionnaire on Children's High Temperature Health

All children complete the survey 5 times at baseline, during intervention and at endpoint, including children's high-temperature health KAP questionnaire, children's mental health questionnaire (SAS Anxiety Scale, CDI Children's Depression Scale), children's respiratory function-related scale (SGRQ), etc., to assess high-temperature knowledge, risk perception, changes in protective behaviors, high-temperature-related psychological stress, respiratory symptoms, etc.

6.3.5 Questionnaire on Children's Awareness of High Temperature Early Warning Information and Short-Term Behavior

Parents and children in the intervention group report children's awareness of high-temperature health forecast information and short-term behavioral patterns respectively after each release of high-temperature health risk early warning, including forecast information reception and transmission, as well as short-term behavioral changes such as outdoor activities, water drinking, sun protection and cooling.

6.3.6 Disease and Injury Surveillance

All parents complete 5 questionnaires on children's diseases and accidental injury outcomes at baseline, during intervention and at endpoint. Combined with school registration forms, data on absenteeism days and occurrence frequency of heat-related diseases, gastrointestinal diseases and accidental injuries are also obtained.

6.3.7 Academic Performance

Main subject academic performance of all participants is collected through schools at baseline and endpoint respectively to objectively reflect students' learning status and academic performance during the intervention period.

6.3.8 Mini-Program Check-in

Mini-program check-in is a process for the intervention group, used to record the completion of early warning information reception, reading, transmission and health monitoring. When the high-temperature health risk reaches yellow/orange/red warning level, the mini-program pushes early warning information. Within 24 hours after pushing, head teachers (non-summer vacations) and parents (summer vacations) operate and upload as required, with data synchronized to the study background in real time as the core basis for compliance evaluation and intervention process quality control.

Blood pressure monitoring check-in: Routine cycle is once weekly, uploading blood pressure and heart rate data at fixed time; daily during high-temperature warnings, uploading immediately after measurement. Fill in measurement values accurately, and the system automatically records measurement time and frequency.

Drawing activity check-in: Completed once at baseline and at the 3rd month of intervention. After children finish high-temperature protection themed drawings, parents take clear photos of the works, upload them via the mini-program and submit for check-in. Uploaded pictures must be clear, unobstructed and include the complete drawing.

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7. Statistical Analysis

7.1 Sample Size

Sample size calculation is initially set with reference to relevant studies on cognitive function indicators, with a set difference $\Delta=1.6$, standard deviation $SD=1.88$, significance level $\alpha=0.05$ (two-sided), power $1-\beta=0.90$, intra-class correlation coefficient $ICC=0.02$, coefficient of variation of cluster size $COV=0$. Considering the conventional class size (35 students) and 20% follow-up dropout risk, a total of 200 children are included.

7.2 Definition of Analysis Sets

7.2.1 Intention-to-Treat Analysis Set (ITT Set)

Includes all participants randomized with at least one baseline observation, analyzed according to initial grouping regardless of subsequent dropout or complete intervention acceptance, serving as the core analysis set for primary outcomes.

7.2.2 Per-Protocol Analysis Set (PP Set)

Includes participants with good compliance, no major protocol deviations, and completion of all specified follow-ups and tests, used for sensitivity analysis of primary outcomes.

7.2.3 Safety Analysis Set

Includes all participants who received at least one intervention arrangement and underwent safety follow-up, used for analysis of adverse events, diseases and accidental injuries.

7.3 Statistical Methods

All statistical analyses are performed using R software, strictly following the intention-to-treat (ITT) principle. Two-sided tests are used, with a significance level $\alpha=0.05$, and $P < 0.05$ is considered statistically significant.

7.3.1 Baseline Balance Analysis

Measurement data are described using mean ± standard deviation or median (interquartile range) based on normality test results; inter-group comparisons use independent sample t-test or Wilcoxon rank-sum test respectively. Enumeration data are described using frequency and constituent ratio, and inter-group comparisons use χ^2 test; Fisher's exact test is used when theoretical frequency is insufficient.

7.3.2 Primary Outcome Analysis

Primary outcome: Comprehensive total score of WCST executive function synthesized by TOPSIS entropy weight method at 2.5 months of intervention, with single WCST constituent indicators included for dimensional analysis. Linear Mixed Effects Model (LMM) is used for repeated measurement effect analysis.

7.3.3 Secondary Outcome Analysis

1. Continuous outcomes: Blood pressure, heart rate, pulmonary function, body composition, KAP score, psychological scale score, etc., all adopt Linear Mixed Effects Model (LMM).

2. Binary outcomes: Occurrence of heat-related diseases, gastrointestinal diseases, respiratory diseases, skin allergies, accidental injuries, etc., adopt Logistic Generalized Linear Mixed Effects Model (GLMM).

7.3.4 Subgroup Analysis

Stratified by gender, school location and basic health status, subgroup mixed effects model analysis is performed on the primary outcome (WCST executive function total score) to explore the differential characteristics of intervention effects in different populations.

7.3.5 Sensitivity Analysis

The primary outcome is repeatedly modeled using ITT and PP sets respectively to compare result robustness.

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8. Criteria for Participant Completion and Early Study

Termination

8.1 Participant Completion of the Study

Participants who meet inclusion and exclusion criteria, complete all measurements at baseline, intervention follow-up and post-intervention follow-up, and have no major protocol deviations are deemed to have completed the study.

8.2 Participant Discontinuation and Withdrawal Criteria

Participants may terminate the study early for the following reasons:

1. Voluntary withdrawal by participants at any time during the study.

2. Loss to follow-up of participants.

3. Death of participants.

4. If any clinical adverse event, other medical condition or other situation unsuitable for continued participation occurs, the participant will stop receiving further study intervention to protect their best interests.

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9. Protocol Deviations

Researchers will conduct the study in strict accordance with the study protocol, and protocol deviations are not allowed in principle. Any changes, inconsistencies or protocol deviations during the study will be promptly addressed with corrective measures formulated and implemented immediately by the study site.

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10. Ethical Considerations

1. The study has been approved by the Ethics Committee;

2. Participation is completely voluntary with signed informed consent, and withdrawal is allowed at any time without affecting rights and interests;

3. All data are anonymized and strictly confidential;

4. Timely management and reporting of adverse events.

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11. Quality Control

1. Unified personnel training and assessment before onboarding;

2. Unified instrument calibration and standardized operation;

3. Double data entry by two researchers, logical verification and encrypted storage;

4. On-site supervision, regular quality control, and no modification after data locking;

5. Whole-process monitoring and management of adverse events.

References

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Informed Consent Form

Dear Parents/Guardians and Children,

Thank you for your interest in this research project. To protect children's physical health and preserve their cognitive and learning performance under extreme high temperature, the National Institute of Environmental Health, Chinese CDC launches the Study on Intervention Effect of Heat-related Health Risk Early Warning Digital Technology for School-age Children. Funded by UNICEF, the research is implemented by the Department of Climate Change and Health, National Institute of Environmental Health, China CDC. A total of 200 Grade 4 primary school students will be enrolled, with the formal 2.5-month intervention period.

A cluster randomization design will be applied; participating schools are randomly assigned by computer to either the intervention group or control group. Random allocation is entirely computer-generated beyond human control.

If your child's school belongs to the **intervention group**: the child completes questionnaires, physical examinations and regular home/school blood pressure monitoring, and receives tiered heat risk early warnings plus heat protection guidance via WeChat mini-program whenever heat alerts are issued during the intervention period.

If your child's school belongs to the **control group**: the child completes identical questionnaires, physical examinations and blood pressure monitoring only, with no access to the digital heat early warning service.

All participants contribute equally to the study regardless of group assignment.

Five rounds of assessments including one baseline surveys, three interim follow-ups and one endpoint evaluation will be conducted for all enrolled children, detailed as below:

Baseline

1. On-site physical assessments at school: executive function (WCST), blood pressure, cardiopulmonary function, body composition;
2. Questionnaires covering household & child demographics, heat-related KAP, mental health, respiratory symptoms, injuries and disease incidence.

Intervention Period

1. Three rounds of online WCST and three rounds of online mini-program questionnaires covering heat KAP, mental health, respiratory symptoms, injuries and diseases. Children in the intervention group complete extra online surveys

regarding early warning awareness and behavioral changes whenever heat warnings are released.

2. Routine blood pressure monitoring: school teachers supervise measurements on non-holiday days ; parents conduct home monitoring during the holiday. Blood pressure is measured once every 7 days under ordinary weather; daily measurement is required during heatwaves.

Post-intervention Endpoint

1. On-campus physical examinations including executive function, blood pressure, cardiopulmonary function, body composition;
2. Final questionnaires about heat KAP, mental health, respiratory conditions, injuries and illnesses.

Confidentiality Commitment

All personal identifiable information and health data are strictly protected. Names, residential addresses and other private information will be removed from the research database; each child is identified solely by a unique coded ID. All collected data are used exclusively for research on the effectiveness of heat early warning intervention, and never for commercial or other harmful purposes.

Voluntary Participation

Your child's participation is completely voluntary. You have the right to decline enrollment or withdraw from the study at any time without any penalty or negative impact on your child's medical benefits and legitimate rights.

All participating children receive free individualized physical examination reports and an official UNICEF-certified honor certificate upon completion of study assessments.

For any questions regarding this study, please contact project staff: Ban Jie: +86 10-50930137; Du Jie: +86 58900328

We sincerely appreciate your support and cooperation.

Consent Statement

I have fully read and understood all information stated above and agree my child to take part in this research.

Child's Full Name: _____

Relationship between Guardian and Child: _____

Guardian's Contact Phone Number: _____

Guardian's Signature: _____

Date: _____ / _____ / _____ (MM/DD/YYYY)