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An observational, multigenerational platform for health systems and population health interventions to minimise intergenerational transmission of non-communicable diseases in India: the YUVAAN cohort study protocol

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ABSTRACT

Introduction Non-communicable diseases (NCDs) pose a significant health burden in India, with preventable risk factors contributing to their prevalence. In rural populations, inequalities may be reinforced by health risks passed down through generations. Taking a life course perspective, this multigenerational cohort study aims to investigate behavioural, socioecological, and socioeconomic determinants of growth and NCD risk, as well as healthcare access and utilisation among preadolescents and their parents.

Methods and analysis The study is being implemented by the Hirabai Cowasji Jehangir Medical Research Institute (HCJMRI) using a prospective, multigenerational cohort design to investigate NCD risk over 15 years. Data are being collected from 14 villages around Pune, Maharashtra, India. The target population is asymptomatic (ie, healthy) children aged 8–10 years and their parents. The study commenced on 13 September 2022. Participants (children and their parents) are being enrolled through household visits, and by arranging subsequent visits to the primary health facility of HCJMRI. After obtaining informed consent from participants (parents and their children), comprehensive data are being collected from both children and parents, including clinical, behavioural, healthcare access and utilisation, as well as socioeconomic determinants of health. Clinical assessments include anthropometric measurements, blood samples for a wide range of NCD indicators, bone health and muscle function. The long-term data analysis plan includes longitudinal modelling, time-series analyses, structural equation modelling, multilevel modelling and sex-based analyses to investigate growth trajectories and intergenerational patterns of health risks. As of November 2024, 1070 families from 14 villages have been enrolled (1264 preadolescents and 2140 parents). Given the double

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Previous studies have shown an increasing prevalence of non-communicable diseases (NCDs) such as obesity and diabetes in rural areas of India, traditionally seen more in urban populations. There is evidence of a transition towards unhealthy behaviours and diet due to urbanisation influences, with rural communities experiencing higher vulnerability due to low socioeconomic status and limited healthcare access.

WHAT THIS STUDY ADDS

⇒ The YoUng adolescents' behaViour, musculoskeletAl heAlth, growth & Nutrition (YUVAAN) Cohort Study is unique in its multigenerational approach, focusing on understanding and mitigating intergenerational health risks. It integrates a comprehensive collection of socioecological, dietary, and behavioural data from preadolescents and their parents, expanding to future generations. This approach provides insights into the determinants of health and the dynamics of NCD risk transmission in rural India.

burden of malnutrition, with undernutrition and overweight/obesity coexisting among children and parents in India, the study findings will contribute to the development of focused interventions aimed at lowering NCDs, addressing the generational transmission of health risks, and improving health outcomes for rural communities.

Ethics and dissemination Ethics approval was obtained from the institutional ethics committee, Ethics Committee Jehangir Clinical Development Centre, No: JCDC/BHR/24/047.

Trial registration number NCT05603793.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings from the YUVAAN Cohort Study will inform targeted interventions aimed at breaking the cycle of NCDs within families and communities. The study's holistic and longitudinal design will contribute to the development of tailored public health strategies and policies that address the specific health needs of rural populations, ultimately improving health outcomes and reducing health disparities.

INTRODUCTION

Non-communicable diseases (NCDs) burden global health immensely; most research focuses on treatment techniques rather than prevention.[1] According to the WHO, NCDs are responsible for approximately 71% of all global deaths, which is equivalent to around 41 million people per year.[2] Among the complex factors that influence NCD risk,[3] early life exposures, parental health, and social circumstances can predispose an individual to a cycle of intergenerational transmission of health risks.[4–6]

Adolescence is an important phase during which many NCD risk factors are developed. Recent research elucidates how investment in the adolescent period offers a critical window of opportunity to break the intergenerational cycle of NCD.[7] In understanding and potentially preventing intergenerational transmission of health risks, it is critical to take a life course perspective,[8] with a particular emphasis on the vital phases of growth and development in children.[9–11]

Moreover, given the parental influence on shaping both pubertal growth spurt as well as NCD-related health behaviours,[12 13] a multigenerational approach that is intersectoral, integrated and comprehensive is necessary for maximising growth and minimising NCD risks, especially in the global south.[14 15] Health inequities continue to drive intergenerational transmission of health risks due to pervasive economic, political, and social inequities.[16 17]

However, while taking a multigenerational approach to address health inequities and enhance health outcomes, it is crucial to understand how socioecological determinants of health influence children's health, especially in countries like India, where children face significant challenges in early years due to malnutrition and food insecurity[18–22]—a health inequity, which can widen due to impact of climate change on food security.[23 24]

More importantly, intergenerational transmission of NCD risks needs to be mitigated through the development and implementation of health systems and population health interventions during critical phases of childhood.[12 25] Yet, there is little longitudinal evidence in the mitigation of intergenerational transmission of NCD risk, particularly among communities in rural areas in countries such as India. Further, adolescence is a critical period for personal growth and development, and social and behavioural change communication (SBCC) during adolescence may assist in creating lifetime behaviour patterns, such as good nutrition and physical exercise choices.[26]

To address these gaps, the YUVAAN (YoUng adolescents' behaViour, musculoskeletAl heAlth, growth & Nutrition) multigenerational platform was conceptualised to understand and influence trajectories of growth and NCD risks among rural preadolescents (8–10 year old children) and their parents over a period of 15 years. YUVAAN's overall goal is to not only capture the broad range of socioeconomic and socioecological determinants of health across generations, but also to understand healthcare access and utilisation among a rural cohort—evidence that currently does not exist in India.

Investing in adolescent health and well-being pays off in three ways: during their adolescence, in adulthood, and for future generations. Therefore, to achieve this, the cohort study aims to (1) understand trajectories of growth among rural preadolescents (aged 8–10 years) and their parents over a period of 15 years, (2) investigate intergenerational patterns of NCD health risks and growth (including muscle and bone health) among preadolescents including the health of their parents and future offspring in rural areas, (3) identify and address socioeconomic and socioecological determinants of health (ie, climate change impacts, sociocultural factors) associated with growth trajectories and intergenerational NCD risk and (4) strengthen community-based, SBCC strategies as part of tailored interventions that improve the nutritional and health status of preadolescents and their parents.

MATERIALS AND ANALYSIS

Study design and setting

YUVAAN is a longitudinal, prospective, multigenerational, interventional cohort study set in the rural areas (as defined by the Census of India) of the Pune district within the Western Indian state of Maharashtra.[27] A total of 22 villages (as defined by the Census of India) were screened between January and June 2022, with 14 meeting the inclusion criteria described in figure 1.[28] The prescreening of villages was conducted in March 2022, followed by a pilot study in April 2022. Primary enrolment began on 13 September 2022 and is expected to conclude by 21 December 2024. The overall study is projected to end in 2039.

The villages chosen are located on either side of the National Highway, NH 753F, which passes through Ranjangaon, the location of the Hirabai Cowasji Jehangir Medical Research Institute's rural centre—the central hub for evaluation and implementation (figure 2) of YUVAAN. This geographical layout provides a unique opportunity to compare subcohorts within the rural setting, such as villages closer to the highway versus those further away, or
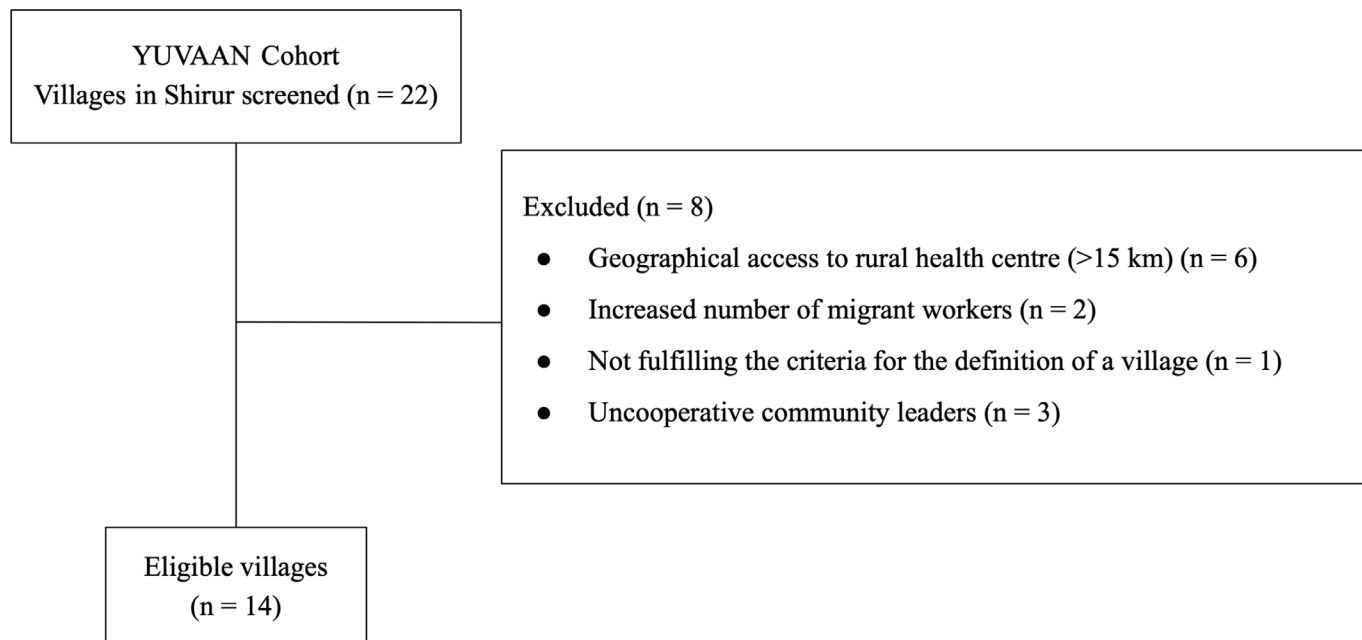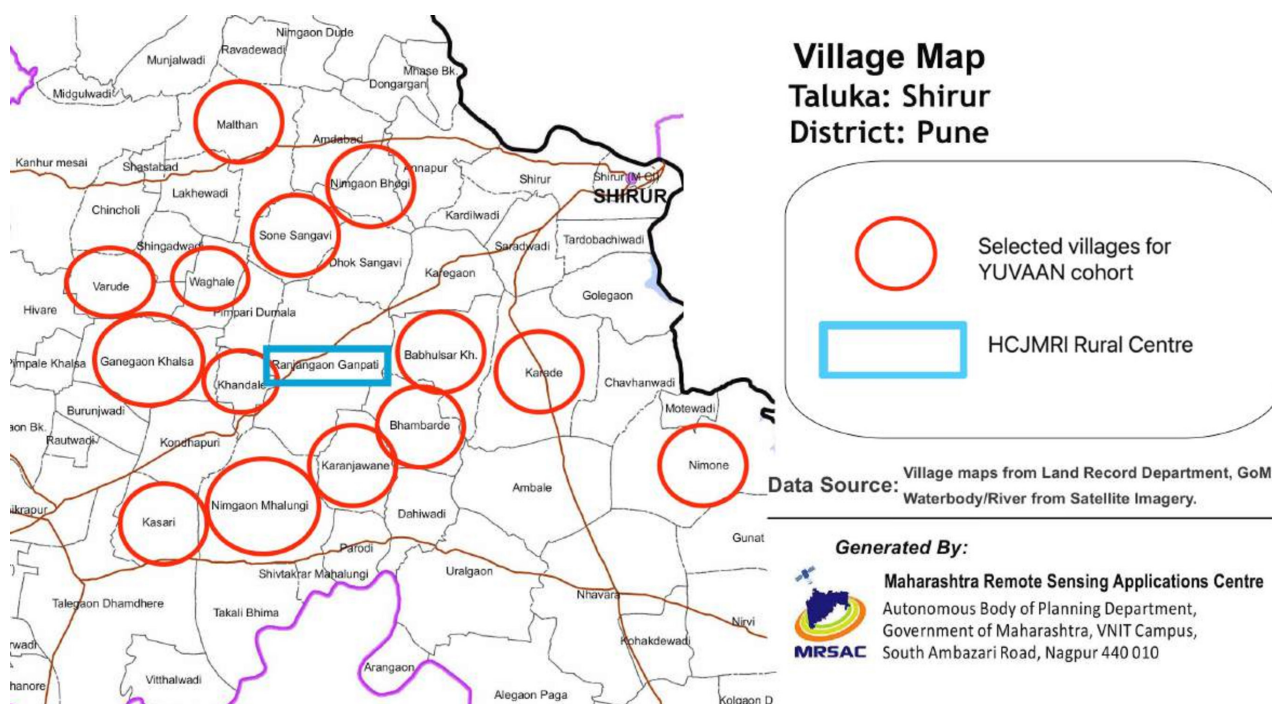
Figure 1 Village selection. YUVAAN, YoUng adolescents' behaViour, musculoskeletAl heAlth, growth & Nutrition. A total of 8 villages were excluded; however, some villages met multiple exclusion criteria, so the sum of villages across individual exclusion criteria exceeds 8.

comparisons between villages with nationally defined boundaries. These analyses could help us explore potential variations in health behaviours, access to healthcare and other socioenvironmental factors across different rural subgroups. While this is not part of the current study design, these comparisons could be a valuable extension of our research in the future. The centre has expertise in growth, nutrition,

paediatric endocrinology and musculoskeletal health, a multidisciplinary team including paediatricians, paediatric endocrinologists, nutritionists, community social workers and psychologists, and houses relevant infrastructure for assessment of participants.[29]

The 14 selected villages have an average population of 2271±646 people. Before enrolling households in the villages into the study, our team of field workers

Figure 2 Map of the included villages. HCJMRI, Hirabai Cowasji Jehangir Medical Research Institute's; YUVAAN, YoUng adolescents' behaViour, musculoskeletAl heAlth, growth & Nutrition.

visited each village to interview the administrative head (Sarpanch) and obtain demographic details about the village.

The interview collected information on village population, primary employment sector, number of families residing in the village, per cent of migrant population, preferred healthcare choice for medical problems, accessibility of the primary health centre (PHC), and designated points of contact for health-related matters.

Both practical and research-oriented considerations guided the selection of villages for this study. We aimed to choose villages at least 5 km from Ranjangaon to ensure a sample of rural populations with minimal influence from urbanisation. We intentionally avoided selecting villages that were too far (>15 km), as this would have posed challenges to project feasibility, including transportation logistics and time constraints.

In addition to geographical considerations, the cooperation of village authorities and the willingness of villagers to participate played a crucial role in our selection. We also prioritised villages with a sufficient population size to ensure a meaningful sample for the study.

Regarding the generalisability of our findings, the selected villages exhibit characteristics common to many rural areas in India. For example, access to healthcare services varies significantly depending on the proximity to urban centres. In our study, villages closer to Ranjangaon benefited from better infrastructure and more accessible healthcare options such as PHCs and private clinics, while those further away faced some barriers, like limited healthcare access, transport and infrastructure challenges. These findings align with the broader trends seen in rural India, where healthcare access and infrastructure are often less developed than in urban areas, especially in remote regions.

Additionally, the primary occupation of most villagers in our study area is agriculture, which is typical of many rural regions in India. However, the availability of other livelihood opportunities, such as non-agricultural work or local businesses, can vary depending on the region's proximity to urban centres and industrial zones. This occupational pattern is consistent with rural India, where farming remains the dominant livelihood but often coexists with other forms of employment, particularly in more accessible or economically diverse areas.

Study participants

The primary study units are households comprising preadolescent boys and girls aged 8–10 years and their parents (figure 3).

Inclusion criteria: Participants are considered eligible if they are apparently healthy (ie, asymptomatic) preadolescents, aged between 8 and 10 years, during the period of enrolment; have both apparently healthy biological parents (mother and father) present during the period of enrolment; have parents in the average range of adult height with reference to national representative sample (Indian men: 177±2 SD cm; Indian women: 162±2 SD cm).[28]

Exclusion criteria: Participants are excluded if they have any chronic untreated/progressive condition that would adversely affect the growth, bone and/or muscle health of the children; are migrant families or temporary residents as defined by the Census of India[29]; or if consent is refused.

The eligibility criteria for this study are designed to focus on households with relatively healthy participants to understand the impact of modifiable behaviours on NCD risk. By focusing on 'apparently healthy' preadolescents and their parents, defined as asymptomatic and without untreated or progressive conditions, we aim to reduce confounding variables that could obscure the impact of lifestyle, sociodemographic, and environmental factors on health outcomes. The criterion of parental height within the average range, based on national standards, further ensures that families without significant developmental or health issues are included.

The primary reason for excluding migrant families from the study is due to their mobility and temporary residence status which complicates consistent data collection and follow-up, especially in longitudinal studies. Frequent relocations and exposure to diverse environmental, economic, and healthcare contexts introduce variability that may act as confounding factors, potentially impacting health outcomes and behaviours differently from non-migrant families.

We have enrolled 1264 adolescents, of whom 21 (1.66%) have been excluded due to chronic conditions (as of November 2024), migrant family status, or lack of interest in participation. This exclusion is necessary to maintain internal validity and focus on households with stable health baselines, ensuring accurate assessment of modifiable behaviours. While approximately 2% of potential participants (in future) may be excluded due to these criteria, this ensures that the study provides a clear baseline, avoiding interference from existing health challenges. Although this limits insights into high-risk populations, the findings from this initial cohort will serve as a foundation for future studies targeting families with existing health conditions, allowing for deeper exploration of the impact of lifestyle and environmental factors on NCD risk in vulnerable groups.

Regarding healthcare utilisation, we acknowledge that children with symptomatic conditions and those facing access barriers are critical subgroups, but the majority of rural children use healthcare services intermittently for preventive care or minor illnesses. This study population reflects the typical healthcare users in rural settings, allowing us to analyse patterns of healthcare utilisation in the majority demographic.

Additionally, by studying relatively healthy cohorts, we can identify early signs of emerging health risks and potential issues, providing an opportunity for preventive interventions. This aligns with our objective of assessing modifiable behaviours and socio-demographic
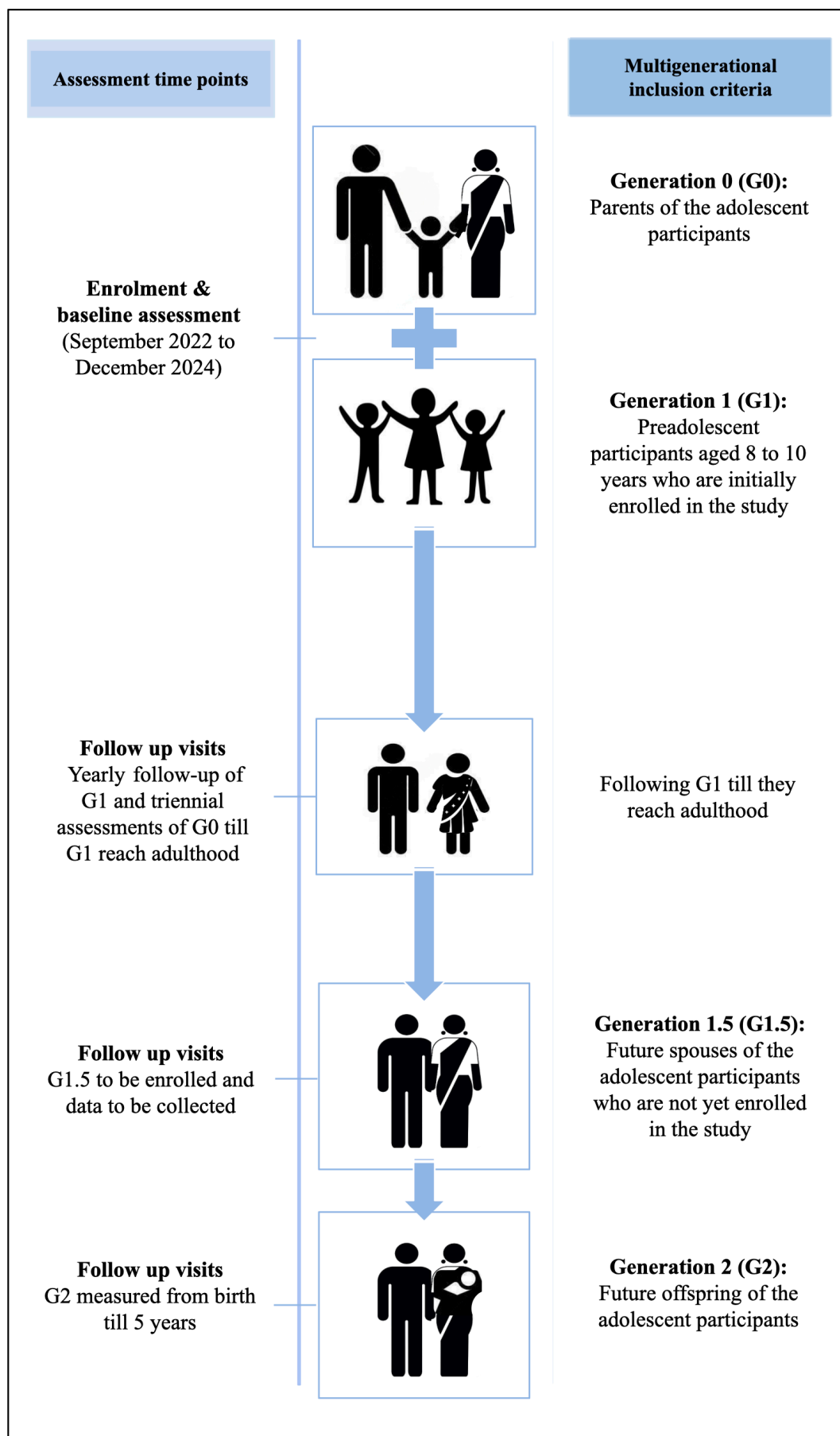
Figure 3 The flow of assessments targeting the multigenerational cohort.

influences, which is crucial for informing sustainable health interventions in rural settings.

Recruitment process and informed consent

The general procedure for recruitment is as follows: after obtaining permission from the local education and health administration, a list of prospective preadolescents is collected from each village head's office. School health visits are then conducted to screen children and parents of prospective participants are approached to determine their interest in the study. Figure 3 shows the comprehensive plan of current and future enrolment across generations.

Written informed consent is being obtained from adults and written informed assent from children. Consent for a child's participation in this study is being obtained from the parent. Yet, this study prioritises the child's autonomy and children have the right to decline participation in any aspect of data collection, including procedures that may cause discomfort or distress, such as blood sampling. This approach has been clearly communicated to child participants and their families, ensuring that participation remains entirely voluntary, and that no child is compelled to undergo procedures they are uncomfortable with.

Sample size

For sample size determination, the growth trajectory of preadolescents was prioritised to capture changes over time and reference data on height-for-age was used from the Indian population.[30] The software package G*Power V.3.1.9.7 was used to calculate the sample size.[31] Cohen's D effect size was found to be d=0.01 with an SD of 4 cm in the heights of males (mean=153 cm) and females (mean=148 cm). With a 20% expected drop-out rate, a total sample size of 1300 was calculated at a 95% significance level and 80% power with a small effect size of f=0.02.

Based on previous literature, this sample size not only supports the study's primary objectives, but also provides sufficient power to evaluate the effectiveness of future SBCC strategies to influence health behaviours and reduce NCD risk factors.[32]

Data collection and analysis plan

Data are being collected using paper-based questionnaires, which are completed by a team of research assistants and healthcare workers who undergo regular training to ensure consistency and reliability. These staff administer the data collection forms and are closely monitored by a research assistant to maintain data quality and protocol adherence. The data collection forms are collected on a weekly basis and sent back to the main centre for review.

As shown in figure 4, longitudinal data for the YUVAAN study is being collected on physical health, behavioural health, healthcare access, and socioeconomic factors on an ongoing basis. A detailed timeline of data collection

and assessments is presented in online supplemental material table 6-8.

Physical health

The following measures will be collected from preadolescents and parents.

Anthropometry (objectives 1 and 2)

This includes measurement of height and sitting height (Seca 213 Portable Stadiometer; Seca, Hamburg, Germany), weight (Tanita Body Composition Analyzer, MC-780 MA; Tanita Corporation of America, Arlington Heights, Illinois), waist circumference (for parents and children) and mid-upper arm circumference (MUAC) (for children) (stretch-resistant Seca 201 tape). Height for age, weight for age, and body mass index (BMI) for age (BAZ) Z-scores for children are being computed using ethnic-specific growth references.[33] Categorisation of primary participants into normal weight, thin, or obese is also being done based on MUAC.[34]

Biochemical and clinical parameters (objectives 1 and 2)

The following biochemical and clinical parameters are being assessed:

1. For preadolescents:

a. **Serum 25OHD** by the ELISA technique using standard kits (DLD Diagnostika (Hamburg, Germany); intra-assay coefficient of variation (CV): 5%; interassay CV: 7.8%),

b. **Serum parathyroid hormone PTH)** by the ELISA technique using standard kits [Biomerica (Irvine, California); sensitivity: 0.17 pmol/L; interassay CV: <4%; intra-assay CV: 3%–6%),

c. **Serum luteinising hormone (LH)** by the Chemiluminescent Microparticle Immunoassay method using the ARCHITECT LH Reagent Kit (6C25), and

d. **Indicators of bone metabolism and growth modulators** such as serum calcium, phosphate, alkaline phosphatase on the Selectra Pro S Automatic Biochemistry Analyzer using the QLine BioTech (India) Rapid Test Kit.

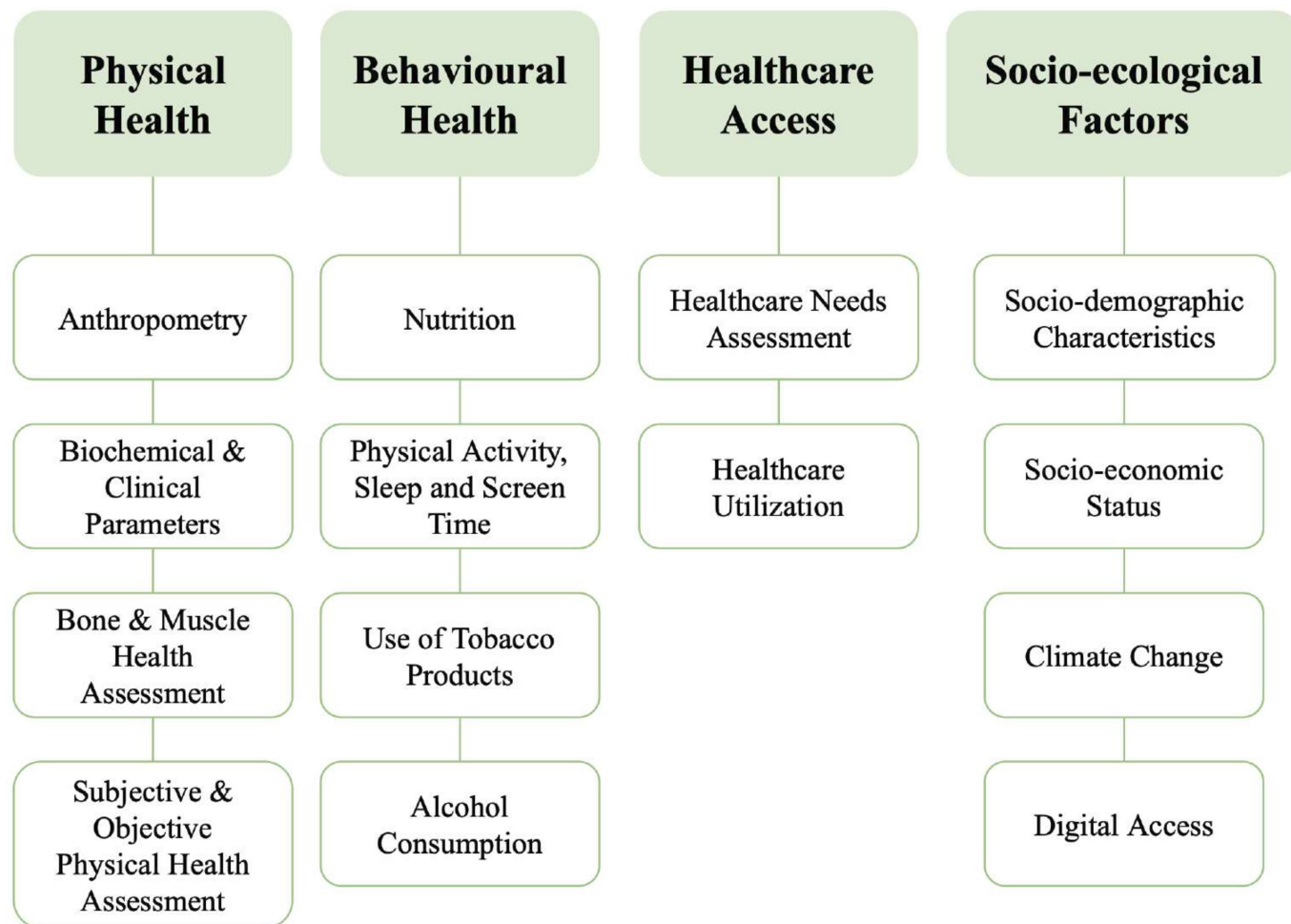2. For Parents:

a. **Fasting blood sugar** by a glucometer and

b. **Lipid profile** on the Selectra Pro S Automatic Biochemistry Analyzer using the QLine BioTech (India) Rapid Test Kit.

3. For preadolescents and parents:

a. **Haemoglobin concentrations** on the Horiba Yumizen H500 by spectrophotometry.

Subjective and objective physical health assessment

Medical history including history of fractures, surgeries, and medical conditions and consumption of or allergies to any medications or supplements are being gathered using clinician-administered surveys to address study objectives 1, 2, 3, and 4. Reproductive history, including menstrual history for the primary participant and her mother, and obstetric history for the mother, is being collected using a questionnaire (objectives 2 and 4).[35 36]

Figure 4 Data collection variables.

Bone and muscle health assessment

Physical fitness parameters reflecting muscular strength, power, and force are assessed for parents and children using the Leonardo Mechanograph Ground Reaction Force Plate (Novotec Medical, Pforzheim, Germany) (objectives 1 and 2). Body composition, whole-body and volumetric bone mineral density, and bone mineral content are measured for parents and children using the dual-energy X-ray absorptiometry (GE Lunar iDXA (Wisconsin, Maryland, USA)) (Software encore V.16) and the Stratec XCT 2000 peripheral quantitative computed tomography (pQCT) equipment (Stratec, Pforzheim, Germany) (objectives 1 and 2).

Behavioural health

The following measures are being collected from preadolescents and parents.

Nutrition

Dietary data are being collected by 24-hour dietary recall, multiple pass method over 2 days (1 weekday+1 weekend day). Trends in dietary patterns, food security, and the influence of climate change (parents and children) will be noted[37] (objective 3).

Physical activity, sleep and screen time

Information collected about physical activity comprises activities listed in the questionnaire that are participant-specific; that is, occupational activities have been listed for adults and more play-related activities have been listed for children. Additional activities (if the participant engages) in them are classified as light, moderate or vigorous based on the Metabolic Equivalent of Task scores.[38] Data related to the time spent performing the activity, including sleep and time spent watching screens (television/mobile screen) during a weekday and a weekend day (Saturday or Sunday), are also being collected (objectives 1 and 2).[39]

Use of tobacco products

Information is being gathered on the use of tobacco products including smoking habits (frequency and quantity of cigarettes or other tobacco products consumed) and the use of smokeless tobacco products, such as chewing tobacco or mishri (roasted tobacco leaves) (objectives 2 and 4).[40]

Alcohol consumption

Data on alcohol consumption are being collected to assess the drinking habits of the participants (objectives 2 and 4).[41]

Healthcare access

The following data will be collected from preadolescents and parents.

Healthcare needs assessment

Includes an evaluation of the participant's health status by conducting a physical examination. This involves assessing various aspects of their physical well-being by conducting a clinical examination and assessing vital signs and medical history (objectives 1, 2 and 3).

Healthcare utilisation

Information (objective 4) includes tracking referrals made to healthcare professionals. The study staff follows up with participants to inquire about their utilisation of these referrals, including whether they sought the recommended healthcare services, took prescribed medications, and attended follow-up appointments. The objective of collecting these data is to assess the participants' healthcare-seeking behaviours, adherence to medical recommendations,and the effectiveness of the referral system in meeting their healthcare needs.

Socioecological factors

These data are being collected from the parents.

Sociodemographic characteristics

The education level and occupation details of the adults and the education level of the primary participant are collected using a questionnaire.

Socioeconomic status (objective 3)

Socioeconomic status (SES) is being assessed using the BG Prasad Scale[42]; data on number of members in the household and the total monthly family income are collected. We compute the per capita monthly income by dividing the total monthly family income by the total number of members residing in that household. Based on the per capita income of the family, the BG Prasad scale classifies the SES of rural families into the following categories: upper class, upper middle class, middle class, lower middle class, and lower class. To update the BG Prasad Scale for the year 2022, we incorporated the latest Consumer Price Index (CPI) for Industrial Workers obtained from the Labour Bureau's website.[42] The most recent CPI, dated January 2022, was recorded as 125.1.[42]

Climate change

The impact of climate change on health behaviours and risk factors is being evaluated using both qualitative and quantitative approaches (objectives 2 and 3). We will connect data on seasonal weather events and variations to dietary habits (ie, impact of extreme heat or floods or droughts on crop yields or types of seasonal food consumed) with health outcomes (ie, changes in physical activity levels or stress). Focus group discussions are underway to understand the perspectives of residents on the impact of climate change on health and livelihood. Qualitative assessment of stress and mental health has been planned to gain insights into participants' experiences and coping mechanisms especially during or following climate-related events.

The collected stress and mental health data will then be linked to the impacts of climate change on health behaviours, such as dietary adjustments related to food availability and reduced physical activity caused by environmental constraints. This linkage will allow the study to examine the connection between climate events, mental health, and changes in health-related behaviours, offering a deeper understanding of how climate change influences overall health.

Digital connectivity and access

Data collected include participants' accessibility to and availability of mobile devices and active internet plans which may impact their health-related knowledge, behaviours, and management (objectives 3 and 4).

SBCC interventions

The YUVAAN platform's longitudinal framework provides a unique opportunity to design and implement a wide range of interventions aimed at fostering SBCC. While the full scope of interventions will be determined after analysis of baseline data, our initial work in this area has identified several critical target areas such as:

- ▶ Promoting balanced diets with locally available nutrient-rich foods.
- ▶ Encouraging physical activity and reducing sedentary behaviour.
- ▶ Improving awareness and utilisation of healthcare services.
- ▶ Mitigating climate change impacts on health.

Additionally, the interventions will focus on addressing the risks of tobacco and alcohol use and will include strategies tailored to gender-specific health needs. A participatory research approach involving active engagement with communities will be employed to ensure these interventions are comprehensive, culturally relevant, and sustainable. This approach will involve active engagement with stakeholders and communities, facilitating iterative development and adaptation of interventions to meet the diverse needs of the population effectively.

Future work will include the development of detailed protocols to guide the design, implementation, and evaluation of these interventions, ensuring rigour and alignment with the overarching goals of the YUVAAN platform.

Incentives for study participation

To encourage participation and as a gesture of appreciation for participants' time and contributions, appropriate incentives (compensation for hourly wage lost and

healthy snacks) are given to the families. At enrolment, each family is given a 'Hygiene Kit' comprising toothbrushes, toothpaste, bathing soap, detergent soap bar, and hair oil. We also hope to plan incentives to correspond with seasons/events (eg, caps during summer).

Data management
Data quality control
Once the filled-out data collection forms arrive at the main centre, they are first checked by research assistants to ensure completeness and accuracy. Any discrepancies identified during this process are resolved by cross-checking the data with the research assistant and healthcare workers or directly with the families involved. This step is critical to maintaining the integrity of the data and addressing any potential errors in real-time.

Data entry and verification
After the initial verification, the data are entered into a secure database by a trained data entry operator. Following this, the entered data undergo a second verification process by a research officer, who cross-checks the data on the desktop system to ensure that no errors are introduced during the data entry process. This two-step process helps to minimise any potential issues with data accuracy and consistency.

Confidentiality and data storage
All data are pseudonymised, with personal details known only to the field team, who receive regular training on maintaining confidentiality. Access to the data is strictly controlled by the principal investigator, supported by the data manager.

Completed, paper-based questionnaires are securely stored in locked cupboards, while electronic copies are saved on a password-protected computer and a secure cloud server. These digital copies will be stored for a decade.

To manage data sharing responsibly, a formal process for handling data requests has been set up. This includes the submission of a request form, ethical review to ensure the appropriate use of data, and the signing of a data-sharing agreement to protect participant confidentiality and ensure proper acknowledgement of the data source. The data manager, under the supervision of the principal investigator, will oversee data access and sharing. We also plan to allocate resources for an additional research assistant or data coordinator to facilitate and monitor data usage as the study progresses and external interest increases.

Analysis plan
1. **Outputs:**

   The study aims to produce the following key outputs:
   ► Identification of behavioural, socioecological, and socioeconomic determinants of NCD risk in rural populations.
   ► Insights into intergenerational health risks and the transmission of malnutrition and NCDs.
   ► Trends in healthcare access and utilisation across generations.
   ► Policy-relevant findings to improve health outcomes in rural settings, with a focus on addressing both undernutrition and overweight/obesity.
2. **Methodological details:**

   To achieve these objectives, we will employ the following analytical techniques:
   ► Longitudinal modelling: To track the progression of NCD risk factors over time, adjusting for variables such as age, sex, and SES.
   ► Time-series analyses: To identify seasonal or event-driven patterns in health behaviours, such as dietary changes and variations in physical activity linked to weather events or crop cycles.
   ► Structural equation modelling: To explore relationships between socioeconomic factors, healthcare access, and health outcomes, allowing us to test hypothesised models of intergenerational health risks.
   ► Multilevel modelling: To account for the hierarchical structure of the data (eg, children nested within families, families nested within villages) and identify both village-level and family-level factors influencing NCD risk.
   ► Sex-based and gender-based analyses: To examine gender-specific differences in health outcomes and risk factors, which can inform targeted interventions.
3. **Data use and dissemination:**

   Findings will be shared through peer-reviewed journal publications, national and international conference presentations, and reports provided to local healthcare providers and policy-makers. These results will guide the development of specific health interventions to reduce generational transmission of NCD risks and address disparities in healthcare access.

DISCUSSION
The YUVAAN Cohort takes an innovative approach to tracking and addressing multigenerational health behaviours and outcomes among preadolescents and their parents in India. Taking a life course perspective, this is the only study to date which will enable understanding of the complex socioecological determinants of health that influence growth trajectories and intergenerational NCD risk among rural communities—many of which experience greater vulnerability to low SES, varied healthcare access and increasingly, the brunt of adverse climate change impacts.[43] As India contributes a significant proportion of the global workforce,[44] the burden of NCDs will impact the health, social and economic well-being of society at home and abroad, thus requiring dedicated focus, particularly among the rural populations.

As of 30 November 2024, 1070 families have been successfully enrolled in the YUVAAN Cohort, comprising 1264 preadolescents and 2140 parents. In the future, data will be collected from future spouses and children of

the enrolled preadolescents, thereby expanding the data collection to three generations. This holistic approach allows for a comprehensive understanding of intergenerational health risks, as well as the potential to break the cycle of NCDs within families and communities.

Studies from India and other low-income and middle-income countries like Brazil and Mexico have demonstrated the increased prevalence of obesity in rural areas and lower to middle socioeconomic groups, the coexistence of different forms of malnutrition within populations, and the shifting NCD patterns from urban to rural burden.[45–49] Studies have also highlighted urbanisation-induced characteristics in the food environments and transitioning to more sedentary and unhealthy behaviours among rural areas as significant promoters of obesity, diabetes, and other cardiometabolic diseases.[50]

The YUVAAN cohort study will collect dietary data to understand how the consumption of culturally-specific and processed foods (ie, bread, puff pastries called 'khari') impact diet quality, the increasing threat of obesity, and other NCDs.[45 51] Moreover, yearly data collected on physical activity, sedentary behaviour, and screen time will offer valuable insights into changes in these behaviours and how this influences NCD risk. The data will also make it possible to track indicators of active living, such as active transport. Evidence has encouragingly shown an increasing trend of active transport from the 2016 to 2022 India Report Cards,[52] which has been reported to be higher among children and adolescents in rural areas. Thus, the YUVAAN cohort will enable the examination of the influence of socioecological factors such as climate change and urbanisation on these behaviours over time.

In terms of the overall approach and focus of implementation, where previous studies have primarily focused on documenting the prevalence of NCDs[52–54] the YUVAAN Cohort study takes a more holistic approach by studying growth trajectories to break patterns of intergenerational transmission of health risks. This approach involves a shift from participant observation to interventions where possible—an ethical approach in global health to provide communities with necessary healthcare and support.[55] Moreover, this comprehensive approach will allow for a deeper understanding of the complex dynamics involved in developing and preventing NCDs across generations, particularly among rural populations.

It is also important to note that this study is taking place during the age of climate emergency.[50] In addition to the cumulative risk factors that rural families face for NCDs, climate change-related events—including increasingly frequent and severe heat waves, droughts, and extreme storms—further burden NCD prevention and management. Thus, it is critical to take a life course perspective in this work and a systems thinking lens that captures the complexity of socioecological determinants of health.[56] As a result, the YUVAAN cohort study will explore the impacts of climate change on NCD risk and work to integrate advanced digital epidemiological approaches to improve data collection processes for both objective climate-related data as well as health behavioural data.[57–59]

Systems thinking takes a non-linear perspective on disease pathways and provides a framework for understanding reciprocal relationships and interactions between variables within systems (eg, food access—food production within food systems) and across systems (eg, between food access and nutrition across health and food systems).[56] This approach is inherently symbiotic not only with the complexity of NCD risks, but also critical in understanding and addressing interdependent risks of NCDs in the age of climate emergency. Global population health crises in the 21st century are extremely complex, with links to economic disasters,[60–62] warfare,[63] and climate change.[57 62] Nevertheless, the digital age offers new opportunities and challenges to tackle these global crises.[64 65] For instance, digital tools and technologies are increasingly being used to not only address urgent humanitarian crises,[65] but also to facilitate citizen participation, health system and population health interventions, and knowledge transfer.[66–68] Given that addressing the intergenerational transmission of health inequities is one of the primary goals of the YUVAAN study, there is a role for digital tools and technologies in contributing to the reduction of health disparities, where citizen-owned digital tools can be used to amplify their voices.[69 70]

As identified during enrolment, the vast majority of YUVAAN study participants own smartphones, which corroborates existing evidence on the penetration of these ubiquitous tools in India.[70] Thus, we intend to ethically leverage citizen-owned smartphones to improve not only our longitudinal data collection and compliance but also the implementation and evaluation of potential interventions. This approach can aid in minimising loss to follow-up in longitudinal cohorts,[71] improve adherence to interventions,[72] and perhaps more importantly, enable real-time support to the most vulnerable populations.[66 73]

In the future, we will use SBCC interventions to leverage the comprehensive data collected through the YUVAAN Cohort study. By identifying specific behavioural and socioecological determinants of health within these rural communities, we will design targeted SBCC strategies to promote healthy behaviours and mitigate NCD risks. Previous studies have highlighted the effectiveness of SBCC in improving health outcomes by addressing cultural and social norms, increasing awareness and changing behaviours.[74 75] Additionally, using digital tools and platforms will enable real-time engagement and support, enhancing the effectiveness of SBCC initiatives. This approach aligns with evidence suggesting that digital interventions can significantly improve health behaviours and outcomes[68 69] and also emphasises the significant impact health communication campaigns can have on behaviour change. Through these interventions, we aim to break the cycle of NCDs and improve overall health outcomes in rural India. The YUVAAN study

provides a robust platform for implementing and evaluating these interventions, ensuring they are evidence-based and context-specific.

There are several key strengths of the YUVAAN cohort study. First, the dynamic expertise of the team and the diversity of data collected will enable targeted interventions in the future (ie, randomised clinical trials, natural experiments, and smartphone-based digital health interventions) tailored to the specific health needs and concerns of rural populations. Second, this study is being conducted through an Indo-Canadian partnership, which involves combining interdisciplinary expertise in population health, health systems, healthcare, digital epidemiology, and community-based participatory research. This partnership focuses on equity in collaboration and capacity strengthening over time, which is critical for research being conducted with vulnerable populations in the global south.[74]

However, given the longitudinal nature of this cohort study, we anticipate numerous challenges including compliance and retention across generations, and continuous communication with multiple villages as the study advances. These challenges highlight the need for sustained community relationships and a shift to digital data collection to enable remote communication and accessibility for long-term study participation. There are also potential limitations with several of the measures used. For example, while BMI will be computed it does not capture abdominal adiposity which is considered to be riskier for specific NCDs.[75] However, the use of several clinical measures and objective data collection tools for growth, body composition, bone density, muscle strength and function, and biochemical parameters will minimise reliance on single variables to determine health behaviours and associated risks. Also, the use of the 24-hour dietary recall method and physical activity questionnaire may lead to inaccuracies in the information collected. So, we are collecting dietary data over two non-consecutive days using the multiple-pass method and food models to aid in accurate recall and minimise bias, and are using a validated questionnaire for physical activity data collection.

In conclusion, the YUVAAN cohort study will contribute significantly to the progress in investigating and understanding intergenerational transmission patterns of NCDs in rural India. The innovative study design, multigenerational life-course perspective, and socioecological approach will enhance our understanding of NCD prevalence, prevention, and the impact of various factors on health outcomes. The findings of this study will have implications for public health, including expanding our understanding of complex health systems and associated interventions and policies, which will be necessary to address the specific health needs and concerns of rural populations. By breaking the cycle of NCDs within families and communities, the study aims to improve the overall health and well-being of rural communities in India and contribute to global efforts in combating NCDs.

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Competing interests None declared.

Patient and public involvement Patients and the public were first involved in the research during the initial planning stages in early 2022. Community meetings were held in the 14 target villages around Pune, Maharashtra, where researchers from the Hirabai Cowasji Jehangir Medical Research Institute (HCJMRI) engaged with local leaders, healthcare workers and residents to discuss the study's objectives and relevance to their community. Feedback from these sessions was integral to shaping the study's focus and design. The research questions were developed through a series of discussions and interviews with community members, including parents, teachers, and healthcare providers. These interactions highlighted the community's concerns about the increasing prevalence of non-communicable diseases (NCDs) and the need to understand intergenerational health risks. Priorities such as healthcare access and the need for preventive measures were emphasised, shaping the final research questions to address these areas. Patients and public members were actively involved in the design and conduct of the study. During the design phase, community advisory boards were established in each village to provide ongoing input on study protocols, ensuring cultural sensitivity and appropriateness. These boards helped refine the data collection methods, making them more community-friendly. During the conduct of the study, local health workers were trained and employed to assist with household visits and data collection, fostering trust and improving participation rates. The choice of outcome measures was influenced by community consultations and feedback. Measures such as anthropometric assessments and blood samples for NCD indicators were selected based on their relevance to the community's health concerns. The public expressed a particular interest in understanding the effects of behavioural factors on health, which guided the inclusion of behavioural assessments. Recruitment strategies were developed with input from the community advisory boards and local leaders, ensuring they were culturally

appropriate and effective. Strategies included information sessions at schools and health facilities, as well as personal invitations during household visits. Community members also played a vital role in spreading information about the study through word-of-mouth and social networks, significantly enhancing recruitment efforts.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and ethics approval was obtained from the institutional ethics committee, Ethics Committee Jehangir Clinical Development Centre, No: JCDC/BHR/24/047. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. The data generated and analysed during the YUVAAN cohort study will be available on reasonable request. Interested researchers must submit a formal request form, which will undergo ethical review to ensure appropriate use of data. A data-sharing agreement must be signed to protect participant confidentiality and ensure proper acknowledgement of the data source.

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