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NOTES FROM THE FIELD

The Preconception Stress and Resiliency Pathways Model: A Multi-Level Framework on Maternal, Paternal, and Child Health Disparities Derived by Community-Based Participatory Research

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Abstract Emerging evidence supports the theoretical and clinical importance of the preconception period in influencing pregnancy outcomes and child health. Collectively, this evidence affirms the need for a novel, integrative theoretical framework to design future investigations, integrate new findings, and identify promising, evidence-informed interventions to improve intergenerational health and reduce disparities. This article presents a transdisciplinary framework developed by the NIH Community Child Health Network (CCHN) through community-based participatory research processes. CCHN developed a Preconception Stress and Resiliency Pathways (PSRP) model by building local and multi-site community-academic participatory partnerships that established guidelines for research planning and decision-making; reviewed relevant findings diverse disciplinary and community perspectives; and identified the major themes of stress and resilience within the context of families and communities. The PSRP model focuses on inter-relating the multiple, complex, and dynamic biosocial influences theoretically linked to family health disparities. The PSRP model borrowed from and then added original constructs relating to developmental origins of lifelong health, epigenetics, and neighborhood and community influences on pregnancy outcome and family functioning (cf. MCHJ 2014). Novel elements include centrality of the preconception/inter-conception period, role of fathers and the parental relationship, maternal allostatic load (a composite biomarker index of cumulative wear-and-tear of stress), resilience resources of parents, and local neighborhood and community level influences (e.g., employment, housing, education, health care, and stability of basic necessities). CCHN's integrative framework embraces new ways of thinking about how to improve outcomes for future generations, by starting before conception, by including all family members, and by engaging the community vigorously at multiple levels to promote resiliency, reduce chronic and acute stressors, and expand individualized health care that integrates promotive and prevention strategies. If widely adopted, the PSRP model may help realize the goal of sustaining engagement of communities, health and social services providers, and scientists to overcome the siloes, inefficiencies, and lack of innovation in efforts to reduce family health disparities. Model limitations include tremendous breadth and difficulty measuring all elements with precision and sensitivity.

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Advances in Re-framing Maternal-Child Disparities

In 2002, the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD) issued a request for proposals to establish a highly innovative, multidisciplinary research network focused on reducing maternal and child disparities related to reproductive outcomes. This RFA coincided with newly emerging evidence from disparate sources about the multi-faceted correlates of poor maternal health, high-risk pregnancies, prenatal development, and elevated health risks and delayed development in children born into very low resource families [1–7]. Unlike most NIH research networks, the Community Child Health Network (CCHN) explicitly required applicants to form strong local partnerships between community representatives and scientists to generate novel approaches and insights for conducting research. The final CCHN included five sites—Baltimore, MD; Chicago/Lakeshore County, IL; Los Angeles, CA; Eastern North Carolina; and Washington, DC—selected through peer review on the strengths of their proposed scientific approaches and their community-academic partnerships, then later added a Data Coordinating and Analysis Center at Penn State. The CCHN included investigators who had contributed substantially to the maternal and child health field, including the etiology and consequences of prematurity and low birthweight; randomized controlled trials of specific preventive efforts from treating maternal infections to providing high-quality, comprehensive prenatal care; effects of prenatal maternal stress and anxiety on fetal development; effects of maternal smoking, alcohol use, and recreational/illegal drugs; pregnancy spacing and rapid repeat pregnancies; maternal and fetal nutrition; neighborhood and community effects on pregnancy outcome; adolescent pregnancy; prevention of child neglect and abuse; and environmental and race/ethnicity factors in children's health risks, notably asthma and cardiometabolic risks (see Acknowledgements for identification of CCHN investigators. To achieve brevity and maintain focus in this article, we provide only selective citations of these many contributions that set the stage for CCHN's new work.) For example, by 2003 Lu and Halfon [2] proposed an integrated model of developmental programming of the infant and a cumulative life course pathway model for the mother as a means to understand the large disparities in pregnancy outcomes between Black/African-American and White/non-Hispanic women. Specifically, the Lu and Halfon model nominated multiple plausible biological mechanisms for maternal-child health disparities including (1) the direct effects of the prenatal environment on the developing fetus, impacting expression and regulation of genes (epigenetics) and future childbearing capacity; and (2) the cumulative effects of stress exposure and other health-related issues on the mother's physiological systems that support reproductive processes. By broadening the approach to studying health disparities to consider the *contextualization* of the lives of individuals with elevated risk for chronic and severe diseases and premature death, Lu and Halfon helped pioneer a new era of scientific inquiry. Their framework inherently challenged the traditional health care assumption that the best way to improve pregnancy outcomes (e.g., reducing prematurity, low birthweight, delivery complications, stillbirths, and neonatal deaths) was to provide early, continuous, high-quality prenatal care.

By 2006 Lu et al. [8] advanced ideas about the importance of preconception care, particularly during the interconception period. This team strongly recommended that future "research needs to be guided by the principles and methods of community-based participatory research (CBPR) and be held to scientifically rigorous standards [8, p. 120]." Later, Dunkel Schetter [3] synthesized a large body of research on prenatal exposure to maternal stress, anxiety, and depression and reached two strong conclusions: first, "Despite decades of scientific publication about "psychosocial" influences in pregnancy on birth outcomes, no attempt has been made to model psychological processes in any detail [3, p. 547];" and second, "Societies that nourish resilience in mothers and their families are surely likely to see maternal optimality [3, p. 549]." Then in 2014, the Maternal and Child Health Journal (MCHJ) [9] dedicated an entire issue to the topic of "Advancing MCH life course." As editors of that issue, Pies and Kotelchuck [10] advocated strongly for future "programs that approach a child's development holistically; *endorse an intergenerational continuity framework*; address the social determinant roots, health inequities, and current facilitators of disparities; and *fully engage communities* with local, State, and national MCH and associated organizations [10, p. 337, emphases added]."

Highly compatible with the key concepts and findings summarized in the 2014 MCHJ special issue, CCHN had designed and applied an integrated conceptual framework in 2004 to conduct a five-site prospective study of more than 2,500 families, the majority facing multiple risk conditions, often living in under-resourced communities, yet displaying many strengths and utilizing resilience resources [11–13]. In this article, we describe this unified framework, descriptively named the Preconception Stress and Resiliency Pathways (PSRP) model, identify the

rationale for its novel features, and reflect on how it supports the goal of facilitating discourse, innovation in practice and longitudinal research, and design and rigorous testing of multi-level, community-partnered interventions to improve intergenerational and lifespan health, particularly among vulnerable populations living in poor communities.

Brief Overview of the Complexities Related to Non-optimal Maternal and Child Outcomes

For at least three decades, intensive scientific inquiry in the United States has focused on understanding the large health disparities between Black/African-American and White/non-Hispanic women and their children, including more than double the rates of prematurity, low birthweight, infant mortality, and infant and child morbidities, including respiratory illnesses, allergies, diabetes, overweight, and language and learning delays and disabilities [e.g., 1, 2, 14–19]. Although low-income Hispanic/Latina women do not show comparably high rates of poor pregnancy outcomes, their children demonstrate many of the same health and developmental problems reported for Black/African-American children [e.g., 19–21]. The strong individual maternal correlates of these disparities include living in poverty, being unmarried, low maternal education, smoking and exposure to tobacco smoke, substance abuse and addiction, poor quality nutrition, maternal infections (e.g., bacterial vaginosis, periodontal infection, asymptomatic bacteriuria, sexually transmitted infections), maternal stress and anxiety, trauma exposure, and low levels of maternal social support [e.g., 1, 2, 19, 22–32]. At the contextual environmental level, major predictors of poor pregnancy outcome and child health are inadequate community resources, often indexed by income-related variables and composite measures of neighborhood deprivation and specific environmental toxins that are physical and psychosocial [e.g., 1, 4, 32].

Despite the many plausible etiological factors, most preventive prenatal interventions have produced negligible or no significant improvements in pregnancy outcome. Conventionally, these preventive interventions began after confirming the pregnancy, such as randomized controlled trials to improve the quality, comprehensiveness, quantity, and cultural adaption of prenatal care for very high-risk African-American women, treatments for maternal infections, increased social support, efforts to reduce excessive weight gain during pregnancy, and interventions to reduce smoking, alcohol use, and/or substance abuse [cf. 19]. The fact that most trials were implemented after prenatal care began, rather than in the pre-conception period, may be a major factor in their weak impact—a conclusion endorsed

Table 1 Examples of Community-Based Participatory Research (CBPR) principles[a] used in developing the Preconception Stress and Resiliency Pathways (PSRP) Model

Principle 1. Community is formally recognized as unit of identity so that collaborative partnership operates in all phases of the research. After receipt of funding, the network endorsed that the community be placed on equal level, with universities—including community Co-Principal Investigators at each site, and community as well as faculty members identified as Co-Investigators. To minimize having a community versus academic side to decisions, the Steering Committee decided that each site or entity in the network would have a single vote, thus further strengthening local partnerships to work efficiently, discover their own unified voice, and increase respect for and knowledge about diverse perspectives. The network requested that NIH learn more about CBPR, important because the project operated under a federal cooperative funding mechanism. This helped formally recognize the community at all phases of developing the framework and later implementing a large research study
Principle 2. Research needs to build on the strengths, resources, and relationships within the community. For CCHN, the early planning period involved conducting local pilot studies, information gathering, and building the research infra-structure. Accordingly, CCHN members acquired greater recognition of the strengths and resources within the community. Note: because the CCHN network included representation (community and academic) from social, behavioral, and biomedical sciences, we invested time in identifying these strengths and resources, which we reflect in the final conceptual framework. Perhaps one of the greatest difficulties was fully capturing the depth and detail of the final constructs or elements displayed visually in the Preconception Stress and Resiliency Pathways model (see Fig. 1)
Principle 3. The partnership integrates knowledge and action and promotes co-learning for the mutual benefit of all partners. In the early stages, at local sites and during cross-site in-person meetings (initially held quarterly the first 2 years, then twice a year), network members shared their experiences, observations, research findings, and interest in pursuing new topics related to maternal and child health disparities. This getting acquainted phase included formal presentations and many informal work sessions; later, we continued to distribute and integrate new findings from our own research and from that of others. Examples of co-learning activities involved interactive sessions in which network members (community and academic) conducted topic-specific exchanges, such as about principles of CBPR, data analytic approaches that take into account multiple influences co-occurring, and progress from other clinical interventions and/or national meetings, such as National Summits on Preconception Care in which many network members participated. As we sought to realize "mutual benefit of all partners," we discovered strong differences among network sites in terms of perceived value of conducting an intervention research project with incomplete knowledge versus enacting a descriptive longitudinal study intended to fill critical knowledge gaps before testing new interventions
Principle 4. The partnership considers health and well-being from both positive and ecological perspectives. This principle surfaced early on, with enthusiastic support from both community and academic partners. Specifically, this principle influenced our final conceptual framework that recognizes biosocial homeostasis in the form of an active set of processes potentially influenced by both stressors (chronic and acute) and resilience factors. Further, the ecological perspective added valuable information, because the impact on individuals or groups of particular stressors or facilitators may depend, in part, on whether these occur in environments that have low, moderate, or high levels of resources. The network endorsed the idea that psychological or subjective interpretation of events (positive or negative) can vary among individuals within the same community, in part based on other factors in their current life and their earlier life history

Principle 5. The partnership honors co-equal power, transparency, and resource-sharing appropriate to their community and academic partners, with a commitment to enhancing the opportunities for partners and building longer-term relationships and solutions to health disparities. The network created two major operational levels—(1) a national Executive Steering Committee comprised on the Co-PIs from the five sites, NIH scientists, the Data Coordinating and Analysis Committee, that was chaired by an individual from outside the network who was selected by NIH as an expert in the MCH themes and committed to the CBPR; and (2) major work groups or committees, each co-led by someone from the community and someone from academia. Both groups met largely via regularly schedule conference calls that yielded minutes distributed to all members of the network. All meetings were open to all network members, thus allowing newcomers to the network (membership changed over the years) and those with a particular interest in a topic under consideration to join in whenever they so chose. Individuals who could not join these meetings regularly could make contributions in writing or through communicating in a variety of ways with committee members. All sites included some members who were relatively junior in their professional development, and many received supplemental grants for training individuals from historically under-represented groups. Integral to this inclusive approach of CBPR, many junior network members sought and obtained more advanced professional education or training, complemented by opportunities to attend and present at local and national meetings. Mentoring occurred within and across sites, as well as within and across disciplines and the community and academic "sides."

Principle 6. The partnership disseminates findings and knowledge gained to all partners, including evaluating progress and impact. This principle largely applies to the research results of joint activities, although for our network, we had several iterations of the conceptual framework. Specifically, we achieved strong consensus early on about the multiple forces or influences we considered likely to be important in promoting (vs. deterring) good health outcomes during the reproductive years of a family's life course. In contrast, we diverged in opinions about the value of conducting an in-depth, descriptive longitudinal study versus testing an intervention derived from the new conceptual framework. With a split vote of three sites favoring a descriptive study and two sites favoring intervention, we proceeded to develop plans and then later implement a five-site descriptive study that provided first-ever measures of allostatic load in women during the inter-partum period and throughout a subsequent pregnancy. The network monitored progress in recruitment, cohort maintenance, data errors, and protocol deviations, as well as supporting the design and conduct of a self-study about perceptions within the network regarding how well we operated the community-participatory partnered research [37]. Since completing the first phase of the planned study, network teams have been working to finalize and conduct planned data analyses and disseminate findings and knowledge both within the network and outside. Although the CBPR process sometimes is cumbersome and slow, many network members have affirmed how much they have learned through the participatory partnership

[a] These CBPR principles reflect an amalgamation of those articulated by Israel et al. [35], Jones and Wells [37], Shalowitz et al. [12]; Ramey et al. [13]. This table does not provide a full listing of all CBPR principles

by the Centers for Disease Control and Prevention in their recommendations regarding universal preconception care [33]. As Lu [34] recently summarized "Over the past decade, there has been a groundswell of federal, state, and local efforts to translate life course theory into MCH practice. ([34], p. 340)" yet this "growing recognition of the need for broad, early and preemptive, multi-level, cross-sector interventions" has *not* sufficed to overturn the pattern of working in siloes and separate sectors, rather than creating "a common agenda, shared measurement systems, mutually reinforcing activities, continuous communication, and backbone organizations to achieve greater collective impact ([34], p. 341)." Consonant with this summary, CCHN presents the PSRP model in anticipation that many will be interested in dialogue about embracing it as a foundational, broad conceptual framework—one that is intentionally planned to permit future modifications and greater specification, as a means to transform the field *from* enhanced awareness *to* demonstrable changes in how research, funding, services, and communities address issues of maternal, paternal, and child health. In CCHN, we applied CBPR principles (see below) in the development of the PSRP model, resulting in a transdisciplinary, multi-level, and longitudinal framework that has helped identify testable hypotheses about divergent and co-existing pathways to better (vs. compromised) health.

Community-Based Participatory Research (CBPR) Principles Implemented by CCHN

CCHN is the first and only NICHD-supported CBPR network addressing perinatal health issues. The CCHN network adopted and implemented principles of CBPR, building on early and ongoing work of Israel and colleagues [35, 36] as well as network colleagues working from community [37–40] and academic [12, 13] perspectives. Table 1 provides examples of CBPR principles that our network used to develop the integrative PSRP model. (Note: Our network studied together and then sought to apply many of the principles identified regarding community-academic research partnerships, although we did not adopt a single set of principles formally.)

The first two principles—recognizing the community formally at all stages and identifying community strengths and resources—provided an exceptionally strong foundation for our network's productivity. The third principle affirms the importance of active co-learning and knowledge-action integration and facilitated how we worked, especially during the first 2 years of planning and becoming acquainted across a large multi—site, geographically wide network. We shared, read, and discussed many seminal publications related to community-based and community-participatory research partnerships. After a few challenging meetings in which everyone voted individually, but not all sites had equal representation, we decided as a network that each entity (the local sites, NIH, and the data center) would have only one vote. This decision supported timely, active deliberation at each site, ensuring that the one vote was the best reflection of each local partnership. At the foundation of successful CBPR efforts,

members recognized and valued the tremendous diversity in their kinds of expertise and knowledge, their use of language, and their different working priorities and timetables. This foundation then prompted sharing and revising of perspectives, encouraged mutual mentoring relationships, and stimulated new insights and approaches. Because CCHN was not a static or closed network, members needed to work to maintain cohesion while honoring the continuity of leadership and participation that we considered vital to progress.

A fourth principle articulates the importance of seeing strengths and considering the ecological context when studying health. This principle has strong evidence from empirical studies and community wisdom: there are individuals, families, and entire neighborhoods that discover and apply effective means of promoting health and overcoming adversities. Importantly, this emphasis on strengths and ecology rather than just risks and problems has opened new lines of scientific inquiry and documentation of alternative or multiple pathways to achieve desired health outcomes. CCHN thus chose to study resilience resources and look for strengths at the individual, family, and community level, while also considering stressors and threats to health [11, 41–43]. Theoretically, searching for supports and resilience may reveal influences on biology that are outside the boundaries of conventional biomedical thinking or practice. Socially, engaging partners in ways that highlight positive dimensions, while not denying serious challenges that may co-exist, contributes to the above foundation of respect for the achievements and life experiences that all partners bring to a mutual endeavor.

Finally, the fifth and sixth principles are closely linked—supporting transparency and sharing of resources and responsibilities in the partnership and then rapid sharing of new findings so that all have a full opportunity to consider the meaning of new findings and to use these in multiple ways to improve outcomes and reduce disparities. A key reality in proposing a broad and complex conceptual framework is that the volume of data to be collected and approaches to analyzing multi-level, multivariate, and longitudinal datasets are highly specialized areas. Our network actively anticipated this, and provided multiple ways to engage individuals who did not have statistical expertise (from both the community and academic sides)—by providing webinars and discussions and by insisting that both community and academic partners be present at all stages of planning data analyses and reviewing results. Our network sought to have a level of trust and engagement so that as new findings emerge related to the conceptual framework we jointly developed, members could be sufficiently prepared and empowered to explain, use, and even challenge these findings. Examples from CCHN are that community partners sometimes challenged standard definitions for health outcomes, such as whether the same cutoff values should be used to define overweight and obesity for all ethnic and racial groups, and ensuring that the men and fathers in the community were not defined solely based on legal or biological relationships to the children and mothers.

In retrospect, we have difficulty accurately identifying which ideas and novel features "came from" the community versus academic partners, because the close collaborations we developed supported a sense of shared innovation and insight. With little doubt, we found wide consensus for all of the key constructs in the final conceptual framework (described below). As our network sought competitive funding for a prospective study, we discovered how helpful this integrated framework was in identifying what to measure and the gaps in previous research. Although network members retained differential levels of interest in and expertise related to different constructs in the framework, we acquired a new common set of terms and stayed focused on understanding the interdependent, co-occurring, and sequential forces that likely impact health outcomes. Many members commented about how valuable this was (in contrast to using multiple frameworks on different topics) in establishing an infrastructure for science and intervention that could help overcome the siloes of the past.

The CCHN Stress and Resiliency Pathways Model: Novel Features and their Dynamic Inter-Relatedness Over Time and Across Generations

Figure 1 illustrates the CCHN framework that addresses multiple primary pathways that contribute to differential outcomes for pregnancy, fetal programming, and child health and development.

Novel features of the model include: (1) maternal allostatic load (described below) as a critical set of dynamic processes that impact pregnancy and child outcomes, as well as the mother's own current and future health status; (2) the quality of the parental relationship and the home environment as direct influences on maternal physiology; (3) the father's stress and resilience factors as a direct (not just moderating) influence on the mother's health and on the pregnancy and child outcomes; and (4) community level variables as causal agents (rather than mere correlates) capable of improving, as well as degrading, the health and well-being of all family members.

Figure 1 depicts the neighborhood, community, and societal influences as "the frame" that surrounds the intertwined life courses of family members. Through the CBPR process (described above), this frame became a multidimensional set of variables, some of them tangible

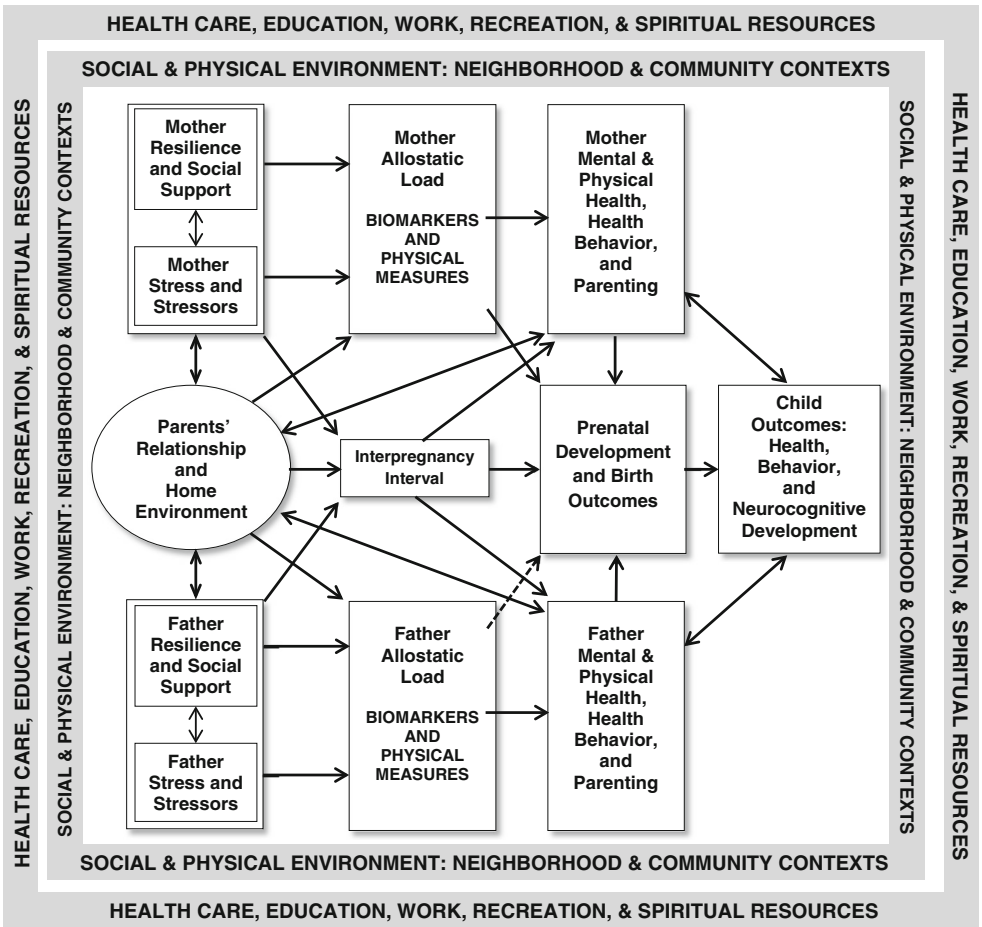

Fig. 1 The Preconception Stress and Resiliency Pathways (PSRP) model developed by CCHN reflects the integration of ideas, research findings, clinical impressions, and community perspectives about how multiple influences combine to influence the health of mothers, fathers, and children. Novel features include the focus on the preconception or inter-conception period, inclusion of fathers and the mother-father relationship, balanced consideration of stress and risk factors versus resilience resources and positive coping mechanisms, and maternal allostatic load (a composite measure of wear-and-tear associated with cumulative stress) over a longitudinal period—spanning the pre-pregnancy period, pregnancy, and post-delivery. CCHN used this model to design and implement a five-site prospective study of >2,500 families (see [11] for report of early descriptive findings)

and amenable to objective measurement, many of them intangible or subjective or not easily measured with equal sensitivity to the various ecological contexts that surround the lives of particular subgroups or individuals. The PSRP model does not, at this stage in its evolution, place greater or lesser emphasis on particular components within the environmental frame. Instead, the model supports the view that societal attitudes, ranging from negative (e.g., racism, unfair treatment, negative stereotypes, mistaken beliefs about pregnancy and parenting) to positive (e.g., affirming the value of fathers, celebrating childbearing as a valuable endeavor, endorsing health promotive behaviors in community settings) as well as specific societal investments (e.g., the quality, availability, and continuity in health care, social services, early child care and education, employment-related supports and opportunities, and crime prevention) impact not only the local communities and neighborhoods as a whole, but have the strong potential to alter the biology of individuals and groups of individuals. This PSRP model specifically hypothesizes that the health outcomes for subsequent generations cannot be adequately understood or sufficiently improved if the focus remains just at the level of the mother and child. Further, this model predicts that the identical interventions or services likely will produce different effects *depending on the broader environmental context*, including the psychosocial attributes of those being served as well as the physical dimensions of their environments. This hypothesis does not preclude the value of individual health care and healthy lifestyles, but instead states that the magnitude of benefits will depend on other concurrent (and prior) levels of support to the family unit including family history.

To address the critical issue of likely *causal pathways* specifically associated with the longstanding reproductive and child health disparities, CCHN hypothesized that the *combination* of interpersonal, environmental, and biomedical factors *over time*—serves to elevate or reduce health disparities overall. In other words, the dyadic parental relationship, their multi-level stress experiences, and their multi-level resilience resources become intertwined with the biosocial development of the next generation. We recognize that this is a broad, sweeping view—one that skeptics could claim makes it nearly impossible to know what matters the most and where to begin to change things. Alternatively, the PSRP model affords a way to realize that the collective impact of the activities or variables that

historically have been addressed in siloes could be vastly greater with changes in both thinking and acting—so that there is strong strategic coordination (i.e., not competition), non-duplication (i.e., reducing waste and problems in the field), and transparency (i.e., open access to information about efforts, particularly those with public and philanthropic funding). This contrasts with the longstanding stalemate where independent groups, including scientists, often compete for limited resources, despite sharing very similar or even identical goals. If communities, agencies, service providers, and scientists actually jointly shared information about how much money, effort, and impact they have, and also agreed to re-allocate and re-direct activities based on measured outcomes, or the emergence of a more promising approach, then the PSRP model would predict lower stress levels for both mothers and fathers, higher supports for positive parent relationships, improved mental health status, and reinforced social stability. In turn, this could set the stage for delivery of personalized medicine within a healthy everyday context, such that individual level interventions might exert more consistent and higher level benefits. In other words, the PSRP model underscores *the necessity* of engaging in activities that are sufficiently broad, intensive, well-timed, and individualized for the specific conditions of each family (i.e., meeting the needs of each parent and their future children) within the context of their local communities and psychosocial supports.

The Rationale for the Central Role of Maternal Allostasis and Allostatic Load

In the center of Fig. 1, maternal allostatic load assumes prominence, receiving direct input from the stressors and support that parents experience. Many maternal and childhood health problems, including asthma, overweight/obesity, diabetes, hypertension, and allergies, have been associated with stress-regulation processes over the life course [e.g., 45–52]. Parenting practices, family and child care supports, parental mental health, and community resources and dangers also show bi-directional effects related to stress and thus directly influence children's growth, health status, and neurocognitive and social-emotional development, with some effects enduring well into adulthood [e.g., 3, 5–56].

Allostasis is a continuous biological process of adaptation to achieve homeostasis under conditions of exposure to multiple physical and psychological stressors. *Allostatic load* is the cumulative "wear and tear" on body systems from adjusting to chronic and acute stress. This construct emerged as a promising approach to studying the adult aging process; early findings showed that allostatic load in middle-age groups significantly predicted morbidity and mortality in old age [e.g., 41–43, 45, 46].

Allostatic load is a composite index derived from various biomarkers that theoretically reflect systemic wear on the body. We developed a method that involved collecting and using 10 objective biomarkers: systolic and diastolic blood pressure, heart rate, body mass index (BMI), waist-to-hip ratio, glycosylated hemoglobin, cholesterol, C-reactive protein, and salivary cortisol levels obtained upon arising and in the evening. When we finalized the PSRP model, no study had proposed that allostatic load be directly measured and prospectively monitored in women during their childbearing years, including at multiple intervals during pregnancy. To what extent there would be a direct correspondence between current measures of a mother's psychological stress/distress (including perceived stress, anxiety, depression, trauma exposure) and her allostatic load was not known. Despite uncertainties about how best to measure the individual components of allostatic load (see below for the measurement approach that CCHN used), our network chose to focus on allostatic load. Our rationale was that a composite indicator of multiple biomarkers, already related to many disease conditions and poor pregnancy outcomes, as well as predictive in some older age samples, might set the stage for considering this as an integral part of the maternal life course and an indicator of many of the key maternal physiological systems needed to support optimal embryonic, fetal, and postnatal development.

What was, and still is, unknown is how best to capture the biological toll of chronic and acute stress, particularly the dimensions that are most important for pregnancy and prenatal development. Conversely, whether supports and resilience produced biological benefits—detectable in the mother's allostatic load, was an intriguing yet unanswered question. In the PSRP model, both the mother's and the father's allostatic load are displayed as having potential direct effects on each parent's own physical and mental health, their health seeking and health promoting behavior, and their parenting behavior. That is, if stress impairs multiple dimensions of a parent's physiological well-being, *even at levels below the threshold for diagnosing or treating specific conditions* (e.g., those that often have onset in later years after childbearing such as hypertension, diabetes, asthma, obesity, arthrosclerosis), the parent may be at elevated risk for other conditions (e.g., low energy, loss of interest in exercise or healthful eating, poor self-esteem, sleep disorders, withdrawal from certain relationships and social engagement in the community, abusing alcohol or substances). To test these hypotheses about causal pathways, the PSRP model required collecting data over time so that there are multiple measures of these constructs. From such a prospective, longitudinal dataset, then deviations in some areas, such as changes in stress levels, resilience resources, or allostatic load could be linked *sequentially* to whether the predicted changes occur in other areas, such as mental health,

health promotion behaviors, parenting engagement, or better pregnancy outcomes.

How the PSRP Model Can Inform the Design and Conduct of Prospective Studies

The PSRP model affords an integrative framework to guide the design of studies focused on the life course of mothers, fathers, and children, especially studies that seek to reduce health disparities. In fact, CCHN used this framework for a five-site study of 2,510 mothers and their newly born children, including a subset of fathers (with permission from mothers) and/or the co-parenting partner designated by mothers. For those mothers who had a subsequent pregnancy, we continued to measure these constructs during and after the next pregnancy. CCHN focused on testing two major hypotheses from the PSRP model. Hypothesis 1 was that *higher levels of perceived stress by mothers and fathers would lead to higher allostatic load in mothers.* Hypothesis 2 was that *higher maternal allostatic load would be associated with less optimal outcomes for mothers and fathers* (e.g., their mental health), *children* (e.g., on-time developmental milestones, optimal physical growth), *and future pregnancies*. Table 2 identifies data collected for the nine major constructs in the PSRP model. Just as the generation of the conceptual framework was a community-academic participatory partnership, we continued using CBPR principles in selecting and refining measures, developing study-specific methods if no satisfactory ones existed, and then finalizing the strategies for recruiting and retaining the study population over time. We faced the same set of challenges that any large-scale prospective study encounters—namely, how to collect everything of interest without overburdening study participants and while staying within the means available to collect, enter, and analyze the data. Like all NIH major studies, the CCHN study will enter the public domain in a timely manner; and CCHN eagerly supports active use of the rich dataset that has been generated.

Interviewers (mostly local community citizens) received common training in the protocol and collected data in-person at 1, 6, and 12 months after the index baby's birth; during telephone interviews at 18 and 24 months; and during all subsequent pregnancies and births (four of five sites collect inter-pregnancy and subsequent pregnancy data up to 4 years after study enrollment; one site ended at 2 years). Although the measures are extensive, CCHN pilot-tested these and concluded the data collection process was not unduly burdensome.

Parental Relationship and Home Environment

Both mothers and fathers provided information about their relationship, including the current nature of their relationship (marital status, satisfaction), their living arrangements (e.g., cohabitation), intendedness and planning of the target pregnancy (retrospective as it occurred prior to study enrollment) and subsequent pregnancy (if any occurred), and degree of father involvement with the baby. CCHN hypothesized that intact and high-quality mother-father relationships would serve to reduce levels of perceived stress and maternal allostatic load as well as to foster better parenting practices and more favorable parent mental health. In addition, interviewers collected data about the quality of the child's postnatal home environment.

Psychosocial Stress and Resilience Measures

This CCHN domain covers individual level reports of stress and resilience resources that may buffer the effects of stress over time. A set of 20 measures assess parental psychological stress and resilience. We administer some measures more than once and a few at each time interval. On the whole, the standardized instruments selected had strong psychometric properties as well as evidence of cultural appropriateness, congruence, and acceptability. These tools assess: prenatal stress (retrospectively), perceived stress, major negative life events, chronic stress, racism and discrimination, interpersonal violence, and parenting stress (see Dunkel Schetter et al. [11] for full details). CCHN conceptualized "resilience" as "the process involving an ability to withstand and cope with ongoing or repeated means and maintain healthy functioning across different domains of life [41, p. 637]." More specifically, CCHN measured a number of "resilience resources," which include a wide span of interpersonal and social resources (e.g., perceived social support), world views and culturally-based beliefs and values (e.g., spirituality and religious practices), behavioral and cognitive skills (e.g., active coping), and tangible resources (income, educational attainment, healthy behavioral practices) [11].

For some items in standardized instruments, CBPR processes led to making slight wording modifications to increase clarity and relevance. CCHN also developed an innovative Life Stress Interview providing interviewer ratings of life domains as well as an optional interview about "Good things happening in my life." Regarding racism and discrimination, CCHN collected data from mothers and fathers about their experiences of lifetime, childhood, and current everyday unfair treatment based on race, income, and other characteristics including memories of childhood racism/discrimination. One of CCHN's central hypotheses is that *psychological stress will be significantly associated with higher levels of maternal allostatic load, lower quality of mother-father relationship, and increased rates of poor outcome in a subsequent pregnancy*

Table 2 Illustration of the application of the PSRP model to the measurement approach for the first phase of the CCHN prospective study focused on advancing knowledge about combined biosocial influences on health disparities for diverse families and communities

CCHN Study Constructs	Study enrollment +2 years						Inter-pregnancy interval (varies)	Next pregnancy trimester		Birth of next baby	
	Birth of index child	+1 month	+6 months	+12 months	+18 months	+24 months		2nd Tri-mester	3rd Tri-mester		+2 months
1. Resilience and social support Mothers and fathers		✔	✔	✔	✔	✔	From delivery of index child to next pregnancy	✔	✔		✔
2. Stress and stressors Mothers and fathers		✔	✔	✔	✔	✔		✔	✔		✔
3. Within family relationships and home environment	✔	✔	✔	✔	✔	✔		✔	✔		✔
4. Allostatic load[a] Mothers			✔	✔		✔		✔	✔		✔
5. Mental and physical health and parenting: mothers and fathers	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔
6. Prenatal development and birth outcomes	✔									✔	✔
7. Child outcomes		✔	✔	✔	✔	✔				✔	✔
8. Neighborhood and community contexts		✔	✔								
9. Resources: health care, social, educational, work, recreational, spiritual Mothers and fathers	✔	✔	✔	✔	✔	✔		✔	✔		✔

Sites also collect demographic and family descriptive data repeatedly throughout the study

[a] One site measures allostatic load of fathers at the same time intervals as for mothers

(*e.g., one or more of the following: having a stillbirth or neonatal death, preterm and/or LBW baby, low Apgar score, extra hospital days after delivery*).

Mental and Physical Health and Health Behaviors

A parent's mental and physical health status is a strong determinant and consequence of both positive and negative health behaviors, with direct effects on their children as well. CCHN used standardized screening tools for assessing symptoms of depression, anxiety, and post-traumatic stress as well as for obtaining histories of psychiatric conditions and chronic and acute health conditions. Other data collected included health care access, and perceived quality and adequacy of health insurance. CCHN hypothesized that *the physical and mental health of each of the parents influences maternal allostastic load as well as their parenting behaviors, since health can affect energy levels, motivation, decision-making, memory, patience, and expression of positive affect*.

Child Health and Development Measures

CCHN collected birth or pregnancy outcome data from medical records, including gestational age and preterm birth (<37 weeks), birthweight, Apgar scores, head circumference, type of delivery, days in the Neonatal Intensive Care Unit, and diagnoses of major birth defects and diseases. Measures of later child outcomes included growth adequacy, major developmental milestones, pediatric health problems, major injuries, and hospitalizations. (Note: A subgroup of CCHN investigators received funding to follow the subsequent birth cohort to study cortisol regulation, neurocognitive development, growth, cardiometabolic risk, and biological aging as indexed by telomere length.) Availability of maternal psychosocial and biological stress data during the preconception period permits an unprecedented opportunity to assess the timing (as well as levels) of maternal stress, thus adding to the emerging findings about prenatal stress and child cognition and psychosocial outcomes.

Neighborhood Environment and Community Resources Measures

The physical and built environment and community social and economic context in which families live and work have been associated with many health outcomes. CCHN relied on geocoding using U.S. Census and local surveillance datasets to create a rich dataset for analysis about how these environmental factors related to stress and its buffering at the level of individuals and the family unit. Variables obtained include concentrated community poverty/low wealth, community safety, and residential segregation to provide a general community profile. Several local sites developed ways to estimate community cohesion, collective efficacy, and community resources, such as recreational areas, local public services, and facilities. Several sites collected qualitative data from father focus groups about what factors promoted versus hampered their ability to fulfill their goals as fathers. Other sites conducted neighborhood inventories of family resources, while some documented the availability of innovative new services that potentially could help families, such as a community-based birth center.

Conclusions: How our Model can advance our Understanding

The CCHN conceptual framework and the use of CBPR has produced an integrated conceptual framework for the field of maternal, paternal, and child health that builds upon a highly divergent knowledge base relating stress and disease risk, from pregnancy through the lifespan. The creation of CCHN and its evolution correspond to the past decade of accelerated understanding of what is captured by the various terms of maternal-child health life course perspective, developmental programming of adult onset diseases, epigenetics (wherein environmental and genetic forces exert mutual, time-distributed effects to co-determine the outcomes for an individual child), and intergenerational effects of stress and resilience. In this framework, distinctive themes include the importance of what happens prior to conception and between subsequent pregnancies, the psychological and social well-being of both the mother and father—with strong emphasis on both strengths and supports as well as stress and risks, and allostatic load as a representation of how psychosocial factors and the environment "get under the skin" to affect the integrity of multiple biological systems and health outcomes for the parents and their children.

We acknowledge potential limits of this integrative model. These include its tremendous breadth and the difficulty of measuring all of the constructs in the model with comparable precision and sensitivity for all of the constructs. Additionally, this model does not display all of the specific detailed pathways and potentially testable plausible mechanisms of interest. Analytically, the complex longitudinal datasets are inherently thorny, and often aspects of the distributional properties of the data cannot be fully anticipated when estimating the power to test hypotheses, particularly when the hypotheses themselves indicate that different outcomes (or interactional effects) are expected as a function of individual community level variables and the environment. Even when the data analytic strategies are highly sophisticated and appropriate for a

model such as PSRP, explaining the results can be difficult and knowing how to take action as a result of new findings is not always clear or supported by the model itself. Finally, because allostatic load is so central to the PSRP model, we realize that the field faces hurdles about how best to combine the multiple individual biomarkers into a composite score, and perhaps there are age-specific or gender-specific aspects of measuring allostatic load that have yet to be refined sufficiently.

Despite the limits, we advance the proposition that widely sharing this multi-level, multidisciplinary, and longitudinal conceptual framework may facilitate new coalitions and research approaches, including testing promising interventions that start prior to conception and simultaneously target multiple levels of influence and is of timely potential value to our field. We think the creation and endorsement of this framework by community and academic partners from highly divergent backgrounds is a strength and may encourage dialogue as the model becomes further specified and hypotheses are subjected to evaluation about the relative strength of certain pathways or associations among the constructs in this model. CCHN's enthusiasm for analyzing and widely sharing this novel, prospective, and rich dataset is also tempered by knowing that it is rare, time-consuming, challenging, and expensive to launch such a multidisciplinary and CBPR-partnered research network. The study sample transcends those that rely solely on large university clinic samples of convenience and increases measures of the psychosocial and environmental determinants of intergenerational health. The anticipation is that such investments may lead to substantial revision and refinement related to etiological pathways and multiply determined risk profiles and help to foster greater originality in thinking about the transformation of health care services (e.g., timing, content, and continuity) related to reproduction and parenting. CCHN's database and expected future publications will serve, in a pioneering way, to help answer the question of how productive this multifactorial and CBPR approach can be.

In an era of concern about rising health care costs, unresolved health disparities, and elevated signs or precursors of major health problems in young children and their young parents, the CCHN framework offers a strong starting position for re-framing the issues. Prevention, early detection, and effective treatments will necessitate partnerships that actively engage community residents, health care providers, social services, educators, and community leaders. These partnerships will be pivotal in planning, implementing, and improving effective strategies to increase supports, promote resilience, decrease racism and inequities, and administer timely and effective medical interventions and treatments for specific risks and diagnoses to all mothers, fathers, and young children who could benefit.

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