Chapter 15
Public Health and Social Policy Perspectives on DOHaD

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Abstract This chapter introduces the role of public health to the developmental origins of health and disease (DOHaD) primarily through social policy approaches. Social policies affect people's well-being. The chapter provides background to various levels of prevention and actions needed in relation to DOHaD. DOHaD research underscores the importance of an individual's circumstances and surrounding environment, particularly during the most vulnerable times of life, which provide great implications for improving social policy. Several social and environmental factors are discussed in relation to DOHaD, including among underserved or disadvantaged populations. The lack of action on social policy may well be due to policymakers' lack of awareness of DOHaD. Suggestions for improving social policy incorporate peer-reviewed-policy recommendations. Finally, the chapter concludes with multiple factors that both public health practitioners and policymakers can consider to more systematically develop social policies in response to the mounting evidence supporting DOHaD.

Keywords Developmental origins of health and disease (DOHaD) · Life-course · Social policy · Public health

15.1 The Scope of Public Health's Responsibility

Public health serves the population. Its responsibility to society has been traditionally abbreviated into three words: ***promote***, ***protect***, ***prevent***. Public health promotes and protects the health of families and communities through healthy behavior, education, research, health services, policy advocacy, disaster response, and by preventing disease, injuries, and disabilities (Institute of Medicine—Committee for the Study of the

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Future of Public Health 1988; Centers for Disease Control and Prevention 2014). To safeguard the health of populations, public health has three core functions: to assess the health needs of communities, to develop policy, and to assure the "conditions in which people can be healthy" (Institute of Medicine—Committee for the Study of the Future of Public Health 1988). These core functions were expanded by the Public Health Functions Steering Committee of the U.S. Centers for Disease Control and Prevention (CDC) into the ten essential health services that are necessary to improve population health:

> (1) monitor health status to identify and solve community health problems; (2) diagnose and investigate health problems and health hazards in the community; (3) inform, educate, and empower people about health issues; (4) mobilize community partnerships and action to identify and solve health problems; (5) develop policies and plans that support individual and community health efforts; (6) enforce laws and regulations that protect health and ensure safety; (7) link people to needed personal health services and assure the provision of health care when otherwise unavailable; (8) assure competent public and personal health care workforce; (9) evaluate effectiveness, accessibility, and quality of personal and population-based health services; and (10) research for new insights and innovative solutions to health problems (Centers for Disease Control and Prevention 2018).

The principles and practice of public health are rooted in the words of Winslow (1920), bacteriologist and first head of Yale's Department of Public Health, whose definition set the standard for public health:

> Public health is the science and the art of preventing disease, prolonging life, and promoting physical health and efficiency through organized community efforts for the sanitation of the environment, the control of community infections, the education of the individual in principles of personal hygiene, the organization of medical and nursing service for the early diagnosis and preventive treatment of disease, and the development of the social machinery which will ensure to every individual in the community a standard of living adequate for the maintenance of health; organizing these benefits in such fashion as to enable every citizen to realize his birthright of health and longevity.

Public health is a collective societal effort. Even the health sector does not have the sole jurisdiction on population health. Every discipline, every sector can contribute to the nation's health. Winslow's definition made it clear that health and longevity are basic human rights. Ensuring such rights is the principle aim of "organized community efforts" (Winslow 1920) of public, private, and voluntary health and safety agencies, healthcare providers, and various organizations, which collectively constitute the public health system (Centers for Disease Control and Prevention 2018).

15.2 Upstream Public Health and the Social Determinants of Health

Prevention is a core public health responsibility. It is classified into various levels of strategies: primordial, primary, secondary, tertiary, and quaternary (Leavell and Clark 1965; Last 2007). Except for primordial-level strategies aimed at addressing the community determinants of health, the rest of the levels of prevention strategies focus on individual-level behavior, risk factors, screening, care and rehabilitation.

A guide to choosing the most effective prevention strategy is conveyed in the classic public health parable attributed to medical sociologist Irving Zola (McKinlay 1975). In this parable, a man was constantly rescuing people who fell into a fast-flowing river and were swept downstream (McKinlay 1975). Although rescuing people who were swept downstream is crucial, similar to the public health duty of responding and assisting in emergencies, this parable concluded with an emphasis on moving "upstream"—addressing the factors that cause people to fall into the river in the first place, a key public health mandate on health promotion and disease prevention. This river story has given rise to the terms "upstream," "midstream," and "downstream" as a way of classifying public health efforts according to the direction and setting of intervention.

Moving "upstream" is acting on the root of the problem. It is finding out why the problem occurred in the first place in order to effectively and sustainably control the downstream consequences of chronic diseases and health inequities. Because upstream interventions target macro-level determinants or the "causes of the causes" (Marmot 2006), the more upstream an intervention is, the larger the number of people benefited, and the more meaningful its impact on population health.

Upstream determinants are the conditions in which people are born, live, work and play that influence health and are collectively referred to as the social determinants of health (World Health Organization 2008; Solar and Irwin 2010). These are the social, economic, political, and environmental structures that shape how money, power, and resources are distributed in society, consequently resulting in health inequities. The impact of these macro-level structural determinants are mediated by "midstream" or intermediary factors at the local and regional levels and include housing, employment, food security, health care system, and even health behavior (Solar and Irwin 2010). Both upstream and midstream causes result in the "downstream" consequences of chronic disease, injury, and disability (Solar and Irwin 2010). Such fallout is made worse by the inequities in access, quality, and delivery of care, particularly among marginalized populations.

15.3 Developmental Origins of Health and Disease (DOHaD)

Important as healthcare is, it is not a major determinant of population health. Four other factors have a far greater influence in shaping population health: genetics, behavior, social, and environmental factors. When broken down into the impact of each of these factors on premature deaths in the U.S. population, healthcare accounts for only 10% of health outcomes, behavior accounts for 40%, genetics at 30%, with both social and environmental factors collectively at 20% (McGinnis et al. 2002). Therefore, the key to impacting population health lies in addressing the nonmedical determinants through practice, research, and policy: behavior and social factors, which together make up 60% of untimely deaths (McGinnis et al. 2002; Schroeder 2007).

Social factors, such as education, socio-economic class, ethnicity, poverty, employment, housing, food security, even the neighborhood where one lives, can adversely impact health. A growing body of research has repeatedly affirmed the characteristic l pattern of early deaths, unhealthy behavior, and chronic diseases among those within the financially-challenged brackets of society (Isaacs and Schroeder 2004; Adler et al. 1993; McDonough et al. 1997; Marmot 2001). Such deleterious impacts of social factors on health can be explained not only by material deprivation, as in the absolute and relative scarcity of resources and opportunities, but also biologically, through the pathophysiological and emotional impact of stress on the body (Marmot 2006; Schroeder 2007).

Although one's genetics predetermine susceptibility to disease, studies have also shown that environmental exposures within and outside the womb can alter the expression of inherited risks. These associations led to the Barker Hypothesis, which is currently referred to as the Developmental Origins of Health and Disease or DOHaD. Originally developed by British epidemiologist Barker (1990), DOHaD posits that events in early life exposures could explain an individual's risk for noncommunicable disease later in life.

In 1993, Barker and colleagues studied the association between the anthropometric measures of newborns (birthweight, birth length, Ponderal Index, head circumference, and placental weight) and deaths later in life from cardiovascular disease in a cohort of 10,100 men and 5,600 women born between 1911 and 1930 from Hertfordshire, England (Barker 1994). Their results showed a significant inverse correlation between small birthweight and the risk of developing and dying from heart disease. This relationship remained significant with weight at one year of age and premature mortality among those younger than 65 in both men and women (Barker 1998). Barker's findings showed that infants who were small at birth, a measure of fetal undernutrition, had the greatest risk for cardiovascular disease and metabolic syndrome as a factor of (1) maternal nutritional status and body composition before, during, and after pregnancy; (2) maternal diet during pregnancy; and (3) postnatal nutrition and growth (Barker 1994, 1998). Two other sets of data from Sheffield and Preston likewise supported the Hertfordshire findings. The Sheffield data showed a

decreasing trend in cardiovascular mortality with increasing head circumference and Ponderal Index (PI) at birth (Barker et al. 1993; Wilson 1999). Similarly, the Preston study, which looked at the risk of hypertension in adult life, showed among the low placental weight group, those with adult hypertension were also more likely to have had a low Ponderal Index, where Ponderal Index serves as a measure of leanness calculated as birth weight/birth length^3 (Wilson 1999; Barker et al. 1992). These and other animal and human population studies have investigated the underlying mechanisms that explain how in utero exposure to a stressful environment leads to programmed outcomes for chronic diseases (Morrison et al. 2018). Such research affirms a prevention approach with an upstream focus on the social, economic, and environmental factors that influence the mother's nutritional status before, during, and after pregnancy and the baby's growth and development within and outside the womb.

Other concepts, such as the Life Course Theory and the Fetal Origins Hypothesis, have been studied in relation to DOHaD. The Life Course Theory, also known as the Life Course Perspective or Life Course Approach, was developed in the 1960s and analyzes the course of an individual's life within structural, social, and cultural contexts. While DOHaD tends to emphasize environmental conditions both before and immediately after birth, the Fetal Origins Hypothesis proposes that the gestational period has significant impacts on the developmental health and wellbeing outcomes for an individual ranging from infancy to adulthood. This hypothesis has been expanded to cover associations between fetal undernutrition and other non-communicable diseases (NCDs) such as metabolic syndrome or syndrome X, type 2 diabetes mellitus, pulmonary disease, abnormal cognitive development, Wilms' tumor, leukemia, breast cancer and prostate cancer (Barker 1994; Wilson 1999).

To date, DOHaD's findings underscore the importance of an individual's circumstances and surrounding environment, particularly during the most vulnerable times of life. It constitutes a paradigm change "impact[ing] psychological, social, economic, ethical and legal sciences" and "forming a basis for prevention policies across the globe" (Rial-Sebbag et al. 2016). The research on DOHaD establishes the basis for how health and disease factors emerge before birth and through life and is increasingly used to understand the building of one's health capital (Rial-Sebbag et al. 2016; Junien et al. 2016). This new understanding on the susceptibility for chronic disease and its development over the life course could redefine how we look at prevention, shifting the discussion towards translational interventions to achieve effective disease prevention. More than ever, this calls for knowledge sharing and collaboration to maximize opportunities for discovery and replication (Prescott et al. 2016).

15.4 Public Health and DOHaD

15.4.1 The Public Health Response to DOHaD

Though the supportive scientific evidence is strong, there is still a current dearth of articles and systematic reviews on public health programs and policies that were specifically influenced by the Developmental Origins hypothesis (Barnes et al. 2016). Further, there is limited evidence that public health practitioners and policymakers are aware of the DOHaD hypothesis. Even more scarce is the evidence demonstrating the influence of DOHaD in legislating bills or in designing public health programs and interventions.

Although researchers have recommended future programs and policies grounded in the DOHaD hypothesis, a scoping review of the literature from January 2016 to June 2018 shows a gap in the application of a DOHaD framework in public health and policy. Nevertheless, public health programs and interventions exist whose underlying principles can be linked to the prenatal origin of the risks for adult-onset NCDs (see Table 15.1). Though not exhaustive, the following examples may form a foundation upon which future public health programs, services, policies and interventions may build.

15.5 Public Health's Role in Developing and Informing Social Policy Based on DOHaD

One of the primary roles of public health is to develop and inform social policy. Throughout history, public health practitioners have regularly and successfully advanced social policy changes by shedding light on various public health concerns and by engaging directly in the policymaking process. For example, the sanitation movement of the mid-nineteenth century resulted in sweeping changes to urban infrastructure, such as implementation of large-scale sewer systems, zoning ordinances separating residential and industrial areas, and other urban planning decisions (Perdue et al. 2003).

DOHaD findings serve as an evidence-based foundation for directing key prevention-based policies primarily at the societal level (Rial-Sebbag et al. 2016). Thus, focusing health promotion efforts on DOHaD and addressing it through public policy could prove crucial. This is particularly true in low- and middle-income countries where the prevalence of NCDs risk destabilizing local economies (Reddy and Mbewu 2016). The "Operational Plan for Comprehensive HIV and AIDS Care, Management and Treatment for South Africa," is an example of an effective policy that utilizes the DOHaD framework (Reddy and Mbewu 2016). This initiative, started in 2003, allows pregnant women and those who are planning to become pregnant should have access to food, multivitamins and antiretroviral therapy to improve women's health before and during pregnancy (Reddy and Mbewu 2016). This serves

Table 15.1 Public health and policy implications of the Developmental Origins of Health and Disease (DOHaD)

Developmental Origins of Health and Disease (DOHaD)	Public health implications	Policy implications
The Manifesto of The International Society for Developmental Origins of Health and Disease (DOHaD) reflects how far the original Barker Hypothesis has gone and it articulates how the translation of the DOHaD research findings could make a significant difference in reducing the risks and the burden of chronic diseases The Society, comprised of scientists from around the world and from various backgrounds, aims to promote research coordination and public health implementation of findings on early developmental exposure and chronic diseases, including the funding, training opportunities, research discussions, and the translation of findings into significant interventions International Society for Developmental Origins of Health and Disease (2015), **The Cape Town Manifesto, November 2015** (Selected paragraphs) "Whether acting through the mother, father or directly on the infant and child, adverse environmental exposures during early development shape the body's responses to later challenges such as unhealthy diets, sedentary lifestyle, inadequate sleep, excess screen time, high levels of stress and exposure to environmental toxicants. These biological responses are exacerbated by the rapid changes in lifestyle occurring between generations with urbanisation and socio-economic progress in low- and middle-income countries, in migrants and displaced populations. Reducing the burden of NCDs across the life course thus requires interventions to promote healthy early development, beginning even before conception, as well as interventions aimed at sustaining health in children, adolescents and adults." "Harmful environments during early development may cause failure to achieve full physical and mental potential, and a loss of human capital. Combined with increased susceptibility to NCDs, this widens inequalities in health and has adverse economic consequences for individuals, families and communities. Moreover, an unhealthy lifestyle in prospective parents, along with NCDs such as diabetes, cardiovascular disease or obesity before conception and in pregnancy, passes greater risk of NCDs to the next generation. This perpetuates cycles of poor health, reduced productivity and shorter life expectancy, trapping populations in a trough of low human capital from which they cannot easily escape."	**Public Health Programs** Designing public health programs that account for the multiple "hits" or biological insults that occur at critical periods throughout the life course with emphasis on appropriate solutions (Winett et al. 2016) Establishing an integrated health system with a multi-sector delivery of health services and a comprehensive approach to disease prevention that addresses the multiple nutritional and environmental stressors to maternal and child health (Barnes et al. 2016; Heindel et al. 2015) Focusing on upstream health by promoting conditions that support healthy environment, lifestyle and behavior (Barnes et al. 2016) Potentially using epigenetic profiling in looking at childhood experiences and the risk for adult-onset NCDs (Barnes et al. 2016)	Supporting health and economic policies directed at improving living conditions by emphasizing the long-term impact of the DOHaD hypothesis, particularly among pregnant women (Reddy and Mbewu 2016) Creating and supporting policies on the education, respect, and autonomy of women and how social, economic, political, historical, and ideological factors affect the health and nutrition of mothers and children (Moore and Davies 2001) Advocating for policy changes based on the DOHaD that emphasize societal-level versus individual-level accountability in addressing health inequalities (Ismaili M'hamdi et al. 2018; Haas and Oi 2018; Hanson and Gluckman 2016) Implementing multidisciplinary and multi-sectoral discussions on prevention by combining the DOHaD and the United Nations' Sustainable Development Goals (Pentecost et al. 2018) Designing global programs and policies to increase awareness of the life course and transgenerational effect of the DOHaD (Heindel et al. 2015) Incorporating a knowledge of ecological health in the education, examination, and clinical training of physicians (Reddy and Mbewu 2016)

(continued)

Table 15.1 (continued)

Developmental Origins of Health and Disease (DOHaD)	Public health implications	Policy implications
	Women's Nutrition Promoting women's and children's health and involving other stakeholders in inclusive life course approaches (Kajee et al. 2018)	Creating policies that will address the advertising of unhealthy foods and increasing the intake of fruits and vegetables (Prescott and Logan 2017)
	Prenatal Nutrition 1. Maternal nutrition programs (Binns et al. 2001); UNICEF's Care Initiative (Moore and Davies 2001) 2. Protein-calorie and micro-nutrient supplementation to pregnant women to reduce insulin resistance and arterial stiffness (Uauy et al. 2011) 3. Prenatal care (Barnes et al. 2016; Binns et al. 2001; Soubry 2018; Paneth 2016)	Providing public health and policy interventions and a Health in All Policies approach to improve the health of pregnant women and children (Barnes et al. 2016; Reddy and Mbewu 2016)
	Intrauterine Nutrition **Postnatal Nutrition and Early Childhood** 1. Child health clinics and growth monitoring to address under- and over-nutrition (Binns et al. 2001) 2. Promoting exclusive breastfeeding in the first six months of life especially in low- and middle-income countries (Binns et al. 2001) 3.Providing protein-calorie supplementation to children under 5 (Uauy et al. 2011)	Investing in family-based interventions and parenting workshops (Barnes et al. 2016) and on formal and informal education that focus on key points of the DOHaD trajectory (Davies et al. 2018)

(continued)

Table 15.1 (continued)

Developmental Origins of Health and Disease (DOHaD)	Public health implications	Policy implications
	Precursor Conditions to Chronic Diseases • Obesity • Insulin Resistance • Metabolic Syndrome Developing a prevention agenda centered on pregnancy and the first two years of life and on increasing physical activity among mothers and children to reduce obesity (Moore and Davies 2001; Uauy et al. 2011) Promoting increased initiation and duration of exclusive breastfeeding (Binns et al. 2001)	Using innovative health messaging directed at children and adolescents (Davies et al. 2018) Changing existing public health policy by targeting risk factors for NCDs by having stricter tobacco control policies (reducing smoking in pregnancy) and a Strategic Plan for NCDs on hypertension, smoking, obesity, sedentary lifestyle, and an unhealthy diet (Reddy and Mbewu 2016)
	Non-communicable Diseases (NCDs) • Type 2 Diabetes Mellitus • Cardiovascular Disease (CVD) • Stroke • Hypertension Continuous monitoring of indicators to determine NCD trajectory (maternal weight before and during pregnancy; stunting and wasting) (Uauy et al. 2011) Introducing public health initiatives directed at indigenous populations such as the "Strong Women, Strong Babies, Strong Culture" among Australian aborigines (Moore and Davies 2001)	Providing social grants for women and children to reduce NCDs in South Africa and other low- and middle-income countries (LMICs) (Reddy and Mbewu 2016) Introducing a tax for sugar-sweetened beverage (South Africa) (Davies et al. 2018)

(continued)

Table 15.1 (continued)

Developmental Origins of Health and Disease (DOHaD)	Public health implications	Policy implications
	Communicable Diseases • HIV/AIDS—public health interventions that focus on both treatment and provision of food to address food insecurity, which could exacerbate the infection, especially among pregnant women, ex: Operational Plan for Comprehensive HIV and AIDS Care Management and Treatment for South Africa (Reddy and Mbewu 2016)	
	Adolescent Health Promote reproductive health programs with emphasis on delaying pregnancy among adolescents (Moore and Davies 2001)	Transforming communities into biodiverse neighborhoods, particularly vacant lots in urban areas, to encourage physical activity, positive neighborhood perceptions, and reduced violence, while promoting access to such communities (Prescott and Logan 2017)

as an example for other countries whose economic situations could be improved if public programs and policies are modeled after the DOHaD hypothesis (Reddy and Mbewu 2016).

DOHaD studies draw attention to the fact that the health of mothers and children are of foremost importance while also emphasizing the need to include fathers and the whole family unit as additional foci of interventions. This is supported by DOHaD research showing that the female and male gametes in the pre- and periconceptual periods of development are both *targets* and *vectors* of epigenetic changes resulting in multigenerational effects (Chavatte-Palmer et al. 2016). Such findings can influence changes in traditional public health programs. For instance, Pentecost and colleagues (2018) called for inclusive interventions that go beyond mothers or pregnant women to involve men and adolescents. Similarly, Prescott and colleagues (2016) emphasized the need for ecological justice that recognizes both support and responsibility to be distributed across individuals, and includes the recognizing that the influence of the father's environment on children's health outcomes and in supporting the health of fathers (Soubry 2018). Such an approach invests in preventive measures to ensure that later life disease and disability is reduced (Haas and Oi 2018). These comprehensive efforts will help overcome the criticism that DOHaD focuses on maternal conditions alone without consideration for the environment of fathers, thus erroneously perpetuating the notion that pregnant women and mothers alone are responsible for the health outcomes of their children.

Because individual experiences and exposures can impact future generations, public health practitioners and policymakers need to consider a life-course approach for multiple windows of interventions over time. For instance, both the UN's Sustainable Development Goals and DOHaD emphasize that "early exposures in life affect not only future health, but that the effects of [such] exposure can be transmitted across generation" (Vaiserman et al. 2017). To implement such a focus on prevention, multi-sectoral and multi-disciplinary discussions are critical in translating science into policy so that health impacts can be felt. Conferences or summits have been used to create awareness about DOHaD and to facilitate collaborations. For instance, the Prenatal Programming and Toxicity (PPTox) Conferences help to create cross-sectoral collaborations that facilitate more in-depth research on the impact of environmental stressors to human health during key phases of development (Heindel 2018). The resulting action from these discussions may help form ongoing collaborations and research for more specific interventions based on DOHaD concepts. It should be evident for policymakers that investing in prevention-focused research, policy, and programs can help reduce the prevalence of NCDs.

Lessons from DOHaD studies prompt public health to take a broader and upstream stance on prevention that addresses root causes—the socio-ecological context in which risk factors exist and are perpetuated that impact not only mothers and children but also fathers and the whole family. This may mean modifying current public health priorities to emphasize family-level 'health, education, and empowerment' (Hanson and Gluckman 2016) throughout the life course.

15.6 Moving Forward: Overcoming the Barriers in Translating DOHaD into Research, Practice and Policy

There are multiple factors hindering action on DOHaD for both public health practitioners and policymakers. First, there is little evidence to suggest sufficient awareness of the DOHaD framework among typical public health practitioners and policymakers. While the core concepts of DOHaD resonate with public health's focus on health promotion and disease prevention, few public health practitioners are familiar with DOHaD as the unifying framework for these concepts. For example, public health practice has long focused on primary prevention strategies—interventions directed at individual-level risk factors to prevent disease occurrence such as behavioral interventions to reduce cardiovascular disease. A current call to action invites public health to direct its strategies further upstream—at the societal-level health determinants that result in health disparities especially among at-risk populations. Upstream approaches include examining for lead in drinking water sources or in old housing, both of which disproportionately affect those in the lower socio-economic bracket. Such action can reduce the unethical and preventable cognitive impairment in children. These public health prevention strategies are supported scientifically by a DOHaD framework. However, awareness for DOHaD is clearly lacking among public health practitioners, thus limiting its utilization within a discipline that aims to improve population health.

Second, it is challenging to translate the results of animal-based DOHaD studies into meaningful changes in public health practice and policy. While such baseline research is critical to our understanding of the underlying biological processes in DOHaD, there can be a substantial delay in applying the findings at the clinical and population-levels. More cross-sectoral collaboration is necessary to translate the findings from basic biological research to actual community health practice (Winett et al. 2016). Laboratory findings need to be connected to the social and environmental realities of individuals and communities to become actionable for public health practitioners.

Third, for biologic research to have greater impact, there is a critical need to consider societal-level perspectives along with individual lifestyle factors. There is a tendency for researchers to discuss the implications of DOHaD from an individual responsibility level rather than from a societal-level accountability. For example, lifestyle issues such as an individual's stress, nutrition status and other factors are commonly cited as the focus for DOHaD findings, but may not also acknowledge environmental factors such as socio-economic status or access to education as contributory needs. While personal lifestyle factors are important, policymakers need to recognize the important interplay between personal choices and environmental factors (Delpierre et al. 2016). Researchers can help in identifying the policy and social responsibility implications of their studies.

Fourth, parallel research tracks associated with the DOHaD hypothesis are receiving substantial research attention on their own, but little has been done to unify these

research tracks into a more holistic framework. For example, several environmental factors have been implicated in disease burden as part of the DOHaD framework. However, these environmental factors are being investigated independently without consideration of their possible additive or synergistic effects such as under- and over-nutrition (Gluckman et al. 2010); exposure to various environmental chemicals that act as endocrine disruptors (Grandjean et al. 2008); and the impact of prenatal stress on glucocorticoid levels (Entringer et al. 2010; Harris and Seckl 2011). Moreover, there is relatively little coordination in the translation of the epigenetic impact of various environmental factors. This calls for a greater emphasis on developing comprehensive environmental research and public health programs using the DOHaD framework (Heindel et al. 2015).

Fifth, there are substantial challenges in developing a meaningful synthesis of research ideas and findings across parallel research tracks (Winett et al. 2016). The seemingly disparate fields of epigenetics, social determinants of health, and family studies have important implications in creating a comprehensive DOHaD framework, though each has a vastly different research history and lexicon. A few empirical studies have tried to bridge the gap between research tracks. For example, some studies have looked at the social determinants of DNA methylation and telomere length (Notterman and Mitchell 2015). Others have drawn connections between family functioning or family conflict and gene expression level (Ehrlich et al. 2015; Robles et al. 2018). The number of these research studies are relatively few and many of them have been based on animal models. Consequently, additional research studies are needed to further elucidate the biological and social connections in a DOHaD perspective. Longitudinal studies on human subjects would greatly assist public health practitioners to implement a DOHaD framework that affects individuals, families, and communities.

Sixth, multi-disciplinary studies are critical to help validate DOHaD to policymakers (O'Donnell and Meaney 2017). However, researchers must also present actionable policy and public health recommendations. Researchers speak of the policy implications of their DOHaD findings, but few offer ways in which such implications could be feasibly acted upon at the policy level.

Seventh, greater effort is needed to recommend or develop specific interventions that are actionable for public health practitioners. It is not sufficient to merely identify the social and biological determinants of health and disease in early life. This information needs to be taken a step further and developed into an actionable plan to target the most vulnerable populations using targeted disease prevention and health promotion approaches. As research recommendations shift towards interventions and the translational strategies for disease prevention, DOHaD meetings will be needed to foster collaboration and the sharing of information and data (Prescott et al. 2016). Studies that demonstrate measurable improvements in health outcomes from a specific intervention will go a long way in bringing DOHaD to the forefront of public health practice.

Eighth, there is a need for more thoughtfully-coordinated research designs to identify emerging topics that contribute to larger social policy efforts. Topics for DOHaD research that supports social policy considerations include research designs to (1)

initiate the use of a life course analysis for one generation using phenotypic data collected before conception to capture the human life cycle well into the demands of aging (Hanson and Gluckman 2016); (2) reduce the prevalence of mental disorders over a lifespan through interventions and study designs that extend beyond observational research to examine factors such as maternal diet and exercise during pregnancy (Van Lieshout and Krzeczkowski 2016); (3) examine the potential long-term health consequences to offspring of reproductive technology, such as in vitro fertilization, given the sensitivity of the embryo to its environment (Feuer and Rinaudo 2016); and (4) focus on epigenetic research that can inform policies and human practices to improve health and well-being (Dickinson et al. 2016). Ultimately, specialized research techniques and designs should emphasize findings that are replicable and comparable (Hanson and Gluckman 2016; Gage et al. 2016).

Ninth, health promotion interventions should be planned to address a wider range of actors and actions that include not only women, mothers, or pregnant women, but also men and adolescents (Pentecost et al. 2018). A potential public health intervention could use the "first-hit/second-hit framework" to advance an understanding of DOHaD's etiology in program planning efforts (Winett et al. 2016). For instance, Barker's work showed how an initial insult or a "first hit" occurs before birth leading to the epigenetic programming of risk in the fetus. However, multiple varied stressors are further experienced in childhood and during critical developmental periods across the life course. These comprise the "second hits" such as behavioral, environmental, and/or social influences (Winett et al. 2016). This framework offers a systems viewpoint that expands on the range of possible solutions compared to a variable-by-variable approach to a problem (Winett et al. 2016). Such an approach to multi-faceted health problems can identify better starting points for public health interventions, in turn, demonstrating how the timing and effects of multiple insults across the lifespan can shape the trajectory of individual health and the health of future generations.

Finally, DOHaD research needs to be translated into social policies and public health priorities that can positively affect the family and household settings throughout the life course. Three decades of epidemiological research have shown that adverse events in utero can trigger epigenetic alterations leading to an increased predisposition to developing and dying from chronic diseases. The most proximal influence on the mother and her child is the family. Within the family, daily interactions, rituals, and routines become the building blocks of individual behavior and lifestyle, which in turn impact the health of children, adolescents, women, men, and future mothers and fathers. This does not discount the role of community or societal-level influences. Both family and community-levels factors can adversely affect the health of three generations: the mother, the child, and the next generation. Therefore, implementing the DOHaD message from a life course context necessitates the active involvement of the family. Public health programs and interventions can target not only specific periods of prenatal development, but also other periods of exposure to various risks across the life course.

15.7 Conclusions: DOHaD Implications for Social Policy

DOHaD research underscores the importance of an individual's circumstances and surrounding environment, particularly during the most vulnerable times of life. The greatest implications of these findings may very well be aimed at improving social policy. Social policies affect people's well-being. The lack of action on social policy may well be due to the lack of awareness on DOHaD among policymakers. Understanding the etiology of DOHaD and its potential if used during program planning is vital for policies to have long-lasting effects (Winett et al. 2016).

Developing and enacting social policy is often a difficult and drawn-out process. First, policymakers may have a limited understanding of the health concerns in their communities, often requiring substantial educational outreach efforts from public health practitioners. Second, scientific research alone is often not enough to convince policymakers to act on a specific health concern. Results of scientific inquiry must be contextualized to local circumstances to gain the attention of policymakers. For instance, what are the social consequences of a certain scientific finding to the communities within a policymaker's jurisdiction? Making connections between research findings and actual people is essential to move social policies forward that can make significant impacts on population health.

Social responsibility for health will require serious ethical debate and prompt new actions from policymakers to counteract health inequalities (Ismaili M'hamdi et al. 2018). The next step is to develop policies aimed at addressing social and health needs while expanding funding opportunities for prevention efforts. Although existing research is promising, ongoing research must be supported, strengthened, and prioritized to better understand the environmental factors that surround individuals, families, and relational groups (Delpierre et al. 2016). Cross-disciplinary collaborations in public health that focus on actions across the life course will be able to shape the prioritization and delivery of disease prevention and intervention activities that have been born through decades of DOHaD research.

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