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Nonlinear Dynamics and Positive Health: The Case of Menstruation/Menopause

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Abstract: *This paper is a theoretical journey through possible ways that complexity research can contribute to health promotion, especially for understanding, encouraging, and facilitating positive health. The concept of “positive health” regards health as an actual state or independent dimension, not simply freedom from physical disease or the absence of a problem. The subjective aspect of positive health is often described with the concept of “well-being.” Nonlinear paradigms have implications for health because they direct attention to different facts, dynamics, theories, and basic assumptions, and also because language, in both its denotative and connotative aspects, has the potential to influence health-promoting or undermining attitudes, self-attributions and narratives, all of which impact positive health. This is explored specifically for perimenopause/menopause. Our previous research provided evidence that the menstrual cycle, before and during perimenopause, is the output of a nonlinear system in a chaotic trajectory. This article explores implications of a nonlinear paradigm for understanding the science underlying menopause, interpretations of variability and linear causality, importance of system structure, interpretations of perimenopause/menopause as senescence and disorder, and resultant self-attributions about menopausal experience and the nature of midlife.*

INTRODUCTION

What are the implications of complexity-based research for health promotion? In our previous work, my collaborator and I provided experimental evidence that menstruation is the outcome of a nonlinear dynamical system in a chaotic trajectory, both before and during the menopausal transition, and we discussed implications of our results for conceptualizing menstruation and menopause (G. Derry & P. Derry, 2010, 2018; G. Derry, Mullen, & Marcelino, 2020; P. Derry & G. Derry 2012, 2014). In this paper, I explore the implications of our results for important health issues, especially the implications of a nonlinear dynamical framework for understanding, encouraging, and facilitating positive health, especially through health promotion, in the specific case of menopause.

How to define health, and what is a whole-person approach to health, are current areas of great interest and uncertainty (e.g., National Center for Complementary and Integrative Health, 2021). Positive health, as one aspect of a whole-person approach, is an independent dimension rather than the absence of disease, but is also intertwined with the likelihood or experience of disease. How to conceptualize the interrelationships between biological, psychological, social, environmental, and cultural components or contributors to health promotion and positive health is an important question. If menopause is the output of a nonlinear dynamical system, understanding these issues involves a different set of assumptions, analyses, and language, than does a linear approach.

Nonlinear research is related to health promotion because, with regard to the science underlying health care, nonlinear systems address different facts about the body

and its dynamics and operate according to different principles than do linear models. In this way, the science guiding researchers and practitioners, and the communications that then follow to clients or the general public, differ. Researchers and practitioners have established that nonlinear dynamical systems are ubiquitous in nature and important to understanding health and disease in a large number of bodily systems (e.g., Sturmborg & Martin, 2013; Varela, Ruiz-Esteban, & Mestre de Juan, 2010). With regard to perimenopause/menopause, one health-related issue is understanding menopause-associated pathology. However, whether menopause itself is a disease has been a fraught issue. Both understanding disease and asking questions about the distinctions between health and unhealthy pathways through perimenopause/menopause can be enriched by exploring their nonlinear aspects.

In addition to guiding research, a complexity perspective is related to health promotion by influencing what are the accurate ways of selecting, reporting and interpreting data, for professionals and in communications to patients and to the general public. For example, as summarized by Schuldborg (2015), in linear systems means, standard deviations, and other measures of central tendency are regarded as accurate representations of collective data and often conflated with the “real” result, often representing the optimal or normal; variability is the error in measurement of the true value, a sign of pathology, or other meaningless noise, rather than reflecting interesting individual differences or personal vicissitudes over time. In contrast, in nonlinear systems, measures of central tendency like means are not accurate representatives of patterning in data. Variability is expected, interesting, patterned or otherwise meaningful, and has been used as an indicator of health.

Further, nonlinear dynamical systems have different logical and theoretical implications than do linear systems, with different basic assumptions about what defines or underlies disease and less common or even novel definitions of health. Varela, Ruiz-Esteban, and Mestre de Juan (2010), for example, explore linear meta-assumptions that contrast with those of nonlinear thinking: Disease as disorder vs. a change in complexity, sharp cutoffs between health and illness, naïve causal reasoning, homeostasis as correcting deviation from normality, disease as a real entity, either/or thinking (that is, a need to dichotomize as in normal/abnormal lab readings).

In this article, the influence of a nonlinear dynamical systems orientation to menopause will be explored for these three dimensions. In addition, a fourth difference is explored. The facts, assumptions, and implications of a paradigm, be it linear or complex, form an overarching narrative that guides researchers and clinicians, and also influences the information or metessages that are communicated to patients. More broadly, as will be discussed below, these narratives can become part of the cultural landscape, contributing to socially shared assumptions and individual cognitions that can bear on health, and, with regard to menopause, the broader narratives bear on implicit theories of the human life course.

To further clarify the perspectives and definitions in this article and their contrast with linear perspectives, after a brief overview of the role of conceptual paradigms, definitions of health and health promotion are explored, followed by discussion of linear vs. complexity-based approaches to menstruation/menopause and contributions of complexity to health promotion. Directions for future research are then explored.

CONCEPTUAL PARADIGMS

Research and practice are necessarily guided by conceptual frameworks, that is, the paradigms or basic assumptions within which thinking occurs. These paradigms organize facts and ideas in a coherent manner. They never capture the complexity of reality and are necessarily selective. They influence what observations are made and how their significance is understood. Facts and ideas inconsistent with underlying assumptions may appear less plausible and may be systematically overlooked or ignored. Health-related paradigms have practical importance because they influence what counts as a fact, what theories appear plausible and important, what research questions should be pursued, and what health-care interventions make sense. Even when a given perspective, such as linear or nonlinear, may not require thinking a certain way, it can direct attention in one direction or another because that direction seems natural. Paradigms, in addition to organizing facts into coherent theoretical structures, contain implicit underlying ideas about broader issues, such as the definitions of health and illness and the nature of the life course.

Linear and nonlinear paradigms for understanding the science underlying perimenopause/menopause direct attention to different facts, theories, and basic assumptions. In addition, paradigms also have implications for health because language, in both its denotative and connotative aspects, has the potential to influence health-promoting or undermining attitudes, self-attributions and narratives. That is, people are dependent on language to organize experience, language that has implicit as well as explicit meanings. The language of a paradigm provides imagery with which experience is understood and evaluated, and can influence how a woman orients to experience, the felt-sense of experience, the core imagery of how things fit together, the story of one's

body and of health/illness. This includes experiences of owning experience vs. an alienated stance towards experience, efficacy vs. helplessness, construing experience as pathological or not. The experience, behavior, and health outcomes of clients, are potential outcomes of connotative as well as denotative aspects of paradigms.

Caveats: Dichotomies like “linear vs. nonlinear” and “biomedical vs. nonbiomedical” are accurate up to a point and are useful, sometimes necessary, to clarify important distinctions conceptually. However, reality is typically more nuanced, with models often containing elements of each other and real people mixing elements of different models. Models of models, like models themselves, do not capture the complexity of reality. Further, the suggestion is not that complexity theory replaces more traditional work, but that different paradigms and methodologies will be relevant to different contexts and to answer different questions. With regard to perimenopause/menopause, more recent theory and practice is more likely to show a nuanced view, but the stark contrasts discussed with regard to the nature of perimenopause/menopause still exist.

HEALTH

What Is Health?

Health is, first, the absence of physical disease. A healthy person is not physically ill, is resistant to becoming ill, or who, if getting sick, has the physical resilience to fight off disease and to recover. Health has also been defined as maximal functioning: A person at the physiological “peak of health” is physically fit, physically robust, with physiology working at peak performance or maximally efficient functioning, as when a woman is maximally fertile or task performance is maximized.

The concept of positive health adds another dimension to understanding what health is. Here, health is not defined purely in terms of its relationship to disease or maximal functioning. It is an independent dimension or an actual state, a biopsychosocial phenomenon, a lived quality of experience that involves more than physiology. Positive health has been conceptualized and researched as an independent phenomenon. However, it is also intertwined with health as the absence of physical disease. On the one hand, it is correlated with vulnerability to physiological disease and recovery and to engaging in health-promoting behaviors; on the other hand, a person can have a high level of positive health, such as a sense of meaning, while being physically, even terminally, ill (Centers for Disease Control, 2018; National Institutes of Health, 2018).

The subjective aspect of positive health is often described with the concept of “well-being.” The classic World Health Organization (World Health Organization, 1946) definition, for example, was that health is “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.” Well-being does not simply mean experiencing pleasant, rather than unpleasant, subjective emotional states; it is a multidimensional concept. While different researchers have defined terms differently, one set of terms that captures the varying dimensions commonly included in positive health is this: “Hedonic” well-being, that is, emotions such as joy, contentment, happiness, sadness, stress, worry, pain, or suffering; “Evaluative” well-being, that is, judgments/cognitions of how satisfying different aspects of life are and other evaluations; and “Eudemonic” well-being, that is, a sense of meaning and purpose in life, the value of life, the ability to pursue self-defined goals, reflected in positive relationships, social

acceptance, personal growth, environmental mastery (National Institutes of Health, 2018; National Research Council, 2013)

Another dimension of positive health, of more recent interest, is that a healthy person is embodied. Integrative disciplines include, as part of the experience of subjective health, a sense of embodiment, non-alienation from the body, living in the body, experience of the body as important to the experience of self. In a large survey, practitioners from a broad variety of integrative, body-oriented therapies shared the common idea that encouraging relaxed interoceptive awareness (that is, awareness or sensing of the internal state of the body) underlies health and facilitating health (Mehling, et al., 2011). Social psychologists Chrisler and Johnston-Robledo (Chrisler & Johnson-Robledo, 2018) regard embodiment as multidimensional. As a vehicle for experience, the body is the basis for subjectivity and self-expression. People learn about the world and themselves through the body. Embodiment can be experienced as positive or negative, empowering or disempowering. In addition, as a tangible or visible form of an idea, quality, or feeling, embodiment is a cognitive sense of self, an idea of who we are as individuals. It is part of one's self-identity, and how others respond is a component of self-worth. Others may react to stereotypes based on perception of the body.

In this article, health is regarded from a biopsychosocial, holistic, "whole person" perspective, that is, as the outcome of physical, psychological, and social dimensions integrated into a whole. Experiences of illness involve both physical changes and the meaning given to those changes, experiences of positive health are influenced by bodily change. Positive health is a positive state of well-being, a lived experience that includes efficacy, ability to cope, meaning, embodiment; these in turn rest on a positive self-

concept and a sense of efficacy, a positive regard for and comfort with one's body, interoceptive awareness, and a positive concept of one's life stage, as well as accurate information about health problems and health-promoting practices (Derry, 2004).

Health Promotion and Health Education

Health education can be defined as formal, explicit experiences, such as classes or books that provide information. Health promotion can be defined as a broader term that also includes conditions that make it more likely that an individual will experience health (Centers for Disease Control and Prevention, 2018), both intentional interventions and the de facto effects of context. For example, for the World Health Organization (1946, 1984) de facto effects of context include economic, political, and environmental constraints and interventions.

Health education provides information and guidelines for evaluating information. For disease prevention, where goals include avoiding disease or increasing resilience, information might include facts about diseases, information about what prevents disease onset such as recommendations for a healthy lifestyle and other health behaviors, guidelines for evaluating information. Health education also includes information to identify what's normal and what can be a sign of a problem that requires medical evaluation. In addition to providing information, health education includes promoting underlying attitudes that influence whether information is sought or used. For example, in addition to knowing about exercise programs or good nutrition, people need to choose and keep to these lifestyle changes.

Health promotion for positive health involves providing information. However, influencing well-being also means addressing subjective psychological experience.

Examples include: Evaluative well-being can be promoted through cognitive/behavioral techniques for growing more aware of and re-defining problematic cognitions, such as promoting cognitions that encourage active coping rather than catastrophizing and re-evaluating core ideas/suppositions that amplify distress. A subjective sense of well-being can be encouraged through body-oriented techniques that encourage a sense of comfort and safety living in one's body and increased sensitivity to and nonalienation from internal experience, as opposed to an evaluative or alienated stance towards bodily experience. Eudonomic well-being—creating a sense of meaning and purpose to one's life and ability to pursue self-defined goals, as reflected in mastery, personal growth, social acceptance, and positive relationships—can be encouraged through narrative techniques.

Narrative techniques reflect the fact that experiences are organized into stories or narratives that can be explored, understood, and re-written. Narratives have explicit content and also implicit connotations and implications, and imagery with which we understand and evaluate experience, with implications for how people orient to experience, the felt sense of experience, the core imagery of how things fit together. Stories and language can encourage or discourage a sense of meaning, feeling empowered or helpless, a sense of well-being.

Messages from the social context may parallel the personal factors known to influence subjective well-being, as when friends, medical professionals, advertisements, medical paradigms, and cultural norms provide information and narratives (e.g., Derry, 2010). For example, from a personal cognitive/behavioral viewpoint, catastrophizing and taking a passive stance towards experience contribute to feelings of danger and

helplessness, and therefore increased distress and poorer coping. Social messages portraying worst-case scenarios as common parallel the cognitions in individuals that encourage catastrophizing, for example that it is common for menopausal symptoms to be inevitable, unbearable, and to go on for years.

MENSTRUATION

Traditional View of Menstruation and Menopause

The menstrual cycle is conventionally viewed as due to regularly recurring, cyclic variations in a number of interacting hormones that re-create, month after month, a well-functioning, predictable system (e.g., Goodman, 2009). In this view, what underlies menstruation is a closed system in which feedback relationships, especially those among a number of hormones, create regularly recurring cyclic processes and prevent the system from deviating too far from its usual patterns. A menstrual cycle length canonically defined as 28-days-or-so involves cyclic hormonal changes, the consequent build-up of the uterine lining, ovulation, and other events. These events are orchestrated by three levels of hormonal control—from the ovary, pituitary gland, and hypothalamus—that have bidirectional feedback relationships that underlie multiple levels of control, with other parts of the brain also playing a role.

Stability is the hallmark of the system, with homeostatic mechanisms that correct for or prevent deviations, creating a healthy system that operates at maximum efficiency. Variability, when observed, has often been ignored or interpreted as uninteresting randomness (around a real 28-day-or-so mean), due in teenagers to developmental immaturity, caused by stresses to the system, or a symptom of pathology. When, in the years preceding menopause (the permanent end to menstruation or the last menstrual

period), periods become irregular and otherwise odd, this increased irregularity and unpredictability has most often been interpreted as senescence or pathology.

My research collaborator and I were especially interested in the menstrual cycle changes that occur later in the human lifespan. Menopause is understood to be one point in a much longer physiological process. The later changes are most often defined as a discrete stage called perimenopause and conceptualized as physiological changes that lead directly to menopause. Perimenopausal physiology is characterized by puzzling irregularity, by unpredictability, and by deviations from previous feedback relationships (see P. Derry & G. Derry, 2012; Hale & Burger, 2005; Prior, 1998, for discussions of these changes). Menstrual cycles become irregular in length. Estrogen levels do not linearly decline, as was originally assumed, from premenopausal levels to their postmenopausal low; instead, they oscillate unpredictably, with spikes where decreases were expected. Feedback relationships change, as when estrogen levels no longer elicit predictable responses from other hormones like follicle stimulating and luteinizing hormones. These changes might exist during some menstrual cycles with hormone levels and feedback relationships then returning to premenopausal patterns. Instead of following universal laws, hormone and other menstrual cycle changes are found to vary within and between women, apparently unpredictably.

The most typical interpretation of the perimenopausal research literature, in keeping with the biomedical model (P. Derry & G. Derry, 2012; Voda, 1997; Voda & Ashton, 2006), is that perimenopausal physiology is best understood as senescence and/or pathology in which an unstable and disordered system no longer responds normally to hormonal and other signals. Many researchers have pointed to the value-laden language

with which changes have been described (see discussions in P. Derry & G. Derry, 2012; MacPherson, 1982; Martin, 1992). For example, feedback relationships might be said to change because the ovary has become “resistant” or otherwise less able to respond normally to hormonal signaling. Unpredictable or unexpected changes in hormone levels are “erratic,” or hormones are being released at the wrong time or in the wrong amounts. Deviations from the norm at younger ages, like increased menstrual cycle variability or increased numbers of anovulatory cycles, are defined as “abnormal” or “ovulation disturbance.” Indeed, the World Health Organization (World Health Organization, 1996) definition of menopause is the cessation of menstruation associated with loss of ovarian function—“loss,” not “change” or “completion”—and perimenopause is the changes leading directly to this cessation.

Menstruation and Menopause as a Nonlinear Dynamical System

We hypothesized that the puzzling patterning during perimenopause could reflect the dynamics of a chaotic system rather than breakdown and disorder. Our rationale was that extreme values, individual trajectories differing from the mean trajectory, and puzzling changes in pattern that return to preexisting patterns are all consistent with what would be expected in a chaotic system. While often overlooked, in reality there is much variability in the menstrual cycle throughout life. Further, the menstrual system is the right kind of system to have chaotic dynamics: multiple systems of control with bidirectional feedback loops.

We therefore designed research that asked whether the menstrual cycle is the output of a nonlinear dynamical system in a chaotic trajectory rather than a linear system or a system in disorder, among women beginning at age twenty when the cycle is

conventionally presumed to be cyclic and predictable, through perimenopause when the cycle is conventionally presumed to be unpredictable because of the dynamics of senescence, breakdown, and disorder. Our data came from the archives of the Tremin Research Program on Women's Health—the TREMIN Trust (Mansfield & Bracken, 2003). This study of menstrual cycles and women's health across the lifespan, begun in 1934 and continuing through the 1980s, provided a rich source of data. Subjects maintained a daily record of when they were menstruating and when they were not, eliminating memory errors. We randomly selected 143 women who had recorded their menstrual cycles daily from approximately age 20 until the final menstrual period (FMP). These lifelong menstrual cycle records provided data for time series analysis of the time intervals between successive menstruations (i.e., successive menstrual cycle lengths). Informally, the rationale for this technique is that these menstrual events are an output of the dynamics of the entire system and that hence their time variations are a reflection of these dynamics. Employing the data in a series of studies, and supporting results found with further modeling work, (G. Derry & P. Derry, 2010, 2018; G. Derry, Mullen, & Marcelino, 2020) we examined whether nonlinear dynamics existed among women beginning at age twenty through the FMP. We computed a variety of quantities that indicate the presence of chaos (correlation dimension, positive Lyapunov exponent, KS entropy) using multiple methods and testing the results with surrogate data sets. We defined a new measure, the inter-event correlation parameter (Icp), computed analogously to the correlation dimension, to summarize data analyzed with procedures developed by Grassberger-Procaccia and by Judd.

Consistent results were found across the multiple methods of data analysis: The menstrual cycle is characterized by chaotic dynamics rather than disorder, randomness, or linearity throughout the life cycle, from age twenty until the FMP. When data were analyzed separately for each year, the shape of the strange attractor changed during the lifespan, especially a small increase in I_{cp} approximately seventeen years prior to the FMP and a large monotonic decrease during the 5-8 years before the FMP, both shifts corresponding in time to significant phenomena identified in menstruation research. The best interpretation of the shifts remains unclear at this time. However, the consistent age-dependent behavior of the I_{cp} supports the interpretation that menstrual variability is generated by an underlying nonlinear dynamical process that is governed by developmental physiology and that changes in a coherent manner (though environmental influences also play a role).

LINEAR VS. COMPLEXITY-BASED HEALTH PROMOTION

The Existence of Normal Variability

Complex systems research contributes to health education and health promotion by influencing what counts as accurate information. Women look to science to understand the workings of their bodies, what to expect, what a normal woman experiences vs. what is unusual or abnormal, what is a cause for concern. If menstruation is the outcome of a nonlinear dynamical system, the language describing the normal course of menstruation and menopause shifts. Variability in the menstrual cycle from woman to woman and cycle to cycle, the common existence of individual lifespan pathways, and other research findings, become important data rather than

overlooked. Averages can provide useful guideposts rather than absolutes, and the meaning of deviations from the average shifts.

Health education about menopause and menstruation begins with information about what to expect and what is “normal.” One important parameter is how variability is regarded; this can be emblematic for how to understand and evaluate other facts. With a complex systems perspective variability may come into focus, attended to rather than overlooked, because variability is an intrinsic aspect and a meaningful part of the structure of a chaotic system. For example, menstrual cycle length has been canonically defined as 28 days, as when oral contraceptives were designed to mimic a 28-day cycle with length consistent from one cycle to the next so that women would feel their menstruation was “normal.” For some women, their menstruation is indeed “regular as clockwork” but this is far from universal. Normal menstrual cycle patterns have much variability, within and between women. A classic paper by Treloar and colleagues published in 1967 and largely ignored had already established this, by documenting the wide range of normal menstrual cycle lengths and patterns of change from month to month and across the lifespan (Treloar, Boynton, Behn, & Brown, 1967). Later research similarly documented that the lifelong pattern of menstruation is both variable and individual, with cycle lengths varying from month to month, with physiological trajectories through perimenopause differing from woman to woman, and with mean results not corresponding to or representing the trajectories of individual women (e.g., Gorrindo et al., 2007; Harlow, Lin, & Ho, 2000).

Although not universally the case, in linear systems means or other averages are often taken to define the “real” result (Schuldberg, 2015). When measures of central

tendency define the “real result” and indicate a stable system, the assumption may be that the normal amount of variability is limited, and the existence of variation and unpredictability in a normally functioning system may then be overlooked. Variation around the mean, as in a range, standard deviation or confidence interval, may be reported but regarded as random variation or measurement error, rather than included as expected data and important information when interpreting the nature or dynamics of the system. For example, many (though this is not universally the case) trustworthy medical websites present the average, or what is common, when providing facts to community women. However, averages do not accurately report the range of normal experience or reflect the true nature of women’s experiences. For example, the average age of menopause is 51 years (the normal range is defined as 45-55 or 40-60, depending on the source), the average length of perimenopause is 4-6 years (it can last far longer or shorter), a woman has reached menopause if she has not bled for twelve months and therefore will not bleed again except for a medical pathology (5-10% do for no apparent cause). Sometimes, women have been told that what they are experiencing could not, for example, be a hot flash, because they are “too young.”

From a linear perspective, in addition to means, the “real” result can also be described by identifying universal stages, with deviations from stages considered exceptions or pathological pathways. For example, the Staging of Reproductive Aging Workshop (STRAW) created a staging system for menstruation throughout life, postulating a series of stages—premenopausal, perimenopausal, postmenopausal, each divided into substages--that the average woman progresses through (Harlow et al., 2012; Soules et al. 2001). Perimenopause is often described, as in the classic World Health

Organization (1996) definition, as a discrete stage, when the changes that lead directly to menopause occur, beginning when these endocrinological, biological, and clinical features commence. However, no specific changes that define when perimenopause is initiated have been identified, and operational definitions of stages typically do not provide a reliable, universal distinction between stages, as when symptoms like hot flashes occur earlier (Prior, 1998). In addition, research has documented that a variety of pathways exist, with women skipping stages, going back and forth, or remaining for very different numbers of years in stages (Mansfield, Carey, Barsom, & Koch, 2004).

Controlled experiments and correlational research studies provide evidence that, for example, a difference exists between an experimental and a control group or that two variables co-vary. However, these results are for average differences between groups. There is always, in reality, a spread of data points within groups, that is, a spectrum of individual differences. For example, a woman seeking information may read that rates of depression are higher during perimenopause than at other times. However, this may be reported without also stating that there is a spectrum of data points in which many women do not get depressed and some may be less depressed. Further, the existence of differences between groups may be reported without also stating the absolute rates, for example that rates of depression increase but remain relatively low.

The invisibility in linear systems of normal variability, or the lack of assimilation of variability into a coherent conceptual understanding, is important from a health education perspective, where women need information about what to expect and whether what they are experiencing is normal. Perimenopause involves novel experiences and uncertainty about what to expect. Many women want to know what to expect and how to

make sense of experience. Averages and stage systems that do not correspond to real experience are limited in providing this information. In addition, a linear orientation in which the mean tends to be regarded as the real result can encourage value-judgements about variability. For example, part of normalcy is that things happen at the right time. Thus, if the average age of menopause is 51, then menopause at 45 might seem “really early” or a woman who is not menopausal by age 54 may be waiting, waiting, waiting, and wondering why she is “so late.” In general, changes during perimenopause are defined as aberrations or changes from normal functioning, for example when heavy periods during perimenopause are by definition a “problem” rather than “different” or “really annoying.” Importantly, reliance on norms based on means and averages can encourage understanding one’s own experience by comparing it with these external standards, that is, objectifying one’s body as an object of scrutiny.

In complex systems, on the other hand, means and universal stages do not define the “real result.” Variability is endemic to the system rather than an aberration. The odd extreme value is expected, change over time may result from the internal dynamics of the system. Our research on chaotic dynamics and therefore the existence of a strange attractor implies that there are limits to variability but that individual pathways or lifelong trajectories by definition differ from each other, that is, do not correspond to a measure of central tendency. All of these characteristics influence the nature of health education.

A complex systems perspective encourages noticing the real individual differences that exist, and provides neutral, nonevaluative language for describing them along with a rationale for why this is meaningful. Importantly, change need not be conceptualized as the consequence of a cause destabilizing a previously stable system.

Changes from earlier patterns, as when periods become heavier or more irregular and therefore unpredictable, are not automatically or implicitly deviations from normal functioning or markers for aging. The language is consistent with regarding experience as simply what is happening at the time (i.e., the current state of a system in constant movement) rather than as a transition to be judged, worried about, and completed. If the task is to understand one's unique pathway, then, in addition to gathering information from expert sources, information is needed about one's own experience. Noticing one's individual experience involves a nonalienated stance, interoception or embodiment. These are implicitly encouraged by the facts about variability and nonevaluative language.

This kind of thinking is not excluded by a linear system, but it is not necessary, intrinsic to or coherently explicated within one. Further, what is commonly the case remains useful information or a guideline even when it is not a prescriptive blueprint, and deviations from the average can provide important information, as when they do indicate disease.

The Meaning of Variability

In linear systems predictability and variability serve further roles in the language of underlying paradigms. They define or explicate the meaning of system stability, dysfunction, senescence, and pathology, with central tendency a basis for understanding underlying patterns. This is seen in the definition of menopause with its implicit view of the human life cycle: The reproductive system during the twenties and early thirties is the norm, with variability before this indicating an immature system and after this a disordered senescing system. The very fact that perimenopause is associated with

menstrual cycle patterns and characteristics that differ from those at an earlier age reflects, and is described with, the language of pathology, senescence, or disorder. For example, menopause is included in many medical websites in their list of medical conditions. Other websites state that menopause is “perfectly natural” but nonetheless associated with the onset of chronic illnesses and problematic symptoms. Menopause education often consists of information about uncomfortable symptoms and vulnerability to chronic diseases, with menstrual cycle changes like irregular or heavy flow regarded as symptoms. While research has been inconsistent about whether a variety of changes or medical issues, ranging from hair loss to cardiovascular disease, are truly associated with perimenopause/menopause, these possibilities gain plausibility from the conceptualization that reproductive changes result from a disordered system.

There is not a clear distinction between healthy progress through perimenopause and complications or pathological pathways. Variability, of course, can be an important indicator of medical pathology. For example, heavy bleeding can indicate a variety of important medical problems, from fibroids to cancer, and excessive perimenopausal bleeding can be problematic. However, perimenopausal heavy bleeding has been assigned medical diagnoses like “abnormal uterine bleeding” or “dysfunctional uterine bleeding” and menstrual irregularity has been treated with medications to restore predictable periods. Hot flashes, heavy bleeding, and other experiences can cause severe distress. However, if problems are seen as symptoms of menopause itself, or regarded as having a simple linear cause like changes in estrogens, this discourages considering whether problems and distress are complications of menopause whose cause and remediation need further investigation.

Linear biomedical paradigms about menopause can influence personal narratives about what it means to be a midlife woman and common interpretations of experience with ramifications for subjective well-being and health-seeking behaviors. If perimenopause is a system in breakdown, if unpredictability is evidence of disorder or a “crazy” system, if changes are conceptualized as symptoms, this encourages: perceiving changes as a problem, for example “my body is failing me” rather than “my body is changing, how interesting”; discomfort with uncertainty; and wanting definitive “facts” as an anchor against threat. If perimenopause indicates a transitional state of breakdown, this is consistent with the idea that perimenopause is something to be “gotten through” rather than simply experienced. “How long will this last?” becomes an important question. Symptoms indicate a body letting a woman down, an intrusion on a previously efficient young body. This can encourage an alienated stance towards the body, vigilance in monitoring bodily changes for possible problems with an expectation that changes indicate problems; an inability to predict when changes will end becomes a potential source of uncomfortable uncertainty. If common experiences, like irregular bleeding, are “abnormal” or indicative of reproductive failure or aging, this encourages underlying evaluations that “there is something wrong with my body,” that the body is becoming unreliable in being unpredictable, or an alienated sense that this should not be happening. The likelihood that problems will exist may be focused on, for example when symptoms/experiences like mood changes are described as simply part of menopause. The likelihood of distress may be exaggerated, as when hot flashes are described as affecting 80% of women without distinguishing how frequently or under what conditions coping is problematic.

The language of paradigms can influence whether an experience is regarded as problematic and needing to be coped with, and also influences how to cope with experience when it is problematic. Coping with distress begins with acknowledging distress, which may be facilitated by a linear paradigm. Some women will have severely debilitating, inescapable symptoms well served with a biomedical paradigm. However, for many women, the paradigm facilitates conditions that are not conducive to coping as it contributes to positive health. Coping is facilitated by a sense of efficacy, active engagement with experience, active rather than passive coping, and a sense of self that includes living in one's body, attributes inconsistent with a negative valuation of self and experience and a catastrophizing expectation that severe distress is likely and physiologically determined. Negative or critical evaluations of bodily experience, in addition to being self-alienating, can result in resisting, fighting, or controlling experience, which can amplify and be a component of the experience of distress.

Complexity theory contributes more neutral language. If perimenopause is, as our data indicate, the outcome of a chaotic nonlinear process, this implies that the observed changes in physiology are not those of a disordered system, but, rather, a system in the process of change. This of course leaves open many questions about the nature and meaning of this change (see G. Derry & P. Derry, 2018 for a discussion of possibilities). Hormonal and menstrual flow changes found during perimenopause are consistent with the workings of a nonlinear system rather than in themselves defining a breakdown in physiological mechanisms. Odd patterns are not unexpected or necessarily outside of a coherent system. Variability and unpredictability can define a healthy rather than an unhealthy system. This provides language for regarding

uncertainty, change, and distressing experiences without negative evaluation or anxious vigilance.

A complexity perspective on the underlying physiology is consistent with existing theories that regard menopause as part of a life stage of healthy post-reproductive adulthood rather than health-threatening aging (Derry, 2006; Hawkes & Coxworth, 2013; Kaplan, Gurven, Winking, Hooper, & Stieglitz, 2010). Menopause is an oddity in nature, almost unique to humans: Unlike what is found in other animals, the reproductive system universally shuts down many years before the end of the possible life span and about twenty years before significant senescence of other bodily systems. Post-reproductive women in modern hunter-gatherer societies are present, healthy, and have important social roles. In this view, postmenopause, like other distinctly human as opposed to animal life stages, involves a stretching out of the time that the stage exists, here, a slowing down of aging or a life stage before old age. Again, this perspective is not implicitly inconsistent with a linear view of menopause as senescence (e.g., if menopause did not imply senescence of other bodily systems) but menopause is more typically regarded as emblematic of or accelerating aging.

The Structure of the Underlying System

Much linear biomedical health care proceeds from the assumption of reductionism: Understanding a system means breaking it down into its constituent parts (such as hormones); each constituent is assumed to operate independently as a cause creating a predictable effect (such as the specific effect of a specific hormone); multiple independent cause/effect factors might exist and be added together. This paradigm encourages seeking a “strong” variable with a major impact on health and illness relative

to other independent variables. With perimenopause/menopause, the key causal variable is estrogen. In complex systems, on the other hand, multiple factors interact to form a coherent whole with emergent properties; how parts fit together and interact or are coordinated with each other over time is important; more than one configuration or change can result in the same outcome; systems are typically open systems; interactions with the social and psychological context are expected and make conceptual sense.

A complex systems perspective, for example, can enrich consideration of hot flashes. Hot flashes are a signature symptom of perimenopause/menopause. Flashes are often defined as a transient feeling of heat, sometimes accompanied by sweating or the skin turning red, that typically lasts a few minutes but can persist up to an hour (see Hunter & Mann, 2010). A dominant theory (e.g., see discussion in Hunter & Mann, 2010) is that changing levels of estrogen affect a part of the brain that controls heat regulation, such that small changes in temperature are interpreted by the brain as meaning that the body's temperature is outside the normal range. The hot flash is then the body's attempt to cool down. When acknowledging that a simple change in thermoregulation does not completely account for flashes, other explanations might add that perhaps the hormonal imbalance affects the brain or endocrine glands in additional ways, perhaps some women are simply more sensitive to these changes, and perhaps there are additional causal variables like cortisol.

However, this linear physiology overlooks a lot of known information. Flashes are a family of experiences both physically and psychologically that differ in their configuration from one individual to the next. The experience may not correspond to a physiological pathway, as when a woman feels hot only in an isolated body part like her

back or earlobes, or when the feeling of heat may start in one part of the body (like her head or upper back) and travel. Some women may not realize their feeling of gentle warmth is caused by a flash until later. A woman who is overheated because she is in the desert or at a hot yoga class may not feel like a woman having a hot flash. Further, feeling hot may not be the only experience (see Derry, 2004; Hunter & Mann, 2010). The experience might feel like anxiety. There may be a sharp physical shock or jolt. Some women report other associated sensations such as a racing heart, nausea, breathlessness, dizziness, trouble concentrating. Most women also experience concurrent cognitions and feelings, ranging from empowerment to catastrophic thoughts.

Flashes are clearly related to estrogen. They are more common in the years surrounding menopause and treatment with a hormone medication is often effective. However, flashes are found both during the menopausal transition (when estrogen levels are fluctuating and sometimes high) and after menopause (when estrogen levels are low). Some women have the physiological markers typically associated with flashing but do not experience a flash, while others experience a flash without the expected physiological changes. In addition, distress experienced from flashes is a complex outcome of social, psychological, and physiological factors. The large cross-cultural and socioeconomic differences in flash frequency and perceived distress, and the large placebo effects of medications, are not understood; neither is the role of stress or other psychological or situational factors. Social messages that flashes are embarrassing, cognitions that challenge a woman's self-image (e.g., shaming self-labels), passive (e.g., "grin and bear it") rather than active coping, all have been found to be related to level of distress (e.g.,

Reynolds, 1997, 2000; further discussion of these issues is in Derry & Dillaway, 2013; Hunter & Mann, 2010).

A complex systems perspective encourages attending to, rather than overlooking, the wide range of factors and experiences that describe hot flashes. This broader perspective can promote positive health by encouraging a woman to define her own experience, find positive narratives, take a nonalienated stance towards uncomfortable experience, and in other ways exhibit active coping. Complexity calls attention to the likelihood that multiple factors may be present and that what is helpful for one woman may not be helpful for another. For some women, physiology is most important. However, psychological and social influences and experience make sense within an integrated framework, rather than being add-ons to a primarily physiological experience. Again, catastrophizing expectations that flashes will be unbearable or go on forever, embarrassment that flashes define aging or violate a woman's sense of her competent self, are among the factors that have been associated with increased distress. Resistance to flashes, through fear or anger that they exist, can amplify distress. These cognitions can result from a woman's individual psychology, or may be encouraged socially through, for example, stereotypes, advertising, media first-person accounts.

A complexity framework is useful for integrating the known data and for encouraging a broad, health-promoting paradigm. However, whether hot flashes are the outcome of a mathematically describable nonlinear dynamical system awaits future research. As discussed below, this research could inform understanding of how to treat severe symptoms.

IMPLICATIONS FOR FUTURE RESEARCH

This article has explored how nonlinear, as compared with linear, systems research leads to different facts and dynamics, and, in addition, how basic assumptions and paradigms imply differences in language and orientation that can have important health promotion consequences. However, evidence is needed about whether consequences for health promotion do in fact exist. For example, a sample research study might involve comparing experimental groups that read educational materials or attend in-person lecture or discussion groups based on complexity-based vs. linear language. For a study of education about the normal course of perimenopause/menopause, both groups might receive essentially similar information (e.g., that menstrual cycle lengths become more variable during perimenopause). The linear-based group might receive information with conventional language, for example that the cycle has become irregular and erratic, that perimenopause/menopause are a distinct life stage of aging. The complexity-based protocol might, for example, emphasize that there is a scientific basis for asserting that the menstrual cycle has a dynamic lifelong trajectory, that it is in the nature of the system for there to be unpredictability and individual differences, describe menstrual cycle changes during perimenopause with neutral language. Outcome variables might include retention of factual information, stated willingness to engage in health-promoting behaviors, attitudes towards menopause, interoception vs. an objectified relationship to the body, self-efficacy, or other measures of well-being and positive health. For studying menopause-related distress rather than the normal course of menopause, similar educational groups could be created, for example describing distress with conventional vs. integrative language (especially with regard to biological causation), having subjects track their personal experience of levels of distress/symptoms

vs. track a broader range of variables and moments when distress is low, etc. Outcome variables might include level of distress, coping mechanisms, hopefulness/hopelessness, feelings of self-efficacy, social/behavioral/biological correlates of times women feel lower distress.

In our research, menstrual cycle length was a measure of the output of the entire reproductive system. Additional evidence for nonlinearity comes from research modeling the reproductive system with nonlinear equations (e.g., G. Derry, 2013; Hendrix, Hughes, & Selgrade, 2014). Additional research is needed to explicate system structure, mechanisms or interactions of components, and outcomes. For example, if estrogen is one component of a larger system, how can this system be described? What are its components, and how are they coordinated? Can a healthy baseline be described, with problems variations from this baseline? Can a measure for nonlinearity be developed, that is useful in describing or predicting health problems? For example, can hot flashes, physiologically or experienced as distress, be approached by understanding the coordination of the interacting factors that give rise to them, or as an emergent to be approached in its own terms? Perhaps flash frequency and distress might result from a variety of pathways and might have top-down effects on the constituent factors. As an analogy, pain has been regarded as an emergent experience of danger that can result from local tissue damage, a myriad of other cellular changes or changes in the central or peripheral nervous system, or psychological factors.

An additional important research question is whether estrogen, in addition to being a component of the system, itself has quantifiable nonlinear dynamics. Endogenous estrogens have temporal patterns of release and are released in a pulsatile

manner. Are the fluctuating, pulsatile levels of estrogen the output of a nonlinear dynamic? If so, then the temporal patterning of release, for example too much or too little regularity, may be important to health, as has been found for other biological systems, and might be important to characterizing the presence of or predicting problems in areas ranging from hot flashes to other correlates of menstruation or menopause. Oral contraceptives override the endogenous release of estrogens and override the feedback interrelationships among components of the system. Might this be related to menstrual and fertility problems immediately after discontinuing birth control? At the time this article is being written, menstrual difficulties after coronavirus 19 (Covid) vaccination are being reported: Might these be related to the ability of the system to recapture its resilience, as opposed to causal effects?

If estrogen release is nonlinear, this also has implications for interpretation of data, research design, and broader implications about the nature of menopause. For example, health benefits of postmenopausal hormone medications in preventing chronic illnesses are typically regarded as physiological, replacing needed hormone, rather than pharmacological, that is, due to unusual amounts or patterns of release. However, hormone medications flood the system with estrogen, estrogen that is not released in a pulsatile manner. If estrogen dynamics are nonlinear, might this change in the pattern of amount and release create unusual effects, perhaps best understood as pharmacological rather than physiological? Similarly, women with natural menopause, who have small amounts of estrogen produced physiologically, are often combined in research with women who have had oophorectomies and therefore have no endogenous estrogen

release, and who may be prescribed estrogen medications: Might there be important physiological differences between these groups?

SUMMARY AND CONCLUSIONS

Research conducted by my collaborator and I provided evidence that before and during perimenopause the menstrual cycle is the output of a nonlinear system in a chaotic trajectory. This article explored implications of this finding for understanding important perimenopause-related health issues, especially for understanding, encouraging, and facilitating positive health.

First, this is an important conceptual shift from how the dynamics of perimenopausal physiology is currently understood. If perimenopausal physiology, like the menstrual cycle earlier in adulthood, is chaotic, this means that observed physiology reflects the dynamics of an organized system, not disorder and breakdown. The assumption that senescence or pathology underlie this physiology has guided research design and interpretation, as well as medical interventions and concepts of the role of menopause in the human life cycle. While further research is needed to explicate the structure and dynamics of this system and its changes over time, having a nonlinear dynamical perspective in itself leads to important research questions being asked and previously overlooked facts making sense within a coherent framework. Important implications for perimenopause research include: A model of physiology that is not dependent on assuming disorder, pathology, or senescence; asking whether there is a distinction between normal pathways and problematic variations; the salience of the biopsychosocial perspective in an open and dynamic system; and the importance of

dimensions like the meaningfulness of variability and the importance of considering multiple components of a system and their coordination over time.

Women look to science to understand the workings of their bodies, what to expect, what a normal woman experiences vs. what is unusual or abnormal, what is a cause for concern. Complex systems research contributes to health education and health promotion by influencing what counts as important and accurate information. For example, in complex systems variability in the menstrual cycle from woman to woman and cycle to cycle, with individual differences in the trajectories over the lifespan, become important data rather than overlooked. While averages can provide useful guideposts, they do not define a “real” result. Understanding when experience might indicate an abnormality is important, but individual differences and the wide range of individual experience are normal and expected. Further, since phenomena involve a variety of components organized into a system, this encourages attending to the richness of experience beyond the information contained in a simple definition as, for example, in the variety of experiences that can constitute hot flashes. Making sense of menopause involves examining personal experience in addition to learning objective facts.

Health paradigms, whether linear or complex, form an overarching narrative with connotative as well as denotative, implicit as well as explicit meanings. Connotative and denotative meanings both have the potential to influence health-promoting or undermining attitudes, self-attributions and narratives, all of which impact positive health. The language of a paradigm provides imagery with which experience is understood and evaluated, and can influence how a woman orients to experience, the felt-sense of experience, the core imagery of how things fit together, the story of one’s body

and of health/illness. This includes experiences of owning experience vs. an alienated stance towards experience, efficacy vs. helplessness, construing experience as pathological or not. A nonlinear paradigm can facilitate positive health by providing nonjudgmental, neutral language; encouraging agency in exploring personal experience; validating experience; providing coherent narratives of normal development.

The narratives implicit in scientific paradigms can become part of the cultural landscape, contributing to socially shared assumptions and individual cognitions that bear on health. With regard to menopause, the broader narratives often involve implicit theories of the human life course in which menopause signals disorder, aging, and senescence. A nonlinear perspective provides language for health-promoting narratives with scientific credibility.

For health providers, educating patients/clients about perimenopause and menopause involves communicating important facts. Education based on linear and complexity models will differ, at least in places, in understanding of what are important facts and their meaning. In addition, for both health education and when pathology exists, the clinical relationship, in its important effect on outcomes, involves provider qualities like warmth and authenticity, but there are also connotative as well as denotative aspects of language at play in health encounters. Communications that encourage positive-health-promoting attitudes can build on the implications of nonlinearity discussed above.

In sum, nonlinearity in the menstrual system has important implications for research questions asked, determining what facts are important and how they are conceptualized, and provides positive-health-promoting language.

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REFERENCES

- Centers for Disease Control and Prevention. (2018). *Health-related quality of life. Well-being concepts*. <https://www.cdc.gov/hrqol/wellbeing.htm>.
- Chrisler, J. & Johnston-Robledo, I., (2018). *Women's embodied self*. Washington, DC: American Psychological Association.
- Derry, G. (2013). Chaotic trajectories in nonlinear modeling of the human menstrual cycle. Society for Chaos Theory in Psychology and Life Science, 23rd Annual Conference, Portland, OR.
- Derry, G. & Derry, P. (2010). Characterization of chaotic dynamics in the human menstrual cycle. *Nonlinear Biomedical Physics*, 4, <http://www.nonlinearbiomedphys.com/content/4/1/5>
- Derry, G. & Derry, P. (2018). Lifespan characterization of chaotic dynamics in menstruation. *Nonlinear Dynamics, Psychology, and Life Sciences*, 22, 439-456.
- Derry, G., Mullen, E., & Marcelino, K. (2020). Effects of dynamical time scale mismatch on time series analysis using event intervals. *Communications in Nonlinear Science and Numerical Simulation*, 80. Retrieved from <https://doi.org/10.1016/j.cnsns.2019.104986>.
- Derry, P. (2004). Coping with distress during perimenopause. *Women and Therapy*, 27, 165-177.
- Derry, P. (2006). A lifespan biological model of menopause. *Sex Roles*, 54, 393-399.
- Derry, P. (Sept., 2010). *Developing a healthy stance towards perimenopausal and menopausal distress*. Paper presentation, New York Academy of Sciences symposium "Women, Power, and Aging." New York City.

- Derry, P. & Derry, G. (2012). Menstruation, perimenopause, and chaos theory. *Perspectives in Biology and Medicine*, 55, 26-42.
- Derry, P. & Derry, G. (2014). Analysis of the STRAW operational definition of the early menopausal transition. *Women's Reproductive Health*, 1, 21-30.
- Derry, P. & Dillaway, H. (2013). Rethinking menopause. In M. Spiers, P. Geller, & J. Kloss (Eds.), *Women's Health Psychology*, pp. 440-463. New York: Wiley.
- Goodman, H. M. (2009). *Basic medical endocrinology (4th edition)*. Amsterdam: Elsevier Academic Press.
- Gorrindo, T., Lu, Y., Pincus, S., Riley, A., Simon, J., Singer, B., et al. (2007). Lifelong menstrual histories are typically erratic and trending. *Menopause*, 14, 74-88.
- Hale, G., and H. Burger. (2005). Perimenopausal reproductive endocrinology. *Endocrinology and Metabolism Clinics of North America*, 34, 907-922.
- Harlow, S., Gass, M., Hall, J., Lobo, R., Maki, P., Rebar, R., de Villiers, T. (2012). Executive summary of the Stages of Reproductive Aging Workshop + 10: Addressing the unfinished agenda of staging reproductive aging. *Journal of Clinical Endocrinology and Metabolism*, 97, 1159-1168.
- Harlow, S., X. Lin, and M. Ho. 2000. Analysis of menstrual diary data across the reproductive life span: Applicability of the bipartite model approach and the importance of within-woman variance. *J Clin Epidemiol* 53:722-33.
- Hawkes, K. & Coxworth, J. (2013). Grandmothers and the evolution of human longevity: a review of findings and future directions. *Evolutionary Anthropology*, 22, 294-302.

- Hendrix, A., Hughes, C., & Selgrade, J. (2014). Modeling endocrine control of the pituitary-ovarian axis: Androgenic influence and chaotic dynamics. *Bulletin of Mathematical Biology*, 76, 136-156
- Hunter, M. & Mann, E. (2010). A cognitive model of menopausal hot flushes and night sweats. *Journal of Psychosomatic Research*, 69, 491-501.
- Kaplan, H., Gurven, M., Winking, J., Hooper, P., & Stieglitz, J. (2010). Learning, menopause, and the human adaptive complex. *Annals of the New York Academy of Sciences*, 1204, 30-42.
- MacPherson, K. (1981). Menopause as disease: The social construction of a metaphor. *Advances in Nursing Science*, 3, 95-113.
- Mansfield, P. & Bracken, S. (2003). *Tremin: A history of the world's oldest ongoing study of menstruation and women's health*. Lemont, PA: East Rim Publishers.
- Mansfield, P., Carey, M., Anderson, A., Barsom, S. H., & Koch, P. B. (2004). Staging the menopausal transition: Data from the Tremin research program on women's health. *Women's Health Issues*, 14, 220-226.
- Martin, E. (1992). *The woman in the body*. Boston: Beacon Press.
- Mehling, W., Wrubel, J., Daubenmier, J., Price, C., Kerr, C., et al. (2011). Body awareness: A phenomenological inquiry into the common ground of mind-body therapies. *Philosophy, Ethics, and Humanities in Medicine*, www.peh.med.com/content/6/1/6.
- National Center for Complementary and Integrative Health. (2021). NCCIH Strategic Plan FY 2021-2025: Mapping the Pathway to Research on Whole Person Health.

- National Center for Complementary and Integrative Health website accessed at <https://nccih.nih.gov/about/nccih-strategic-plan-2021-2025> on October 1, 2021.
- National Institutes of Health. (2018) *Emotional well-being. Emerging Insights and questions for future research*. Roundtable meeting report, April 3-4, 2018.
- National Research Council. (2013). *Subjective well-being: Measuring happiness, suffering, and other dimensions of experience*. Washington, DC: The National Academies Press.
- Prior, J. (1998). Perimenopause: The complex endocrinology of the menopausal transition. *Endocrine Review*, 19, 397–428.
- Reynolds, F. (1997). Psychological responses to menopausal hot flushes: Implications of a qualitative study for counseling interventions. *Counseling Psychology Quarterly*, 10, 309–321.
- Reynolds, F. (2000). Relationships between catastrophic thoughts, perceived control and distress during menopausal hot flushes: Exploring the correlates of a questionnaire measure. *Maturitas*, 36, 113–122.
- Schuldberg, D. (2015). What is optimum variability? *Nonlinear Dynamics, Psychology, and Life Sciences*, 19, 553-568.
- Soules, M., Sherman, S., Parrott, E., Rebar, R., Santoro, N, Utian, W., & Woods, N. (2001). Stages of Reproductive Aging Workshop (STRAW). *Journal of Women's Health and Gender-Based Medicine*, 10, 843–848.
- Sturmberg, J. & Martin, C. (Eds.). (2013). *Handbook of systems and complexity in health*. New York, N.Y.: Springer.

- Treloar, A., Boynton, R., Behn, B., & Brown, B., (1967). Variation of the human menstrual cycle through reproductive life. *International Journal of Fertility*, 12, 77-126.
- Varela, M., Ruiz-Esteban, R., & Mestre De Juan., (2010). Chaos, fractals, and our concept of disease. *Perspectives in Biology and Medicine*, 53, 584-595.
- Voda, A. (1997). *Menopause, me and you*. Haworth Press: Binghamton, NY.
- Voda, A., & Ashton, C. (2006). Fallout from the Women's Health Initiative Study: A short-lived vindication for feminists and the resurrection of hormone therapies. *Sex Roles*, 54, 401-411.
- World Health Organization. (1946). Preamble to the constitution of WHO. Official Records of WHO, no. 2, p. 100.
- World Health Organization. (1984). *Health promotion. A discussion document on the concept and principles*. Working group on concept and principles of health promotion. Copenhagen, 9-13, July 1984.
- <https://apps.who.int/iris/bitstream/handle/10665/107835/E90607.pdf?sequence=1&isAllowed=y>
- World Health Organization. (1996). *Research on the menopause in the 1990s: A report of the WHO scientific group*. Geneva: WHO.