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In Memoriam

Dr. Salvador Villalpando Hernández (1943–2024): A Tribute to his Scientific Legacy

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This tribute manuscript is dedicated to Dr. Salvador Villalpando Hernández, an outstanding figure in Nutrition and Health, who left an indelible mark on the public health community in Mexico and beyond. He was born in Aguascalientes, Mexico, on April 3, 1943. His distinguished career spanned over 4 decades, during which time he tirelessly advanced research, capacity building, and policy development in health and nutrition. It is a formidable challenge to capture in this manuscript what Dr. Villalpando meant to the field. In this piece, we recognize his contributions to research and training in nutritional sciences, with an emphasis on the period in which he conducted research in nutritional epidemiology and public health. We have selected and listed at the end of the manuscript, examples that illustrate Salvador's relevant contributions to knowledge and public health. The authors of this tribute were Dr. Villalpando's colleagues for 25 y, who benefited from his wisdom and enjoyed his friendship.

Dr. Salvador Villalpando Hernández was trained as an M.D. and Endocrinologist in Mexico, continued his education in pediatric endocrinology and metabolism at the Children's Hospital of Pittsburgh, United States, and completed a Doctorate in Medical Sciences from the National Autonomous University of Mexico.

Dr. Villalpando started his research career at the Mexican Institute of Social Security (IMSS), where he worked from 1972 to 2001, and later at the National Institute of Public Health (INSP) from 2001 until 2023.

His research career can be divided into three distinct periods: The first period was from \sim 1980 to 1990, during which he participated with a research team at IMSS conducting clinical research in endocrinology, primarily in children and adolescents with diabetes, renal diseases, and other health conditions. His research during this period was published in international journals. A second period, from 1990 to 1997, while still working at IMSS, was devoted to the study of human milk composition in Mexican indigenous women relative to Caucasian women [1], and to different dietary patterns [1] and nutritional status [2]. His research on human milk and breastfeeding was ground-breaking, making important contributions to the field. His research revealed, for example, that mothers with lower BMI produced milk with lower fat content but higher volume, ensuring equal energy intake for infants regardless of maternal BMI [3]. He also studied the breastfeeding performance of weaning mothers of different nutrition and health statuses and the growth and health of breastfeed children [4].

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The third and last period started in 1998 when one of the authors of this manuscript (J.A.R.), leader of Nutrition and Health Research at INSP at the time, invited Dr. Villalpando to collaborate. During that period, J.A.R, with the support of the INSP leadership, sought to start a new generation of National Health and Nutrition Surveys (ENSANUT) and recruited T.S.L, the second co-author of this tribute, and Dr. Villalpando to collaborate with ENSANUT. TSL coordinated the entire effort, and Dr. Villalpando developed a nutrition laboratory and determined the biomarkers to be collected by ENSANUT. This period, which spanned until 2023, marked a shift in Dr. Villalpando's career toward epidemiology and public health research. His research focused on the micronutrient status of the population and the efficacy and effectiveness of interventions and programs to address micronutrient deficiencies in the population.

Dr. Villalpando's contributions during this period were instrumental in enhancing public health as he led the biological measurements for ENSANUT from 1999 to 2012. In 1999, he and his colleagues published, for the first time, the results of the micronutrient status of the Mexican population in a national

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random sample (ENSANUT) and highlighted the high prevalence of anemia [5] and several micronutrient deficiencies [6] (particularly iron and zinc) [7] in children younger than 2 y. ENSANUT has become a regular monitoring instrument in Mexico, and the micronutrient status of the population continues to be monitored, as a legacy of Dr. Villalpando's introduction of micronutrient determinations at the inception of ENSANUT.

The high prevalence of anemia, micronutrient deficiencies, and undernutrition in young children, revealed in the 1999 survey, was used by the INSP Nutrition team to advocate the need for large-scale nutrition interventions in Mexico. This led to 2 nationwide programs: a national conditional cash transfer program (Progresa) that covered 2.3 million low-income households and provided nutrition supplements, containing essential micronutrients for young children and their pregnant and lactating mothers, and the fortification of whole milk distributed at low cost by a Government Agency (Liconsa) to \sim 4.2 million children living in poverty.

Dr. Villalpando's research was essential in identifying appropriate bioavailable fortificants for the Progresa nutrition supplement that would not compromise its acceptability owing to changes in the organoleptic characteristics of the product [8]. By comparing ferrous sulfate, ferrous fumarate, and reduced iron with Na(2)EDTA, he demonstrated that ferrous sulfate had significantly higher bioavailability, making it a superior option for meeting the daily iron requirements of young children when used in fortified foods. However, sensory evaluations revealed issues such as metallic taste and alterations in the color and flavor of the supplement fortified with ferrous sulfate, resulting in a lower consumer acceptance; therefore, the encapsulated form of ferrous sulfate was ultimately adopted to avoid changes in the acceptability of the supplement while increasing its bioavailability.

Two key publications, in which Dr. Villalpando was a coauthor, ratified his involvement in the effectiveness evaluations of large-scale nutrition programs. One of the articles showed evidence of the effectiveness of Progresa in improving linear growth and reducing anemia in infants who received nutritional supplements [9]. The second publication showed that fortification of milk with iron, zinc, and other micronutrients reduced anemia and iron and zinc deficiencies among low-income children 12–30 months of age who were beneficiaries of this large-scale fortified-milk program [10].

In other food fortification efforts, Dr. Villalpando advocated for more bioavailable forms of iron, such as ferrous fumarate, in fortified corn flour. He even designed a dosing device for nixtamalized maize dough mills to improve nutritional quality.

Villalpando's scientific legacy was published in 171 peerreviewed scientific articles with over 13,500 citations.

Dr. Villalpando was a dedicated educator for undergraduate and graduate students. He served as a professor of half a dozen courses at different universities and institutions. At INSP, he was the lead professor of Physiology and Biochemistry of Nutrition in the Master's in Nutrition Science Program from 1997 to 2020. He supervised 34 undergraduates and 27 graduate theses. He also mentored many young researchers who are currently productive investigators.

His career and contributions have been widely recognized in Mexico and abroad. In Mexico, he was a member of the National Academy of Medicine, the Mexican Academy of Sciences, and the Mexican Academy of Pediatrics. He also served as Secretary of the National Academy of Medicine and held the roles of Secretary, Vice President, and President of the Mexican Society of Nutrition and Endocrinology.

Internationally, he served on the Board of the International Society for Clinical Research, was a full member of the American Society for Nutrition, and a full member of the International Society for Human Milk and Lactation, where he held several leadership roles before serving as President between 1998 and 2000.

Dr. Villalpando received numerous awards in recognition of his remarkable contributions, including the Alfonso Rivera Award from the Mexican Society of Nutrition and Endocrinology (1985), Dr. Alejandro Celis, and Dr. Everardo Landa awards from the National Academy of Medicine (1986, 1992); the Alfonso Caso Summa Cum Laude Medal from UNAM (1998); the Salvador Zubirán Award for his distinguished career in Nutrition and Endocrinology (1999); the National Public Health Award "Gerardo Varela" (2007); and the Aguascalientes Award for Science and Technology Development (2008).

He was a consultant for numerous events hosted by the Pan American Health Organization and the WHO, contributing to the summits on complementary feeding, flour fortification, and iron and folate status indicators. His consulting roles also extended to the International Atomic Energy Agency, Vatican Academy of Sciences, and University College London.

Salvador was also a dedicated husband, father, and grandfather. He married Adriana Carrión, with whom he begot 3 children: Adriana, Salvador, and Mónica who are married and have given Salvador and Adriana 11 grandchildren.

The legacy that Dr. Villalpando leaves behind is a testament to his unwavering dedication to conducting research aimed at improving public health. All those who had the privilege of working with him remember not only his scientific contributions but also the mentor and friend who inspired generations of researchers.

Conflicts of interest

The authors report no conflicts of interest.

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