

# Perspectives on the Role of Bioengineering for Sustainable Development in the Health of Women

Chrysanthus Chukwuma Sr\*

Executive Director, Centre for Future-oriented Studies, Abakaliki, Ebonyi State, Nigeria

## ABSTRACT

Sustainable development in health is broadly associated with policies, projects and investments which offer benefits without inimical inputs on environmental, social and personal health. Bioengineering solutions are primordial, pivotal and critical to advance the health of women, and are key drivers to achieve the United Nations Sustainable Development Goals (SDGs), with particular focus on SDG 3 (Good Health and Well-being) and SDG 5 (Gender Equality). The focus of bioengineers is on the extant healthcare contradictions which have created the pertinence to develop innovative diagnostic and therapeutic apparatus designed to female physiology. Global critical reflections expose significant imbalances and invariance in bioengineering for the health of women, which suppress sustainable development goals. This work addresses in scope and depth, a critical intersection of bioengineering, sustainable development and the health of women. It essentially enacts an endowed tapestry of extant technological advancements and their potential applications, framed within the urgent global context of SDGs, demonstrating a topical coverage from advanced biomaterial applications and diagnostics to wearable technologies. The article links bioengineering advancements to more expansive health and gender equitable objectives with relevance and timeliness of this research sphere, and significant value in future perspective of both extant benefits and potential future trajectories.

**Keywords:** Biomedical Engineering, Fertility, Gynaecological Challenges, Ageing, Pregnancy, Economic Burden.

## INTRODUCTION

It is evident that global experts map out the practical trajectories which enhance the extension of life expectancy, especially in women. In order to share advances in ageing biology, lifestyle medicine, and community-based modalities for healthy longevity [1-3] the 1st World Longevity Summit in Kyotango, Japan gathered global experts [4]. The joint declaration enacted four core tenets, such as social connection, plant-focused diet, diurnal activity, and reciprocity or sense of obligation, as pillars to globally extrapolate healthy life expectancy. On May 28, 2025, in cognizance of The International Day of Action for Women's Health, an assemblage of

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## \*Corresponding Author

### Dr Chrysanthus Chukwuma Sr,

Executive Director, The Chrysanthus Centre for Future-Oriented Studies, Abakaliki, Ebonyi State, Nigeria, Phone: +2348144752275, ORCID: 0000-0001-9162-6604, E-mail: chukwumasr@gmail.com

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concerned citizens narrated the pertinence for innovative solutions to confront protracted challenges and issues in the health of women [4] from the perspective of bioengineering, as ageing populations globally confront incessant challenges, issues, priorities and opportunities in promoting and improving healthy longevity. Inordinate amount of common diseases manifests disproportionately in women, a paucity of understanding of the underlying mechanisms and deficiency of defined therapeutic approaches incessantly impact health outcomes and prognosis. The SDG goals for maternal health are that by 2030, there must be diminished global maternal mortality ratio less than 70 per 100,000 live births, with ensured global accessibility to sexual and reproductive healthcare services, such as family planning, information, education, and integrated reproductive health, national strategies and programmers.

### **Bioengineering devices for the health of women**

Bioengineered organoids, organ-on-chip systems, and biomaterials are objective tools to explore, unravel or elucidate pathological mechanisms in reproductive and musculoskeletal milieu [5-7], cancer, autoimmune disorders, while patterned diagnostic and treatment modalities are capable of advancing clinical intervention efficacy. The multidimensional assemblage of strategic technological, translational, and clinical investigation essentially presents the complete potentiality of bioengineering solutions for the improvement of the health of women [8]. The thematic apperception of Interface Focus articulates the priorities, challenges, issues and opportunities of bioengineering in the health of women. Inasmuch as there has been a protracted collaborative engagement between engineers and the medical genre in orthopaedics and cardiovascular medicine, for instance, interest has grown within the past decade for multidimensional collaborations in other medical disciplines. This is evident in the health of women, that exposes a conventional underprivileged and neglected research spectrum in the scientific sphere wherein primordial essence regarding female physiology is grossly required. The health of women categorically expansively compasses normal and abnormal pregnancy or reproduction and possibly associated sequelae at problematic child birth, fertility, and maternal health status. Furthermore, the health of women embraces pathologically sex-associated cancer, pain, cardiac disorder, osteoporosis and other anomalies exposed due to technological

advances on the evolving medical discourse for all and sundry. Bioengineering focuses on the advances in the investigation of the non-pregnant female person, and highlights essential developments in pelvic floor derangements, biomedical apparatus, fertility, breast cancer, breast implant failure [9], discomfiture and sequelae. Within global healthcare systems, the incessant sex and gender biases have benefited cisgender males, resulting in women and transgender persons not to be properly researched and represented in the medical transect or precinct. Therefore, these entities are perspicuously neglected in health policy and decision making. Persistent and incessant inequitable gender, socioeconomic, and racial-ethnic segregation, discrimination, especially in vulnerable and low-resource communities have invariably culminated in the exacerbation of concerns in the position of the health of women, with procrastinating and regarding progress and improvement in quality of care and accessibility to adequate resources. Despite these untoward features, there have been emergence of tracking technologies and wearable devices which potentiate resilient biomonitoring of pivotal health biomarkers which tend to facilitate early disease diagnosis for women generally. These newfangled trajectories benefit education, information and accessibility which can subvert or overcome impediments to healthcare access and management which have historically impacted women globally. Thus, emerging biomonitoring tools for the critical diagnosis and management of the health of women according to the World Health Organization encompass vaginal infections, breast and gynaecological cancers, pregnancy, fertility, and post-menopausal osteoporosis. It is imperative to explore the extant commercial spectra of the health of women technologies, with special emphasis on the barriers to adoption, such as medical insurance accessibility, socioeconomic status and opportunities for innovations in the future [10].

The trajectory to the health of women significantly impacts sustainable development [11,12] by progressive improvement of health outcomes (SDG 3): Emphasizing female-specific states, such as maternal morbidity and mortality, which remains a profound challenge worldwide, particularly in vulnerable populations and low-income countries, constitute target delivery goals of the UN. The prioritization and promotion of gender equality (SDG 5), become enhanced as women grab control over inter alia their health, reproductive choices, expansive access to education and economic prowess, empowerment and equality fostering. Driving economic

growth will perspicuously bridge the gap in the health of women, may trigger an estimated increment of \$1 trillion yearly to the global economy by 2040, depicting a prominent economic stance for investment [13]. The health of women constitutes a pivotal driver of sustainable development [12,14] as it impacts encompass health, economic growth, equality and equitable distribution of resources. Although, there have been progress in certain spheres, significant challenges are outstanding, especially in low-income countries [13] and vulnerable populations globally.

### **Bioengineering Innovations and Applications in the health of women**

Bioengineering is the driver in paramount innovations regarding the health of women by developing novel diagnostics, targeted treatment, progressive and improved monitoring tools encompassing conditions which disparately impact women, disproportionately or exclusively. Bioengineering historically focuses on research biases, such as employing male-centric models by addressing sex-specific disparities with the development of defined technologies. Pivotal spheres of innovation encompass: Advanced diagnostics as evidenced in bioengineered point-of-care (POC) devices and biosensors which potentiate earlier, greater accessibility in the detection of conditions, such as osteoporosis, vaginal infections, breast and gynaecological cancers. Therefore, bioengineered point-of-care (POC) devices and biosensors provide newfangled strategies to healthcare by enhancing the prompt, highly accessible, and usually non-invasive detection of diverse precarious states. These devices progressively enhance patient outcomes through the facilitating prompt intervention and decreasing dependence on exorbitant, centralized laboratory tools [10].

Wearable technologies, such as smart clothing, wireless sensors, and patches provide the latitude for uninhibited, real-time monitoring and evaluation of vital signs and hormonal disruptions associated with chronic pain, fertility and pregnancy, improvement of protracted health management. Wearable health devices are of increasing importance in the management of chronic disorders as they provide real-time monitoring and individualized care [15]. Physiological modelling relates to developing bioengineered organoids and organ-on-chip systems employing anthropogenic female cell lines to unravel disease mechanisms in, for instance, autoimmune and musculoskeletal diseases which present

differentially and distinctively in women with resultant highly effective therapeutic regimen. Current research emphasizes the potential of organoids, a category of auto-organizing mini-organs obtainable from diverse cell sources and tissue biopsies, to replicate precisely the major anatomical characteristics and physiological attributes of vital body organs localized inside the torso. Due to the multiple trajectories, this technology has made available for biomedical studies, progressive opportunity for innovative engineering to enact, configure, manufacture, extrapolate the study of organoids and their microambients [16].

Biomaterial science or engineering of nascent biomaterials are accessed to address repair of reproductive tissue, safety of breast implant, and targeted drug delivery [17,18] systems development. A biomaterial is a substance that interacts with biological systems to access, assess, treat, improve, or substitute an organ, tissue, or bodily functionality. The potential of a material not to be entangled in biological rejection and non-toxicity, while undergirding appropriate cellular or tissue responses, correlate biocompatibility. These substances are not capable of producing or discharging toxic, deranging, or immunologic response in/to living tissue. The biomaterial discipline is an aggregate of basic, applied and medical sciences, recent incorporation of materials science and tissue engineering as well as significant expansion due into tissue engineering, regenerative medicine, and associated disciplines. Metals [19,20], other abiotic, and biotic materials, such as cells and tissues are amenable to biomaterials. In application for biomedical devices and products, they are reengineered into molded or machined ingredients, coatings, fibers, films, foams, and textiles, and formidable functionalities in healthcare systems. Tissue structuring constitutes a subset of biomaterials that is rapidly gaining traction as a therapy for multiple restorative states. Progressive tissue planning in combination with discoveries from natural, cell, nuclear and material sciences create three-dimensional structures with formidable attributes which enable biomaterials to compensate degraded portions. Biomedical engineers are primordial in tailoring healthcare future. The requisite demand for more optimistic, safe, precise, improved and versatile medical technology does not seem to falter as biomedical engineers are tenaciously at the forefront of the demand [21] for sustainable development [11].

### Challenges and future directions in the health of women

The health of women confront challenges associated with gender bias, deficient research, issues of reproductive rights, mental health deficit and disparities, non-communicable diseases, NCDs, domestic violence, and socioeconomic burden and barriers. In this regard, future directions must incorporate precision medicine, digital health, life-course strategies, targeted research on menopause, PCOS, enhanced policies in the workplace and healthcare access, and addressing intersectionality per race, age, poverty for equitable holistic care [22] and personalized distribution of resources and the commonwealth. The evolution of the geopolitical landscape, highlighted by accelerated multipolarity, steadfastly influences the health of women, especially with incessant resistance to change on sexual and reproductive health and rights [23]. Despite grim efforts to progressively accelerate multidimensional focus areas to diminish maternal and perinatal mortality [24] with their influences on women, and tackling reproductive cancers [25] aggravated challenges pertain. Increasing awareness of gender and health inequities and inequitable in planned commitments in primary healthcare and global healthcare, indicate the excruciating need for pertinent action [26].

Within an expansive range of diseases, there are pronounced disparities influencing prevalence, incidence, and severity between the sexes, however, the magnitude of the disparities is not completely unravelled [27]. Although, dire efforts have been applied, grave barriers inhibit broad implementation in the health of women. Historically, research gaps in the health of women have resulted due to inchoate funding and neglect, culminating in a paucity of robust models and data. Advances in global health equality are continuously suppressed due to differences in the data of the health of women. Irrespective of comprising an excess of 50% of the global population, women are still underrepresented or disenfranchised in numerous health datasets [28]. For accessibility and usability, technologies must be designed for varied populations, taking into consideration age, socioeconomic attributes, and digital literacy, particularly in diminished resource ambient. The universal demographic shift predilect to an ageing population requires a subtle and intricate strategy to develop and adopt assistive technologies pertinent for elderly individuals [29] and other vulnerable populations such as women and children [12].

Decline in universal and cohesive policymaking as well as egalitarian funding streams result in impediments in commercialization and widespread technological adoptability. Numerous international bodies and initiatives are in the forefront to address these issues using diverse modalities. The multitudinous, unpredictable and frequently inflexible characteristics of DAH funding has spurred several non-governmental organizations to search for other conducive outlets of funding and associations of varied partnerships for the achievement of sustainable development goals. Collaborations with multiple funding groups provide the latitude to leverage sole funder interests in the achievement of increased comprehensive programmes and sustainable decision-making [30,31].

The future of bioengineering in the health of women attracts multidimensional incentives, enhanced input and investment, as well as the leveraging of technologies to explicate complex data to unravel healthcare complexities for equitable solutions concerning the health of women. The access to quality healthcare is a global task, especially in restricted geopolitically disadvantaged and vulnerable spheres, depicting incessant and persistent inequities in the distribution of wealth and resources. The emergence of machine learning (ML) is considered a transformative instrument, providing progressive and predictive potential and data-correlated hallmarks to tackle nuanced disparities. Through the analysis of expansive datasets, ML drives healthcare systems to identify patterns, optimize resource allocation, and improve decision-making processes. These innovations are crucial in areas such as early disease detection, patient outcome prediction, and operational efficiency [32].

### Reproductive Health and Fertility

Reproductive health is the entire well-being of the reproductive system, encompassing menstruation, infertility, pregnancy, contraception, and family planning, with impact on physical, mental, and social spheres of life, and fertility depicting ability to conceive, directed tremendously via lifestyle attributes, such as exercise, diet, weight, stress, smoking, alcohol, and correlated untoward conditions. The sustainable sustenance of reproductive health incorporates safe sex, preventive care, management of chronic disorders, and healthy behaviours to undergird fertility for both sexes [33].

Tissue engineering is a multidimensional discipline that aggregates cells, engineering, and diverse materials for the creation of biological surrogates for the restoration, improvement and sustainable sustenance of degraded tissues or organs, with the sustainable objective to prevent organ shortfalls and immune rejection by creating functional tissue in the laboratory precinct by employing biomaterials, scaffolds, and growth factors. It constitutes a pivotal aspect of regenerative medicine, with sustainable objective of generating living tissues for transplants, whether xenograft, isograft, allograft, and auto graft, and for biosensors and drug appraisal testing. Tissue engineering are applicable in the construction or formation of operative or operational ovarian, uterine, and vaginal designs via the application of 3D bioprinting or decellularised extracellular matrix (ECM) scaffolds as a therapeutic construct in infertility or organ degradation. Tissue engineering employs 3D bio printing and decellularised ECM scaffolds to create functional ovarian, uterine, and vaginal tissues, in the semblance of natural structures with cells and biomaterials, such as collagen and alginate for fertility renovation, hormone formation, and organ infertility or impairment refurbishment, with provision for personalized therapeutic measures, and restoration complex organ issues and vascularization. Thus, extant uterine tube tissue engineering depicts that natural polymers, such as collagen and decellularised extracellular matrix, create the latitude for biocompatible scaffolds potentiated to substitute innate extracellular milieu. Synthetic polymers enhance adaptation of mechanical attributes and reproducibility, whereas hydrogels provide a biomimetic 3D micro ambient that undergirds angiogenesis, embryo development, and epithelial differentiation. Uterine tube-derived organoids, wherein the polymeric ingredient is significantly involved, are of physiological pertinence as in vitro models for investigating pathological states, drug testing and appraisal, and translational applications. Therefore, current accounts in 3D bio printing and magnetic bio printing have spurred improvement of artificial regarding uterine tube models tissue architecture and cell organization. These substantiate the translational prowess of biomaterial-based approaches in uterine tube regeneration, with integrative measures into reproductive medicine making provision for newfangled therapeutic trajectories for the restoration of tubal functionalities, fertility improvement outcomes and prognosis, including the progression patient-specific

strategies in the sustainable management of female infertility [34].

The development of 3D models, such as hydrogel-encapsulated follicles for growing of ovarian tissue and fertility preservation following cancer therapies are pertinent for fertility preservation. This measure is an emerging and pertinent investigation trajectory that has been significant in animal models but remains to be excavated from its preclinical anthropogenic investigation spectrum. The sustainable primordial objective is to generate a formidable bio prosthetic ovary with the potential for the restoration of both endocrine functionalities and fertility. A three-dimensional, 3D prosthetic ovary can restore ovarian functionalities with fertility preservation in younger female patients presenting with ovariectomies or ovarian impairment. Focus is on future clinical research to unravel the 3D ovarian tissue production for human implantation, and the crucial sustainability issues confronted on creating a 3D ovary for in vivo implantation incorporate ovarian follicle sustenance, vascular infiltration into the host tissue, and hormone circulation restoration. The compartmentalized and restricted intricately complex ovarian micro ambient causes the bio simulation of the 3D ovary burdensome concerning biomaterial selection and bioink status. The pertinent restoration of these factors in animal models has contributed to promise for human ovary development for implantation, and to articulate and evaluate the optimal 3D models of ovarian structures, sustainable functionalities, safety and efficacy concerns for future research [35-39].

The employment of organoids and microfluidic systems [40], for instance, organ-on-chips as substitute for reproductive organs for disease modeling and drug screening, diminishes animal testing. Organoids-on-chips, OrgOCs combine 3D organoids with microfluidic systems to construct miniscule, human reproductive functional organ models, with dynamic environments simulating in vivo states, such as flow and gradients for investigating development, drug testing appraisal, disease such as infertility and cancer, and significantly diminishes dependence on animal models due to resultant increasingly accurate, personalized safer, faster development and drug screening. Organoid-on-a-chip constitutes an innovation depicting the physiological spheres of the human body via the integration of the complex 3D organoid morphology with the microfluidic system. The

organoid culture within the microfluidic system is depicted by the evaluation of pivotal parameters, such as cell content, extracellular matrix (ECM), and synthetic environmental conditions. Furthermore, the organoid-on-a-chip influences the structural and functional characteristics of disparate organs, static and dynamic models, enacting physiological microambients to manage the ethical status of *in vivo* studies. Of essence, recent advances are inculcated in multi organoid-on-a-chip for the analysis of drug metabolism and toxicity by means of organ to organ interactions and connectivities, thereby unravelling the potential in achieving technologies of human-on-a-chip. There is the expectation that organoid-on-a-chip can revolutionize biomedical research and personalized medicine in the precise and accurate *in vitro* reproduction of the human milieu. The 3D cell culture transition has attracted momentum due to resultant accurate data for development of novel drugs, drug disease modelling, cancer therapies, and personalized medicine investigation, vital for the provision of ostensible anthropogenic physiologic environment-simulated *in vivo* models via the substitution of normal cell culture systems. Organoids introduce complex structures of disparate organs from stem cells which incorporate convergence of heterogeneous technologies to simulate a highly accurate internal corporeal ambient. Research must intensify discourse on trends in organoid-on-a-chip, that can sustainably imitate organ-specific functionalities and disease mechanisms introducing real-time regulating dynamic culture environments by merging organoid culture and microfluidic systems [40], and avoiding the pitfalls of geopolitics, gain-of-function research, emerging and reemerging infectious diseases [41-43].

### **Gynaecological conditions and anomalous states**

Gynaecological conditions impact on the female reproductive system and extend from conventional disturbances such as menstrual disorders, infections, PCOS, fibroids, endometriosis, and ovarian cysts, extending to excruciating circumstances, such as cancers cervical, ovarian and uterine cancer, pelvic floor disorders, for instance, incontinence and prolapse, accompanied by frequent pain, untoward bleeding, discharge, or infertility, which are managed via lifestyle modifications, therapies, and periodically from surgery, but early detection being pivotal through regular checkups [44]. Biomaterials or scaffolds, such as silk and hydrogels are designed to manage cervical insufficiency or undergird pelvic

floor tissues. Biomaterials, especially silk and hydrogels are being investigated as potential alternatives to conventional therapies, such as cervical cerclage for impairments, for instance, cervical insufficiency and pelvic floor anomalies. The sustainable goal is the designing of scaffolds for the restoration of innate tissue attributes and improve regeneration. Cytocompatible, enzyme cross-linked silk protein biomaterials are indicative as tissue bulking agents. The biomaterials were produced to be compatible as the innate mechanical attributes of human cervical tissues. It is pertinent that these biomaterials are studied extensively as a substitute to cerclage supporting the cervix during pregnancy [45].

The application of finite element analysis to explicate biomechanics of pelvic floor disorders, such as prolapse is important in the health of women. Finite element modeling (FEM) is a tool that is critical in biomechanics and biomedical engineering, and provides crucial dimensions if *in vivo* or *ex vivo* investigations are restricted [46]. Targeted delivery connotes nanoparticles engineering for localized drug delivery for the treatment of infections, endometriosis, or pregnancy issues such as preeclampsia. Engineered nanoparticles are prominent spheres of preclinical studies for targeted delivery of therapeutics for infections, endometriosis, and pregnancy sequelae, viz, preeclampsia. Nanomaterials are significant delivery carriers for drugs and promote therapeutic efficacy. Numerous applications, ranging from conventional and gene therapies, immunotherapy, photo thermal therapy, and magnetic hyperthermia, depict the key role of nanotechnology in tackling the problems evidenced in endometriosis. The lack of a cure and paucity of durable therapies require newfangled modalities, particularly taking into consideration the procrastinating diagnosis and limitations in denoting disease severity. There is growing interest to explore nanotechnology-based solutions for therapy and diagnostics improvement for endometriosis, for leveraging the benefits of biocompatible and less problematic alterable NPs. The exclusive features of nano medicines, hyperthermia, drug delivery, gene therapy, and immunotherapy, indicate expansive improvement in patient care transformation. Also, improvement in sensors and imaging agents undergird prompt detection, and confronting crucial elusive requirements in the management of endometriosis [47].

## **Diagnostics and Monitoring concerning the health of women**

The diagnostics and monitoring of the health of women inculcates pertinent screenings of Pap/HPV, mammograms and bone density, reproductive health evaluations of hormone panels, fertility test appraisals, ultrasounds for pregnancy or gynaecological anomalies, infection checks of vaginal swabs and STIs, as well as general wellness labs from blood counts, lipids and glucose to apprehend untoward presentations like cancers, osteoporosis, hormonal disequilibria, PCOS, and metabolic disruptions promptly, in convergence with progress in research and wearables augmenting real-time, personalized care extending from pregnancy to menopause. Globally, pregnancy is existentially a health concern to the health of women. Approximately, 10 to 20 million women are entangled in pregnancy sequelae, incorporating ectopic pregnancy, preterm birth, gestational diabetes, hypertension, preeclampsia and eclampsia. Irrespective of the research progress in the health of women, there remains an expansive lacuna in the diagnostic tools present to screen, diagnose, and monitor these anomalies [48].

Wearable devices are smart sensors for continuous monitoring of reproductive cycles and physiologic alterations which improve the tracking of fertility. Emerging digital health technology has advanced into the reproductive health spectrum for women. Previously, mobile health apps were employed for the monitoring of the menstrual cycle via manual entry. Novel technological trends use wearable devices to track fertility by evaluating physiologic alterations of temperature, cardiac and pulmonary rates [49].

Microfluidic devices are miniaturized labs for high-throughput screening and diagnostics potentially applied for the prompt detection of disease or sorting of sperm. Microfluidic devices are referred to as "lab-on-a-chip" systems, and are miniaturized equipment which manipulate small quantity of fluids via micro-channels. These devices are modifying high-throughput screening and diagnostics as they induce faster, and increasingly efficient analysis, with applications encompassing early detection of disease to enhanced fertility therapies. Sperm selection constitutes a pivotal start in assisted reproductive technology (ART), and has protractively been morphologically restricted at the preliminary physical level but subsequent fertilization and embryogenesis are complex biochemical mechanisms. An expansive lacuna

such as this presents complicated quagmire for a couple entrenched with infertility, particularly in extremely severe or total asthenozoospermia [50].

## **Cancer and systemic health in women**

Cancer preponderantly impacts on the systemic health of women, induced by an intricately complex interplay of lifestyle and gene-environment interactions [51,52] and other factors. Globally, the burden and varied cancer typologies are complicated as a result of socioeconomic factors and access to healthcare [53,54], with higher prevalence rates of breast and cervical cancers. Environmental and lifestyle factors extremely augment gynaecological neoplastic features. A tremendously fatal gynaecological cancer is the risk of ovarian cancer associated with obesity and diabetes [55,56] poor nutrition, and environmental contaminants and pollutants [57-59], aggravating hormonal disruptions, inflammation, and oxidative stress [60,61]. Protective factors, such as the Mediterranean diet and oral contraceptives, are able to modulate risk by diminishing ovulatory cycles, especially in women who are genetically vulnerable or susceptible. Uterine cancer correlates with metabolic factors, with obesity inducing hormonal imbalances and systemic inflammation. Physical inactivity and animal fat rich diets elevate the risk of endometrial cancer, concomitantly with atmospheric pollution and microbiome [62] imbalances are contributors to endometrial carcinogenesis. Cervical cancer is primarily triggered by incessant high-risk HPV infection, with smoking augmenting viral resilience and oncogenesis. Nutritional deficiencies in antioxidants and folate depreciate immune defenses, while vaginal and gut microbiome dysbiosis promote neoplastic progression. Despite the ostensible rarity of vulvar and vaginal cancers, they are commonly susceptible to risk factors such as obesity, smoking, and occupational hazard exposure, debilitating immune responses and epithelial integrity. Microbial imbalances aggravate these malignancies, thus, producing a pro-inflammatory micro ambient. The complex interplay between alterable attributes and genetic predisposition, high-penetrance mutations and polygenic risk scores, depicts the complexity of gynecological cancer prevention and inhibition. Epigenetic mechanisms [63,64], such as DNA methylation and histone alterations, increasingly modulate vulnerability and tumor progression, induced by environmental and lifestyle attributes. The promoting and undergirding of healthy lifestyle features,

such as smoking cessation, shunning physical inactivity, and balanced nutrition, are vital for the improvement of long-run outcomes and quality of life in gynecological cancer survivors. Taking these factors into consideration, and addressing them by personalized prevention, leveraging predictive models, merging genetics and alterable risks are capable of defining lifestyle interventions and restricting environmental hazard exposures. Globally, combined with sustainable and equitable public health nuances [65], these approaches can diminish the excruciating burden of gynecological cancers, for instance, and improve the health of women [66].

## DISCUSSION

The interventions to address the health of adult women must recognize the changing disease burden, and concretely respond to disorders which culminate in severe morbidity and ultimate mortality in the absence of bioengineering compliance and methodology of global indexes for equitable evidence-informed policy towards sustainable development. This review tends to unravel inter alia the molecular networks showcasing diet, nutrition and metabolism [67,68], as female persons are significantly more likely than their male counterparts to undergo the discomfort of irritable bowel syndrome, a chronic state that causes abdominal pain, bloating, and digestive perturbations. The minimization of carbohydrate intake rather than lipids could adequately regulate appetite in women. Research depicts that low carbohydrate diets may elevate appetite regulation and diminish food cues in women with lipedema/lipedema, providing a dietary intervention benefit [69]. Lipedema is a chronic disorder with preferential discharge to women, characterized by anomalous fat deposition in the extremities, resulting in pain, mobility perturbations, and psychological trauma. This review aims to present the extant understanding of diverse health and conditions impacting women generally, as to address and ameliorate such within inter alia bioengineering spheres and the tenets and precepts of sustainable development, taking into cognizance challenges in diagnosis, extant guideline recommendations for clinical care, associated comorbid conditions and sequelae.

Global collaboration accelerates progress toward the eradication of cervical cancer. Cervical cancer is considered the first human cancer eradicated through coordinated global action due to examining the progress, challenges, and innovations in prevention, screening, and therapy [70].

Progress in the global eradication of cervical cancer as a public health concern is retarded, and extremely not balanced across countries, whereby high-income countries have decreasing incidence rates, whereas several sub-Saharan African countries incessantly express incidence rates exceeding sustainable development limits. Thus, numerous frequently encountered diseases manifest differentially in women, and an inexplicable underlying mechanism, and deficiency of proper therapeutically modalities may incessantly impact health outcome and prognosis [8]. A multidimensional strategy merging technological, translational, and clinical investigation is pertinent to appreciate the full potential and advantages of bioengineering resources and solutions to improve the health of women for sustainable development [11,12]. This work contributes to the worldwide crises, incessant disequilibria and inequitable presentations of the extreme invariance on the public health challenges associated with complex disease interactions due to disparate bioengineering technologies for sustainable development. It advances the discourse on the roles of access, diet and metabolic health for disease management in women, with differential trajectory and platform for future research and clinical interventions. The profound and expansive implications for clinical practice and policy underscore the priority and relevance for the health of women globally for sustainable development.

In essence, biomedical engineering in reproductive health is defined by the approaches or strategies to not merely improve the fundamental elucidation of the development of sperm and follicle in bioengineered devices in combination with microfabrication, biomaterials, and pertinent cells, but in addition to the application of the reparation of uterine, ovarian, and cervicovaginal tissues and restoration of tissue functionalities. In the face of challenges and issues, bioengineering prioritizes opportunities and solutions for the health of women [12,71] via advanced tissue engineering (3D printing organs, such as uteri/ovaries), biomaterial scaffolds to repair tissues (cervix, pelvic floor), advanced in vitro models (organoids, organ-on-chips) for drug discovery, target and testing, individualized/personalized diagnostics (wearables, microfluidics), as well as targeted drug delivery systems [18] regarding infection, cancer, and fertility problems, in order to restore functionalities, enhance therapies, and explicate intricately-complex reproductive and systemic health of women [12].

## RECOMMENDATION

This submission presents a comprehensive exploration of the role that bioengineering can play for the health of women, concomitantly with sustainable development goals. The work of both governmental nongovernmental organizations underscores the profound potential that bioengineering needs to enact in gender-specific health issues and disparities, in order to achieve the United Nations Sustainable Development Goals, essentially in pertinence to health and gender equality, with enhanced clarity and cohesion in presenting global Health for All [53]. Researchers and organizations must explore the intersection of bioengineering and sustainable development for the improvement of the health of women. These must emphasize advancements, such as 3D printing, biomaterial scaffolds, and organ-on-chip systems, whereby, addressing intricately complexity concerning reproductive and systemic health quagmire in women. Central to the discourse must include the United Nations Sustainable Development Goals (SDGs), especially SDG 3 (Good Health and Well-being) and SDG 5 (Gender Equality), with bioengineering contextually being a pivotal driver. As in this study, developments must cover new diagnostic tools, wearable health technologies, and tissue engineering, and tailored within healthcare inequalities and enhancing the accessibility of the healthcare of women globally, as well as augmenting specialized bioengineering concepts and systemic healthcare priorities. Policies must benefit from more cohesive framing, and the narrative should not shift focus without defined transitions, which are liable to disrupt administrative flow [72] but adhere to an enhanced focus on weaving through defined precincts of ethical considerations, potential risks, consent issues, sociocultural impacts, diagnostics, therapeutics, and policy intersections inherent in diverse settings. Just as this work embodies pronounced interdisciplinary potential, bridging critical correlated spheres of bioengineering, the health of women, policy, and global health initiatives, larger research networks must pose critical research questions on how innovation-driven interventions can navigate systemic health inequities and imbalances, and explicitly challenge researchers and policymakers to take into cognizance the entire scope of gender-based health disparities and to address bioengineering as a transformative pivotal fulcrum within the healthcare system.

## CONCLUSION

This article contributes by aligning technological innovations with broader societal pertinence in the health of women. Its strength in the confluence of high-level technological advances with imperatives of sustainable development. This work serves as an essential catalyst in discourse of bioengineering as it impacts the health of women at both local and global levels. Globally, the health of women is in a transitional phase, however, certain aspects have significantly improved in recent times, with certain requirements not yet accomplished. Ageing populations and transformations as social determinants of health have enhanced the coexistence of disease burdens associated with reproductive health, nutrition, and the emerging and reemerging epidemics of communicable and non-communicable diseases. Concurrently, global priorities in the health of women have been metamorphosing from a restricted focus on maternal and child health to an expansive sphere of sexual and reproductive health, on to the encompassing spectrum of the health of women which is based on a life-course and sustainable development platform. This all-inclusive mode inculcates health perturbations which impact women over their reproductive years, and those which they experience with their men counterparts, but with outcomes and presentations which impact women disproportionately due to biological, gender, and other social attributes. Gender, biological sex, and hormones discretely impact health and disease, with frequent resultant differences for women across the lifespan and from disparate racial, ethnic, geopolitical and socioeconomic dispositions. In the absence of any determined venture and infrastructure to undergird good health and wellbeing for women, a vast majority of the global population continue to be susceptible to preventable morbidity, comorbidity and mortality in the face of dysfunctional sustainable development, or lack, thereof. Overall, the analytical presentation creates the potential for pertinent and significant contributions to the bioengineering and sustainable development in harnessing the complexity of communicable and non-communicable diseases management concerning the health of women.

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## CONFLICTS OF INTEREST

The author declares that no conflicts of interest.

## REFERENCES

1. Chukwuma Sr C. (2023). Pathophysiology of Insulin and Ageing with Concomitant Risk Variables and Sequelae. *Int J Diabetes*. 5(1):173-178.
2. Chukwuma Sr C. (2023). Pathogenesis, Implications and Therapeutics in Ageing and Insulin. *Biomed J Sci & Tech Res*. 49(3): 40693-40698.
3. Chukwuma Sr C. (2023). Insulin and Ageing: Interventions for Healthier Lifestyle and Prolonged Lifespan. *Int J Med Case Reports & Reviews*. 2(1):1-6.
4. Kitani T, Matoba S, Naito Y, Horvath S, Yoshimori T, Chane FKL, et al. (2025). Towards global healthy longevity: report from the 1st World Longevity Summit in Kyotango, Japan. *npj. Aging*. 11:89.
5. Chukwuma Sr C. (2024). The Persistent Incurable Prevalence and Impact of Sarcopenia, Obesity and Rare Disorders, Including Gene Expression and Drug Response Using Functional Genomics Strategies. *Biomed J Sci & Tech Res*. 59(1):51125-51142.
6. Chukwuma Sr C. (2024). Exploring the Repositioning of Health, Extreme Hydrologic Events, and Global Change. *International Journal of Medical Research and Medical Case Reports*. 1(2):1-9.
7. Chukwuma Sr C. (2024). Molecular mechanisms Which Regulate Skeletal Muscle Mass Against Obesity and The Clinicopathological Correlates. *International Journal of Medical Case Reports and Medical Research*. 3(1):1-11.
8. Klapperich CM, Vunjak-Novakovic G, Robinson J, Horton R, Kreeger PK, Mahmoudi M, et al. (2025). Bioengineering solutions to improve women's health. *Med*. 6(5):100699.
9. Miller KS, Myers K, Oyen M. (2019). Bioengineering in women's health: part I. *Interface Focus*. 9(4):20190042.
10. Moghimikandelousi S, Najm L, Lee Y, Bayat F, Prasad A, Khan S, et al. (2025). Advances in biomonitoring technologies for women's health. *Nat Commun*. 16(1):8507.
11. Chukwuma Sr C. (1996). Perspectives for a sustainable society. *Environ Manage & Hlth*. 7(5):6-20.
12. Chukwuma Sr C. (1995). Social welfare and population dynamics in Egypt with particular reference to the status of women. *Int J Env Edu & Inf*. 14(1):45-62.
13. Chukwuma Sr C. (2024). Geopolitics of the nature and crises of the environment, economics and health in a sustainable society for human progress and survival. *Journal of Scientific and Innovative Research*. 13(1):16-21.
14. Giulianoa M, Joannab K-B, Dianac P, Miriam M, Dinae S, Neerjaf B, et al. (2017). Improving women's health in low-income and middle-income countries. Part I. challenges and priorities. *Nucl Med Commun*. 38(12):1019-1023.
15. Eman A Jafleh EA, Fatima A Alnaqbi FA, Almaeeni HA, Faqeeh S, Alzaabi MA, Al Zaman K. (2024). The Role of Wearable Devices in Chronic Disease Monitoring and Patient Care: A Comprehensive Review. *Cureus*. 16(9):e68921.
16. Yang Y, Sheng J, Sheng F, Liang X, Ma C, Chen R, et al. (2025). Advances and Applications of Organoid-on-a-Chip in Disease Modeling. *The Analyst*. 150(21):4870-4881.
17. Chukwuma Sr C. (2016). Macromolecular interactions: Trends and Targets. *Asian Journal of Microbiology and Biotechnology*. 1(1):7-13.
18. Chukwuma Sr C. (2020). Regulation of protein-nucleic acid interactions in biosynthetic pathways of bacteria and fungi: Channels for drug leads. *Iatrology Archives*. 1(1):1-17.
19. Chukwuma Sr C. (2018). Flaws in risk assessment. *International Journal of Food Safety, Nutrition, Public Health and Technology IJFSNPHT*. 10(2):10-17.
20. Chukwuma Sr C. (2018). Paradigm on sustainable human health, environment and petroleum contamination: constraints and challenges. Preprints. DOI:10.20944/preprints201810.0044.v1
21. Haleem A, Javaid M, Singh RP. (2025). Exploring biomaterials for healthcare: An extensive insight into capabilities and applications. *Cure & Care*. 1(1):100003.
22. Kihara AB. (2025). FIGO at 70: Navigating challenges in the global women's health landscape. *Int J Gynaecol Obstet*. 168(3):855-856.
23. UN General Assembly. (2024). Seventy-fifth session Agenda item 131 Global health and foreign policy Geneva Consensus Declaration. Available at: <https://documents.un.org/doc/undoc/gen/n20/344/>

24. PMNCH. (2024). Maternal, Newborn and Child Health (MNCH) Strategy 2021–2025. Available at: [https://pmnch.who.int/docs/librariesprovider9/governance/2023022122-workplanning-retreat-mnch-advocacy-strategy.pdf?sfvrsn=fc799bcf\\_5](https://pmnch.who.int/docs/librariesprovider9/governance/2023022122-workplanning-retreat-mnch-advocacy-strategy.pdf?sfvrsn=fc799bcf_5)
25. World Health Organization. (2024). Accelerating the elimination of cervical cancer as a public health problem: Towards achieving 90–70–90 targets by 2030. Available at: <https://iris.who.int/handle/10665/361138>
26. UHC2030. Voluntary national reviews country reporting on UHC SDG 3 Targets: Ensure healthy lives and promote well-being for all at all ages. Available at: [https://www.uhc2030.org/fileadmin/uploads/uhc2030/4\\_News\\_and\\_events/2022/VNR\\_Lab\\_SDG3\\_WHO.pdf](https://www.uhc2030.org/fileadmin/uploads/uhc2030/4_News_and_events/2022/VNR_Lab_SDG3_WHO.pdf)
27. Regensteiner JG, McNeil M, Faubion SS, Bairey-Merz CN, Gulati M, Joffe He, et al. (2025). Barriers and solutions in women's health research and clinical care: a call to action. *Lancet Reg Health Am.* 44:101037.
28. Delanerolle G, Sivakumar A, Haddadi M, Kurmi O, Phiri P, Al-Kharusi L, et al. (2025). Mind the Women's Health Data Gap: A Critical Factor for Global Health Equity. *Biomed J Sci & Tech Res.* 63(3):55636-55643.
29. Stamate A, Marzan M-D, Velciu M, Paul C, Spiru L. (2024). Advancing user-centric design and technology adoption for aging populations: a multifaceted approach. *Front Public Health.* 12:1469815.
30. Holmes CB, Sikazwe I, Raelly R, Freeman B, Wambulawae I, Silwizya G, et al. (2015). Managing multiple funding streams and agendas to achieve local and global health and research objectives: lessons from the field. *J Acquir Immune Defic Syndr.* 65(01):S32-S35.
31. Chukwuma Sr C. (1996). Acquired immunodeficiency syndrome in Sub-saharan Africa: epidemiological, sociological and preventive perspectives. *Scandinavian Journal of Development Alternatives.* 15(2):74-89.
32. Iyorkar V & Ezekwu E. (2025). Enhancing Healthcare Access Through Data Analytics and Visualizations: Bridging Gaps in Equity and Outcomes. *International Journal of Computer Applications Technology and Research.* 14(1):116-129.
33. Sharma R, Biedenharn KR, Fedor JM, Agarwal A. (2013). Lifestyle factors and reproductive health: taking control of your fertility. *Reprod Biol Endocrinol.* 11:66.
34. Culenova M, Kleinova M. (2025). Enhancing female fertility by biomaterial-based regeneration of uterine tubes. *Cell Transplant.* 34:9636897251397047.
35. Chukwuma Sr C. (2025). The Prevalence of Fissured Peace, Justice and Sustainable Development in Nigeria and other Developing Countries. *Grn Int J Apl Med Sci.* 3(4):206-212.
36. Chukwuma Sr C. (2025). The Impact of Pro Forma and Strategic Ambiguity Approaches in Research and Governance for Ecological Sustainable Development. *Journal of Environmental Engineering and Studies.* 10(3):1-15.
37. Chukwuma Sr C. (2025). Explicating Spheres of Pro Forma and Strategic Ambiguity in Governance and Research for Sustainable Development. *Journal of Bio-Med and Clinical Research, RPC Publisher.* 2(2):1-10.
38. Chukwuma Sr C. (2025). Assessment of Pro Forma and Strategic Ambiguity in Research and Governance for Sustainable Development. *RPC Journal of Medical Sciences. RPC Publishers.* 2(2):1-10.
39. Nair R, Kasturi M, Mathur V, Seetharam RN, Vasanthan KS. (2024). Strategies for developing 3D printed ovarian model for restoring fertility. *Clinical and Translational Science.* 17(7):e13863.
40. Park B, Park J, Han S, Kwon T, Sung JY, Kim J, et al. (2025). Advances in organoid-on-a-chip for recapitulation of human physiological events. *Materials Today.* 84:75-94.
41. Chukwuma Sr C. (2022). Features of the emergence and re-emergence of infectious diseases, geopolitics and gain-of-function research. *International Journal of Coronaviruses.* 3(4):10-18.
42. Chukwuma Sr C. (2022). Perspectives in the emergence and re-emergence of infectious diseases, geopolitics and gain-of-function research. *Scholars International Journal of Biochemistry.* 5(1):1-7.
43. Chukwuma Sr C. (2022). Features in the emergence and reemergence of infectious diseases, gain-of- function research and geopolitics. *Biomed J Sci & Tech Res.* 40(5):32555-32560.

44. CDC. (2024). Common Reproductive Health Concerns for Women. Available at: <https://www.cdc.gov/reproductive-health/women-health/common-concerns.html#:~:text=At%20a%20glance,other%20parts%20of%20the%20body>
45. Brown JE, Partlow BP, Berman AM, House MD, Kaplan DL. (2016). Injectable silk-based biomaterials for cervical tissue augmentation: an in vitro study. *Am J Obstet Gynecol.* 214:118.e1-9.
46. Moseley T, Hicks AJ, Cosgriff-Hernandez EM, Rausch MK, Hakim K. (2025). Finite element modeling in obstetrics and gynecology: advances, applications, and challenges. *Front Med (Lausanne).* 12:1606989.
47. Talukdar S, Singh SS, Mishra MM, Singh R. (2024). Emerging Trends in Nanotechnology for Endometriosis: Diagnosis to Therapy. *Nanomaterials (Basel).* 14(11):976.
48. Gronowski AM, Yarbrough ML. (2018). The Women's Health Diagnostic Gap. *Endocrinology.* 159(2):776-778.
49. Lyzwinski L, Elgendi M, Menon C. (2024). Innovative Approaches to Menstruation and Fertility Tracking Using Wearable Reproductive Health Technology: Systematic Review. *J Med Internet Res.* 26:e45139.
50. Mu Y, Zhou X, Li L, Liu X, Wen X, Zhang L, et al. (2024). Automatic high-throughput and non-invasive selection of sperm at the biochemical level. *Med.* 5(6): 603-621.e7.
51. Chukwuma Sr C. (2014). Information-Base and Determinants of Medical Specialization and Primary Care: A View Point, *JBAH.* 4(8):10-18.
52. Chukwuma Sr C. (2014). Is Diabetes a Model for Gene-environment Interaction in Premature Senescence? *4(25):84-93.*
53. Chukwuma Sr C & Bjurulf P. (1990). A case study of the information-base needed for effective evaluation of primary health care programmes in Anambra State, Nigeria. *Int J Hlth Sc.* 1(2):137-148.
54. Chukwuma Sr C. (1994). Health concepts, issues and experience in Abakaliki area, Nigeria. *Env Hlth Persp.* 102(10):854-856.
55. Chukwuma Sr C. (1996). Microsporidium in AIDS patients - A perspective. *East African Medical Journal.* 73(1):72-75.
56. Chukwuma Sr C. (2025). The Challenges, Issues and Opportunities of Glp-1/Glp Receptor Agonists in Research and Patient Care. *J Cur Tre Clin Case Rep.* 6(3):1-12.
57. Chukwuma Sr C. (1995). Latent constraints for improved environmental health management in non-industrialised countries. *Env Manage & Hlth.* 6(4):9-14.
58. Chukwuma Sr C. (1995). Environmental, developmental and health perspectives in Egypt. *Env Manage & Hlth.* 6(1): 38-46.
59. Chukwuma Sr C. (2011). Environmental impact assessment, land degradation and remediation in Nigeria: current problems and implications for future global change in agricultural and mining areas. *International Journal of Sustainable Development & World Ecology.* 18(1):36-41.
60. Chukwuma Sr C. (2019). Aging, cellular senescence and diabetes mellitus: Clinicopathological correlates, trends and targets. *IGRPS. International Journal of Pharmacy and Infections Therapy. IJPIT.* 2(1):105.
61. Chukwuma Sr C. (2020). The complexity of communicable and non-communicable diseases in vulnerable populations. *ABBSR.* 3(1).
62. Chukwuma Sr C. (2021). Gain-of-Function Research and Geopolitics in the Emergence and Reemergence of Infectious Diseases and Microbiome Variants. *International Journal of Chemical and Life Sciences.* 10(8):2197-2205.
63. Chukwuma Sr C. (2022). Epigenetics and its essence in understanding human growth, development and disease. *The Journal of Medical Research, JMR.* 8(5):165-172.
64. Chukwuma Sr C. (2022). Characterization of the Clinical and Molecular Perspectives of Epigenetics. *Archives of Clinical Investigation.* 1(1).
65. Chukwuma Sr C. (2025). Reflections and Perspectives on the Determinants for Risk Reduction in Biodiversity, Environment and Health Vulnerabilities Due to Climate Change and Extreme Hydrological Events: An Ecological Framework. *Greenfort International Journal of Applied Medical Science.* 3(3):134-140.
66. Farina S, Sabatelli A, Boccia S, Scambia G. (2025). Environment, lifestyle, and cancer in women. *Int J Gynaecol Obstet.* 171(Suppl 1):138-146.

67. Chukwuma Sr C. (2025). Understanding The Pathophysiologic Mechanisms and Interplay Between SARS-CoV-2 /Covid-19, Obesity and Diabetes with Incursions into The PostPandemic Era. *World Journal of Pharmaceutical and Healthcare Research*. 2(12):17-25.
68. Chukwuma Sr C. (2025). Approaches in diverse issues of glucagon-like peptide-1 receptor agonists (GLP-1 RAS) in global health strategy, economic burden, geopolitical implications and gain-of-function research. *World Journal of Pharmaceutical and Healthcare Research*. 2(11):1-6.
69. Carvalho R. (2024). Lipedema: A common though often unrecognized condition. *Chinese Journal of Plastic and Reconstructive Surgery*. 6(3):149-153.
70. Basu P. (2025). Progress toward cervical cancer elimination: global disparities and China's contributions. *Cancer Biology & Medicine*. 22(9):991-996.
71. Chukwuma Sr C. (2025). Correlated Critical Risk Reduction of Invariance Challenges and Issues Concerning Extreme Hydrologic Events and Climate Change on Environment and Health. *Journal of Public Health Care Research and Epidemiology*. 1(2):1-12.
72. Chukwuma Sr C. (2024). Whither the Trends, Innovations and Expertise of the New Public Administration? *Innovation in Economy & Policy Research*. 5(1):7-16.