

**Behavioral Insights into Vaccine Hesitancy Determinants in Sub-Saharan
Africa**

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Table of Contents

GENERAL INTRODUCTION	6
VACCINATION AS A GAME CHANGER	7
VACCINATION DEMAND TREND IN SUB-SAHARAN AFRICA	10
VACCINE HESITANCY IN SUB-SAHARAN AFRICA	12
REGIONAL COMPARISON OF VACCINE UPTAKE	13
VACCINE HESITANCY AMONG PREGNANT WOMEN	14
VACCINE HESITANCY AND ITS DETERMINANTS	17
5C PSYCHOLOGICAL ANTECEDENCE OF VACCINE HESITANCY	20
INSIGHT INTO THE WHO/UNICEF JOINT REPORTING FORM (JRF) ON VACCINE HESITANCY IN SUB-SAHARAN AFRICA	25
GOAL OF THE DISSERTATION	27
PRIMARY OBJECTIVES OF THE DISSERTATION	27
ORGANIZATION OF THE DISSERTATION	27
REFERENCES (GENERAL INTRODUCTION)	28
OVERVIEW OF PUBLICATIONS	36
GENERAL DISCUSSION	38
DRIVERS OF VACCINE HESITANCY AMONG VULNERABLE GROUPS (PREGNANT WOMEN)	38
<i>Insights from beyond Sub-Saharan Africa (Europe)</i>	38
<i>Empirical evidence from Sub-Saharan Africa</i>	41
DRIVERS OF VACCINE HESITANCY AMONG CAREGIVERS IN SUB-SAHARAN AFRICA	45
<i>Evidence from Ethiopia, Kenya, and Malawi</i>	45
<i>Empirical evidence from Nigeria</i>	47
<i>Empirical evidence from Malawi</i>	49
<i>Multi-stakeholder evaluation in Malawi</i>	54
<i>Policy brief contribution</i>	55
TRANSTHEORETICAL BEHAVIOR MODEL AS EXPLANATORY FRAMEWORK	57
DRIVERS OF VACCINATION INTENTION AND BEHAVIOR, AND THE INFLUENCE OF THE FORMER ON THE LATTER IN SUB-SAHARAN AFRICA	58
THE 5C MODEL AS AN ADAPTABLE MEASURE FOR UNDERSTANDING VACCINE HESITANCY PREDICTORS IN SUB-SAHARAN AFRICA?	60
CONCLUSION	66
ACKNOWLEDGEMENT OF ROYALTIES	68

ABSTRACT

To ensure a healthy society and minimize outbreaks of vaccine-preventable diseases, high levels of vaccine uptake is expected. Because vaccination provides protection against infection, especially for vulnerable groups (e.g., children and pregnant women). Vaccination has averted 14 million deaths, prevented 250 million disability-adjusted-life years, generated over \$150 billion economic benefits and saves two-three million child deaths yearly.

However, one-in-five children globally remain un/partially vaccinated, which contributes to about 1.5 million preventable deaths annually, half of which are in Sub-Saharan Africa. In addition to having the highest child mortality globally, vaccination in the region has stagnated in recent years for several reasons, e.g., vaccine hesitancy. More so, the knowledge gap associated with vaccine hesitancy are yet to be identified, studied, measured, and addressed.

Therefore, this dissertation aims to increase understanding on drivers of vaccination decision-making in Sub-Saharan Africa by examining intention, especially among pregnant women, as well as behaviour among caregivers using the 5C psychological antecedence model and additional variables such as rumour, religious belief and masculinity, among other measures.

The outcomes of five peer-reviewed articles and one policy brief published in open access journals made up this dissertation. Two articles are reviews, two articles are quantitative, one article is qualitative research, and the final article is a policy brief.

The outcomes were mixed. Vaccination decision-making at prenatal (pregnancy) and postnatal (after childbirth) stages are driven by different factors. The behaviour aligned with the concept of Transtheoretical Model (theory of stages of change). The added variables were significant predictors at prenatal (intention) than postnatal (behavior). This dissertation has helped to unravel some missing gaps on why vaccination demand creation does not have as much success, especially at increasing vaccination uptake in the Sub-Saharan Africa region.

Keywords: Vaccination behaviour, Vaccine hesitancy, Caregivers, Pregnant women, Sub-Saharan Africa, Determinants.

GENERAL INTRODUCTION

Vaccination as a game changer

The role, impacts, and importance of vaccination in public health and the general well-being of society cannot be reiterated enough. Indeed, the efficacy of vaccination leading to monumental drops in mortality, morbidity, and disability from vaccine-preventable-diseases (VPD) has led experts to conclude that vaccination is a global health development success story, saving millions of lives yearly [1,2]. According to Dr Tedros Adhanom Ghebreyesus (WHO Director-General) “Vaccines are one of the most powerful tools in the history of public health...more children are now being immunized than ever before” [3]. Copenhagen Consensus Centre described vaccination as, “Life expectancy hardly changed before the late 18th century...it is hard to overstate the magnitude of the improvement since 1900, from a life expectancy of 32 years to 69 now, to 76 in 2050: and the biggest factor is the fall in infant mortality” [4].

Vaccination is the world’s safest method to protect children from life-threatening diseases, and for over 200 years it has drastically reduced the scourge of preventable diseases such as polio, pertussis, and measles [5]. Vaccination saves more than five lives every minute of the day—preventing up to 3 million deaths and over 75,000 disabilities a year [6,7]. Due to these immunization successes, children now live longer, happier, and do better in school, which benefits communities economically.

Vaccination is fast becoming arguably one of the most cost-effective ways of redistributing global welfare. In addition to being an incredible life saver for children, vaccination has produced immense net economic benefits to society amounting to almost \$69 billion in the United States alone [8]. Following economic analysis of 10 vaccines in 94 low-and-middle-income countries, an investment of \$34 billion into immunization programs translated into

savings of \$586 billion reduction in costs of illness and \$1.53 trillion when contextualized in broader economic benefits [9].

Current evidence suggests that the value of providing these recommended vaccines extends beyond childhood as they have been found to impact health and socioeconomic outcomes throughout the life-course of an individual and communities [10]. In addition, vaccination decreases the overall disease burden in communities, reduces pressure on local health systems, and contributes to an improved national economy [11,12]. According to a study led by the Harvard T.H. Chan School of Public Health, 24 million people in 41 of the world's poorest countries will be prevented from falling into poverty due to vaccination between 2016 and 2030 [13]. Furthermore, child deaths have been reduced by more than half, from 90 to 43 deaths per 1000 live births between 1990–2015 [14]. By 2019, global diphtheria-tetanus-pertussis (DTP3) vaccination coverage was about 86%, an increase from 20% in 1980 [15].

Between 2000 and 2019, over 822 million children have been immunized worldwide, 1.1 billion vaccinations were supported via multiple campaigns, an estimated 14 million deaths were averted, and \$150 billion economic benefits were generated due to immunization [16]. An additional 300 million children were immunized against potentially fatal diseases by the end of 2020, saving between 5 and 6 million lives, preventing 250 million disability-adjusted life years, and reducing mortality in under-5 children by 10% [17,18]. The number of under-vaccinated children fell by over 1.8 million between 2010 and 2017 [19] and vaccination is revolutionizing the eradication of deadly historical diseases: for example, the world is on the brink of eradicating maternal and neonatal tetanus [20–22]. Meanwhile, in the last 20 years, tremendous progress has been achieved leading to a decrease in child mortality. Among under-5 children, deaths worldwide fell from 12.5 million in 1990 to 5.3 million in 2018, owing to the critical role played by vaccination programs [23].

Since the launched of the Expanded Program on Immunization (EPI) in 1974 by WHO, the disease burden of African countries has declined tremendously. In SSA, vaccination has played a huge role in facilitating positive health-seeking behaviors in communities during recent decades, and it has been at the epicenter of national and regional public health strategies for the past 4 decades. Indeed, there has been tremendous increase in vaccination uptake following the introduction of EPI [24]. Childhood vaccination covering the full series of basic DPT3 vaccines, for instance, has risen from 57% in 2000 to 74% in 2016 [25–27], with a national uptake of 90% in 18 countries [28], and an overall coverage of over 70% for the first dose of the measles vaccine has been achieved [29].

In SSA, over 400 million people were saved from serogroup A meningococcal meningitis by 2020 [30]; measles-related incidences and deaths declined by 75% and 79%, respectively, between 2000–2015; and wild polio has been eradicated [31,32].

There have been several other equally amazing success stories regarding the introduction of new or previously under-utilized vaccines, such as hepatitis B, Haemophilus influenzae type B, and pneumococcal conjugate. In 2020, 39 out of the 57 eligible countries for GAVI vaccine support are in SSA [33]. Moreover, due to its intervention between 2010 and 2015, child mortality declined by an average of 3.6% yearly, saving 4 million children's lives and immunizing 300 million more children [34]. In South Africa, within 1 year of introduction of rotavirus vaccine, hospitalization of children under-5 was reduced by 60% [35]. Therefore, immunization programs as public health interventions are making a tremendous difference in SSA.

Despite these unprecedented positive outcomes, immunization coverage at national and sub-national levels have stagnated and, in some cases, have reversed in many countries. Still, 1 in 5 children globally remain unvaccinated or partially vaccinated, which contributes to about 1.5 million deaths from vaccine-preventable diseases annually [36–38]. About 20 million

children miss basic vaccination (three doses of DPT3 vaccine) and two-thirds of these children live in countries supported by global vaccination intervention such as SSA [39]. As much as 83% of children did not receive the last recommended doses of antigens before their first birthday, and more than 10 million children in GAVI-supported countries (most of whom are in SSA) have not received even their first dose of basic vaccinations [39].

Pneumonia and diarrhea account for over 2 million deaths among young people and 29% of all under-5 mortality [39]. Similarly, 71 million children did not receive the three doses of pneumococcal conjugate vaccine (PCV) in 2018, while 32% of suspected pediatric pneumonia cases were not taken to a health facility [40].

Unfortunately, maternal vaccination rates are part of this negative trend. A very important vaccination is rubella, which is the main vaccine-preventable cause of birth defects. More than 100,000 children each year are born with severe birth defects due to congenital rubella syndrome because mothers were infected during pregnancy with rubella since they received no vaccination against it [40]. Of additional concern, extreme disparities in child deaths continue to pose challenges across regions as well as within and between countries [41].

Vaccination demand trend in Sub-Saharan Africa

Despite the unmatched changes generated by vaccination, the SSA region is in a dire situation. While vaccination delivery is promising in SSA, basic childhood vaccination uptake remains low in several countries in the region [42]. SSA still accounts for the highest child mortality rate in the world at 76 deaths per 1000 live births in 2019; meaning 1 in 13 children die before their fifth birthday [41,43]. This is huge compared to other regions—the rate is 16 times more than the 1 in 199 children average ratio in high-income countries [43].

Eighty percent of the 5.2 million child deaths recorded worldwide in 2019 occurred in SSA, and three (Ethiopia, Nigeria, and the Democratic Republic of Congo) of the five countries

responsible for half of the world's child deaths are in SSA [43–45]. Unfortunately, these deaths are preventable using vaccination interventions [46]. About 20 million children remained under-vaccinated or unvaccinated with DTP3 in 2019, of which 48% were in SSA, mostly Nigeria, Ethiopia, the Democratic Republic of Congo, Angola, and Guinea [47].

Some SSA countries have experienced a reversal in gains after a long period of great progress towards eliminating vaccine-preventable childhood diseases. Moreover, vaccination coverage and results has been very unequal—from 92% in the Gambia to 56% in Nigeria, plus a large measles outbreak in the Democratic Republic of Congo [48,49]. Approximately 1 in 5 African children do not receive all the necessary and basic vaccines—as a result, more than 30 million children under-5 still suffer from vaccine-preventable diseases (VPDs) every year in Africa [50]. Of these, over half a million children die from VPDs annually representing approximately 58% of global VPD-related deaths [51]. Pneumonia kills one child at least every 39 seconds worldwide and SSA countries account for more than half of these cases [52]. Hence children in SSA are 15 times more likely not to experience their fifth birthday than those from high-income countries, with more than half of these deaths being preventable with immunization [43].

The top 20 countries with the highest burden of cervical cancer cases globally in 2018 were all in SSA, except for Bolivia [53,54]. Malawi has the second highest burden of cervical cancer globally and the highest in the SSA region [55]. Cervical cancer is the most common cancer in women in the country, accounting for 45.4% of all female cancer incidences and of all diagnosed cancers among women in Malawi, 80% will die prematurely [54,56]. Overall, about 5 million Malawian women aged 15–44 years are at risk of developing cervical cancer [57,58]. Despite these staggering data, HPV vaccine uptake remains low in Malawi [59,60].

Despite the possibility of safe protection against VPD and vaccine availability, vaccine uptake remained below targets and on a disappointing trend as well, both at global and SSA

levels due to several factors including vaccine hesitancy [61,62]. Although many factors may be responsible for low childhood and adolescent vaccine demand, vaccine hesitancy is recognized as an important contributor [63,64], hence the underlining motive of this dissertation, to understand what the contributors are and how to measure them, and to strategically intervene.

Vaccine hesitancy in Sub-Saharan Africa

Since the millennium, vaccine coverage for preventable infectious diseases in SSA has reached multiple targets, although acceptance and uptake still have the steepest height to climb [65]. Even where successes have been recorded (increased vaccine uptake), the erosion of these gains owing to unclassified determinants or drivers and other vaccine-specific-related controversies in the region complicates responses and makes interventions even harder [66]. In SSA, where vaccination has been the hallmark of public health intervention for development in the last 40 years, vaccine hesitancy is causing vaccination uptake to slow down, stagnate, or even decrease [66–69]. Even where successes have been recorded, in terms of coverage and sizeable uptake/acceptance, the erosion of these gains owing to social and behavioral determinants and other vaccine-related controversies in the region makes intervention even harder. This roller-coaster will continue to plague the region if the knowledge gap associated with determinants of vaccination hesitancy in SSA is not identified, studied, measured, and addressed [66,70].

In the WHO African region, basic coverage remains sub-optimal, stagnating over the past 5 years at about 76% [15,71–73], and the region contribute the highest proportion of under-vaccinated and consequent child deaths from vaccine-preventable diseases globally [74–76]. Of the 10 countries that account for 11.7 (60%) of the 19.7 million non- or under-vaccinated children globally, 40% are in SSA, including Nigeria, Ethiopia, Democratic Republic of Congo, and Angola [32]. Similarly, of the more than 3 million people who still die annually

from vaccine preventable diseases, approximately half are children less than 5 years old who predominantly live in SSA [40,65,77].

Out of the countries with the highest prevalence of cervical cancer in 2018, more than 90% were in the SSA region [54,78]. Malawi has the highest incidence of cervical cancer in the world and is number one for women aged 15–44 years with a 50% mortality rate [54,56,79]. In Nigeria, progress in under-5 mortality has declined considerably compared to previous years, as fatality rates have increased again with about 120 deaths per 1000 live births and infant mortality at 70 per 1000 in 2016 [80]. In 2019, Nigeria had an under-5 child mortality ratio of 201 per 1000 live births, meaning that 1 in 5 Nigerian children do not celebrate their fifth birthday [80,81]; most of these children die of a vaccine-preventable disease. Despite the widespread availability of vaccines, 4.3 million children in Nigeria still miss immunization annually [82]. Moreover, Nigeria remains one of the 10 countries in the world where most children are without complete immunization [83]. Vaccines remain available in Nigeria and are free, however uptake is still relatively poor. The reasons for the surge in under-5 mortality and declining vaccine demand in SSA can be attributed to ineffective intervention due to knowledge gaps [66]. Hence, identifying appropriate measures is critical in order to understand vaccine hesitancy drivers in the region.

Regional comparison of vaccine uptake

Table 1 below shows childhood vaccination progression of some basic vaccines in SSA compared to other WHO regions. The African (AFR) region was unable to achieve the national coverage target (90%) for any of the vaccines and it also has lowest uptake of vaccines in the world.

Table 1: Progress towards reaching the 90% coverage target for vaccines in 2018

Vaccines	Global	AFR	AMR	EMR	EUR	SEAR	WPR
BCG	89	80	91	87	93	91	96
DTP1	90	84	92	87	97	92	94
DTP3	86	76	87	82	94	89	93
HepB_BD	42	4	68	33	39	48	83
HepB3	84	76	81	82	84	89	90
IPV1	72	62	86	62	85	74	86
MCV1	86	74	90	82	95	89	95
MCV2	69	26	82	74	91	80	91
Pol3	85	74	87	82	93	89	95

Source: WHO/UNICEF Estimate of National Immunization Coverage 2018 revision (Data of July 2019). AFR=Africa; EMR=Eastern Mediterranean Region; EUR=Europe; SEAR= South-East Asia Region; WPR=Western Pacific Region.

Parents or caregivers in general, and mothers in particular, can strongly influence childhood vaccination decisions [84]. However, little is known about vaccine hesitancy among pregnant women, and hesitancy among mothers can affect childhood vaccination rates [85–87].

Vaccine hesitancy among pregnant women

While substantial progress has been recorded globally on infant and child mortality rates by preventing infectious diseases, this has not always been the case for vulnerable populations, such as pregnant women and newborns, through maternal immunization [88]. Studies have shown that more than 50% of the 2.76 million annual neonatal deaths are due to vaccine-preventable infections (22%) or pre-term births (35%), while about half of stillbirths result from the effects of maternal infections [89,90]. Although child health has improved substantially through vaccination over the years using EPI, this has not been the case for other equally vulnerable groups, such as babies who are too fragile to receive routine immunizations in the first months of life [91]. As “vaccines are one of the most successful interventions to protect pregnant women and their fetuses, and infants from diseases that cause substantial morbidity and mortality” [88,92,93], maternal immunization is beginning to receive increasing attention.

Pregnant women are more likely to refuse influenza (flu) vaccines compared to DTP3 [94]. In addition, pregnant women and babies are the most vulnerable groups because immunological and serological changes that occur during pregnancy can alter the mother's and the fetus's susceptibility to various infectious diseases [95], and they can increase the risk of preterm birth and fetal death [96].

Pregnant women are among the most vulnerable groups at greater risk of VPD morbidity and mortality [97,98]. A study of 20,000 pregnant women over a period of 6 years in the United States, Australia, Israel, and Canada showed that there was a 40% decline in hospitalizations from influenza amongst those vaccinated [99]. The European Centre for Disease Control (ECDC) classified pregnant women as among high-risk groups for VPD and they hold a protective role for their unborn children and early births [100]. Moreover, the burden of vaccination in infants can be greatly reduced through increased vaccination among pregnant women [101].

Despite the risks of VPD and the protective assurances of vaccination, one-third of pregnant women still refuse to get vaccinated despite recommendations, and only about half of eligible women received vaccinations in 2018 [94,102,103]. In Italy, during the 2016–2017 influenza season, 96% of pregnant women were unvaccinated, citing concerns such as adverse events following immunization (AEFIs) [104]. According to the assessment, vaccine coverage in the WHO European Region has been declining among high-risk groups [67] and may hinder responsive preparedness and affect the capacity to protect populations against negative impact of emerging outbreaks and public health emergencies, such as COVID-19.

Vaccination of pregnant women can achieve a dual goal: protecting the mother from preventable diseases and preventing infection/disease transmission to the fetus or newborn. Despite the potential benefits, pregnant women who doubt the real advantages of vaccines still resist them [101–103,105]. Apart from vaccine-preventable infections being among the

leading causes of morbidity and mortality in pregnant women, they can also put children in a vulnerable state early in their lives. Hence, supporting the maternal vaccination decision is critical during pregnancy because receiving vaccines generates maternal immune protection, transfers antibodies to the infant for early protection, and helps to assess vaccination attitude of future mothers during prenatal. Therefore, it is crucial to understand drivers and determinants of the vaccination decision.

In SSA, contemporary knowledge on the gaps and drivers of vaccine hesitancy, the extent of their impact on vaccine coverage, and the design of appropriate interventions are all poor [66]. Hence, to address these shortcomings, there is a need to test and validate measures on determinants of vaccine hesitancy in SSA.

Currently, vaccine hesitancy is galvanizing unprecedented global attention in view of the COVID-19 pandemic. However, there is a vacuum of knowledge, especially in the SSA region, which limits the extent of evidence-based intervention. In addition, there is an absence of a suitable scientific model in the region to measure vaccine hesitancy and compare the relative impacts of these influencing factors. Hence, one of the objectives of this dissertation is to systematically find a successful model that can explain factors that influence vaccine hesitancy in the SSA region, especially among vulnerable groups such as pregnant women and caregivers of infants under-5. Vaccine hesitancy is a multifaceted issue, and its magnitude varies across countries in the region, and factors influencing vaccine hesitancy do not affect everyone the same because the settings and nature of individuals and countries are different [106]. However, the SSA region has some social, cultural, and environmental similarities. Two countries, Nigeria and Malawi, were chosen for the empirical aspect of the research in this dissertation.

Vaccine hesitancy and its determinants

Addressing low vaccination demand requires an adequate understanding of the determinants in order to develop evidence-based strategies to improve uptake. Vaccine hesitancy is driven by a complex mix of historical, sociopolitical, cultural, and behavioral determinants. The complexity of vaccine hesitancy can be seen in individuals who despite generally accepting the principles behind vaccines remain concerned about them, including those who refuse or delay some vaccines but accept others, and those who refuse all vaccines outright [61,62].

The Strategic Advisory Group of Experts (SAGE) on immunization described vaccine hesitancy as a “delay in acceptance or refusal of vaccines despite availability of vaccination services” [61,62]. This description suggests that vaccine hesitancy is a demand-side problem that influences vaccination uptake because of several complex factors, including perception about vaccines, fear of adverse events, religious values, and a general lack of trust in healthcare professionals or the healthcare system. Therefore, vaccine hesitancy is considered a continuum between delay in acceptance of vaccines to complete refusal (Figure 1). Vaccine hesitancy is also perceived to be driven largely by factors such as confidence (level of trust in vaccine or provider), complacency (do not perceive a need for a vaccine or do not value the vaccine), and convenience (access) [61]. However, it is also complex and context-specific depending on the time, place, and the vaccine [1].

VACCINE HESITANCY CONTINUUM

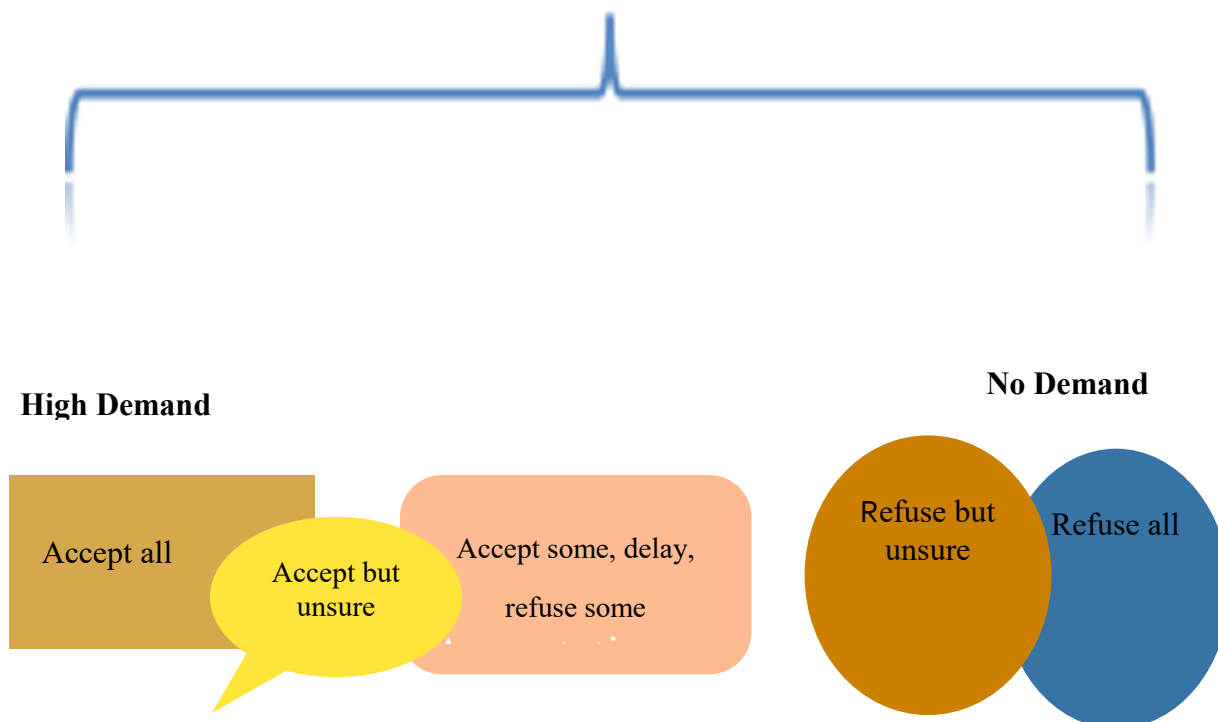


Figure 1: Vaccine hesitancy continuum

While vaccines save millions of lives annually, a recent paradigm has suggested global health stakeholders including WHO raise the alarm that vaccine hesitancy is on a dangerous global trend—to the extent that it is considered one of the top 10 threats to global health in 2019 [107]. This is primarily because of its ability to reverse all the gains already made, not only with respect to the geometrical decline in mortality and morbidity associated with vaccine preventable diseases, but it being a potential obstacle to global vaccination uptake. Hence, since 2014, intensive collective efforts have been made to study and report on the determinants of vaccine hesitancy in order to appropriately design suitable interventions.

According to the SAGE working group, behavior resulting from the decision-making process is driving vaccine hesitancy, along with outcomes of different effects (internal or external) that may influence the decision either to accept or refuse vaccination. However, the group realizes that vaccine hesitancy determinants are too broad to be predicated on simple sets of

factors. Hence a comprehensive matrix is developed from a mixture of sources (academic, practice, and reviews) that embraces contextual, individual/group, and vaccine/vaccine-specific influences [68]. As the working group evolves, the factors influencing behavioral changes are also non-static and evolving. Therefore, new knowledge and evidence-based conclusions will emerge, including outcomes of this dissertation. Therefore, it is important that national immunization programs and global health stakeholders championing equitable access to vaccines develop standard models that can track and measure factors driving vaccine hesitancy across multiple communities and contexts, with a goal of initiating appropriate evidence-based interventions.

A broad spectrum of social and psychological determinants of vaccine hesitancy have been identified, ranging from attitudes, antecedence, and cognitive biases [103]—to trust [16,63,69], social norms/processes, and moral values [108,109]. Therefore, vaccine demand promotion campaigns and their accompanying messages should be designed based on behavioral and social evidence, designed to suit a context-specific population, before and during implementation [110].

Several models have been propagated to understand vaccine hesitancy, as shown in Table 1. The 3C model puts determinants of vaccine hesitancy into three categories: confidence, convenience, and complacency [111]. According to the model, confidence measures trust in vaccines, the systems delivering them, and the motivation behind policy actions on which vaccines are provided [111]. The model describes complacency as when risk perception of vaccine-preventable diseases is low and/or there is a weak perceived importance put on the vaccination. Convenience looks at the quality of immunization services, its delivery methods, and the environment and cultural circumstances that enables vaccine uptake. Another, albeit complex, model was developed in which determinants of vaccine hesitancy were grouped

into three categories: contextual factors, individual and group level factors, and vaccine/vaccination specific factors [61].

Recently, researchers have supported a more rigorous conceptualization of vaccine hesitancy grounded in established theoretical frameworks [16,112]. This has led to the development of the 5C model [16]. The model focuses on exploring psychological antecedents of vaccination by looking beyond definitions of vaccine hesitancy [113]. The 5C psychological antecedents of the vaccination model are confidence, complacency, constraints, calculation, and collective responsibility [61]. Studies have emerged providing empirical evidence that this 5C model is effective as a measure for vaccine hesitancy [114–117], and this has improved the intervention scope and knowledge toolkit in the hands of a policymaker for addressing skepticism about childhood vaccines in these regions and countries. While empirical studies have been very consistent and have grown in high-income countries (HIC), progress in low-income countries (where hesitancy is perceived to be greater) has lagged, especially in SSA countries [113].

5C psychological antecedence of vaccine hesitancy

Betsch et al.'s [16] comprehensive study on the psychological determinants of vaccine hesitancy attempted to understand why a considerable number of people in identified populations do not receive recommended vaccinations; and then to measure patterns over time in order to design appropriate strategies to address and increase vaccine uptake. The study accessed widely beyond confidence and safety in vaccines and the system delivering them. The model show that factors such as complacency (not perceiving diseases as high risk), constraints (structural and psychological barriers), calculation (engagement in extensive information searching), and collective responsibility (willingness to protect others) equally determine vaccination intention.

The Betsch study is one of the most comprehensive studies ever done, albeit in high income countries, but it is now being validated in low-income country settings such as Nigeria and Malawi. It represents one of the most comprehensive sets of behavioral models on vaccination decision-making ever carried out in the region.

Multi-dimensional tools and ways to measure vaccine hesitancy exist, but little is known about their validity in non-Western settings, such as SSA [66]. Other factors may be relevant in SSA, but no tool currently exists to assess and extend existing measures. Therefore, identifying the drivers of vaccine demand has become a subject of interdisciplinary research, and one of the most studied approaches is the 5C psychological antecedent model.

Based on the 5C models [16], confidence represents trust in the effectiveness and safety of vaccines and the healthcare system delivering it, including (but not limited to) vaccine-related risk perceptions and attitudes toward vaccination. Meanwhile, complacency exists where the perceived risks of vaccine-preventable diseases are low, and vaccination is not deemed a necessary preventive action. Complacent caregivers or individuals reveal an uninterested attitude towards vaccination and are they are insufficiently interested to garner knowledge and awareness around it. Constraints are an issue when physical availability, affordability, willingness-to-pay, geographical accessibility, ability to understand (language and health literacy), and appeal of the immunization service affect uptake. Moreover, constraints affect people with low self-agency regarding vaccination decisions. Calculation refers to individuals' engagement in extensive information searching and therefore relates to perceived assessment of vaccination benefits and disease risks. Collective responsibility is the willingness to protect others by one's own vaccination decision. Individuals with these intentions value communal interest, well-being, and willingness to play their part within a system.

The model posited that vaccination increases with confidence (perceiving a vaccine as safe and effective) and collective responsibility (valuing the protection of others)—but decreases with complacency (assuming a low risk of infection), constraints (encountering structural or psychological barriers), and calculation (weighing up the perceived benefits and risks of vaccination). Vaccination interventions based on these antecedents have produced varying outcomes. This dissertation adds new knowledge to the existing body of evidence on the subject.

The outcomes of the 5C model could be very influential in addressing low vaccination uptake globally and/or the stagnant vaccination situation in the SSA region if interventions are harnessed well, especially in solving/improving not only the opt-out and reminder phenomena, but also norms and social actions that influence behavior against positive childhood vaccination decision-making. Therefore, this dissertation explored the 5C model as the sole measure of vaccination decision-making in the SSA region.

Table 2: Vaccine Hesitancy Measurement Across General Studies [16]

Models			Measures							
SAGE Working group: The 3C model [111]	The 4C model (extended 3C model) [70]	The 5A model: Taxonomy for the determinants of vaccine uptake [118]	Parental Attitudes - Childhood Vaccines (PACV) [119]	Vaccine Confidence Scale (VCS) [120]	Global Vaccine Confidence Index (GVCI) [69]	Vaccine Hesitancy Scale (VHS) [121]	Vaccine Acceptance Scale (VAS) [122]	Vaccine Confidence Index (VCI) [123]	5C antecedents of vaccine acceptance [16]	5C+ Vaccination decision-Making [124,125]
3 factors	4 factors	5 determinants	15 items 3 sub-scales	8 items 3 sub-scales	4 items no sub-scales	9 items 2 sub-scales	20 items 5 sub-scales	8 items 3 sub-scales	5 or 15 items 5 sub-scales	8 or 18 items 8 sub-scales
confidence: trust in effectiveness and safety of vaccines and the system that delivers them (health care workers, politics)	confidence: negative attitudes, belief in misinformation, perceptions of vaccine-related risks	acceptance: individuals accept, question or refuse vaccination	beliefs about safety and efficacy general attitudes and trust immunization behavior	benefits trust harms	safety effectiveness	lack of confidence risks of vaccination	perceived safety of vaccines perceived effectiveness and necessity of vaccines acceptance of the selection and scheduling of vaccines positive values and affect toward vaccines perceived legitimacy of authorities to require vaccinations	trust confidence importance	confidence	confidence
convenience: physical availability, affordability and willingness-to-pay, geographical	convenience: structural barriers, perceived behavioral	access: ability of individuals to be reached by, or to reach, recommended vaccines	--	--	--	--	--	--	constraints	constraints

accessibility, ability to understand (language and health literacy) and appeal of immunization service	control	affordability: ability of individuals to afford vaccination								
complacency: perceived risks of diseases are low; vaccination not seen as necessary	complacency: low involvement, low general knowledge, awareness, vaccination not seen as the injunctive norm	awareness: knowledge (need for/availability of vaccines)	--	--	importance	--	--	--	complacency	complacency
--	calculation: individuals' engagement in extensive information search		--	--	--	--	--	--	calculation	calculation
--	--	activation: degree to which individuals are nudged towards vaccination uptake	--	--	--	--	--	--	--	
		(awareness: social benefits)	--	--	--	--	--	--	collective responsibility	collective responsibility
			--	--	compatibility with religious beliefs	--	--	--	--	Religion: religion not compatible with vaccination
										Masculinity: decision to vaccinate child rest on perception of the father
										Rumors: vaccines contain birth control agents

Insight into the WHO/UNICEF Joint Reporting Form (JRF) on vaccine hesitancy in Sub-Saharan Africa

Vaccine hesitancy is a growing global phenomenon, and the list of cited reasons varies, although in many instances a pattern seems consistent with Lane's 1–3 matrix classification [61,62]. To provide a broad view on vaccine hesitancy determinants and their measurement models in SSA, 5 years of reporting (2014–2018) by Kenya, Malawi, and Nigeria on the WHO/UNICEF Joint Report Form (JRF) was examined to determine the reporting frequency of data in the region as well as the reasons reported for vaccine hesitancy. Based on the data (Table 3), only 1 out of the 5 years was reported, and they seem to fixate on the SAGE vaccine hesitancy definition and its applicability in reporting reasons for hesitancy. Sadly, the assessments were not based entirely on empirical evidence, but instead more on administrative data, which were not specific to the three countries in focus [126]. Only about 25% of the reported reasons for vaccine hesitancy were based on empirical evidence in most of these countries [126].

The JRF has no data for most SSA countries between 2014–2018 [127]. For Kenya, only 2018 was reported and the three reasons for vaccine hesitancy in chronological order were: (i) fear of adverse event following immunization (AEFI), (ii) religious belief, and (iii) mythical/conspiratorial and misconception about vaccination. A similar scenario was seen in Malawi; the three drivers of vaccine hesitancy reported were: (i) religious reasons, (ii) perception of vaccines, and (iii) inadequate knowledge/awareness. In Nigeria, the reasons were: (i) religious misconceptions, (ii) no faith in vaccines (confidence), and (iii) fear of side effects (AEFI).

The conclusion of the JRF data and the significance of the reported determinants of vaccine hesitancy is that (based on the WHO SAGE classification [61]) vaccine/vaccination-specific

influence was not cited as a predictor. Therefore, despite the confounding subjectivity associated with the reasons cited, it further raises the stake on the assumptions surrounding vaccine hesitancy: i.e., the primary drivers are largely social and behavioral. Overall, the JRF was a good window to understand how perception was driving vaccination decision-making in the region. Unfortunately, this cannot be entirely relied upon for evidence-based intervention because of the nature of its assessment. Hence, the reason for this dissertation (to address this research gap).

Table 3: WHO/UNICEF JRF reported reasons for vaccine hesitancy in Kenya, Malawi and Nigeria.

ISO	Country	Region	Status	Indicator Code	Year	Value
Kenya						
KEN	Kenya	AFRO	member	Vaccine Hesitancy Assessment	2014	No data
KEN	Kenya	AFRO	member	Vaccine Hesitancy Assessment	2015	
KEN	Kenya	AFRO	member	Vaccine Hesitancy Assessment	2016	
KEN	Kenya	AFRO	member	Vaccine Hesitancy Assessment	2017	
KEN	Kenya	AFRO	member	Vaccine Hesitancy Assessment	2018	Fear of AEFI
KEN	Kenya	AFRO	member	FIRST REASON		Religious Factor
KEN	Kenya	AFRO	member	SECOND REASON		Myth & Misconception
KEN	Kenya	AFRO	member	THIRD REASON		
Malawi						
MWI	Malawi	AFRO	member	Vaccine Hesitancy Assessment	2014	No data
MWI	Malawi	AFRO	member	Vaccine Hesitancy Assessment	2015	
MWI	Malawi	AFRO	member	Vaccine Hesitancy Assessment	2016	
MWI	Malawi	AFRO	member	Vaccine Hesitancy Assessment	2017	
MWI	Malawi	AFRO	member	Vaccine Hesitancy Assessment	2018	Religious Factor
MWI	Malawi	AFRO	member	FIRST REASON		Perception
MWI	Malawi	AFRO	member	SECOND REASON		Ignorance
MWI	Malawi	AFRO	member	THIRD REASON		
Nigeria						
NGA	Nigeria	AFRO	member	Vaccine Hesitancy Assessment	2014	No data
NGA	Nigeria	AFRO	member	Vaccine Hesitancy Assessment	2015	
NGA	Nigeria	AFRO	member	Vaccine Hesitancy Assessment	2016	
NGA	Nigeria	AFRO	member	Vaccine Hesitancy Assessment	2017	
NGA	Nigeria	AFRO	member	Vaccine Hesitancy Assessment	2018	Religious Misconception
NGA	Nigeria	AFRO	member	FIRST REASON		No faith in vaccines
NGA	Nigeria	AFRO	member	SECOND REASON		Fear of side effect
NGA	Nigeria	AFRO	member	THIRD REASON		

Source: WHO/UNICEF JRF – June 2019

Goal of the dissertation

In order to inform evidence-based policies, intervention, and practices, this dissertation aimed at assessing determinants of vaccination decision-making (e.g., vaccine hesitancy) as well as contextual-associated factors driving this phenomenon.

Primary objectives of the dissertation

1. To understand the dynamics of vaccination decision-making and vaccine hesitancy determinants in SSA.
2. To test and validate the 5C model as an adaptable and practicable framework for measuring vaccine hesitancy in SSA.
3. To determine whether vaccination intention (prenatal) predicts behavior (postnatal) in SSA.

Organization of the dissertation

The dissertation begins with a systematic and scoping overview of existing literature on drivers of childhood vaccination decision-making among pregnant women and caregivers in SSA. While there is significant amount of literature on caregivers (parents of infants under-5), there is little on pregnant women and childhood vaccination decisions in SSA, except for three articles that focused on influenza, pertussis, and tetanus vaccines [128–130]. Of these, none covered childhood vaccination intention among this vulnerable group in the region.

Hence, the first undertaking of the dissertation in determining the background was to examine a region elsewhere in the world (Europe) to generate insights. A total of five peer-reviewed articles and one policy brief constituted the body of the dissertation, while two articles unrelated to the goal of the dissertation (but giving behavioral insights) were added as other publications.

The first article focuses on drivers of vaccination decision-making or behavior among pregnant women in Europe. The second article is on caregivers in selected countries in SSA (Ethiopia, Kenya, and Malawi), assessing vaccination behavior among caregivers. The third

article is a longitudinal study, with two time series data collection points: during pregnancy (prenatal) and 12 months after delivery (postnatal) in Nigeria, with the goal of assessing vaccination intention and behavior. The fourth article is a cross-sectional study on caregivers' willingness to vaccinate their children against recommended childhood and adolescent diseases such as HPV in Malawi. The fifth article is qualitative research, targeting multiple stakeholders (both demand and supply sides) to generate deeper and context-specific insights on vaccination decision-making in Malawi. The sixth article is a policy brief generated from the fifth article to guide policy action. Finally, the general discussion will briefly discuss key results of the respective articles in order to answer the research questions, and ends with a conclusion.

References (General Introduction)

1. Oyo-Ita, A.; Wiysonge, C.S.; Oringanje, C.; Nwachukwu, C.E.; Oduwole, O.; Meremikwu, M.M. Interventions for improving coverage of childhood immunisation in low- and middle-income countries. *Cochrane Database Syst. Rev.* 2016, 7, CD008145. Wiley-Blackwell: Hoboken, NJ, USA.
2. WHO/UNICEF. (2020, July 15). WHO and UNICEF warn of a decline in vaccinations during COVID-19. News release, Geneva/New York. <https://www.who.int/news/item/15-07-2020-who-and-unicef-warn-of-a-decline-in-vaccinations-during-covid-19> Accessed on Dec. 7, 2021.
3. VOA News (2021, July 15). Vaccinations Against Preventable Childhood Diseases in 'Alarming Decline,' UN Says. https://www.voanews.com/a/covid-19-pandemic_vaccinations-against-preventable-childhood-diseases-alarming-decline-un-says/6192865.html Accessed on Dec. 18, 2021.
4. Jamison, D., Jha, P., Malhotra, V., & Verguet, S. Human Health: The Twentieth-Century Transformation of Human Health – Its Magnitude and Value. In B. Lomborg (Ed.), *How Much Have Global Problems Cost the World: A Scorecard from 1900 to 2050* (pp. 207-246). Cambridge: Cambridge University Press. 2013. doi:10.1017/CBO9781139225793.009
5. UNICEF. 2021. Immunization. <https://www.unicef.org/immunization>. Accessed on Dec. 19, 2021.
6. Ansong D, Tawfik D, Williams EA, et al. Suboptimal vaccination rates in rural Ghana despite positive caregiver attitudes towards vaccination. *J Vaccines Immun* 2014; 2:7–15.
7. Oduwole EO, Pienaar ED, Mahomed H, et al Current tools available for investigating vaccine hesitancy: a scoping review protocol. *BMJ Open* 2019; 9:e033245. doi: 10.1136/bmjopen-2019-033245
8. Walter A.O. and Ahmed Rafi. Simply put: Vaccination saves lives. *Proc Natl Acad Sci USA.* 2017, 18; 114(16): 4031–4033. doi: 10.1073/pnas.1704507114
9. Ozawa S, Clark S, Portnoy A, Grewal S, Brenzel L, Walker DG. Return on Investment from Childhood Immunization in Low- And Middle-Income Countries, 2011-20. *Health Aff (Millwood)*. 2016 Feb;35(2):199-207. doi: 10.1377/hlthaff.2015.1086.
10. Tate J, Aguado T, Belie JD, et al. The life-course approach to vaccination: harnessing the benefits of vaccination throughout life. *Vaccine. Internet*]. 2019;37(44):6581–6583. Available from: <http://www.sciencedirect.com/science/article/pii/S0264410X19312046>.

11. Bärnighausen T, Bloom DE, Cafiero ET, et al. Valuing the broader benefits of dengue vaccination, with a preliminary application to Brazil. *Semin Immunol. Internet* 2013, 252:104–113. Available from <http://www.sciencedirect.com/science/article/pii/S1044532313000262>.
12. Bärnighausen T, Bloom DE, Cafiero-Fonseca ET. et al. Valuing vaccination. *Proc Natl Acad Sci USA. Internet*]. 2014; 111:12313. Available from <http://www.pnas.org/content/111/34/12313>.
13. Adepoju, Paul. 2017. Vaccines will help prevent 24 million people from slipping into poverty by 2030. *Healthnews*. <http://www.healthnews.ng/vaccines-will-help-prevent-24-million-people-slipping-poverty-2030/>. Accessed Dec. 1, 2021.
14. Kagina, Benjamin M. Hussey, Hannah. Muloiwa, Rudzani. Hussey, Gregory D. 2018. *Immunising Africa*. Sept. 1, 2018. <https://www.dandc.eu/en/article/immunisation-programmes-are-making-huge-difference-africa>. Accessed Sept., 5, 2021.
15. WHO/UNICEF Estimates of National Immunization Coverage (WUENIC). 30-June-2021. Available online: https://apps.who.int/immunization_monitoring/globalsummary/timeseries/tswucoveredtp3.html (accessed on 9 Sept. 2020).
16. Betsch, C., Schmid, P., Heinemeier, D., Korn, L., Holtmann, C., & Böhm, R. Beyond confidence: Development of a measure assessing the 5C psychological antecedents of vaccination. *PLOS ONE*, 2018; 13(12), e0208601. <https://doi.org/10.1371/journal.pone.0208601>
17. Martin, R.; On Behalf of the SAGE DoV GVAP Working Group. Decade of Vaccine Action Plan: Summary of the GVAP Implementation Progress; SAGE: Geneva, Switzerland, 2013.
18. Global Alliance for Vaccine and Immunization (GAVI) Annual Progress Report 2018.
19. Strategic Advisory Group of Experts on Immunization (SAGE): Assessment Report of the Global Vaccine Action Plan. Geneva: World Health Organization; 2018.
20. Gulland, Anne (2019, May 20). Africa set to be declared polio free as Nigeria marks three years without the disease. *The Telegraph*. <https://www.telegraph.co.uk/global-health/science-and-disease/africa-set-declared-polio-free-nigeria-marks-three-years-without/>
21. Shah MP, Tate JE, Mwenda JM, Steele AD, Parashar UD. Estimated reductions in hospitalizations and deaths from childhood diarrhea following implementation of rotavirus vaccination in Africa. *Expert Rev Vaccines* 2017; 16:987–95.
22. Troeger S. et al., Rotavirus Vaccination and the Global Burden of Rotavirus Diarrhea Among Children Younger Than 5 Years. *JAMA Pediatr*. 2018 Oct; 172(10): 958–965.
23. United Nations Inter-agency Group for Child Mortality Estimation (UN IGME). Levels & Trends in Child Mortality: Report 2019, Estimates developed by the United Nations Inter-agency Group for Child Mortality Estimation', United Nations Children's Fund, New York, 2019. New York,: United Nations Children's Fund; 2019.
24. Machingaidze, S. Wiysonge, C.S. Hussey GD. Strengthening the expanded programme on immunization in Africa: looking beyond 2015. *PLoS Med* 2013;10(3):e1001405. doi:10.1371/journal.pmed.1001405. PMID:23526886.
25. Feldstein L.R, Mariat S, Gacic-Dobo M, Diallo S, Conklin L, Wallace A. Global routine vaccination coverage, 2016. *Wkly Epidemiol Rec* 2017;92(46):701–7. PMID:29148273.
26. World Health Organization. Global vaccine action plan: Regional vaccine action plans 2016 progress reports. Geneva: WHO; 2016. Available at http://www.who.int/immunization/sage/meetings/2016/october/3_Regional_vaccine_action_plans_2016_progress_reports.pdf (accessed 2 January 2020).
27. WHO. WUENIC Estimates, 2020f. https://www.who.int/immunization/monitoring_surveillance/data/en/ Accessed Dec. 20, 2020).
28. Immunization Africa. Progress Report 2014. <http://immunizationinafrica2016.org/immunization-in-africa>. Retrieved Dec. 2, 2021.
29. WHO. 2015. Regional Strategic Plan for Immunization 2014-2020. World Health Organization Regional Office for Africa. https://www.afro.who.int/sites/default/files/2017-06/oms-ivb-rvap-afro-en-20150408_final_sent140317_0.pdf?ua=1 Accessed July 7, 2021.

30. Centers for Disease Control and Prevention (CDC). Global Immunization: Meningitis. Feb. 5, 2020.
https://www.cdc.gov/globalhealth/immunization/infographic/meningitis_a_infographic.htm. Accessed June 5, 2021.
31. Patel MK, Gacic-Dobo M, Strebel PM, et al. Progress toward regional measles elimination – worldwide, 2000–2015. *MMWR Morb Mortal Wkly Rep* 2016;65(44):1228–33. doi:10.15585/mmwr.mm6544a6. PMID:27832050.
32. World Health Organization. (2020g). Immunization Coverage: Key Challenges. 15 July 2020. Available online: <https://www.who.int/news-room/fact-sheets/detail/immunization-coverage> (accessed on 16 May 2021).
33. GAVI Annual Progress Report 2017. <https://www.gavi.org/sites/default/files/publications/progress-reports/Gavi-Progress-Report-2017.pdf>. Accessed Feb. 17, 2021.
34. GAVI vaccine Alliance Progress Report 2015: Keeping Children Healthy. <https://www.gavi.org/sites/default/files/publications/progress-reports/Gavi-Progress-Report-2015.pdf>. Accessed Feb. 17, 2021.
35. Kagina, Benjamin M. Hussey, Hannah. Muloiwa, Rudzani. Hussey, Gregory D. 2018. Immunising Africa. *D+C*, Sept. 1, 2018. <https://www.dandc.eu/en/article/immunisation-programmes-are-making-huge-difference-africa>. Accessed Sept., 5, 2021.
36. Vanderslott, S.; Dadonaite, B.; Roser, M. Vaccination. 2019. Published online at OurWorldInData.org. Available online: <https://ourworldindata.org/vaccination> (accessed on 2 January 2020).
37. WHO SAGE. National Immunization Technical Advisory Groups: Background Paper. World Health Organisation (WHO). April 2017d. Available online: https://www.who.int/immunization/sage/meetings/2017/april/1_NITAGs_background_document_SAGE_April_2017.pdf (accessed on 28 December 2020).
38. Okwo-Bele, J.-M. Together We Can Close the Immunization Gap; World Health Organization (WHO): Geneva, Switzerland, 2015.
39. Global Alliance for Vaccine and Immunization (GAVI). Facts & Figures: Statistics Measuring Our Impact on Global Immunization. February 2021. Available online: <https://www.gavi.org/sites/default/files/document/2021/Gavi-Facts-and-figures-February-21.pdf> (accessed on 17 May 2021).
40. UNICEF analysis, based on the United Nations Inter-agency Group for Child Mortality Estimation estimates for the year 2018 and WHO and Maternal and Child Epidemiology Estimation Group (MCEE) interim estimates. 11 November 2019c. <https://www.unicef.org/press-releases/one-child-dies-pneumonia-every-39-seconds-agencies-warn>. Accessed Dec. 8, 2021.
41. United Nations Inter-agency Group for Child Mortality Estimation (UN IGME). Levels & Trends in Child Mortality: Report 2019, Estimates developed by the United Nations Inter-agency Group for Child Mortality Estimation’, United Nations Children’s Fund, New York, 2019. New York,: United Nations Children's Fund; 2019.
42. Machingaidze, S. Wiysonge, C.S. Hussey GD. Strengthening the expanded programme on immunization in Africa: looking beyond 2015. *PLoS Med* 2013; 10(3):e1001405. doi:10.1371/journal.pmed.1001405. PMID:23526886.
43. Fenta, S.M., Biresaw, H.B., Fentaw, K.D. et al. Determinants of full childhood immunization among children aged 12–23 months in sub-Saharan Africa: a multilevel analysis using Demographic and Health Survey Data. *Trop Med Health* 49, 29 (2021). <https://doi.org/10.1186/s41182-021-00319-x>
44. Khazaei Z, et al. Global cancer statistics 2018: Globocan estimates of incidence and mortality worldwide prostate cancers and their relationship with the human development index. *Adv Hum Biol.* 2019;9(3):245.
45. Yaya S, Uthman OA, Okonofua F, Bishwajit G. Decomposing the rural-urban gap in the factors of under-five mortality in sub-Saharan Africa? Evidence from 35 countries. *BMC Public Health.* 2019;19(1):616. <https://doi.org/10.1186/s12889-019-6940-9>.

46. World Health Organization. Immunization coverage 2019. 2020d. <https://www.who.int/news-room/fact-sheets/detail/immunization-coverage> [accessed January 19, 2021].
47. World Health Organization. Progress and challenges with achieving universal immunization coverage. 2019 WHO/UNICEF estimates of national immunization coverage. World Health Organization: Geneva, Switzerland. 2020e.
48. Kazungu JS, Adetifa IMO. Crude childhood vaccination coverage in West Africa: Trends and predictors of completeness. *Wellcome Open Res.* 2017;2.
49. Grout L, Minetti A, Hurtado N, et al. Measles in Democratic Republic of Congo: an outbreak description from Katanga, 2010–2011. *BMC Infect Dis.* 2013;13(1):232. doi:10.1186/1471-2334-13-232
50. WHO. 1 in 5 children in Africa do not have access to life-saving vaccines. April 28, 2015y. <https://www.afro.who.int/news/1-5-children-africa-do-not-have-access-life-saving-vaccines>. Accessed Jan 2, 2022.
51. WHO. Business case for WHO immunization activities on the African continent, 2018–2030. Brazzaville: World Health Organization; 2018v. <https://www.afro.who.int/health-topics/immunization>. Accessed Nov 17, 2021.
52. UNICEF Report: Immunization: A child dies of pneumonia every 39 seconds. July 2019e. Available online: <https://data.unicef.org/topic/child-health/immunization/> (accessed on 19 October 2020).
53. Ferlay, J.; Ervik, M.; Lam, F.; Colombet, M.; Mery, L.; Piñeros, M.; Znaor, A.; Soerjomataram, I.; Bray, F. Global Cancer Observatory: Cancer Today; International Agency for Research on Cancer: Lyon, France, 2018.
54. Bray, F.; Ferlay, J.; Soerjomataram, I.; Siegel, R.L.; Torre, L.A.; Jemal, A. Global Cancer Statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *Cancer J. Clin.* 2018, 68, 394–424.
55. Bruni, L.; Albero, G.; Serrano, B.; Mena, M.; Gómez, D.; Muñoz, J.; Bosch, F.X.; de Sanjosé, S. Human Papillomavirus and Related Diseases in Africa. In Summary Report; Barcelona, Spain, 2019; p. iv.
56. Maseko, F.C.; Chirwa, M.L.; Muula, A.S. Cervical cancer control and prevention in Malawi: Need for policy improvement. *Pan Afr. Med. J.* 2015, 22, 247.
57. Maseko, F.C.; Chirwa, M.L.; Muula, A.S. Client satisfaction with cervical cancer screening in Malawi. *BMC Health Serv. Resh.* 2014, 14, 420.
58. Chadza, E.; Chirwa, E.; Maluwa, A.; Malata, A.; Kazembe, A.; Chimwaza, A. Factors that contribute to delay in seeking cervical cancer diagnosis and treatment among women in Malawi. *Health Aff.* 2012, 14, 1015–1022.
59. Msyamboza, K.P.; Mwagomba, B.M.; Valle, M.; Chiumia, H.; Phiri, T. Implementation of a human papillomavirus vaccination demonstration project in Malawi: Successes and challenges. *BMC Public Health* 2017, 17, 599.
60. Magombo-Mana, K. Malawi Launches HPV Vaccine Campaign: Minister Muluzi Says Cervical Cancer Leading Cause of Women’s Deaths. 12 January 2019. Available online: <https://www.nyasatimes.com/malawi-launches-hpv-vaccine-campaign-minister-muluzi-says-cervical-cancer-leading-cause-of-womens-deaths/> (accessed on 8 December 2020).
61. Strategic Advisory Group of Experts (SAGE) on Vaccination Hesitancy Report. World Health Organization (WHO). 2014. Available online: https://www.who.int/immunization/sage/meetings/2014/october/SAGE_working_group_revised_report_vaccine_hesitancy.pdf (accessed on 3 April 2021).
62. Lane, S.; MacDonald, N.E.; Marti, M.; Dumolard, L. Vaccine hesitancy around the globe: Analysis of three years of WHO/UNICEF Joint Reporting Form data-2015–2017. *Vaccine* 2018, 36, 3861–3867.
63. Larson, H.J.; Jarrett, C.; Eckersberger, E.; Smith, D.M.D.; Paterson, P. Understanding vaccine hesitancy around vaccines and vaccination from a global perspective: A systematic review of published literature, 2007–2012. *Vaccine* 2014, 32, 2150–2159.
64. Global Alliance for Vaccine and Immunization (GAVI). Annual Progress Report; 2019; Available online: <https://www.gavi.org/progress-report-2019> (accessed on 5 July 2021).

65. World Health Organization. (2017). World health statistics 2017: monitoring health for the SDGs, sustainable development goals. World Health Organization. <https://apps.who.int/iris/handle/10665/255336>. 2017
66. Cooper, Sara. Betsch, Cornelia. Sambala, Evanson. Mchiza, Nosicelo and Wiysonge, Charles S. Vaccine hesitancy – a potential threat to the achievements of vaccination programmes in Africa. *Hum Vaccin Immunother.* 2018; 14(10): 2355–2357. doi: 10.1080/21645515.2018.1460987.
67. Dube, E.; Laberge, C.; Guay, M.; Bramadat, P.; Roy, R.; Bettinger, J. Vaccine hesitancy: An overview. *Hum. Vaccines Immunother.* 2013, 9, 1763–1773.
68. Strategic Advisory Group of Experts (SAGE) on Vaccination Hesitancy Report. World Health Organization (WHO). 2014. Available online: https://www.who.int/immunization/sage/meetings/2014/october/SAGE_working_group_revised_report_vaccine_hesitancy.pdf (accessed on 3 April 2021).
69. Larson, H.J.; De Figueiredo, A.; Xiaohong, Z.; Schulz, W.S.; Verger, P.; Johnston, I.; Cook, A.; Jones, N.S. The State of Vaccine Confidence 2016: Global Insights through a 67-Country Survey. *EBioMedicine* 2016, 12, 295–301.
70. Betsch C, Böhm R, Chapman GB. Using Behavioral Insights to Increase Vaccination Policy Effectiveness. *Policy Insights from the Behavioral and Brain Sciences.* 2015;2(1):61-73. doi:[10.1177/2372732215600716](https://doi.org/10.1177/2372732215600716)
71. Regional Office for Africa WHO. Experts Caution against Stagnation of Immunization Coverage in Africa. Brazzaville, Congo. 2019g. Available online: <https://www.afro.who.int/news/experts-caution-against-stagnation-immunization-coverage-africa>. (Accessed on 1 June 2021).
72. WHO/UNICEF Estimates of National Immunization Coverage. 2019. Available online: https://www.who.int/immunization/monitoring_surveillance/who-immuniz.pdf (accessed on 1 June 2021).
73. Global Vaccine Action Plan 2011-2020 (GVAP). World Health Organization, 2018.
74. LaFond, A.; Kanagat, N.; Steinglass, R.; Fields, R.; Sequeira, J.; Mookherji, S. Drivers of routine immunization coverage improvement in Africa: Findings from district-level case studies. *Health Policy Plan.* 2015, 30, 298–308.
75. Mihigo, R.; Okeibunor, J.; Anya, B.; Mkanda, P.; Zawaira, F. Challenges of immunization in the African Region. *Pan Afr. Med. J.* 2017, 27 (Suppl. 3), 12.
76. Tarantola, D.; Hacen, M.; Lwanga, S.; Clements, C.J. Is Immunization Coverage in Africa Slipping? An Evaluation of Regional Progress to 2013. *Ann. Vaccines Immun.* 2014, 1, 1007.
77. Madhi, S.A.; Rees, H. Special focus on challenges and opportunities for the development and use of vaccines in Africa. *Hum. Vaccines Immunother.* 2018, 14, 2335–2339.
78. Global Cancer Data: GLOBOCAN 2018. (2018, Sept. 12). Retrieved Dec. 5, 2020. <https://www.uicc.org/news/new-global-cancer-data-globocan-2018>.
79. Fort, V.K.; Makin, M.S.; Siegler, A.J.; Ault, K.; Rochat, R. Barriers to cervical cancer screening in Mulanje, Malawi: A qualitative study. *Patient Prefer. Adher.* 2011, 5, 125–131.
80. National Bureau of Statistics (NBS) & United Nations Children’s Fund (UNICEF). Multiple Indicator Cluster Survey, 2016-17. Survey Finding Report, 2018. Abuja: National Bureau of Statistics and United Nations Children’s Fund. <https://www.unicef.org/nigeria/reports/multiple-indicator-cluster-survey-2016-17-mics> (Accessed Nov 4, 2020).
81. United Nations Inter-Agency Group for Child Mortality Estimation (UN IGME). Report. Levels and Trends in Child Mortality. 2020. <https://data.unicef.org/resources/levels-and-trends-in-child-mortality/#> (Retrieved Jan 3, 2021).
82. UNICEF. Nigeria: 4.3 million children in Nigeria still miss out on vaccinations every year. Press release, 24 April 2018r. <https://www.unicef.org/nigeria/press-releases/43-million-children-nigeria-still-miss-out-vaccinations-every-year>. Accessed Dec. 15, 2021.
83. Adedokun, ST., Uthman, OA., Adekanmbi, VT. et al. Incomplete childhood immunization in Nigeria: a multilevel analysis of individual and contextual factors. *BMC Public Health* 2017, 17; 236. <https://doi.org/10.1186/s12889-017-4137-7>

84. Alsharif, F.; Khamis, F.; Sallam, L.A.; Sharif, L.; Alsufyani, A.; Alshulah, F.N.; Alqasimi, R. Assessment of Mothers' Knowledge, Attitudes, and Practices Regarding Childhood Vaccination during the First Five Years of Life in Saudi Arabia. *Nurs. Rep.* 2021, 11, 506–516. <https://doi.org/10.3390/nursrep11030047>
85. Druckman, James. Survey Shows Parents Are More Hesitant to Get Vaccines for Their Kids. Institute for Policy Research, Northwestern University. Mar. 22, 2021. Retrieved from: <https://www.ipr.northwestern.edu/news/2021/survey-parents-more-hesitant-to-vaccinate-their-kids.html>
86. Smith, PJ. Humiston, SG. Marcuse, EK. Zhao, Z. Dorell, CG. Howes, C. and Hibbs, B. Parental Delay or Refusal of Vaccine Doses, Childhood Vaccination Coverage at 24 Months of Age, and the Health Belief Model. *Public Health Rep.* 2011; 126(Suppl 2): 135–146. doi: 10.1177/00333549111260S215
87. Simonson, Matthew D., Hanyu Chwe, David Lazer, Katherine Ognyanova, Matthew Baum, Roy H. Perlis, James Druckman, et al. 2021. "The COVID States Project #49: Vaccinating America's Youth." OSF Preprints. May 4. doi:10.31219/osf.io/stacj.
88. Bardají, Azucena. Steinhoff, Mark. Maceteb, Eusebio and Menéndez Clara. The burden of vaccine-preventable diseases in pregnancy in low-resource settings. *The Lancet Global Health.* 2016; 4 (3), e152-e153
89. McClure EM, Goldenberg RL. Stillbirth in developing countries: a review of causes, risk factors and prevention strategies. *J Matern Fetal Neonatal Med;* 2009; 22, 183–90.
90. Wright, Linda L. Chapter 4 - Global Neonatal Health. In Editor(s): Christine A. Gleason, Sherin U. Devaskar, Avery's Diseases of the Newborn (Ninth Edition), W.B. Saunders, 2012, Pages 23-36, ISBN 9781437701340, <https://doi.org/10.1016/B978-1-4377-0134-0.10004-6>.
91. Vitek, CR. Pascual, FB. Baughman, AL. Murphy TV. Increase in deaths from pertussis among young infants in the United States in the 1990. *Pediatr Infect Dis J,* 2003; 22, 628–35.
92. Bratton, KN. Wardle, MT. Orenstein. WA. Omer, SB. (2015). Maternal influenza immunization and birth outcomes of stillbirth and spontaneous abortion: a systematic review and meta-analysis. *Clin Infect Dis.*, 2015; 60; e11-e19
93. Chu, HY and Englund, JA. Maternal immunization. *Clin Infect Dis.* 2014; 59; 560-568
94. O'Leary, S., Riley, L., Lindley, M. C., Allison, M., Crane, L., Hurley, L., Beaty, B., Brtnikova, M., Albert, A., Fisher, A., Jiles, A., & Kempe, A. Vaccine Refusal Among Pregnant Women: A National Survey of Obstetrician-Gynecologists. *Open Forum Infectious Diseases,* 2017; 4(suppl_1), <https://doi.org/10.1093/ofid/ofx163.1338>
95. Gabutti, Giovanni. Conforti, Giorgio. Tomasi, Alberto. Kuhdari, Parvanè. Castiglia, Paolo. Prato, Rosa. Memmini, Silvia. Azzari, Chiara. Rosati, Giovanni Vitali & Bonanni, Paolo. Why, when and for what diseases pregnant and new mothers "should" be vaccinated, *Human Vaccines & Immunotherapeutics,* 2017: 13 (2), 283-290, DOI: 10.1080/21645515.2017.1264773
96. Fell DB, Savitz DA, Kramer MS, Gessner BD, Katz MA, Knight M, Luteijn JM, Marshall H, Bhat N, Gravett MG, Skidmore B. Maternal influenza and birth outcomes: systematic review of comparative studies. *Int J Obstet Gynaecol.* 2017;124(1):48–59. <https://doi.org/10.1111/147105-28.14143>.
97. World Health Organisation (WHO). Vaccines against influenza WHO position paper– November 2012. *Wkly Epidemiol Rec.* 2012b;87(47):461–76.
98. Meijer WJ, van Noortwijk AG, Bruinse HW, Wensing AM. Influenza virus infection in pregnancy: a review. *Acta Obstet Gynecol Scand.* 2015;94(8):797–819.
99. Thompson MG, Kwong JC, Regan AK, Katz MA, Drews SJ, Azziz-Baumgartner E, Klein NP, Chung H, Effler PV, Feldman BS, Simmonds K, Wyant BE, Dawood FS, Jackson ML, Fell DB, Levy A, Barda N, Svenson LW, Fink RV, Ball SW, Naleway A, PREVENT Workgroup. Influenza vaccine effectiveness in preventing influenza-associated hospitalizations during pregnancy: a multi-country retrospective test negative design study, 2010–2016. *Clin Infect Dis.* 2019;68(9):1444–53. <https://doi.org/10.1093/cid/ciy737>.
100. European Centre for Disease Prevention and Control (ECDC). Scientific advice on seasonal influenza vaccination of children and pregnant women. Stockholm: ECDC. 2012.

101. Adeyanju, G.C., Engel, E., Koch, L. et al. Determinants of influenza vaccine hesitancy among pregnant women in Europe: a systematic review. *Eur J Med Res*, 2021a; 26, 116. <https://doi.org/10.1186/s40001-021-00584-w>
102. Kilich, E., Dada, S., Francis, M. R., Tazare, J., Chico, R. M., Paterson, P., et al. Factors that influence vaccination decision-making among pregnant women: A systematic review and meta-analysis. *PLoS ONE* 2020: 15(7), e0234827. <https://doi.org/10.1371/journal.pone.0234827>
103. Dudley, MZ., Limaye, RJ., Omer, SB., O’Leary, ST., Ellingson, MK., Spina, CI., Brewer, SE., Chamberlain, AT., Bednarczyk, RA., Malik, F., Frew, PM. , & Salmon, DA. Characterizing the vaccine knowledge, attitudes, beliefs, and intentions of pregnant women in Georgia and Colorado, *Human Vaccines & Immunotherapeutics*, 2020: 16(5), 1109-1117, DOI: 10.1080/21645515.2020.1717130
104. Prospero E, Galmozzi S, Paris V, Felici G, Barbadoro P, D’Alleva A, Zocco G, Ciavattini A. Factors influencing refusing of flu vaccination among pregnant women in Italy: healthcare workers’ role. *Influenza Other Respir Viruses*. 2019;13(2):201–7. <https://doi.org/10.1111/irv.12600>.
105. MacDougall, Donna M & Halperin, Scott A. Improving rates of maternal immunization: Challenges and opportunities. *Hum Vaccin Immunother*. 2016 Apr 2;12(4):857-65. doi: 10.1080/21645515.2015.1101524.
106. Mbonigaba E, Nderu D, Chen S, et al. Childhood vaccine uptake in Africa: threats, challenges, and opportunities. *Journal of Global Health Reports*. 2021;5:e2021080. doi:10.29392/001c.26312
107. World Health Organization (WHO). 2019. “Ten threats to global health in 2019” <https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019>. Retrieved Dec. 1, 2020.
108. Amin AB, Bednarczyk RA, Ray CE, et al. Association of moral values with vaccine hesitancy. *Nat Hum Behav*. 2017;1(12):873-880
109. Hornsey MJ, Harris EA, Fielding KS. The psychological roots of anti- vaccination attitudes: A 24-nation investigation. *Health Psychol*. 2018 Apr; 37(4):307-315
110. United Nations Children’s Fund (UNICEF). Vaccine Misinformation Management Field Guide. New York, 2020k.
111. MacDonald NE, Eskola J, Liang X, Chaudhuri M, Dube E, Gellin B, et al. Vaccine hesitancy: Definition, scope and determinants. *Vaccine* 2015;33:4161–4.
112. Ajzen, I. The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes*, 1991: 50(2), 179–211.
113. Adamu, AA., Essoh, Téné-Alima., Adeyanju, GC., Jalo, RI., Saleh, Yusuf., Aplogan, Aristide & Wiysonge, CS (2021): Drivers of hesitancy towards recommended childhood vaccines in African settings: a scoping review of literature from Kenya, Malawi and Ethiopia, *Expert Review of Vaccines*, DOI: <https://doi.org/10.1080/14760584.2021.1899819>
114. Wismans A, Thurik R, Baptista R, Dejardin M, Janssen F, et al. Correction: Psychological characteristics and the mediating role of the 5C Model in explaining students’ COVID-19 vaccination intention. *PLOS ONE*, 2021, 16(11): e0259922. <https://doi.org/10.1371/journal.pone.0259922>
115. Hossain, Bellal Mohammad., Alam, Zakiul., Islam, Syful., Shafayat, Sultan., Faysal, Mahir., Rima, Sharmin., Hossain, Anwer., Mamun, Abdullah Al. Health Belief Model, Theory of Planned Behavior, or Psychological Antecedents: What Predicts COVID-19 Vaccine Hesitancy Better Among the Bangladeshi Adults? *Frontiers in Public Health*, 9, 2021, 1172. DOI=10.3389/fpubh.2021.711066
116. Machida M, Nakamura I, Kojima T, Saito R, Nakaya T, Hanibuchi T, Takamiya T, Odagiri Y, Fukushima N, Kikuchi H, Amagasa S, Watanabe H, Inoue S. Trends in COVID-19 vaccination intent from pre- to post-COVID-19 vaccine distribution and their associations with the 5C psychological antecedents of vaccination by sex and age in Japan. *Hum Vaccin Immunother*. 2021 Nov 2;17(11):3954-3962. doi: 10.1080/21645515.2021.1968217.
117. Nath, Rima, Asif Imtiaz, Shobod D. Nath, and Emran Hasan. "Role of Vaccine Hesitancy, eHealth Literacy, and Vaccine Literacy in Young Adults’ COVID-19 Vaccine

- Uptake Intention in a Lower-Middle-Income Country" *Vaccines*, 2021: 9, no. 12: 1405. <https://doi.org/10.3390/vaccines9121405>
118. Thomson A, Robinson K, Vallée-Tourangeau G. The 5As: A practical taxonomy for the determinants of vaccine uptake. *Vaccine*. 2016 Feb 17;34(8):1018-24. doi: 10.1016/j.Vaccine.2015.11.065.
 119. Opel DJ, Taylor JA, Zhou C, Catz S, Myaing M, Mangione-Smith R. The relationship between parent attitudes about childhood vaccines survey scores and future child immunization status: a validation study. *JAMA Pediatr*. 2013; 167: 1065–1071. <https://doi.org/10.1001/jamapediatrics.2013.2483> PMID: 24061681
 120. Gilkey MB, Reiter PL, Magnus BE, McRee A-L, Dempsey AF, Brewer NT. Validation of the vaccination confidence scale: a brief measure to identify parents at risk for refusing adolescent vaccines. *Acad Pediatr*. 2016; 16: 42–49. <https://doi.org/10.1016/j.acap.2015.06.007> PMID: 26300368
 121. Shapiro GK, Holding A, Perez S, Amsel R, Rosberger Z. Validation of the vaccine conspiracy beliefs scale. *Papillomavirus Res*. 2016; 2: 167–172. <https://doi.org/10.1016/j.pvr.2016.09.001> PMID: 29074176
 122. Sarathchandra D, Navin MC, Largent MA, McCright AM. A survey instrument for measuring vaccine acceptance. *Prev Med*. 2018; 109: 1–7. <https://doi.org/10.1016/j.ypmed.2018.01.006> PMID: 29337069
 123. Frew PM, Murden R, Mehta C, Chamberlain A, Hinman A, Nowak G, et al. Development of an Index for Measurement of Parents' Vaccine Confidence and Linkage to Pediatric Immunization Acceptance; undated; https://www.hhs.gov/sites/default/files/Frew_Development%20of%20a%20Vaccine%20Confidence%20Index%20to%20Measure%20Parental%20Confidence%20in%20Childhood%20Vaccinations_remediated.pdf
 124. Adeyanju, G.C.; Sprengholz, P.; Betsch, C.; Essoh, T.-A. Caregivers' Willingness to Vaccinate Their Children against Childhood Diseases and Human Papillomavirus: A Cross-Sectional Study on Vaccine Hesitancy in Malawi. *Vaccines*, 2021b: 9, 1231. <https://doi.org/10.3390/vaccines9111231>
 125. Adeyanju, G.C.; Sprengholz, P. and Betsch, C. 2022a. Understanding Drivers of Vaccine Hesitancy among Pregnant Women in Nigeria: A Longitudinal Study. *Npj Vaccines*. <https://www.researchsquare.com/article/rs-1097318/private/timeline>
 126. Pan American Health Organization (PAHO), 2020. Frequent Asked Questions (FAQs): WHO-UNICEF Joint Reporting Form on Immunization (JRF) and Estimates of National Immunization Coverage (WUENIC) https://iris.paho.org/bitstream/handle/10665.2/52625/PAHOFPLIM200015_eng.pdf?sequence=1&isAllowed=y Accessed Jun 3, 2021.
 127. WHO/UNICEF Estimates of National Immunization Coverage (WUENIC), 2019: Progress and Challenges with Achieving Universal Immunization Coverage. July 2019.
 128. Kouassi DP, Coulibaly D, Foster L, Kadjo H, N'Zussuouo T, Traoré Y, et al. Vulnerable groups within a vulnerable population: awareness of the A(H1N1)pdm09 pandemic and willingness to be vaccinated among pregnant women in Ivory Coast. *Journal of Infectious Diseases*. 2012;206 Suppl 1:S114–S20.
 129. Larson Williams A, McCloskey L, Mwale M, Mwananyanda L, Murray K, Herman AR, et al. "When you are injected, the baby is protected:" Assessing the acceptability of a maternal Tdap vaccine based on mothers' knowledge, attitudes, and beliefs of pertussis and vaccinations in Lusaka, Zambia. *Vaccine*. 2018;36(21):3048–53. <http://dx.doi.org/10.1016/j.vaccine.2018.03.081> pmid:29653846
 130. Ymba A, Perrey C. Acceptability of tetanus toxoid vaccine by pregnant women in two health centres in Abidjan (Ivory Coast). 2003. p. 3497–500.

OVERVIEW OF PUBLICATIONS

1. *Article Number One*

- **Adeyanju, G.C.**, Engel, E., Koch, L. et al. Determinants of influenza vaccine hesitancy among pregnant women in Europe: a systematic review. *European Journal of Medical Research*, 2021: 26, 116. <https://doi.org/10.1186/s40001-021-00584-w>

2. *Article Number Two*

- Adamu AA, Essoh TA, **Adeyanju GC**, Jalo RI, Saleh Y, Aplogan A, Wiysonge CS. Drivers of hesitancy towards recommended childhood vaccines in African settings: a scoping review of literature from Kenya, Malawi and Ethiopia. *Expert Review of Vaccines*. 2021, 5: 611-621. doi:10.1080/14760584.2021.1899819. <https://www.tandfonline.com/doi/full/10.1080/14760584.2021.1899819>

3. *Article Number Three*

- **Adeyanju, G.C.**, Sprengholz, P. & Betsch, C. Understanding drivers of vaccine hesitancy among pregnant women in Nigeria: A longitudinal study. *npj Vaccines* 2022: 7, 96. <https://doi.org/10.1038/s41541-022-00489-7>

4. *Article Number Four*

- **Adeyanju GC**, Sprengholz P, Essoh T-A, and Betsch C. Caregivers' willingness to vaccinate their children against childhood diseases and human papillomavirus: a cross-sectional study on vaccine hesitancy in Malawi. *Vaccines*, 2021: 9, 1231. <https://doi.org/10.3390/vaccines9111231>

5. *Article Number Five*

- **Adeyanju, G.C.**, Betsch, C., Adamu, A.A. et al. Examining enablers of vaccine hesitancy toward routine childhood and adolescent vaccination in Malawi. *Global Health Research and Policy*, 2022: 7, 28. <https://doi.org/10.1186/s41256-022-00261-3>

6. *Article Number Six*

- **Adeyanju GC**, Betsch C, Head MG, and Essoh T-A. Analyzing vaccine hesitancy in Malawi: a policy brief. *Figshare presentation*. 2021. DOI: <https://doi.org/10.6084/m9.figshare.14604678.v1>.

OTHER ARTICLES

Two other publications are highlighted, but because they are unrelated to the goal of this dissertation, hence, added as other publications. The citations are seen below.

7. Article Number Seven (7)

- **Adeyanju, G.C.**, Solfa, R.P., Tran, T.L. et al. (2021). Behavioural symptoms of mental health disorder such as depression among young people using Instagram: a systematic review. *Translational Medicine Communication* 6: 15. <https://doi.org/10.1186/s41231-021-00092-3>

8. Article Number Eight (8)

- Adeyanju, GC., Augustine, T.M., Volkmann, S. et al. (2021). Effectiveness of intervention on behaviour change against use of non-biodegradable plastic bags: a systematic review. *Discover Sustainability*, 2: 13. <https://doi.org/10.1007/s43621-021-00015-0>

GENERAL DISCUSSION

In order to inform evidence-based intervention and policies, the six articles presented in the dissertation assessed low vaccination uptake in SSA and their determinants, and whether vaccination behavior is influenced by intention.

The discussion centers around how the study outcomes provide explanations to the research questions, including the following. i) What are the drivers of vaccine hesitancy among vulnerable groups such as pregnant women (Articles 1 and 3a) and caregivers in SSA (Articles 2, 3b, 4, 5 and 6)? ii) Are the drivers of vaccination intention (pregnant women) and behavior the same and does the former influence the latter in SSA (Article 3)? iii) Is the 5C model an adaptable measurement scale for understanding vaccination decision-making (vaccine hesitancy) in SSA (Articles 3 and 4)?

Therefore, the results of the articles are summarized and briefly discussed in response to the research questions. Also, windows for practical implications/application of the findings, future research, and limitations are presented in each of the section.

Drivers of vaccine hesitancy among vulnerable groups (pregnant women)

Insights from beyond Sub-Saharan Africa (Europe)

According to influenza (flu) vaccine and 11 other empirical studies that assessed vaccination behavior at prenatal in the European region, psychological, contextual, physical, sociodemographic, and other factors appear to shape pregnant women's willingness to accept, delay, or refuse vaccinations [1].

Psychological determinants: Varying factors help us to understand multiple psychological standpoints on the subject, including low personal risk perception (complacency) among pregnant women resulting from denial of the threats from influenza infection [1]. As much as 23% of women in Spain held the notion that they were not at risk of contracting influenza

while being pregnant [2]. Similarly, without evidence, not only were some women underestimating their personal risk of flu infection, but also they thought that the risks of adverse events from the vaccine were higher compared to the effects of an infection. Hence, vaccination is not a priority for these women. Another psychological factor perhaps contributing the most to prenatal vaccination behavior in the region is vaccine safety and effectiveness (confidence), especially lack of confidence that the vaccine would not harm the unborn. This concern reflects women's feelings of mistrust and personal insecurity when it comes to receiving the flu shot. For example, in Germany and Ireland, many expectant mothers believe that it is unsafe to take a vaccine during pregnancy [3,4]. This shows that negative attitudes toward vaccination can result from low confidence. Furthermore, susceptibility to conspiracy theories or rumors plays a huge role in confidence and vaccination behavior among this vulnerable group. For example, among several reasons cited in an Italian study, pregnant women considered vaccination a business model motivated by Big Pharma's desire for more profit [5].

Contextual determinants: Vaccination behavior is also considered to be partly influenced by the lack of information and adequate recommendations by healthcare providers (constraints). As a result, a significant number of pregnant women do not know about the general recommendation at the prenatal stage of pregnancy. A total of 22% of the pregnant women in a study reported that the vaccine was not directly offered by physicians [5], hence assumptions were built around its acceptance. Similarly, 44% of the unvaccinated women in a German study were unaware of the official vaccination recommendation; while another study found that nearly 30% of pregnant women in Valencia did not know about the flu shot recommendation [3]. The results show that absence of requisite information and recommendation to get vaccinated were relevant factors driving vaccination decisions.

Proximity and multiparity determinants: One of the reasons for not getting vaccinated was proximity to childbirth. Despite vaccination being recommended to women in their second or third trimester of pregnancy, some women fear that getting vaccinated at that stage can be dangerous or not necessary since childbirth is near [2]. Another reason is multiparity, based on previous experiences of not having been infected during prior pregnancies [6].

Other determinants: Other factors driving vaccination behavior at the prenatal stage in the European region include lower sociodemographic status (e.g., being an ethnic minority, being an immigrant or refugee, or having lower educational attainment), perceiving the disease to be less severe, the need for (more) time to think about the risks and benefits before a decision (calculation), the fear of needles, and drug objections [6].

Summary

This study provided insights into pregnant women's vaccination decision-making as well as the drivers behind vaccine hesitancy. These insights gained from the data help us to understand women's behavior and consequently vaccination intention (prenatal) in relation to their children (postnatal) regarding recommended childhood vaccination. Psychological factors such as low risk perception (complacency), concerns about the safety and effectiveness of vaccine (confidence); and others such as lack of information and adequate recommendations by healthcare providers (constraints), the need for time to think about risk and benefit before a decision (calculation) constituted drivers of vaccination behavior among pregnant women. These behaviors are synonymous with those found in the 5C model [7]. Therefore, not only are the drivers of vaccination decision-making at the prenatal stage understood from this study perspective, but they also provided an understanding of what vaccination intention of recommended childhood vaccines could be like. Would the behaviors (in this study) be synonymous with intention to vaccinate (see the study below) for

recommended childhood vaccines and would the 5C model provide the explanatory gaps? This was investigated in the SSA region, prompting the next study in Article 3.

Future research should explore the role of collective responsibility in detail (i.e., taking action in the interests of all stakeholders), as this was not explicitly stated in the study. This psychological variable could be important for prospective mothers or when designing interventions that rely on community opinions. Marginalized populations, such as women with migration backgrounds or groups with specific social or cultural differences, should also be studied.

Empirical evidence from Sub-Saharan Africa

Many successes have been recorded based on vaccination as a public health intervention in SSA. These achievements have lessened, however, owing to several determinants including vaccine hesitancy. In SSA, recommended childhood vaccines are particularly impacted by this behavior-related phenomenon. Even more significant is an understudied group (pregnant women) who are at the center of childhood vaccination decision-making. These women and their unborn babies are the most vulnerable groups because immunological and serological changes that occur during pregnancy can alter the mother's and the fetus's susceptibility to various infectious diseases. Despite this knowledge, some pregnant women doubt, delay, or refuse the protection offered in vaccinations [8–12]; hence, this behavior puts children in a vulnerable state early in their lives [13].

Current knowledge on the gap and drivers of vaccine hesitancy of recommended childhood vaccines in SSA is very limited, alongside the impacts on coverage [14], thereby reducing evidence-based capacity to design and executive context-specific interventions in the region. To address this vacuum, this dissertation tries to assess caregivers from two standpoints: at intention level/pregnancy (prenatal) and at behavior level/after childbirth (postnatal).

Therefore, Article 3 is a longitudinal study (3a and 3b), whose first part (3a) focused on vaccination intention determinants. Using the 5C psychological antecedent scale plus additional context-specific variables, this framework's adaption in measuring drivers of vaccine hesitancy at prenatal in Nigeria shows that age, religion, education, employment, the 5C model, and additional variables such as masculinity (father's attitude), believing in rumors/misinformation (i.e., that vaccination can cause infertility) and thinking that one's religious belief is incompatible with vaccination were considered influential for intention of pregnant women to vaccinate children in future (Article 3). However, only four significant predictors were found. Muslims indicated lower vaccination intention compared to Christians. Vaccination intention increased when confidence in public authorities/health system is high but decreased if participants indicated that their husband's approval was important for vaccination and if they believed in the rumor that vaccination causes infertility.

Summary

Confidence: Confidence seems to be the strongest driver of intention to vaccinate unborn children at the prenatal stage, especially confidence in the public authority/healthcare system or its workers. Confidence in the country's healthcare system is related to a more positive intention to vaccinate children in the future—exposure of mothers to vaccination knowledge at the prenatal stage through healthcare providers, healthcare workers, or public institutions managing vaccination in SSA increased their intention to vaccinate children with recommended vaccines, and vice versa.

Therefore, vaccine confidence plays a huge role in assuring mothers at the prenatal stage; otherwise, vaccinating their unborn children would be very low priority in situations where a lack of trust existed regarding the systems managing vaccination services [15–19]. Interestingly, and in contrast to the kind of trust found in Article 1 (above) on Europe, which is associated with vaccine safety and effectiveness, in SSA the trust is associated with the

healthcare system. It is all about confidence, but what type of confidence? This perhaps demonstrates that vaccination behavior or decision-making are influenced by context, time, and places.

One of the reasons why vaccination intention at the prenatal stage in SSA is determined by trust in the health system could be due to health system managers' exaggeration about immunization efficacy to motivate uptake, thereby giving the false impression that immunization prevents all childhood diseases [20,21]. Hence, the inability or failure of immunization to prevent all diseases erodes trust and confidence in the public health systems and institutions managing immunization programs, and eventually there is a loss of faith in immunization as an intervention to give protection against VPD.

Religion: Religious belief significantly influences vaccination decision-making in many parts of SSA. However, religious influence being a catalyst for vaccination decision-making among pregnant women is novel finding in SSA, particularly the finding that being a pregnant Muslim reduces the chances that an unborn child would be vaccinated as an infant. This unique finding should enable the scope of intervention to be broadened beyond the traditional focus in the future, but now it is included as an intervention at the prenatal stage and to a target population. Also, since religion is not a factor that is part of the 5C model, an extension of the model to accommodate this variable might be suggested, especially when building a suitable measurement scale for vaccine hesitancy in the region.

Masculinity: The fact that masculinity influences vaccination intention was a striking revelation in this study, although several SSA communities are still situated in conservative low-income countries where a strong patriarchal culture exists [22]. The opinion of a child's father or a wife's husband is crucial in the overall decision-making of the family household, and this was reflected in the findings in this dissertation. Indeed, the husband's knowledge and attitude and/or belief about vaccination or vaccines shapes the entire household's

decision on whether a child is vaccinated. When a husband or child's father encourages or approves immunization for the child, a positive relationship to vaccination intention was observed. Invariably, children who are likely to complete full recommended childhood immunization are those whose fathers possess good vaccination disposition. Similarly, a child is less likely to begin or complete a full dosage of recommended childhood immunization if the father's attitude toward immunization is negative. Therefore, vaccine hesitancy or low vaccination intention is common among households where women lack decision-making autonomy.

Childhood vaccination behavior has been influenced by fathers [23], and because of the inequitable power relation in some African households, this patriarchal behavior influences a wide range of issues, including health-seeking behavior such as vaccination decisions [24,25].

Studies looking at vaccination behavior among caregivers found that children from more patriarchal households were less likely to complete recommended childhood immunizations and vice versa [23,26,27]. This dissertation may have found the reason a father's approval or attitude towards vaccination affects whether their child receives full vaccination.

Rumor: Vaccination intention among pregnant women is also driven by belief in rumors or conspiracy theories surrounding vaccination. More expecting mothers are less willing to vaccinate their children if they believe in the rumor that vaccination causes infertility or are a strategic instrument by Western nations to make girls become infertile (birth control medicine). This behavior is not unexpected in a generally Muslim-dominated population, because several studies examining back-end impacts of religion or religious beliefs on vaccine uptake have found religion to be central to vaccination discourse on decision-making in SSA [28–32]. However, this study revealed two important new findings: first, that religious belief is not only a Muslim phenomenon, but is Christian as well, although more

Muslims have lower vaccination intention. Second, it is surprising that this sentiment still persists among pregnant women who supposedly are more likely to pursue positive health-seeking behavior.

In general, using the 5C measure to categorize vaccination intention at the prenatal stage between pregnant women in Europe and SSA, there seems to be a disconnect in terms of drivers that falls within the model. While four variables of the 5C scale (confidence, complacency, constraints, and calculation) are found to be relevant in the European region as drivers of vaccine hesitancy among pregnant women (vaccination intention), only one variable (confidence) seems to be a related factor in SSA. Conversely, while religion, masculinity, and rumor seem to be strong determinants in SSA, they are not relevant determinants in the European region. Therefore, further research is advised, using the same 5C measure as well as additional variables to assess vaccination behavior rather than intention.

Drivers of vaccine hesitancy among caregivers in Sub-Saharan Africa

To understand the research question, what the drivers of vaccine hesitancy among caregivers in SSA are, the dissertation assessed articles 2, 3b, 4, 5, and 6. This section highlights multi-contextual factors in SSA that contribute to low vaccination uptake in the region.

Evidence from Ethiopia, Kenya, and Malawi

The study in Article 2 reviewed a body of evidence to advance the current understanding on vaccine hesitancy influencers toward recommended childhood vaccines within the SSA context, using Kenya, Malawi, and Ethiopia as references. Several factors that affect immunization uptake were identified and mapped into three themes, namely, caregiver-related factors, health systems-related factors, and community context [33], although these factors are complex and interrelated. Community-context factors as broad drivers of low

vaccination uptake include low autonomy among women, masculinity, nomadic settings of many populations in SSA, low vaccination due to the rainy season, belonging to minority ethnic group, and the influence of religious leaders. The health system-related factors are immunization and health system predicaments such as poor knowledge of immunization, childbirth outside a health facility (such as at home using traditional birth attendants), and poor utilization of antenatal and postnatal care services. Caregiver-related factors consists of low vaccination uptake due to actions of individuals/parents such as increasing childbirth order, sickness of a family member at the scheduled time for vaccination, trust in traditional herbal medicines, lack of trust in immunization, fear of side effects of vaccine(s), fear of injections, low birth weight in children, and negative rumors about vaccines [33].

Meanwhile, the main psychological antecedents to low vaccination uptake that were identified and categorized in these settings were confidence and constraints. This relationship is illustrated in the causal loop diagram (Figure 3, Article 2). When caregiver's confidence in the immunization system is low, hesitancy toward vaccines increases and vice versa [7,9]. Similarly, when several constraints exist within and outside a caregiver's control but with low self-agency, vaccine hesitancy will also increase.

The evidence from Ethiopia, Kenya, and Malawi demonstrated a complex network of factors driving vaccination behavior in the SSA region, and a psychological context under which vaccination decision-making can be understood and measured, particularly the extent that intervention to improve vaccine acceptance needs to target multiple stakeholders at community, health system, and caregiver levels.

The main limitation of this study is that only 23 studies were identified, and this might have limited the scope of the identified factors. Also, most studies focused on female respondents; but as seen in this dissertation, men contribute significantly to vaccination decision-making. Methodologically, there seem to be an absence of a suitable significant qualitative or mixed

methods approach to gain deeper insights into the drivers of vaccine hesitancy within SSA-specific settings.

Empirical evidence from Nigeria

Empirical evidence from Nigeria (Article 3b [T2]) [9], based on recommended childhood vaccination behavior among mothers of newborns at the postnatal stage (Table 3), shows that the vaccination decision is more likely to lead to uptake when the mother's religious belief aligns with vaccination (religion); when there is high degree of confidence in the effectiveness of vaccines (confidence); and when mothers consider the interests of the community (including herd immunity) in health-seeking behavior, the demand for childhood vaccination gets better (collective responsibility). On the other hand, a higher level of everyday stress (constraint) increases vaccination hesitancy among caregivers [9].

The influence of a few important demographic indicators (such as age, education, and belief in rumors or conspiracy theories) on these drivers provided further useful insights (Table 4 in Article 3), especially for policy action. Age had no influence on vaccination behavior, and neither did it explain any variance among the discovered determinants of vaccination demand. On the other hand, education did.

The higher the education of mothers, the higher their belief that vaccines are effective and that accepting them is in the interest of everyone in the community. Whereas the belief in negative rumors and misinformation or conspiracy theories about vaccination cuts across all drivers of vaccination behavior.

Although the WHO/UNICEF JRF for Kenya, Malawi, and Nigeria (Table 2 in Article 3) classified the religion factor as a driver of vaccine hesitancy [34], other studies including the Pew survey also considered religious belief as central to the discourse about vaccination behavior and decision-making in SSA [29–32].

Religion as a determinant causing low uptake of recommended childhood vaccination (particularly among Muslim mothers compared to Christian mothers), although not surprisingly it is novel among caregivers of infants who were assessed at the prenatal stage.

Religious beliefs permeate individual, group, and national decision-making, and the immunization system is no exception [28]. Several decisions within populations in the region are filtered or measured according to the lenses and understandings of religious standpoints. For example, the Muslim-dominated northern region in Nigeria has the highest vaccine hesitancy level, which translates to it by being the region with lowest immunization coverage: the least being in the North-West at 8% and the highest being North-Central at 26% [20,35].

Therefore, this dissertation uniquely enriches the insight needed to understand drivers of vaccination decision-making and why uptake is low or stagnant in SSA. Vaccination intention was not meaningfully related to actual behavior. However, vaccination behavior is related to three of the 5C measures on the psychological antecedence scale as well as two additional variables. These three measures are to the fore when confidence in the vaccine effectiveness was high (confidence), when mothers felt responsible for collective well-being (collective responsibility), and when mothers indicated lower levels of everyday stress (constraint). Likewise, out of the three additional variables assessed alongside the 5C scale, mothers of infants were more likely to vaccinate their children when vaccination is supported by religious beliefs (religion).

Rumor and/or misinformation was a very powerful influencer among all four predictors of vaccination behavior (rumor). Specifically, misinformation or rumor about vaccination affects these four determinants and thus indirectly affects vaccination behavior. The significance of confidence, constraints, collective responsibility, religion, rumors, or misinformation as drivers of vaccination decision-making or behavior were a big step

towards increasing the dearth of knowledge on vaccine hesitancy and its determinants, especially among vulnerable and understudied groups in SSA.

The study had some limitations that may (or may not) have affected the outcomes. Based on observations during the fieldwork, the 5C scale did not produce the desired effect for a few reasons. Its original constructs and coinage of the items, as used, are a little too broad for the Nigerian cultural setting. Also, participants with low literacy (i.e., mothers with no or little education) struggled to fully understand the English grammar of some of the 5C items. Therefore, in the future, the 5C scale needs to be rewritten in plain English or translated into local languages.

Empirical evidence from Malawi

Evidence from Malawi (Article 4) provided further good insights for the goal of the dissertation. In Malawi, the percentage of fully immunized children aged 12–23 months has been consistently declining since 1992, when coverage peaked at 82% [36,37]. Between 2010–2016, full immunization uptake decreased from 81% to 76% among children 12–23 months old in Malawi [38]. An insight into some districts' vaccination coverage and timeliness with valid doses completed by children were the low rates of 60% in Dowa District and 49% in Ntchisi District [39]. Besides, 19 out of 20 countries in 2018 with the highest burden of cervical cancer cases are in SSA [40,41], and Malawi has the second highest burden globally and the highest in the SSA region [42].

Despite these staggering data, vaccine uptake remains low, due to several factors including vaccine hesitancy [43–45]. Although several factors may be responsible for the low uptake of recommended childhood and adolescent vaccines, vaccine hesitancy is recognized as the major contributor [46,47]. Hence the underlining motives of this dissertation: to identify the contributors of vaccine hesitancy, to measure them, and to strategically intervene.

Multi-dimensional tools and ways to measure these contributors exist, but little is known about their validity in non-Western settings such as SSA [14]. Other social and behavioral factors may be relevant in SSA; for example, a scientific tool to assess and extend existing measures is limited or non-existent. Therefore, by using an expanded 5C psychological antecedent model, as was done in Nigeria according to Article 3a and 3b, significant outcomes are brought to the fore following assessment of recommended childhood vaccines and adolescent vaccines such as HPV.

For the recommended childhood vaccine, confidence in vaccine safety (confidence), constraints due to everyday stress (constraints), conviction that the topic of vaccination must be fully understood (calculation), and the importance of a husband's approval (masculinity) were the strongest determinants of vaccination decision-making or behavior (Table 2 in Article 4). Further exploratory endeavors on factors confounding higher or lower levels of confidence, constraints, calculation, and masculinity, show that age, gender, religion, education, and employment, as well as belief in rumors and trust in healthcare workers, were considered confounders (Table 3 in Article 4).

Confidence in vaccine safety among caregivers in Malawi drops when belief in rumors or misinformation (such as prayers prevent measles and/or HPV vaccine causes infertility/birth control) is high. Lower confidence in vaccine effectiveness was also caused by general rumor/misinformation, particularly among unemployed caregivers, but confidence was higher among those who had male children and who had more trust in healthcare workers. Conversely, thinking that vaccine-preventable diseases were not severe (complacency) was affected by multiple variables: older adults (35–60 years), males, those believing in traditional religions, and those agreeing with the rumor that vaccination was a means to reduce the population. Caregivers whose child was male, who had at least secondary

education, and who believed prayers prevented measles indicated more strongly that everyday stress (constraints) caused them to be less likely to vaccinate their children.

Those who trusted healthcare workers also agreed with the statement that the topic of vaccination must be fully understood (calculation). Masculinity (husband's approval for vaccination) was more prevalent among caregivers who had primary or secondary education, more trust in healthcare workers, and had a stronger belief that vaccination is a means to reduce the population and that the HPV vaccine causes infertility.

For the HPV vaccine: Using the same 5C model to assess HPV vaccination decision-making determinants among caregivers of adolescent girls, among all the demographic variables only education influenced the willingness to vaccinate daughters. Caregivers with a secondary or tertiary education showed less intention to vaccinate than those with no formal or primary education. More caregivers were willing to vaccinate children when trust in healthcare workers was high, but this willingness decreased when confidence in the safety of vaccines and the system delivering it was low (confidence). Vaccination intentions increased when the children's immune systems were perceived to be strong and as such protect against diseases (complacency), and when there was a need for husbands to give their approval before children can be immunized (masculinity). Similar outcomes were observed for measures of calculation and collective responsibility.

Due to the impacts of rumor or misinformation (i.e., that prayers prevent measles, vaccines are a means to reduce the population, and that HPV vaccine causes girls to be infertile or are a form of birth control) on study outcomes in Malawi, further assessment was done to understand how it affects vaccination decision-making (Table 6 in Article 4).

Age was a significant driver: compared to the youngest group (18–24 years), caregivers aged 25–34 years old have more belief in rumors. For older participants, beliefs decreased, with

the oldest participants (60+ years) showing the least belief. Also, being unemployed increased the average belief in rumors, while trust in healthcare workers reduced it.

In summary, caregivers' vaccination decision-making for recommended childhood vaccination is motivated predominantly by aspects related to the 5C psychological antecedence model as well as added variables such as masculinity and rumors. Lack of trust in vaccine safety and effectiveness (confidence), everyday stress (constraints), and some other influences such as beliefs in the child's immune system (complacency) and husband's approval (masculinity) were also contributing factors in the decision-making.

Other factors include the feeling that vaccine-preventable diseases are not severe (complacency), fear of doctors (constraints), and risk-benefit analysis and understanding vaccine topics (calculation). The lack of trust in public authorities managing the vaccination system (confidence) was also a determinant of vaccination decision-making, especially among adolescent girls (HPV vaccination).

Overall, confidence in vaccine safety was the strongest predictor for vaccination decision-making. Not just the safety of vaccines worries caregivers about childhood immunization but also whether vaccines are effective and whether the caregivers can trust the healthcare system to make the best decision concerning vaccines. Also, rumor permeates the entire vaccination decision-making process. Indeed, every caregiver's behavior and decisions on vaccination are influenced in some way by this factor.

Furthermore, evidence from Malawi produced some unique undertones such as the role of population group, levels of education, and rumor or misinformation. Perceptions that vaccine-preventable diseases are not so severe or are not high-risk diseases and vaccination being unnecessary were surprisingly common among the older population (35–60 years) compared to the young adults (25–34 years). One would have expected that, the older people become,

the higher their health-seeking behavior or self-agency attached to preventive behavior and vulnerability to diseases [48,49].

This is also contrary to expectations that younger individuals have higher risk-seeking and invulnerability behavior due to feelings of positive subjective personal health status [48,50,51]. However, it is remarkable to find this perception among the older generation instead of the younger generation. Another unique undertone was the role of education. It is notable because level of education mostly correlates with positive vaccination attitude [52–54], but interestingly this dissertation found that the opposite was true in Malawi. However, this correlation is not seen in Malawi alone. The influence of education on childhood immunization uptake in Spain was found to be unrelated: the less educated parents had higher childhood immunization rates compared to the more educated once [55]. Similarly, during the state of health emergency declared in Washington state in 2019 due to a measles outbreak, affluent and highly educated parents were the most vaccine-hesitant parents [56].

Rumor or misinformation was another undertone. It has hitherto been underestimated in various vaccine demand creation interventions across the SSA region [57,58], and it is an important revelation of this dissertation. A relationship exists between rumors and vaccination intention among caregivers of recommended childhood vaccines, however, belief in rumors was a major barrier against adolescent girl vaccination for HPV in Malawi [59]. However, young adults having higher belief in rumors is surprising and the reason needs to be further investigated. Although several factors could influence this, including young people's exposure to social media misinformation campaigns where a large amount of vaccination misinformation or fake news is broadcast [60].

Finally, regarding gender undertones, disparities in immunization coverage between boys and girls have been identified in some instances in regard to the child's gender determining vaccine uptake [61–63]. This dissertation provided valuable insights on this debate. In

Malawi, confidence in the effectiveness of vaccines is lower among caregivers whose children are female, compared to male [59]. Therefore, a female child in Malawi is more likely to receive delayed or incomplete vaccination coverage, or their parents will refuse it.

A limitation of this study was that it was associated with a relatively small convenient sample of participants. Additionally, the low internal reliability observed in the 5C scale may be largely due to similar factors identified in the Nigeria study.

Multi-stakeholder evaluation in Malawi

Article 5 examined multiple stakeholders' perspectives (using key informant/in-depth interviews and focus group discussions) on drivers of recommended routine childhood immunization (RI) decision-making and behavior in Malawi. These stakeholders included representatives of WHO, UNICEF, NiTAG, and EPI at central and district levels; religious and community leaders; healthcare workers (HCW); and caregivers. This part of the dissertation examined beyond causal relation, but it also investigated demand and supply viewpoints on drivers of decision-making concerning childhood vaccination (see Figure 2).

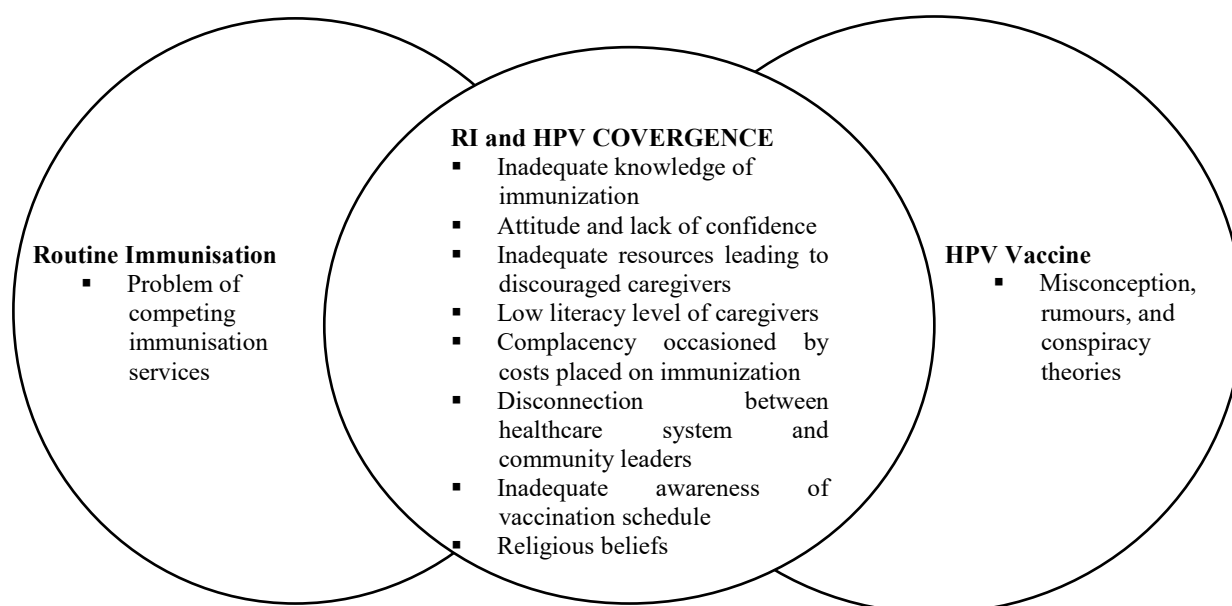


Figure 2: Overview of identified drivers of vaccine hesitancy in Malawi for routine immunization (RI) (left), human papilloma virus (HPV) vaccination (right), and both (middle)

The cross-sectional perspectives in this dissertation identified some key drivers or determinants of vaccine hesitancy, as displayed in Figure 2, to include a lack of awareness of the vaccination schedule, lack of confidence in the safety and effectiveness of vaccines, complacency disposition, religious belief, rumors or misinformation, and belief in conspiracy theories [64].

Misinformation or rumors that vaccination causes infertility as well as the role of fathers or husband's attitude towards vaccination are significant factors that affect whether caregivers get their children vaccinated. As seen in Articles 3a, 3b, 4, and 5, these drivers (rumor, religious belief, and husbands' attitude or masculinity) are intrinsically recurrent phenomena when vaccination decision-making among caregivers are discussed, not just in Malawi but throughout SSA. The same goes for some of the 5C psychological predictors such as confidence, complacency, constraints, calculation, and (in the case of HPV) collective responsibility. Based on the findings, the decision to forego an immunization appointment is not determined by factors beyond the caregivers' control such as distance or cost of transportation (in the case of complacency), but the convenience of doing so vis-a-vis other equally important commitments and the opportunity cost placed on immunization [64].

The main limitation experienced during this study was the problem of the COVID-19 pandemic, which resulted in unanticipated travel restrictions, substitution of earlier planned districts (Nsanje and Rumphi) for convenient ones (Salima and Lilongwe) in Malawi, and inaccessibility to some key stakeholder due to time factors, because some were COVID-19 essential-services personnel.

Policy brief contribution

In order to support Malawi policymakers at EPI and other stakeholders with evidence-based and empirical findings on combating vaccine hesitancy to improve vaccination uptake, a

policy brief (Article 6) [65] was developed based on the findings from Article 5. The policy brief provided useful resources for facilitating evidence-based behavior insight workshops on countering vaccine hesitancy, guided by WHO Tailoring Immunization Program (TIP) toolkit.

Why is the policy brief relevance to Malawi policymakers? Malawi is a poor-resource setting country, with significant successes in reducing child mortality with a series of vaccines [66]. But in recent years, these positive gains are eroding and the country is at risk of severe setbacks if vaccine hesitancy is not addressed [36,38]. Hence, the policy brief is meant to support national and local policymakers with better understanding of the latest sentiments behind low vaccination demand and the need to act urgently. The provided evidence or knowledge is expected to guide interventions appropriate to the local context in Malawi and it also may be relevant to other countries in SSA.

The policy recommendations of the brief focused on a few strategies, such as the need to increase outreach services that enhance visits to hard-to-reach areas; shortening caregiver's travel time and accessing more of the population; and grassroot health promotion and education campaigns should be led by community and religious leaders so that immunization is deemed to be safe and effective, and to dispel rumors during the process. Also, fathers or husbands are an important target group and should be given significant priority when tailoring educational and advocacy strategies, because (based on the findings of the dissertation) household vaccination decisions in SSA frequently depend on them [9,59,64].

Written vaccination messaging directed at low literacy settings should be designed using symbols that are easy to understand. Future campaigns should fully consider rural/remote settings in the production planning and dissemination of immunization knowledge (e.g., using local languages or dialects).

Transtheoretical behavior model as explanatory framework

Several theories exist to understand the mechanisms of health behavior such as health belief model (HBM), transtheoretical model (TTM) otherwise known as stages of change, the theory of planned behavior, and others [67–69]. The central attraction for these theories is the conceptualization that people engage in an internal decision-making process by weighing the risks and benefits of taking a specific action, especially about vaccination [70].

Specifically, people cognitively evaluate the severity of the health threat and the perceived benefits or risks of taking or not taking an action based on that threat. This cognitive risk assessment is motivated by many factors including the perceived risk of a disease, perceived severity and information available about the disease transmissibility, the source of the information, physical and social environment, cultural beliefs, political system, and others [70]. Therefore, in this dissertation, the focus is on a critical section of the population (pregnant women and caregivers) to understand how their decision-making thought-processes determine that the personal and social cost of not vaccinating may outweigh the health benefits of vaccination and vice versa.

In the SSA region, based on outcomes of above articles, especially Article 3a, vaccination decision-making is in stages and is sometimes vaccine-specific (e.g., RI and HPV), which relies on decisional balancing and self-efficacy [71]. The evidence shows that pregnant women were confident in their intention or ability to vaccinate their unborn children when trust in the healthcare system, workers, or authorities managing vaccine is high. However, self-efficacy was not significantly associated with vaccination intention [9]. The absence of a significant relationship may be attributable to the fact that vaccination decision-making among caregivers in SSA is based on stages of maternal progression.

As suggested by the transtheoretical model (TTM) of behavioral change, people's health decision-making tends to be at different stages of their self-efficacy [71,72]. Caregivers with

this orientation would be difficult to convince to make decisions or change behavior about a perceived non-existing problem, especially when there is no immediate perceived susceptibility or when they are yet to get to that stage for building intention to change/decision. At pregnancy, the immediate danger of harm or perceived disease severity to the child owing to VPD may not be imminent. Therefore, TTM of health behavior change considers the readiness and motivation for change among people as a continuum or process, and that process is a series of six independent stages: precontemplation (no intention of change now), contemplation (considering change), preparation (effort on an intention, planning, and committing to change), action (moments of change of behavior), maintenance, and termination (sustaining long-term behavior change) [73,74].

The centerpiece of TTM suggests that behavior change is a process, and that vaccination behaviors and decision-making go through these six stages, although it is not always in this sequential order. Suffice to say, the vaccination decision-making thought-process and motivation at the prenatal stage (intention during pregnancy) are completely different from those at the postnatal stage (actual vaccination behavior). Therefore, the vaccination decision-making process in SSA based on evidence from Nigeria, go through the TTM process. Hence, intervention in SSA to increase uptake needs to become dynamic as well. That is, targeted intervention should be carried out according to stages highlighted by the TTM, beginning from the prenatal stage.

Drivers of vaccination intention and behavior, and the influence of the former on the latter in Sub-Saharan Africa

This research question was tested in the longitudinal study in Nigeria. Based on the findings of this dissertation, and using the 5C model as a measurement framework, drivers of vaccination intention among pregnant women at the prenatal stage (Article 3a) towards recommended childhood vaccines is not the same as those influencing behavior at the

postnatal stage in SSA (see Article 3b). Prenatal vaccination intention was driven by religious beliefs (especially among Muslims compared to Christians,) confidence (especially trust in public authority and healthcare system providing vaccination services), masculinity (such as the husbands' approval or attitude towards vaccination), and rumor (such as "vaccines cause infertility") [9]. In the 5C scale, only confidence was a significant predictor of intention to vaccinate against childhood diseases at the prenatal stage.

However, the driver of postnatal vaccination behavior (Article 3b) was different and related positively to the predictors in 5C psychological antecedence model [7] compared to the prenatal stage in SSA. Although not all variables on the 5C scale were significant in Nigeria, on a broader level, confidence, constraints, and collective responsibility made good impacts. Similarly, the postnatal vaccination behavior drivers using the 5C scale as measured in Ethiopia, Kenya, and Malawi (Articles 2, 4, and 5) showed similarities across scale and determinants.

In Malawi, confidence, complacency, calculation, and collective responsibility were significant predictors of vaccination behavior among caregivers of infants under-5 [59]. These behavioral outcomes are of course exhaustive in Europe, where this model had been tested and validated [7]. Even in an understudied group (pregnant women) in Europe, vaccination decision-making and its drivers are psychologically driven by low-risk perception (complacency), concerns about the safety and effectiveness of vaccine (confidence), lack of information and inadequate recommendations by healthcare providers (constraints), the need for time to think about risk and benefit before making a decision (calculation), among others [1]. These behaviors at the prenatal stage in Europe are synonymous with those found in the 5C model [7]: suggesting behavior driving vaccine hesitancy in high income countries could be similar to those in SSA, especially among caregivers of children under-5.

While the compatibility of drivers of vaccination decision-making at the prenatal and postnatal stages may be difference based on using 5C measurement scale, one variable or factor seems to dominate both: confidence. Confidence is key to overall decision-making regarding vaccination and vaccines in SSA [9,33,59,64,65].

Whether confidence in authority and healthcare system providing vaccines and vaccination or confidence in effectiveness and safety of vaccines, trust seem to be an underlining influence in both decision-making stages of life among pregnant women and caregivers in general. Hence, the common denominator of drivers of vaccination intention and behavior in SSA is confidence in the health system, safety and effectiveness of vaccine.

Therefore, based on this dissertation and in reference to outcomes of Article 3, prenatal vaccination intentions do not play a role in actual vaccination behavior or decision-making [9].

The 5C model as an adaptable measure for understanding vaccine hesitancy predictors in Sub-Saharan Africa?

Reliability analyses for the 5C scale based on the original model and constructs, and the sequel after examination, were directly incompatible in the SSA setting. The internal consistency indicators of the data in SSA were low compared to reliability indicators obtained in Western samples. That is, the items did not do well in their current constructs (interpretations) in SSA (e.g., Nigeria) compared to the Western samples; confidence $\alpha = 0.39$, complacency $\alpha = 0.30$, constraints $\alpha = 0.47$, calculation $\alpha = 0.51$ and collective responsibility $\alpha = 0.22$ [9]. Reliability indicators obtained in Western samples were 0.71 and higher [7]. Therefore, the assumption that the 5C scale or factors that predict vaccine hesitancy was wholly adaptable and valid in SSA was undetermined in this dissertation so further testing is needed. However, when subjected to a different analytical model

(stepwise/backward regression analysis) using the single items but same constructs, it helped to further put the scale into a different and usable perspectives. Nevertheless, items from the scale predicted vaccination behavior more than intention in SSA. Overall, the additional variables such as rumor, religious belief, and masculinity (husband's attitude or approval) were significant contributors to the dissertation as important drivers of vaccination decision-making in SSA [9,59].

Further studies are still necessary to align and further validate suitable scales for measuring vaccine hesitancy in the SSA region, and the 5C scale is potentially a good starting point. Rumor or misinformation, religious belief, and masculinity should be significant parts of a new 5C scale. Future studies may wish to consider the emergence of a new scale using 5C model and the additional variables as a base.

References (General Discussion)

1. Adeyanju, G.C., Engel, E., Koch, L. et al. Determinants of influenza vaccine hesitancy among pregnant women in Europe: a systematic review. *Eur J Med Res*, 2021a; 26, 116. <https://doi.org/10.1186/s40001-021-00584-w>
2. Vila-Candel R, Navarro-Illana P, Navarro-Illana E, Castro-Sánchez E, Duke K, Soriano-Vidal FJ, Tuells J, Díez-Domingo J. Determinants of seasonal influenza vaccination in pregnant women in Valencia, Spain. *BMC Public Health*. 2016;16(1):1173. <https://doi.org/10.1186/s12889-016-3823-1>.
3. Bödeker B, Walter D, Reiter S, Wichmann O. Cross-sectional study on factors associated with influenza vaccine uptake and pertussis vaccination status among pregnant women in Germany. *Vaccine*. 2014;32(33):4131–9. <https://doi.org/10.1016/j.vaccine.2014.06.007>.
4. O'Shea A, Cleary B, McEntee E, Barrett T, O'Carroll A, Drew R, O'Reilly F. To vaccinate or not to vaccinate women's perception of vaccination in pregnancy a qualitative study. *BJGP Open*. 2018;2(2):bjgpopen18X101457. <https://doi.org/10.3399/bjgpopen18X101457>.
5. Prospero E, Galmozzi S, Paris V, Felici G, Barbadoro P, D'Alleva A, Zocco G, Ciavattini A. Factors influencing refusing of flu vaccination among pregnant women in Italy: healthcare workers' role. *Influenza Other Respir Viruses*. 2019;13(2):201–7. <https://doi.org/10.1111/irv.12600>.
6. Descamps A, Launay O, Bonnet C, Blondel B. Seasonal influenza vaccine uptake and vaccine refusal among pregnant women in France: results from a national survey. *Hum Vaccin Immunother*. 2019: Volume 16, Issue 5. <https://doi.org/10.1080/21645515.2019.1688035>.
7. Betsch, C., Schmid, P., Heinemeier, D., Korn, L., Holtmann, C., & Böhm, R. Beyond confidence: Development of a measure assessing the 5C psychological antecedents of vaccination. *PLOS ONE*, 2018: 13(12), e0208601. <https://doi.org/10.1371/journal.pone.0208601>
8. Adeyanju, G.C., Engel, E., Koch, L. et al. Determinants of influenza vaccine hesitancy among pregnant women in Europe: a systematic review. *Eur J Med Res*, 2021a; 26, 116. <https://doi.org/10.1186/s40001-021-00584-w>

9. Adeyanju, G.C.; Sprengholz, P. and Betsch, C. 2022a. Understanding Drivers of Vaccine Hesitancy among Pregnant Women in Nigeria: A Longitudinal Study. *Npj Vaccines*. <https://www.researchsquare.com/article/rs-1097318/private/timeline>
10. MacDougall, Donna M & Halperin, Scott A. Improving rates of maternal immunization: Challenges and opportunities. *Hum Vaccin Immunother*. 2016 Apr 2;12(4):857-65. doi: 10.1080/21645515.2015.1101524.
11. Kilich, E., Dada, S., Francis, M. R., Tazare, J., Chico, R. M., Paterson, P., et al. Factors that influence vaccination decision-making among pregnant women: A systematic review and meta-analysis. *PLoS ONE* 2020; 15(7), e0234827. <https://doi.org/10.1371/journal.pone.0234827>
12. Dudley, MZ., Limaye, RJ., Omer, SB., O’Leary, ST., Ellingson, MK., Spina, CI., Brewer, SE., Chamberlain, AT., Bednarczyk, RA., Malik, F., Frew, PM. , & Salmon, DA. Characterizing the vaccine knowledge, attitudes, beliefs, and intentions of pregnant women in Georgia and Colorado, *Human Vaccines & Immunotherapeutics*, 2020: 16(5), 1109-1117, DOI: 10.1080/21645515.2020.1717130
13. Faucette, AN., Pawlitz, MD., Pei, B., Yao, F., & Chen, K. Immunization of pregnant women: Future of early infant protection. *Human vaccines & immunotherapeutics*, 2015: 11(11), 2549–2555. doi:10.1080/21645515.2015.1070984
14. Cooper, S.; Betsch, C.; Sambala, E.Z.; Mchiza, N.; Wiysonge, C.S. Vaccine hesitancy—A potential threat to the achievements of vaccination programmes in Africa. *Hum. Vaccines Immunother*. 2018, 14, 2355–2357.
15. Woskie L R, Fallah M P. Overcoming distrust to deliver universal health coverage: lessons from Ebola. *BMJ* 2019; 366 :l5482 doi:10.1136/bmj.l5482
16. Maphumulo, Winnie T. and Bhengu, Busisiwe R. Challenges of quality improvement in the healthcare of South Africa post-apartheid: A critical review. *Curationis*. 2019; 42(1): 1901. doi: 10.4102/curationis.v42i1.1901
17. Farrar, Jeremy. 2019. Why the most important tool in healthcare is trust. Wellcome Trust, World Economic Forum. Aug. 26, 2019. <https://www.weforum.org/agenda/2019/08/important-tool-in-healthcare-is-trust-vaccines-africa/>. Accessed Jan.2, 2021.
18. Stoop N, Hirvonen K, Maystadt J Institutional mistrust and child vaccination coverage in Africa *BMJ Global Health* 2021;6:e004595.
19. Maystadt, Jean-François. 2021. Is vaccine hesitancy in Africa linked to institutional mistrust? *Health Europa*, Issue 18. June 10, 2021. <https://www.healtheuropa.eu/is-vaccine-hesitancy-in-africa-linked-to-institutional-mistrust/108929/>. Accessed Aug. 23, 2020.
20. Ophori, E. A., Tula, M. Y., Azih, A. V., Okojie, R., & Ikpo, P. E. Current trends of immunization in Nigeria: prospect and challenges. *Tropical medicine and health*, 2014; 42(2), 67–75. doi:10.2149/tmh.2013-13
21. Feilden Battersby Analysts. Design of Routine Immunization Initiative—Trip Report for DFID. Bath UK: 2005.
22. Barrett, H. Women in Africa: The Neglected Dimension in Development. *Geography*, 1995; 80(3), 215-224. Available from <http://www.jstor.org/stable/40572666> (Retrieved Nov 2, 2020).
23. Tadesse, Tefera. Getachew, Kinde. Assefa, Tersit. Ababu, Yohannes. Simireta, Tesfaye. Birhanu, Zewdie. Hailemichael, Yohannes. Factors and misperceptions of routine childhood immunization service uptake in Ethiopia: findings from a nationwide qualitative study. *The Pan African Medical Journal*. 2017: 28:290. doi:10.11604/pamj.2017.28.290.14133
24. International Men and Gender Equity Survey (IMAGES). 2009. IMAGES measures men’s attitudes and practices – along with women’s opinions and reports of men’s practices – on a wide variety of topics related to gender equality. <https://promundoglobal.org/programs/international-men-and-gender-equality-survey-images/> Accessed June 3, 2021.
25. Geleta, D. Femininity, masculinity and family planning decision-making among married men and women in rural Ethiopia: A qualitative study. *Journal of African Studies and Development*, 2018: 10(9), 124-133.

26. Nguyen VK, Klot J, Phillips A, Pirkie C. Culture, HIV & AIDS: An Annotated Bibliography. *Social Science Research Council*, UNESCO. 2006. <http://unesdoc.unesco.org/images/0014/001472/147244m.pdf>
27. Diddy, Antai. Gender inequities, relationship power, and childhood immunization uptake in Nigeria: a population-based cross-sectional study. *International Journal of Infectious Disease*. 16 (2012) e138 -e145
28. Anyene, BC. Routine Immunization in Nigeria: The Role of Politics, Religion and Cultural Practices. *African Journal of Health Economics*. 2014; 3 (1):0002. https://www.ajhe.org/uploads/55/3075_pdf.pdf
29. Somefun, O.D. Religiosity and sexual abstinence among Nigerian youths: does parent religion matter? *BMC Public Health*, 2019; 19, 416. <https://doi.org/10.1186/s12889-019-6732-2>
30. Pew Forum on Religion & Public Life, Tolerance and Tension: Islam and Christianity in Sub-Saharan Africa. 2010. available at <http://pewforum.org/preface-islam-and-christianity-in-Sub-Saharan-africa.aspx> (Retrieved June 2, 2021).
31. Sarumi, Ro63ah Ololade, Faluyi, Olumuyiwa Temitope and Okeke-Uzodike, Obianuju E. Transcending Ethnic and Religious Barriers in Decision-Making: A Case of a Muslim Women Civil Organisation in Nigeria. *Front*. 2019. <https://doi.org/10.3389/fpsyg.2018.02693>
32. Okonedo, E. "Decision-making Practices in Africa", *Indigenous Management Practices in Africa (Advanced Series in Management, Vol. 20)*, Emerald Publishing Limited, 2018, pp. 221-247. <https://doi.org/10.1108/S1877-636120180000020012>
33. Adamu, AA., Essoh, Téné-Alima., Adeyanju, GC., Jalo, RI., Saleh, Yusuf., Aplogan, Aristide & Wiysonge, CS (2021): Drivers of hesitancy towards recommended childhood vaccines in African settings: a scoping review of literature from Kenya, Malawi and Ethiopia, *Expert Review of Vaccines*, DOI: <https://doi.org/10.1080/14760584.2021.1899819>
34. WHO/UNICEF Estimates of National Immunization Coverage (WUENIC), 2019: Progress and Challenges with Achieving Universal Immunization Coverage. July 2019.
35. National Bureau of Statistics (NBS) & United Nations Children's Fund (UNICEF). Multiple Indicator Cluster Survey, 2016-17. Survey Finding Report, 2018. Abuja: National Bureau of Statistics and United Nations Children's Fund. <https://www.unicef.org/nigeria/reports/multiple-indicator-cluster-survey-2016-17-mics> (Accessed Nov 4, 2020).
36. National Statistical Office (NSO) [Malawi]; ICF. Malawi Demographic and Health Survey 2015-16; NSO: Zomba, Malawi; ICF: Rockville, MD, USA, 2017; p. 143. Available online: <https://dhsprogram.com/pubs/pdf/FR319/FR319.pdf> (accessed on 20 July 2021).
37. National Statistical Office (NSO), 1994. Demographic and Health Survey – 1992. NSO, Zomba
38. Mmanga, Kondwani., Mwenyenkulu, Tisungane E., Nkoka, Owen., Ntenda, Peter A M. Tracking immunization coverage, dropout and equity gaps among children ages 12–23 months in Malawi – bottleneck analysis of the Malawi Demographic and Health Survey, *International Health*, 2021; ihab038, <https://doi.org/10.1093/inthealth/ihab038>
39. Tsega, A.; Hausi, H.; Chriwa, G.; Steinglass, R.; Smith, D.; Valle, M. Vaccination coverage and timely vaccination with valid doses in Malawi. *Vaccine Rep*. 2016, 6, 8–12.
40. Ferlay, J.; Ervik, M.; Lam, F.; Colombet, M.; Mery, L.; Piñeros, M.; Znaor, A.; Soerjomataram, I.; Bray, F. Global Cancer Observatory: Cancer Today; International Agency for Research on Cancer: Lyon, France, 2018.
41. Bray, F.; Ferlay, J.; Soerjomataram, I.; Siegel, R.L.; Torre, L.A.; Jemal, A. Global Cancer Statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *Cancer J. Clin*. 2018, 68, 394–424.
42. Bruni L, Albero G, Serrano B, Mena M, Gómez D, Muñoz J, Bosch F, de Sanjosé S: ICO/IARC information centre on HPV and cancer (HPV information Centre). Human papillomavirus and related diseases in the world. Summary report 17 June 2019. 2019. Accessed on 29 Aug 2019 from <https://www.hpvcntr.net/statistics/reports/XWX.pdf>.
43. Msyamboza, K.P.; Mwangomba, B.M.; Valle, M.; Chiumia, H.; Phiri, T. Implementation of a human papillomavirus vaccination demonstration project in Malawi: Successes and challenges. *BMC Public Health* 2017, 17, 599.

44. Strategic Advisory Group of Experts (SAGE) on Vaccination Hesitancy Report. World Health Organization (WHO). 2014. Available online: https://www.who.int/immunization/sage/meetings/2014/october/SAGE_working_group_revised_report_vaccine_hesitancy.pdf (accessed on 3 April 2021).
45. Lane, S.; MacDonald, N.E.; Marti, M.; Dumolard, L. Vaccine hesitancy around the globe: Analysis of three years of WHO/UNICEF Joint Reporting Form data-2015–2017. *Vaccine* 2018, 36, 3861–3867.
46. Larson, H.J.; Jarrett, C.; Eckersberger, E.; Smith, D.M.D.; Paterson, P. Understanding vaccine hesitancy around vaccines and vaccination from a global perspective: A systematic review of published literature, 2007–2012. *Vaccine* 2014, 32, 2150–2159.
47. Global Alliance for Vaccine and Immunization (GAVI). Annual Progress Report; 2019; Available online: <https://www.gavi.org/progress-report-2019> (accessed on 5 July 2021).
48. Bonem, E.M.; Ellsworth, P.C. Gonzalez, Richard. Age Differences in Risk: Perceptions, Intentions and Domains. *J. Behav. Decis. Mak.* 2015, 28, 317–330.
49. Renner, B.; Knoll, N.; Schwarzer, R. Age and body make a difference in optimistic health beliefs and nutrition behaviors. *Int. J. Behav. Med.* 2000, 7, 143–159.
50. Rolison, J.J.; Hanoch, Y.; Wood, S.; Liu, P. Risk-Taking Differences Across the Adult Life Span: A Question of Age and Domain. *J. Gerontol.* 2014, 69, 69–870.
51. Arnett, J. Reckless behavior in adolescence: A developmental perspective. *Dev. Rev.* 1992, 12, 339–373.
52. Madhi, S.A.; Rees, H. Special focus on challenges and opportunities for the development and use of vaccines in Africa. *Hum. Vaccines Immunother.* 2018, 14, 2335–2339.
53. Matta, P.; El Mouallem, R.; Akel, M.; Hallit, S.; Khalife, M.-C.F. Parents’ knowledge, attitude and practice towards children’s vaccination in Lebanon: Role of the parent-physician communication. *BMC Public Health* 2020, 20, 1439.
54. Sambala, E.Z.; Uthman, O.A.; Adamu, A.A.; Ndwandwe, D.; Wiyeh, A.B.; Olukade, T.; Bishwajit, G.; Yaya, S.; Okwo-Bele, J.M.; Wiysonge, C.S. Inequality in missed opportunities for vaccination in sub-Saharan Africa? Compositional and structural characteristics. *Hum. Vaccines Immunother.* 2018, 14, 2365–2372.
55. Mora, T.; Trapero-Bertran, M. The influence of education on the access to childhood immunization: The case of Spain. *BMC Public Health* 2018, 18, 893.
56. Keneally, M. Parents who don’t vaccinate kids tend to be affluent, better educated, experts say. ABC News, 29 January 2019. Available online: <https://abcnews.go.com/Health/parents-vaccinate-kids-tend-affluent-educated-experts/story?id=60674519> (accessed on 10 November 2020).
57. Wiysonge, C.S. Vaccine Hesitancy, an Escalating Danger in Africa. *Think Global Health*, 17 December 2019. Available online: <https://www.thinkglobalhealth.org/article/vaccine-hesitancy-escalating-danger-africa> (accessed on 2 December 2020).
58. Zhao, L.; Wang, J.; Huang, R. Immunization against the Spread of Rumors in Homogenous Networks. *PLoS ONE* 2015, 10, e0124978.
59. Adeyanju, G.C.; Sprengholz, P.; Betsch, C.; Essoh, T.-A. (2021b). Caregivers’ Willingness to Vaccinate Their Children against Childhood Diseases and Human Papillomavirus: A Cross-Sectional Study on Vaccine Hesitancy in Malawi. *Vaccines*, 9, 1231. <https://doi.org/10.3390/vaccines9111231>
60. Wilson SL, Wiysonge C Social media and vaccine hesitancy. *BMJ Global Health* 2020;5:e004206. <https://gh.bmj.com/content/5/10/e004206>
61. Feletto, Marta and Sharkey, Alyssa. The influence of gender on immunisation: using an ecological framework to examine inter-secting inequities and pathways to change. *BMJ Global Health*. 2019; 4 (5). doi: 10.1136/bmjgh-2019-001711.
62. Merten S, Martin Hilber A, Biaggi C, Secula F, Bosch-Capblanch X, Namgyal P, Hombach J. Gender Determinants of Vaccination Status in Children: Evidence from a Meta-Ethnographic Systematic Review. *PLoS One*. 2015;10(8):e0135222. doi: 10.1371/journal.pone.0135222.
63. Hanifi SMA, Ravn H, Aaby P, Bhuiya A. Where girls are less likely to be fully vaccinated than boys: Evidence from a rural area in Bangladesh. *Vaccine*. 2018 May 31;36(23):3323-3330. doi: 10.1016/j.vaccine.2018.04.059.

64. Adeyanju, G. Collins., Tene-Alima Essoh, Abdu A. Adamu, Khadijah Sanusi Gumbi, Michael G Head and Cornelia Betsch. 2022b. Examining Enablers of Vaccine Hesitancy Toward Routine Childhood and Adolescent Vaccination in Malawi. *Global Health Research and Policy*. DOI: <https://doi.org/10.21203/rs.3.rs-1097242/v1>
65. Adeyanju, GC., Betsch, C., Head, MG., Essoh, Tene-Alima. 2021c. Analysing Drivers of Vaccine Hesitancy in Malawi: A Policy Brief. Figshare. Presentation. DOI: <https://doi.org/10.6084/m9.figshare.14604678.v1>
66. Doherty T, Zembe W, Ngandu N, Kinney M, Manda S, Besada D, Jackson D, Daniels K, Rohde S, van Damme W, Kerber K, Daviaud E, Rudan I, Muniz M, Oliphant NP, Zamasiya T, Rohde J, Sanders D. Assessment of Malawi's success in child mortality reduction through the lens of the Catalytic Initiative Integrated Health Systems Strengthening programme: Retrospective evaluation. *J Glob Health*. 2015 Dec;5(2):020412. doi: 10.7189/jogh.05.020412.
67. Rosenstock, I.M. The health belief model and preventive health behavior. *Health Educ Monogr*. 1974, 2, 354–386.
68. Prochaska, J.O.; DiClemente, C.C. Transtheoretical therapy: Toward a more integrative model of change. *Psychother. Theory Res. Pract*. 1982, 19, 276.
69. Ajzen, I. The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes*, 1991: 50(2), 179–211.
70. Piltch-Loeb R, DiClemente R. The Vaccine Uptake Continuum: Applying Social Science Theory to Shift Vaccine Hesitancy. *Vaccines* (Basel). 2020 Feb 7;8(1):76. doi: 10.3390/vaccines8010076.
71. Lipschitz JM, Fernandez AC, Larson HE, Blaney CL, Meier KS, Redding CA, Prochaska JO, Paiva AL. Validation of decisional balance and self-efficacy measures for HPV vaccination in college women. *Am J Health Promot*. 2013 May-Jun;27(5):299-307. doi: 10.4278/ajhp.110606-QUAN-240.
72. Chu, Haoran and Liu, Sixiao. Integrating health behavior theories to predict American's intention to receive a COVID-19 vaccine. *Patient Educ Couns*. 2021 Aug; 104(8): 1878–1886. Published online 2021 Feb 17. doi: 10.1016/j.pec.2021.02.031
73. Green, Cori M., Gadomski, Anne M. and Wissow, Lawrence. Strategies for Health Behavior Change. In Kliegman et al, 2020. *Nelson Textbook of Pediatrics*, Chapter 17, 111-116.e1. PA. Elsevier - Health Sciences. 2020
74. Mimiaga, Matthew J. Reisner, Sari L. Reilly, Laura. Soroudi, Nafisseh. Safren, Steven A. Chapter 8 - Individual interventions, In Kenneth H. Mayer, Hank F. Pizer, (eds). *HIV Prevention*, Academic Press, 2009, Pages 203-239, ISBN 9780123742353, <https://doi.org/10.1016/B978-0-12-374235-3.00008-X>.

CONCLUSION

Despite immense progress in infant and maternal health in SSA, vaccination coverage (the primary driver of these achievements) has remained at a standstill for several years in the region. Attempts to devise appropriate evidence-based interventions requires understanding what drives vaccination decision-making, and if existing successful measures in a Western setting could be validated in SSA there would be benefits. This dissertation assessed vaccination decision-making and the factors driving low vaccination uptake (vaccine hesitancy) in SSA using six articles presented above.

The outcomes were mixed. While the drivers were succinctly identified, the 5C model as a framework for measurement did not produce the same exact outcome as seen in the original setting because the internal reliability was low; but when used as per item basis, it produced some positive and predictive values. Two sets of results emerged. One, the 5C scale ‘as is’ was not as successful in predicting vaccination intention among pregnant women at the prenatal stage. However, it was valuable for understanding caregivers’ vaccination behavior at the postnatal stage in Nigeria, Malawi, Kenya, and Ethiopia. An analysis of single items in the 5C scale was more useful than an analysis of aggregated items.

First, at the prenatal stage, confidence (especially in the public authority and healthcare system managing vaccination services) seems to be the main driver of vaccination decision-making. At the postnatal stage, almost all the 5C variables were positive at predicting vaccination behavior in Nigeria and Malawi, including some of the secondary data analyzed from Kenya and Ethiopia.

Second, vaccination intention at the prenatal stage did not predict actual behavior at the postnatal stage, and confidence in the safety and effectiveness of vaccines was not a significant predictor of prenatal vaccination intention compared to postnatal actual behavior.

This means, at prenatal, vaccination is not a priority or an important subject, as explained by the TTM in reference to stages, rather the decision about such an undertaking takes place later at postnatal stage.

Third, the outcomes based on the 5C scale show that vaccination prenatal and postnatal decision-making are driven by completely different factors. But that may not be said of the added variables. The added variables such as rumor, masculinity, and religious belief were significant predictors at the prenatal stage (intention) but at the postnatal stage (behavior) not all were significant.

Therefore, this dissertation concludes that the 5C model for understanding vaccination decision-making drivers in SSA is more appropriate for vaccination behavior than intention. However, further validation, after adapting the language and context to the SSA-specific setting, is important in order to produce the desired results. Also, it is imperative that future measures include rumors, masculinity, and religious belief as predictors of vaccination decision-making in SSA. Finally, fathers of children eligible for vaccination or husbands in general should be a key target group for demand creation. Their vaccination decision-making authorities (masculinity) in households is very crucial to uptake in SSA. Also, in SSA, interventions have always centered around vaccination behavior, without knowledge or insights into the feelings and thinking of caregivers during prenatal. This dissertation has helped to unravel this missing research gap, as to why vaccination demand creation interventions do not have as much success as anticipated, especially at increasing vaccination uptake.

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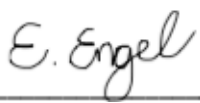
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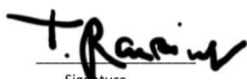
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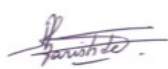
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