Public Health at a Crossroad: Vaccine Hesitancy and the Knowledge–Behaviour Gap among University Students across Three Different Countries

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Abstract

One of the key public heath challenges during the COVID-19 was Vaccine hesitancy (VH), even among populations with high levels of education. This cumulative thesis encompasses four cross-sectional studies conducted in Ghana, Ukraine, and Syria. It utilizes the 5C model of psychological antecedents to explain vaccination behaviour (VB). In Ghana, 69.9% of 1,560 adults exhibited adequate knowledge, yet only 35.3% intended to vaccinate, exposing a persistent knowledge–practice gap. Among 3,486 Ghanaian university students, VB was predicted by Confidence, Constraints, Calculation, and Collective Responsibility, whereas Complacency and religion showed no effect. In Ukraine (n = 936), Confidence and Collective Responsibility enhanced acceptance, while Constraints suppressed both acceptance and refusal, reflecting structural barriers. Among 4,722 Syrian students, 64% remained unvaccinated; VH was higher among non-medical students and linked to Complacency, excessive Calculation, and diminished Collective Responsibility. Across settings, perceived barriers, trust, misinformation, and accessibility shaped behaviour. Knowledge alone proved insufficient. VB is governed by psychological, structural, and socio-contextual forces. Addressing VH, thus requires trust-based, context-sensitive strategies that reduce barriers and enhance collective responsibility for resilient vaccination in future global health crises in many countries across the globe.

Zusammenfassung

Eine der zentralen Herausforderungen der öffentlichen Gesundheit während der COVID-19 Pandemie war die Impfskepsis (Vaccine Hesitancy, VH), selbst unter Bevölkerungsgruppen mit hohem Bildungsniveau. Diese kumulative Dissertation umfasst vier Querschnittsstudien aus Ghana, der Ukraine und Syrien und verwendet das 5C-Modell psychologischer Einflussfaktoren zur Erklärung des Impfverhaltens (Vaccination Behaviour, VB). In Ghana verfügten 69,9 % von 1.560 Erwachsenen über ausreichendes Wissen, doch nur 35,3 % beabsichtigten eine Impfung, was eine Wissens-Praxis-Lücke aufzeigt. Unter 3.486 Studierenden wurde VB durch Vertrauen (Confidence), Einschränkungen (Constraints), Berechnung (Calculation) und kollektive Verantwortung (Collective Responsibility) vorhergesagt, während Selbstzufriedenheit (Complacency) und Religion keinen Einfluss zeigten. In der Ukraine (n = 936) stärkten Vertrauen und kollektive Verantwortung die Impfbereitschaft, während Einschränkungen strukturelle Barrieren widerspiegelten. Von 4.722 syrischen Studierenden blieben 64 % ungeimpft; VH war bei Nicht-Medizinstudierenden höher und hing mit Selbstzufriedenheit, übermäßiger Berechnung und verminderter kollektiver Verantwortung zusammen. In allen Kontexten prägten Barrieren, Vertrauen, Fehlinformationen und Zugänglichkeit das Verhalten. Wissen allein genügt nicht erforderlich sind vertrauensbasierte, kontextsensitive Strategien zur Stärkung kollektiver Verantwortung und einer widerstandsfähigen Impfbereitschaft in künftigen globalen Gesundheitskrisen.

Résumé

L'une des principales difficultés de santé publique durant la pandémie de COVID-19 fut l'hésitation vaccinale (Vaccine Hesitancy, VH), observée même parmi les populations hautement instruites. Cette thèse cumulative regroupe quatre études transversales menées au Ghana, en Ukraine et en Syrie. Elle s'appuie sur le modèle des 5C des antécédents psychologiques pour expliquer le comportement vaccinal (Vaccination Behaviour, VB). Au Ghana, 69,9 % des 1 560 adultes présentaient des connaissances suffisantes, mais seuls 35,3 % envisageaient la vaccination, révélant un écart persistant entre savoir et pratique. Parmi 3 486 étudiants ghanéens, le VB était prédit par la confiance (Confidence), les contraintes (Constraints), le calcul (Calculation) et la responsabilité collective (Collective Responsibility), tandis que la complaisance et la religion n'avaient aucun effet. En Ukraine (n = 936), la confiance et la responsabilité collective renforçaient l'acceptation, alors que les contraintes limitaient à la fois l'acceptation et le refus, indiquant des barrières structurelles. Parmi 4 722 étudiants syriens, 64 % restaient non vaccinés; la VH, plus marquée chez les non-médecins, était liée à la complaisance, à un calcul excessif et à une moindre responsabilité collective. Dans tous les contextes, les obstacles perçus, la confiance, la désinformation et l'accessibilité façonnaient le comportement. Le savoir seul s'est avéré insuffisant. La VH exige des stratégies fondées sur la confiance et adaptées au contexte, visant à réduire les barrières et à renforcer la responsabilité collective pour une vaccination résiliente lors de futures crises sanitaires mondiales.

Resumé

Eng vun de gréisste gesondheetspolitesche Erausfuerderunge wärend der COVID-19 Pandemie war d'Impfzéckt (Vaccine Hesitancy, VH), och bei Bevëlkerungsgruppen mat héijem Bildungsniveau. Dës kumulativ Dissertatioun ëmfaasst véier Querschnittsstudien, duerchgefouert a Ghana, der Ukrain an a Syrien. Si benotzt de 5C-Modell vu psychologeschen Antezedenten, fir d'Impfverhalen (Vaccination Behaviour, VB) z'erklären. A Ghana haten 69,9 % vun 1 560 Erwuessenen adäquat Wëssen, mee nëmmen 35,3 % haten d'Absicht, sech impfen ze loosen, e kloert Wëssen-Praxis-Lach. Bei 3 486 Studenten aus Ghana gouf d'VB duerch Vertrauen (Confidence), Aschränkungen (Constraints), Berechnung (Calculation) an Kollektiv Verantwortung (Collective Responsibility) virausgesot, wärend Selbstzefriddenheet (Complacency) a Relioun keen Afloss haten. An der Ukrain (n = 936) hunn Vertrauen a Kollektiv Verantwortung d'Akzeptanz gestäerkt, Aschränkungen hunn se reduzéiert, e Zeeche vu strukturelle Barrièren. Bei 4 722 syrësche Studenten bloufen 64 % net geimpft; d'VH war méi héich bei Net-Medizinstudente a war mat Selbstzefriddenheet, iwwerdréiwener Berechnung a reduzéierter Kollektiv Verantwortung verbonnen. Iwwer all Kontexter hu perzepéiert Barrièren, Vertrauen, Feelinformatioun an Accessibilitéit d'Verhalen beaflosst. Wëssen eleng ass net genuch. D'Impfverhalen gëtt vun psychologeschen, strukturellen a sozio-kontextuelle Faktoren bestëmmt. D'Bekämpfung vun Impfzéckt erfuerdert vertrauensbaséiert a kontextsensitive Strategien, déi Barrièren ofbauen an d'Kollektiv Verantwortung stäerken, fir eng resilient Impfbereetschaft bei zukünftege globale Gesondheetskrisen ze fërderen.

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List of Abbreviations

Abbreviation	Definition
5A:	....Access, Affordability, Awareness, Acceptance, Activation
5Cs:	Confidence, Complacency, Constraints, Calculation, Collective Responsibility
BCG:	..Bacillus Calmette-Guerin
CDC:	.Centres for Disease Control and Prevention
EPI:	Expanded Programme on Immunization
GHS:	. Ghana Health Service
HBM:	Health Belief Model
HPV:	..Human Papillomavirus
LMIC:	Low- and Middle-Income Countries
NHIS:	.National Health Insurance Scheme
PMT:	.Protection Motivation Theory
SAGE:	...Strategic Advisory Group of Experts on Immunization
sSA:	sub-Saharan Africa
TPB:	..Theory of Planned Behaviour
TRA:	.Theory of Reasoned Action
UNICEF:	...United Nations International Children's Emergency Fund
VA:	Vaccine Acceptance
VB:	...Vaccination Behaviour
VCF:	..Vaccine Confidence Framework
VCI:	...Vaccine Confidence Index
VH:	Vaccine Hesitancy
VHM:	Vaccine Hesitancy Matrix
WHO:	... World Health Organization

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CHAPTER ONE

1. INTRODUCTION

1.1. Background and Context

1.1.1. Historical and Scientific Background of Vaccination

Vaccination has been credited with controlling infectious diseases, extending life expectancy, and preventing millions of deaths annually across the globe [1–5]. Since 1974, the World Health Organization (WHO)'s Expanded Programme on Immunization (EPI) has played a central role in this transformation: it has prevented an estimated 154 million deaths over fifty years, including many among infants and young children, and continues to avert millions more annually by protecting against diseases such as measles, polio, diphtheria, pertussis and tetanus [6,7]. The significant strives of immunization efforts has been emphasised in recent modelling, with projections aiming to save additional 32 million lives across all ages globally. It is further projected to save nearly 28 million children under age five, when pre-pandemic vaccination progress between 2020 and 2030 are sustained [8,9].

Historically, the 20th and 21st centuries have witnessed a major paradigm shift in vaccine developments, achieving transformative vaccine breakthroughs. The global smallpox eradication by 1980 was accomplished via extensive smallpox vaccination [10,11]. WHO's EPI also impacted immunizations, which led to substantial reductions in morbidity and mortality from measles, polio, and hepatitis B. [12]. Moreover, introduction of human papillomavirus (HPV) vaccine in 2006, commenced a milestone in cancer prevention for anogenital diseases. And more recently, the COVID-19 pandemic led to the rapid development of mRNA vaccines in 2020, which demonstrated unparallel scientific dexterity and regulatory coordination [12–15]. Some of these major vaccination highpoints are summarized in Figure 1, which illustrates the periods of key vaccination achievements from Jenner's era to the COVID-19 pandemic.

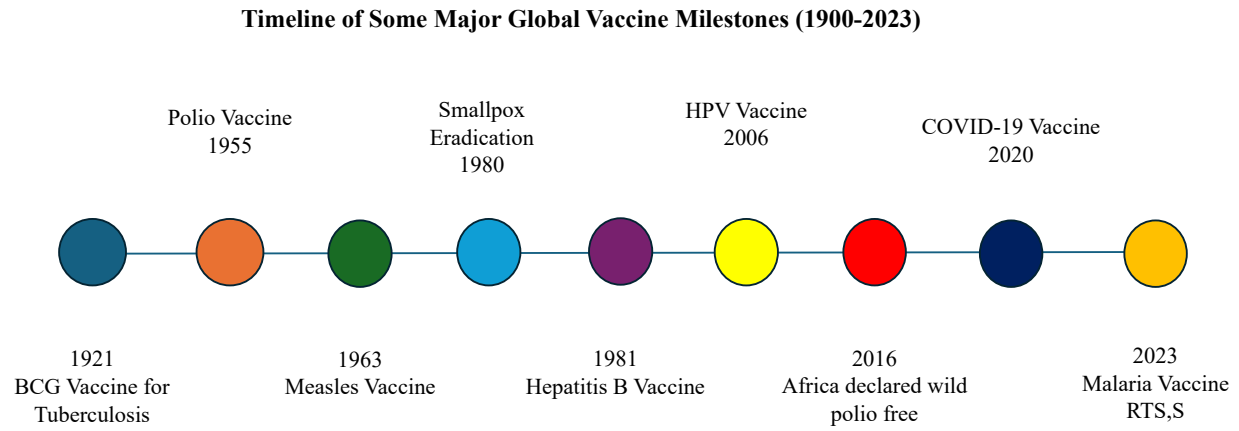

Figure 1. Major vaccination accomplishments with their timelines

Regardless of these milestones, proven efficacy and strong safety profiles, public confidence in VA has not always kept pace with scientific progress. Public vaccine confidence has lagged behind. Even though, countless lives have been saved through vaccinations and being built on advanced technologies, vaccines do not automatically achieve universal uptake. VH continues to erode immunisation gains in multiple regions, threatening reversals of progress achieved over decades [16–22].

1.1.2. Vaccine Hesitancy at Global Crossroads

Vaccine hesitancy, defined as the delay in acceptance or refusal of vaccination despite availability, has emerged as a critical global health challenge [23–25]. VH has formally been identified as one of the top ten threats to global public health in 2019 by WHO, alongside climate change and antimicrobial resistance [24,26,27]. This acceptance points to the extent to which unwillingness to vaccinate undermines infectious disease control and risk losing hard-won gains in immunizations. VH has strikingly cut across all spheres of lives, unlike other health threats that disproportionately affect specific regions or income groups. During the COVID-19 pandemic, survey data gathered between late 2020 and mid-2021 from low-and middle-income countries

(LMIC) implied that about 20% of participants exhibited hesitancy [28–31]. The contributing factors ascribed to these identified patterns included structural barriers, weak health systems, and misinformation. High-income countries, however, have not been spared from entrenched scepticism often influenced by digital misinformation and political divergence. Ultimately, producing comparable levels of unwillingness to be vaccinated [32,33].

It is important to note that, national wealth singly did not predict VA. Current global studies covering 145 countries have predicted public trust in vaccines to significantly influence vaccination coverage, as much as, per capita gross domestic product (GDP) [34–38]. Notably, participants who strongly perceived vaccines to be unsafe were significantly less likely to be vaccinated despite income-levels. These disproportions became pronounced as the COVID-19 vaccines rollout advanced. Vaccine availability and biomedical efficacy, while imperative, are inadequate to secure universal vaccination uptake, as indicated by the global spread of VH. Instead, behavioural, psychological, and cultural determinants have become pivotal in shaping vaccine decisions. It is at this crossroads that the present thesis situates itself, exploring these dynamics comparatively in Ghana, Ukraine, and Syria.

1.1.3. The Challenge of Declining Confidence and Emerging Knowledge–Action Gaps

The onset of COVID-19 pandemic sparked a noticeable decline in vaccine confidence across multiple regions, although global vaccine confidence had been witnessing a gradual improvement [39–42]. A study by Liu et al. (2025), for instance, investigated vaccine confidence among adults aged 65 and older between 2019 and 2022, particularly in lower-income countries. It documented substantial drop in confidence, which was driven by safety concerns and effectiveness [43]. This trend also reflected in a 2023 UNICEF report, which found declines in the perception of the importance of vaccines for children in 52 of 55 countries surveyed, with the steepest drops among those under 35 and in several high-income countries such as France, the United States, Germany, and Japan, pointing toward eroding trust among younger cohorts [44]. These observed decline patterns has been attributed to Trust erosion, misinformation, politicization, and crisis-driven scepticism [44–49] . The Lancet affirmed these concerns via a study which reported setbacks in childhood vaccination coverage, listing rising hesitancy, misinformation, conflicts, and COVID-

19 disruptions as the contributing factors that threaten decades of progress [50–53]. Figure 2 depicts these shifts, showing a clear inflection point around 2020.

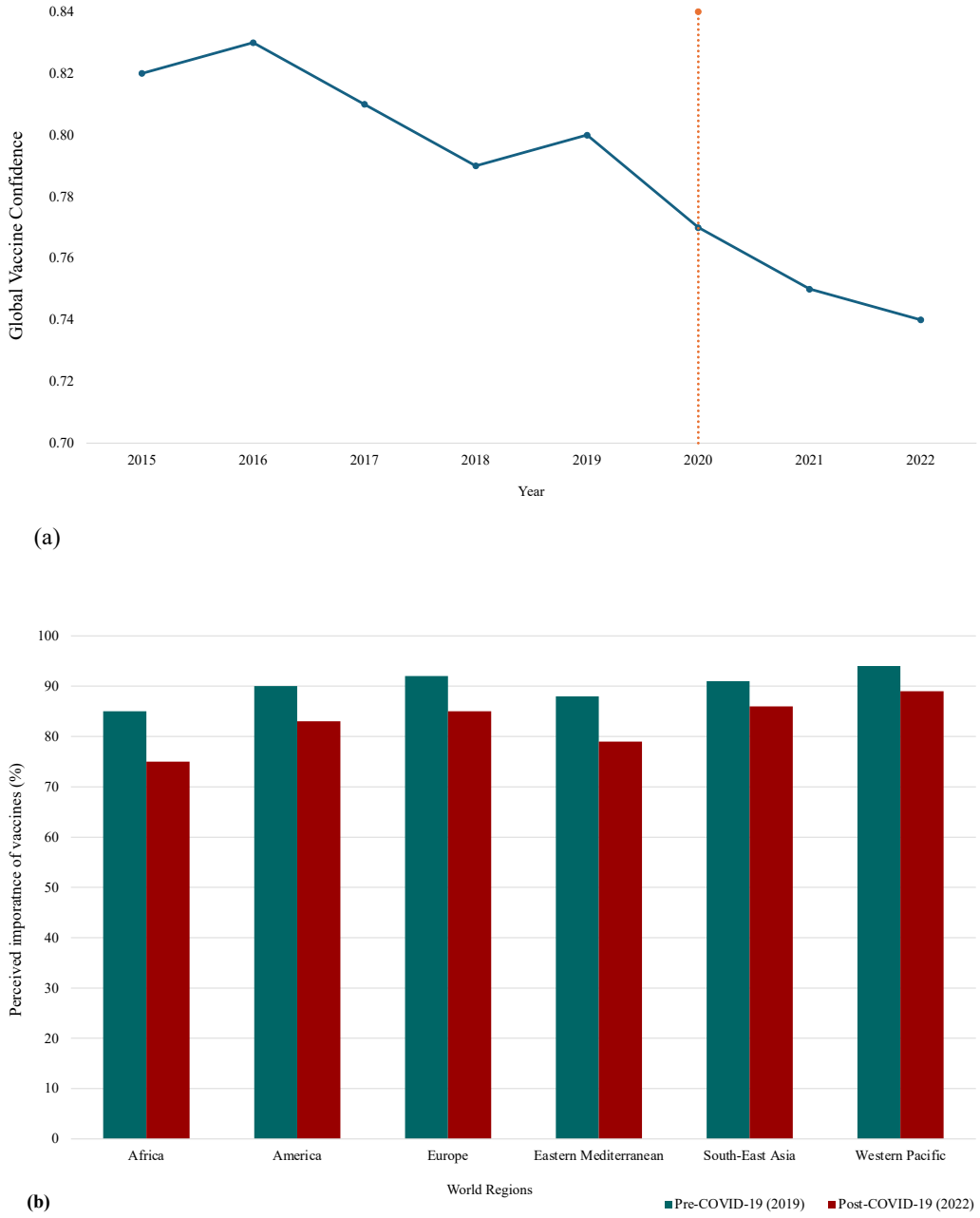

Figure 2. Vaccine Confidence Pre- and Post-COVID-19: (a) Global vaccine confidence trend with an annotated 2020 vertical marker; and (b) Regional pre- *vs.* post-COVID bar chart [54].

Qualitative research in the Volta region of Ghana, for example, has reported a direct association between fake news, conflicting messages from authorities, low institutional trust and VH, despite widespread knowledge of vaccine science [55]. Likewise, some studies across Eastern Europe and the Middle East have shown that, despite adequate vaccine knowledge, psychological and structural barriers, such as safety concerns, institutional distrust, and logistical constraints, remain strong mediators of vaccine hesitancy [56–59]. LMICs and conflict-affected regions also face compounded obstacles with equitable vaccine uptake attainment, accessibility barriers, resource constraints, political instability, and institutional distrust that intersect to further impede both vaccine delivery and acceptance [60–66].

These outcomes show what may be dubbed the "informed sceptic" paradox: where individuals with relatively high education and ready access to vaccine information continues to exhibit low uptake or absolute resistance [67–69]. This paradox poses acute issues and highlights limitations of the traditional public health campaign approaches. It also shades attention to deeper psychosocial dynamics that transcend knowledge shortfalls. Growing evidence confirms this persistence of a knowledge–preventive behaviour gap in vaccination contexts. Although, individuals may demonstrate accurate knowledge of infectious diseases, their risks, and vaccination benefits, yet this knowledge does not translate into vaccine acceptance automatism. The gap is rooted not only in knowledge but also in factors such as trust, perceived safety and efficacy, and the extent to which vaccination aligns with social identity and political context. As routine immunization coverage declines in many settings, the knowledge-action gap threatens to reverse decades of progress in public health [70–72].

1.1.4. The Pandemic as a Social Mirror

The COVID-19 pandemic, among other things also magnified long-standing tensions between health experts' knowledge of infections and societal behaviours towards them. It exemplified a behavioural stress test for public health, its actors and the population. As vaccines, masks, social distancing, and lockdowns became widespread, compliance was not uniformly determined by how well people understood the science but rather by deeply rooted behavioural, social, cultural, and structural factors [73–77]. For example, systematic reviews and recent

empirical studies show that public trust in authorities, perceptions of government legitimacy, and pre-existing norms matter greatly. In cultures with high trust, for instance, adherence to COVID-19 measures tended to be higher, whereas where trust was weak, compliance lagged even among those with good knowledge of risks and benefits [78–82].

Structural determinants also played a central role. Geographic access to vaccination sites, resource constraints, logistic barriers, and healthcare inequalities significantly predicted acceptance in many settings [83–88]. In LMICs especially, but also within marginalized communities in high-income countries, individuals faced real obstacles such as distance to clinics, vaccine stock-outs, complex appointment systems, and costs (direct or indirect) of seeking vaccination, that knowledge alone could not overcome [85,87]. Cultural and social norms shaped how people interpreted risk. In a recent study across 28 countries, "cultural tightness", i.e., how strictly social norms are enforced, was associated with vaccine confidence: people in tighter cultures showed adherence to public health messages, regardless of individual knowledge levels [89–93].

1.1.5. COVID-19 Pandemic as a Stress Test for Vaccine Acceptance

COVID-19 represented an unprecedented stress test for global vaccination systems. Within a year of the virus's identification, several vaccines received emergency approval, a feat unparalleled in scientific history [94–96]. Yet, universal vaccine rollouts were impeded by unequal distribution, delays in LMICs, and widespread scepticism [97–99]. The pandemic also interrupted routine vaccination programmes, increasing surges in vaccine preventable diseases like measles and polio [100–103]. This "double burden", emergency vaccination campaigns alongside reduction in routine coverage, showed the instability of global immunisation systems. In this context, VH emerged not as a marginal concern but as a central determinant of pandemic response. Understanding its drivers is thus critical for future preparedness.

Research on VH has therefore, proliferated since 2020. Systematic reviews report prevalence ranging from 20% to 80%, depending on context [70,104–106]. Across diverse studies, confidence in vaccines and collective responsibility consistently emerged as strong positive predictors of acceptance, while constraints such as access barriers and calculation driven by risk–

benefit weighing were linked to hesitancy [107–111]. In high-income countries, studies have linked declining vaccine confidence to social media misinformation, politicisation of the pandemic, and erosion of trust in authorities [112–114]. In LMICs, structural barriers, weak health systems, and institutional distrust have played equally critical roles [115–117]. Among students, global surveys have identified VH rates of 30–50%, often independent of knowledge levels [118–120]. In summary, this evidence shows that VH is a behavioural and psychological phenomenon that cannot be addressed by information campaigns alone but instead requires comprehensive strategies that integrate trust-building, social responsibility, and barrier reduction [121].

CHAPTER TWO

2. THEORETICAL FRAMEWORKS

2.1. Evolving Frameworks of Vaccine Hesitancy

Explaining vaccine-related decision-making requires more than describing attitudes toward a single intervention; it involves accounting for a complex web of influences operating at the individual, interpersonal, and structural levels. Personal psychology, including perceptions of risk and efficacy, interacts with social pressures, trust in institutions, access to healthcare, and broader cultural narratives [122–127]. These overlapping layers highlight the importance of theoretical models as tools for structuring inquiry, interpreting findings, and guiding policy responses [125]. Without such frameworks, research risks remaining fragmented and interventions less targeted.

The frameworks used to understand VB have evolved over time, reflecting shifts in both scientific thinking and public health priorities. Early studies relied on general health behaviour models developed in the mid-20th century, such as the HBM and the TPB, which emphasized risk perception, attitudes, and social norms [128–133]. As their limitations became apparent, particularly their neglect of systemic and contextual influences, scholars and policymakers advanced vaccine-specific frameworks. Notably, the WHO "3C Model" (2014) [134–136] and the expanded "5C Model" highlighted factors like trust, complacency, convenience, and collective responsibility [137–139]. The urgency of the COVID-19 pandemic further pushed theoretical development, revealing the central role of misinformation, conspiracy beliefs, and digital ecosystems in shaping hesitancy [140,141]. This led to refinements such as the VHM and adaptations of the 5C framework that better capture dynamic, cross-national, and pandemic-specific realities [142–148].

Accordingly, this chapter presents a chronological overview of theoretical frameworks explaining vaccine hesitancy, confidence, and acceptance. It begins with the classical behavioural health models of the 1950s–1980s, proceeds to vaccine-focused frameworks of the 2000s–2010s, and concludes with pandemic-driven refinements of the 2020s. By tracing this theoretical trajectory, the chapter underscores how successive models built on the deficiencies of their predecessors and how each step has contributed to a more comprehensive understanding of vaccination behaviour.

2.2. Classical Health Behaviour Models

2.2.1. Health Belief Model

The Health Belief Model (HBM) is one of the earliest frameworks developed to explain preventive health behaviours. It originated in the 1950s through the work of Irwin Rosenstock and colleagues at the U.S. Public Health Service, who sought to understand why individuals often failed to participate in public health screening programs, particularly for tuberculosis [149,150]. At its core, the HBM is grounded in the assumption that individuals are rational decision-makers who weigh the perceived threat of a health condition against the perceived benefits and barriers of engaging in preventive behaviour. Over time, the model evolved, and in the 1980s the concept of self-efficacy (an individual's confidence in their ability to successfully carry out a recommended health action) was incorporated to strengthen its predictive capacity [151,152].

The model is structured around six key constructs: perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy. These constructs are operationalized through various survey instruments and have been applied extensively to vaccination research. In the context of immunization, perceived susceptibility refers to an individual's belief about their likelihood of contracting a vaccine-preventable disease, while perceived severity reflects their understanding of the seriousness of the illness. Perceived benefits capture the belief that vaccination is effective in reducing risk, whereas perceived barriers encompass both tangible obstacles such as cost, accessibility, or fear of side effects and psychological concerns, such as mistrust in the vaccine or medical system. Cues to action, such as physician recommendations, health campaigns, or witnessing illness among peers, act as triggers to vaccination, while self-efficacy reinforces an individual's confidence to follow through with the behaviour [153,154].

In vaccination research, the HBM has proven especially useful for exploring differences in acceptance across populations. Studies on childhood immunization, for example, show that parents' perceptions of their children's susceptibility to infectious diseases strongly influence their decision to vaccinate, whereas concerns about side effects constitute one of the most significant barriers [155–159]. More recently, the model has been widely applied to understand COVID-19 vaccine uptake. Systematic reviews demonstrate that individuals with higher perceived

susceptibility to COVID-19 and stronger beliefs in the severity of the disease were more likely to accept vaccination, whereas those reporting greater barriers, including safety concerns and misinformation, were more hesitant [160–163]. Similar applications have been made to influenza vaccination, where cues to action, such as strong physician recommendations, emerged as significant predictors of uptake [164–167].

Despite its enduring relevance, the HBM has limitations that reduce its explanatory power in contemporary public health contexts. One of the most common critiques is that it is overly individualistic, emphasizing personal cognitive evaluations while underplaying the influence of social norms, cultural beliefs, structural inequalities, and systemic barriers such as healthcare accessibility [150,168,169]. The model has also been criticized as static rather than dynamic, as it does not fully account for how attitudes toward vaccination evolve over time in response to shifting information environments. Moreover, its predictive strength is moderate; meta-analyses suggest that while HBM variables are consistently associated with health behaviours, they explain only part of the variance in outcomes [170,171]. Finally, the model does not adequately capture collective motivations, such as vaccinating for community protection, which later frameworks like the 5C model explicitly integrate [172–174]. These limitations highlight why subsequent theories, including the Theory of Planned Behaviour and vaccine-specific frameworks developed by WHO, sought to expand upon the HBM's foundation to better capture the multidimensional drivers of vaccine acceptance and hesitancy.

2.2.2. The Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) was introduced by Icek Ajzen in 1985 as an extension of the earlier Theory of Reasoned Action (TRA), which had been developed by Fishbein and Ajzen in the 1970s to predict human social behaviour [175]. While the TRA emphasized the role of attitudes and subjective norms in shaping behavioural intentions, it assumed that individuals had complete deliberate control over their actions. Recognizing that many health-related behaviours are constrained by external and internal factors, Ajzen expanded the framework by introducing perceived behavioural control, a construct that reflects the extent to which individuals feel capable of performing the behaviour. This addition acknowledged that intentions alone are

not always sufficient predictors of action and that both the perception of control and actual control resources can shape whether intentions translate into behaviour [176–178].

The TPB is structured around five sequential constructs: attitudes toward the behaviour, which refer to the overall evaluation of performing the act; subjective norms, or perceived social pressure from significant others such as family, peers, and health professionals; perceived behavioural control, which captures both confidence and perceived barriers to action; intention, the motivational readiness to act; and, finally, behaviour, the actual performance of the health action. These constructs have been operationalized through validated questionnaires that measure beliefs, normative pressures, and perceived control, and they have been widely applied to predict preventive health practices [179].

In the context of vaccination, the TPB has provided valuable insights into the role of social and normative influences. Studies consistently show that subjective norms, particularly recommendations from physicians, encouragement from family members, and peer behaviours, are strong predictors of vaccine acceptance [180–182]. During the COVID-19 pandemic, TPB-based studies demonstrated that positive attitudes toward vaccines, coupled with strong normative support, significantly increased intentions to receive vaccination [183–185]. Perceived behavioural control has also been shown to influence uptake, as individuals with higher confidence in their ability to access vaccination services and overcome logistical barriers were more likely to follow through on their intentions [186,187]. The TPB's emphasis on intention has made it particularly useful for predicting short-term vaccination decisions in contexts where structural barriers are minimal.

However, the TPB is not without limitations. A central critique is the intention-behaviour gap: while intentions are often strong predictors, they do not always translate into actual behaviour due to situational changes, procrastination, or evolving attitudes [188–191]. In addition, the TPB assumes rational and linear decision-making, which makes it less effective at capturing the influence of misinformation, conspiracy beliefs, and rapidly changing narratives that characterize modern "infodemic" contexts [192–195]. Moreover, it underrepresents emotional, cultural, and collective drivers of vaccine acceptance that go beyond personal attitudes and perceived control.

These limitations became particularly evident during the COVID-19 pandemic, where exposure to misinformation on social media often undermined intention despite favourable attitudes or normative support [196].

The transition from the TPB to more nuanced vaccine-specific frameworks reflect the recognition that vaccination decisions extend beyond rational cognitive evaluations to encompass social-psychological complexity. While TPB remains a widely used and empirically supported model, its limitations in explaining hesitancy in the face of misinformation, distrust, and collective responsibility paved the way for models such as the WHO's 3C framework and the 5C psychological antecedents' model, which incorporate broader contextual and psychosocial factors.

2.2.3. Protection Motivation Theory

Protection Motivation Theory (PMT) was first proposed by Ronald Rogers in 1975 and later refined in 1983 as a framework to explain the impact of fear appeals on health behaviours [197]. The original formulation emerged from research on persuasive health communication, particularly the effectiveness of messages designed to arouse fear about health threats such as smoking or unsafe sexual practices. The theory sought to account for how individuals evaluate fear-inducing messages and decide whether to engage in protective behaviour. Rogers' revision in 1983 expanded the model by incorporating concepts from cognitive appraisal theory, emphasizing both threat appraisal and coping appraisal as dual processes underlying protective action [198,199]. According to PMT, protective health behaviours result from two appraisal processes: a threat appraisal, comprising perceived severity and vulnerability; and a coping appraisal, which includes response efficacy, self-efficacy, and perceived costs of action [198]. Together, these appraisals generate a form of "protection motivation," which can lead to adaptive behaviours, such as vaccination, or maladaptive responses, such as denial or avoidance.

In the context of vaccination, PMT has been widely applied to understand how fear of disease interacts with beliefs in vaccine efficacy. During the COVID-19 pandemic, for instance, studies showed that individuals with higher perceptions of the severity of COVID-19 and greater perceived susceptibility were more willing to vaccinate, especially when they also believed strongly in the efficacy of vaccines and their own ability to access them [200–202]. Conversely,

when coping appraisals were weak, for example, if individuals doubted vaccine safety or their ability to overcome barriers to access, fear-based appeals were less effective, and in some cases, counterproductive [203–207]. This dual pathway makes PMT especially useful in designing health campaigns, where fear appeals must be balanced with clear, empowering messages about efficacy and accessibility.

Despite its contributions, PMT faces notable limitations. A key critique is its reliance on fear appeals, which can have unintended consequences. Excessive fear without sufficient emphasis on coping efficacy can lead to denial, avoidance, or psychological reactance, thereby undermining the intended protective behaviour [208–210]. Moreover, the model's focus on individual cognitive processes, while useful for explaining risk appraisal, underplays the role of broader cultural, social, and political contexts that influence vaccine hesitancy [211–213]. In today's "infodemic" environment, were misinformation and conspiracy beliefs shape risk perceptions, PMT may be insufficient to fully capture the dynamics of vaccine acceptance. Nevertheless, PMT provided an important bridge between earlier rational-choice models, such as the Health Belief Model, and later vaccine-specific frameworks. By foregrounding emotion, risk perception, and coping strategies, it highlighted the psychological mechanisms by which fear, and efficacy interact in shaping behaviour. In this way, PMT laid the groundwork for more comprehensive models of vaccine hesitancy that integrate emotional, cognitive, and contextual factors, such as the WHO's "3C" model and the psychological antecedents' framework [214–217].

2.3. The Early Vaccine-Specific Conceptualizations

2.3.1. Vaccine Confidence Framework

The Vaccine Confidence Framework (VCF) emerged in the early 2000s in response to growing concerns about declining public trust in vaccines and the institutions that deliver them. Developed by researchers at the London School of Hygiene & Tropical Medicine (LSHTM**)**, most prominently led by Heidi Larson, in collaboration with the WHO**,** this framework was designed to capture and quantify confidence in vaccines, vaccination programs, and broader health systems [218,219]. Unlike earlier behavioural health theories, which focused on cognitive and motivational processes at the individual level, the VCF was explicitly developed to address the rising global

challenge of vaccine misinformation, political controversies, and erosion of institutional trust. Its foundation rests on the recognition that even when vaccines are physically available and scientifically validated, uptake may falter if people lack trust in the product, the healthcare providers administering it, or the systems and policies supporting vaccination [220,221].

A major contribution of this framework is the Vaccine Confidence Index (VCI)**,** first launched in 2015 as a global tool to measure public trust in vaccines across diverse cultural contexts [222–225]. The index assesses confidence along three dimensions: trust in the safety and effectiveness of vaccines, trust in the competence and reliability of healthcare professionals and providers**,** and trust in the motives of policymakers and institutions overseeing immunization programs. By conducting large-scale, cross-national surveys, the VCI provided an empirical measure of confidence trends over time and across regions, allowing policymakers to identify countries or populations where hesitancy was rising and to design targeted interventions [226,227].

In practice, the VCF has been highly relevant to understanding the decline in vaccine acceptance in high-income countries such as France, where scepticism toward institutions has been historically pronounced, as well as in low- and middle-income countries where distrust is often tied to political instability or colonial legacies [228–230]. During the COVID-19 pandemic, the framework was widely applied to monitor global confidence in new vaccines, highlighting how confidence fluctuated in response to concerns about side effects, speed of vaccine development, and political narratives surrounding vaccine rollout [231–233]. This ability to link attitudinal trust to actual uptake has made the framework a cornerstone of contemporary vaccine hesitancy research.

Nevertheless, the VCF has notable limitations. Confidence, while essential, is not sufficient on its own to explain or predict VB. Individuals may trust vaccines and providers yet remain unvaccinated due to complacency (low perceived risk of disease) or convenience barriers (geographical, financial, or logistical challenges). Furthermore, the framework focuses primarily on attitudes of trust and mistrust, without fully accounting for the psychological processes of risk perception, social norms, or collective responsibility that have since been incorporated into later models. As a result, its explanatory power is limited when applied in isolation, particularly in contexts where access barriers or competing health priorities are significant [24,234–237].

Importantly, these limitations directly contributed to the development of the WHO's "3C Model" of vaccine hesitancy (confidence, complacency, and convenience) in 2014, which sought to provide a more comprehensive categorization of the drivers of hesitancy [238]. In this way, the VCF laid a critical foundation for vaccine-specific theoretical models by emphasising trust as a measurable and central determinant, while also catalysing the recognition that hesitancy is multidimensional and cannot be reduced to confidence alone.

2.3.2. WHO "3C Model" of Vaccine Hesitancy

The WHO's "3C Model" of vaccine hesitancy was developed by the Strategic Advisory Group of Experts (SAGE) Working Group on Immunization in 2014 as part of efforts to provide a comprehensive yet practical framework for understanding the determinants of vaccine acceptance and refusal [239]. The model was informed by growing recognition that declining vaccination rates could not be explained solely by issues of trust, as highlighted in the VCF, but instead required attention to a wider range of psychological and structural drivers. Its development was grounded in extensive literature reviews, consultations with experts, and analyses of global case studies of vaccine hesitancy [240].

The 3C Model offered a simple but powerful categorization of the factors influencing VB: confidence, complacency, and convenience. The first domain, confidence, refers to trust in the safety and effectiveness of vaccines, the competence of healthcare providers, and the integrity of the health system and policymakers responsible for vaccination programs. Complacency captures situations in which individuals perceive a low risk of contracting a vaccine-preventable disease, resulting in reduced motivation to vaccinate. Finally, convenience addresses the accessibility and affordability of vaccines, including logistical considerations such as distance to vaccination sites, clinic opening hours, availability of supplies, and quality of service delivery. By combining these three domains, the model provided a flexible framework that could be applied across settings to identify barriers and guide tailored interventions [241,242].

One of the major contributions of the 3C Model has been its operationalization in surveys and policy assessments. Researchers and health agencies have developed questionnaires that

measure each of the three domains, enabling quantitative analysis of vaccine hesitancy in diverse populations [243–246]. During the COVID-19 pandemic, the model was applied globally to understand how varying levels of confidence in new vaccines, perceptions of personal risk, and accessibility of vaccination services shaped acceptance [247–250]. Its straightforward structure made it particularly attractive for public health practitioners, as it allowed them to categorize VH into actionable domains that could be addressed through communication, education, and service delivery improvements [251].

Despite its widespread adoption and utility, the 3C Model has been critiqued for being too narrow in scope. While it captures critical determinants of hesitancy, it omits cultural, psychological, and contextual dimensions that also influence vaccine decision-making, such as misinformation, social norms, historical legacies of mistrust, and collective responsibility. In practice, this means that while the model can diagnose immediate barriers to vaccination, it is less capable of addressing deeper and more complex issues that underpin vaccine refusal in certain contexts. These limitations became especially visible during the COVID-19 pandemic, when exposure to misinformation and conspiracy theories significantly shaped hesitancy, factors not explicitly accounted for in the 3C framework [252–258].

As a result of these gaps, the 3C Model laid the foundation for subsequent frameworks that sought to broaden and deepen the analysis of VH. Notably, the “5C Model” of psychological antecedents expanded the 3C by incorporating calculation (the tendency to weigh information extensively) and collective responsibility (the willingness to vaccinate to protect others) [259]. Similarly, multilevel approaches such as the Vaccine Hesitancy Matrix (VHM) integrated cultural, political, and systemic influences. Thus, while the 3C Model remains a global reference point and is still widely used, it is best understood as a transitional framework that helped move the field toward more comprehensive, context-sensitive models of VH.

2.3.3. 5C Psychological Antecedents of Vaccination

The "5C Model" of psychological antecedents of vaccination was developed by Cornelia Betsch, Philipp Schmid, and colleagues in Germany in 2015 as an expansion of the WHO's "3C Model" of vaccine hesitancy [260]. While the 3C framework had advanced the field by emphasizing confidence, complacency, and convenience, its primary weakness was its inability to capture more subtilled psychological processes that influence vaccine decision-making. The 5C model therefore sought to build on and extend the 3C framework by including two additional factors, calculation and collective responsibility, to account for individual differences in information processing and prosocial motivations. This refinement reflected the recognition that vaccination decisions are not only shaped by trust and access but also by deeper psychological and social considerations that guide health behaviour.

The five components of the model are: confidence, referring to trust in vaccines, providers, and health systems; complacency, indicating low perceived risk of disease and reduced motivation to vaccinate; constraints, which replace the earlier concept of "convenience" and describe structural and psychological barriers that hinder acceptance; calculation, reflecting the extent to which individuals actively seek and weigh information before deciding; and collective responsibility, which captures the willingness to vaccinate for the benefit of protecting others and contributing to herd immunity [260]. Together, these five constructs offer a more psychologically rich framework, recognizing not only individual risk-benefit appraisals but also social responsibility and cognitive styles of decision-making.

To operationalize the framework, Betsch and colleagues developed the 5C scale, a validated psychometric instrument designed to measure the five antecedents across populations [260]. This scale has been widely applied and adapted across countries and cultural contexts, enabling cross-national comparisons of vaccine hesitancy [261,262]. For example, Ngaybe et al. (2024) demonstrated its predictive validity in assessing vaccine intention across diverse populations [263], while Sun, Li, and Guo (2023) used it to analyse COVID-19 vaccine hesitancy in China, showing how calculation and collective responsibility moderated acceptance levels [264]. By providing a standardized measure, the 5C scale has allowed researchers to generate

cross-sectional and longitudinal data, facilitating more precise analysis of psychological factors driving hesitancy and acceptance.

The 5C framework has proven highly relevant in the context of the COVID-19 pandemic, where hesitancy has been shaped not only by confidence and access but also by the spread of misinformation and the need for collective action. Studies have shown, for instance, that high levels of collective responsibility correlate with greater acceptance of COVID-19 vaccines, while excessive calculation, characterized by overexposure to conflicting information, has been associated with hesitancy [265–270]. This dual insight highlights both the strengths and potential vulnerabilities of populations when confronted with infodemic conditions.

Despite its contributions, the 5C model is not without limitations. A major critique is that it remains largely focused on individual-level psychology, often overlooking broader structural, cultural, and political influences on VB [271]. For example, systemic inequities in healthcare access, media environments, or historical legacies of mistrust cannot be fully explained through the five psychological constructs. Additionally, while collective responsibility addresses prosocial motivations, it does not encompass the full range of community and cultural determinants of VH, such as religious norms or political ideology. These limitations suggest that while the 5C model marked a significant advance over the 3C model, its focus on psychological antecedents needed to be complemented by more systemic frameworks.

In this way, the 5C model can be seen as a transitional stage in the evolution of vaccine hesitancy theory. It successfully deepened the analysis of psychological drivers, particularly by highlighting calculation and collective responsibility, but also paved the way for more holistic models such as the VHM by the WHO, which incorporates contextual, political, and systemic dimensions. Thus, the 5C framework occupies a critical position in the historical trajectory of vaccine hesitancy research: it provides valuable explanatory power while simultaneously showcasing the need for broader, multilevel approaches to understanding vaccine behaviour.

2.4. Systemic & Multilevel Approaches

2.4.1. The Vaccine Hesitancy Matrix

The VHM was developed in 2017 by the WHO SAGE Working Group on VH as part of its ongoing effort to better categorize and understand the complex, multidimensional drivers of vaccine hesitancy [272]. Building on earlier models such as the VCF and the WHO "3C Model," the Hesitancy Matrix was designed to provide policymakers and researchers with a more comprehensive tool for mapping the full spectrum of determinants influencing vaccine acceptance and refusal. Unlike frameworks that focused primarily on psychological or access-related factors, the Hesitancy Matrix aimed to integrate individual, social, contextual, and vaccine-specific factors into a single structure, thereby recognizing the inherently ecological nature of vaccine decision-making [273–277].

The structure of the matrix is organized into three broad domains. The first domain, individual and group influences, encompasses personal beliefs, experiences with vaccination, peer and family influences, and trust in healthcare providers. The second domain, contextual influences, captures external drivers such as cultural values, political climates, religious beliefs, socioeconomic conditions, historical experiences of marginalization, and the influence of mass and social media. The third domain, vaccine- and vaccination-specific issues, includes factors directly related to vaccines themselves, such as perceived efficacy, safety, availability, and the logistics of vaccine delivery. Together, these domains provide a checklist-style framework that can be used to diagnose the multiple layers of factors contributing to hesitancy in a given context [278].

The Hesitancy Matrix has proven especially relevant in contemporary vaccination challenges. During the COVID-19 pandemic, it was used to capture the influence of misinformation, political polarization, and cultural narratives on vaccine attitudes, particularly in cross-national research comparing drivers of hesitancy across high-income and low- and middle-income countries [279–284]. By acknowledging the importance of cultural and contextual influences, the matrix has provided a flexible diagnostic tool that allows for adaptation to different settings. For example, in African contexts, historical distrust of government and global health institutions emerged as a dominant factor, while in Europe and North America, misinformation on social media and political partisanship played more prominent roles [285–288]. This adaptability

has made the Hesitancy Matrix a useful guide for designing multi-level interventions that target not only individual knowledge and attitudes but also systemic and cultural barriers.

Despite its strengths, the VHM is not without limitations. Its breadth comes at the cost of precision, as the framework is more descriptive than predictive. Unlike the 5C model, which offers validated psychometric measures, the Hesitancy Matrix functions more as a qualitative checklist than a quantitative tool. This makes it less effective for empirical testing or for generating standardized cross-national comparisons, although it provides valuable structure for exploratory research and policy design [289–291]. Furthermore, while it captures a wide range of determinants, it does not specify how these interact or which should be prioritized in interventions, leaving much of the interpretive work to researchers and practitioners.

Nevertheless, the VHM marked a significant step in the evolution of vaccine hesitancy frameworks. By broadening the scope of analysis to include cultural, political, and media influences, it moved the field beyond the narrow individual-psychological focus of earlier models. The matrix has since been used as a foundation for multi-level strategies to address hesitancy, combining community engagement, health system strengthening, and tailored communication campaigns. As such, it represents a transitional framework that complements psychological models like the 5C, while paving the way for integrated, systemic approaches to vaccine acceptance.

2.4.2. The 5A Model of Vaccine Uptake

The "5A Model of Vaccine Uptake" was introduced by Angela Crawshaw Thomson and colleagues in 2016 as a practical framework to guide public health interventions by identifying the key determinants of VH [292]. Developed through a synthesis of the literature on immunization barriers and facilitators, the model was intended to provide a clear and actionable structure for policymakers and practitioners working to improve vaccination coverage. Unlike theoretical models rooted primarily in psychology, such as the HBM or the 5C framework, the 5A model was explicitly designed with a programmatic orientation, emphasising service delivery and public health systems as central drivers of vaccine acceptance.

The model identifies five core elements that determine vaccine uptake: access, affordability, awareness, acceptance, and activation. Access refers to the availability of vaccines and the ability of individuals to physically reach vaccination services. Affordability encompasses both direct and indirect costs of vaccination, including financial, time, and opportunity costs. Awareness addresses knowledge about vaccines and diseases, as well as familiarity with the benefits and risks of immunization. Acceptance reflects willingness to vaccinate based on attitudes, beliefs, and trust in vaccines, providers, and systems. Finally, activation emphasizes the role of prompts, reminders, and nudges, such as text messages, appointment reminders, or provider recommendations, in encouraging individuals to act on their intentions [293,294]. Collectively, these five elements offer a multidimensional yet operational framework that is well-suited to guiding program design and evaluation.

In practice, the 5A model has proven highly relevant for identifying and addressing barriers in immunization programs across diverse settings. For example, interventions based on improving access and affordability, such as mobile clinics, subsidized vaccines, or integration of services, have been shown to increase uptake in low- and middle-income countries [295,296]. In high-income contexts, activation strategies like provider reminders and digital nudges have been particularly effective in boosting vaccine coverage [297,298]. During the COVID-19 pandemic, the model was used to evaluate barriers to vaccine rollout, highlighting issues of awareness and acceptance related to misinformation, as well as activation challenges in reaching marginalized populations [299,300]. The framework's strength lies in its adaptability and focus on practical interventions that can be tailored to local contexts.

Despite its utility, the 5A model also faces limitations. One major critique is that it remains programmatic rather than deeply theoretical, focusing on service delivery and external drivers without fully engaging with the psychological or socio-cultural dimensions of vaccine decision-making [301,302]. While "acceptance" addresses attitudinal components, it does not capture the complexity of social norms, misinformation, or collective responsibility that models like the 5C framework emphasize. Furthermore, the model does not explicitly account for the interaction between structural and psychological determinants, limiting its explanatory depth in contexts

where vaccine hesitancy is primarily driven by trust, identity, or ideology rather than access or affordability.

Nevertheless, the 5A model has played an important role in bridging theory and practice by providing a structured, intervention-oriented tool for policymakers. It complements psychological models by underscoring program design, and its emphasis on activation introduced a behavioural science perspective into vaccination frameworks. In this way, the model contributed to the evolution of vaccine hesitancy research by shifting attention toward actionable levers for increasing uptake, while paving the way for hybrid approaches that combine psychological insights with systemic program interventions.

2.4.3. The Expanded 5C Model of Vaccine Hesitancy

While the original 5C framework introduced in 2015 represented a major step forward in identifying psychological antecedents of vaccination, it was during the COVID-19 pandemic that the model was further expanded, validated, and widely applied across countries. Betsch and colleagues (2018) refined the framework into a standardized measurement tool, the 5C scale, which was subsequently adapted for large-scale surveys in multiple contexts [303–306]. This expansion was crucial because COVID-19 presented unprecedented challenges for vaccine acceptance, including rapid vaccine development, widespread misinformation, and divergent national strategies. As such, the 5C model evolved from a largely theoretical construct into a globally validated instrument capable of capturing the complexity of pandemic-era hesitancy.

The expanded application of the 5C model has been demonstrated in a range of empirical studies. For example, Paul et al. (2020) applied the framework in the United Kingdom to examine attitudes toward COVID-19 vaccination, revealing that collective responsibility and confidence were the strongest predictors of acceptance [307]. Similarly, Sun, Li, and Guo (2023) used the model in China to highlight how calculation, when coupled with exposure to misinformation, increased hesitancy, whereas high confidence and collective responsibility promoted acceptance [264]. More recently, Ngaybe et al. (2024) validated the scale across several countries, confirming its cross-national reliability and demonstrating that the relative importance of each “C” varied between cultural contexts. For instance, in some European settings, constraints related to access

were minimal, making psychological factors more salient, while in lower-income contexts, structural barriers remained critical [263]. These studies illustrate how the expanded 5C has become a comparative tool, enabling researchers to map psychological antecedents across national and cultural boundaries.

The relevance of the expanded 5C model lies in its ability to capture subtle psychological processes during the pandemic while remaining flexible enough for cross-national application. It does not only shed light on the drivers of hesitancy in specific populations but also provided a framework for policymakers to design tailored interventions. For example, communication campaigns emphasizing collective responsibility proved effective in contexts where social solidarity was culturally valued, while interventions addressing calculation were more relevant in settings where misinformation was widespread [308,309]. This versatility made the expanded 5C framework one of the most widely cited and applied models during COVID-19. However, despite its broad utility, the expanded 5C model retains certain limitations. Its focus remains predominantly on individual-level psychology, and while it incorporates prosocial dimensions such as collective responsibility, it still underrepresents systemic drivers like political polarization, health system capacity, and socioeconomic inequality [251]. Additionally, while cross-national surveys demonstrate the adaptability of the 5C scale, contextual modifications are often required, raising questions about the universal comparability of results [263]. These limitations underscore the importance of integrating the expanded 5C with broader ecological models, such as the Vaccine Hesitancy Matrix, which capture structural and cultural dynamics.

Overall, the expanded 5C model stands out as one of the most empirically tested and globally validated frameworks of vaccine hesitancy during the COVID-19 era. Its ability to highlight psychological differences across countries makes it uniquely suited for cross-national comparative studies, providing an essential lens for this thesis, which examines vaccine hesitancy among university students in Ghana, Ukraine, and Syria.

2.4.4. COVID-19–Specific Adaptations of Vaccine Hesitancy Models

The COVID-19 pandemic represented a unique global challenge for vaccine acceptance and hesitancy, forcing existing theoretical frameworks to be adapted and expanded to address new

determinants. Unlike previous vaccination contexts, the pandemic unfolded amid an unprecedented digital "infodemic"- a term adopted by the World Health Organization to describe the overabundance of information, both accurate and false, circulating online [263]. Traditional frameworks such as the HBM and TPB, which emphasize individual perceptions of risk and intention, proved insufficient for capturing the influence of conspiracy theories, political polarization, and social media misinformation. As a result, researchers began integrating trust–misinformation dynamics into established models and developing pandemic-specific adaptations.

One key adaptation involved expanding the confidence dimension of the 3C and 5C frameworks to explicitly incorporate susceptibility to misinformation and conspiracy beliefs. Loomba et al. (2021), for example, demonstrated in cross-national surveys of the UK and USA that exposure to online misinformation significantly reduced vaccination intent, even among individuals with high baseline confidence in vaccines [310]. Similarly, Bendau et al. (2021) showed that COVID-19 vaccine hesitancy in Germany was strongly associated with anxiety and misinformation-related fears, suggesting that emotional and cognitive reactions to digital content needed to be included in predictive models [311]. In China, Yang et al. (2023) applied the 5C framework with additional items capturing sensitivity to conspiracy narratives, finding that misinformation acted as a mediator between calculation and hesitancy [148].

Another adaptation concerned the role of collective responsibility. During COVID-19, willingness to vaccinate for the sake of protecting others became an important factor, particularly in contexts where herd immunity was a central public health goal. Studies using the expanded 5C framework demonstrated that collective responsibility was a strong predictor of vaccine acceptance in countries such as the UK and Italy [312,313]. However, its effect was weaker in contexts characterized by low institutional trust or heightened political polarization, where appeals to solidarity carried less motivational weight [314,315]. This highlighted the importance of embedding collective responsibility within pandemic-specific communication strategies.

COVID-19 also underscored the need to account for dynamic trust relationships in models of VH. Trust in governments, pharmaceutical companies, and international organizations fluctuated rapidly as vaccine approval processes, safety concerns, and political narratives unfolded

[316,317]. Hu et al. (2022) showed that in China, trust in government moderated the relationship between intention and uptake, reinforcing the importance of integrating contextual trust factors into behavioural models [318,319]. This insight pushed the adaptation of both TPB and the VCF to explicitly incorporate institutional and political trust as moderating variables.

Despite these advances, COVID-19–specific adaptations of hesitancy models also face limitations. Many remain fragmented, with new variables such as misinformation exposure or conspiracy beliefs added ad hoc rather than systematically integrated into broader frameworks. This has created challenges for cross-national comparability, as different studies operationalize "misinformation" and "trust" in diverse ways. Moreover, while these adaptations have improved explanatory power during the pandemic, their long-term relevance to routine vaccination contexts remains to be tested.

Nevertheless, the COVID-19 crisis accelerated the theoretical evolution of vaccine hesitancy models by foregrounding the centrality of digital ecosystems, misinformation, and political trust in shaping health behaviour. These insights suggest that future models will need to be more contextual and dynamic, combining psychological antecedents with systemic, cultural, and technological factors. For the purposes of this thesis, which examines cross-national differences among university students in Ghana, Ukraine, and Syria, these adaptations highlight why pandemic-specific factors, particularly misinformation and trust in institutions, must be integrated into comparative analyses of hesitancy.

2.5. Comparative Analysis of Models

Table 1 presents a comparative overview of the principal models explaining vaccine hesitancy, including the 3C, 5C, SAGE, HBM, and TPB frameworks. The comparison highlights both their conceptual overlaps such as the emphasis on confidence, perceived risk, and social responsibility and their unique contributions in addressing behavioural, cognitive, and contextual determinants. This synthesis demonstrates how each model offers a complementary lens for understanding vaccine decision-making.

Table 1. Similarities and differences between vaccine hesitancy models

Model	Timeline	Focus	Key strength	limitation	Led to…
HBM	1950s	Individual health behaviour	Simple, predictive	Ignores social context	TPB, PMT
TPB	1985	Intentions & norms	Includes social norms	Intention-behaviour gap	Vaccine-specific models
PMT	1975–1983	Fear & coping	Emotions and efficacy	Can backfire	Vaccine confidence
VCF	2000s	Trust in vaccines	First vaccine-specific index	Too narrow	WHO 3C
WHO 3C	2014	Confidence, complacency, convenience	Global adoption	Misses' psychology	5C
5C	2015 -	Psychology of hesitancy	Adds collective/social	Still individual level	Hesitancy Matrix
Hesitancy matrix	2017	Multilevel factors	Contextual influences	Hard to quantify	COVID-19 models
5A	2016	Service uptake	Operational	Less psychological	Combined with 5C
COVID-19 models	2020 -	Trust and misinformation	Infodemic-awareness	New, evolving	Future integrated models

2.6. Framework utilized in the Thesis

All four articles included in this cumulative thesis are grounded in the 5C psychological antecedents' framework**,** which has become a central model in vaccination research since its

validation by Betsch et al. (2018). The 5C model conceptualizes five psychological drivers of VH: Confidence, Complacency, Constraints, Calculation, and Collective Responsibility [320]. The choice of this framework reflects a broader shift in the literature. Evidence indicates that knowledge-deficit approaches are often ineffective or even counterproductive unless paired with value-based, empathetic, and contextually designed interventions [321,322]. Hence, current discourse advocates for the integration of behavioural and psychological science into vaccine promotion initiatives. Global data support this pivot: de Figueiredo et al. (2024) documented declining vaccine confidence across multiple regions, attributing this trend to misinformation, institutional distrust, and socio-political polarization [323]. Similarly, the State of Vaccine Confidence report highlights the importance of context-specific, psychologically informed interventions to rebuild trust and mitigate VH [324].

Within this discourse, the 5C model has gained prominence for its explanatory robustness across diverse settings. Evidence from cross-national studies consistently shows that confidence and collective responsibility are strong predictors of vaccine acceptance, while complacency and constraints drive hesitancy and refusal [99,325]. Importantly, these associations remain consistent even after controlling for knowledge, sociodemographic, and informational variables [326]. This explanatory capacity makes the 5C model especially suited to reveal why information alone fails to translate into action.

In the four studies that make up this cumulative thesis, conducted among adults and university students in Ghana, Ukraine, and Syria, the 5C framework was operationalized to examine psychological drivers of COVID-19 VH. Across these contexts, it provided a structured yet adaptable tool for identifying patterns of hesitancy and acceptance. To broaden explanatory depth, the 5C framework was complemented by additional perspectives, including the HBM, which emphasizes perceived susceptibility, severity, benefits, and barriers; the TPB which highlights attitudes, subjective norms, and perceived behavioural control; and the WHO SAGE determinants matrix, which situates individual decisions within wider contextual and social influences. Together, these theoretically grounded approaches offered a cohesive foundation for analysing VH and designing psychologically informed interventions.

CHAPTER THREE

3. RESEARCH DESIGN, SCOPE AND STRATEGY

3.1. Problem Statement

Despite widespread awareness of the benefits of vaccination, VH persists globally, including among highly educated populations. This paradox is particularly evident among university students, who represent future healthcare leaders, educators, and policy influencers. The COVID-19 pandemic revealed how psychological, informational, and structural barriers including misinformation, complacency, deficits in trust, and logistical constraints can significantly undermine vaccine acceptance, even when knowledge levels are high.

Emerging literature from LMIC as well as conflict-affected countries, including Ghana, Ukraine, and Syria, indicates that vaccine decision-making among university students is influenced by complex interactions between individual cognition, social trust, and systemic capacity. Contextual challenges, ranging from misinformation and institutional distrust to socio-political instability and disrupted health systems, may shape vaccination attitudes in ways that differ markedly across regions. However, comparative evidence explaining how psychological antecedents and socio-contextual factors jointly determine vaccination behaviour across these diverse settings remains limited.

These challenges are not unique to COVID-19; rather, they reflect broader systemic issues affecting global immunization programs for both emerging and routine infectious diseases. Addressing VH therefore requires moving beyond demographic or informational predictors to focus on the psychological and socio-contextual foundations of vaccine-related behaviour. By interrogating these dynamics in diverse national contexts, spanning sub-Saharan Africa, Eastern Europe, and the Middle East, this thesis contributes to the design of more responsive, resilient, and equitable vaccination strategies that can withstand both misinformation and socio-political pressures.

3.2. Research Aims and Scope

3.2.1. Aim

This cumulative thesis aims to investigate the psychological and behavioural determinants of vaccine hesitancy and acceptance among adults and university students in Ghana, Ukraine, and Syria. Using the COVID-19 pandemic as a case study, the research examines the persistence of the knowledge–behaviour gap, where high awareness of vaccines does not consistently translate into uptake. The overarching aim is to generate cross-national insights that inform vaccination policy and practice in resource-constrained and crisis-affected settings, while contributing to broader understanding of vaccine decision-making.

3.2.2. Scope of the Thesis

The scope of this thesis is articulated in three dimensions:

- Empirical
    - To document the prevalence and determinants of vaccine hesitancy in Ghana, Ukraine, and Syria, and to analyse the influence of the 5C psychological antecedents alongside sociodemographic, informational, and contextual factors.
- Theoretical
    - To assess the explanatory power of established behavioural frameworks including the 5C model, the HBM, the TPB, and the WHO SAGE determinants matrix in explaining the persistence of the knowledge–behaviour gap.
- Practical
    - To propose evidence-informed interventions that strengthen vaccine confidence and acceptance among young adults, particularly in settings characterized by resource limitations, institutional distrust, or conflict, while also generating transferable lessons beyond the COVID-19 pandemic.

3.2.3. *Research Questions*

General Question

- How does the knowledge–preventive behaviour gap, in conjunction with psychological and contextual determinants, shape vaccine hesitancy and acceptance among university students during the COVID-19 pandemic?

Specific Research Questions

1. To what extent does knowledge about infectious diseases (COVID-19) and vaccination translate into preventive practices and vaccine acceptance, and how is this gap manifested across the three study contexts?
2. Which psychological antecedents, as conceptualized in the 5C model (Confidence, Complacency, Constraints, Calculation, Collective Responsibility), most strongly predict vaccine hesitancy or acceptance?
3. How do sociodemographic characteristics, prior vaccination experiences, institutional trust, exposure to misinformation, and information sources interact with knowledge and psychological antecedents to influence vaccine-related behaviour?
4. In what ways do contextual factors such as resource constraints, political instability, and conflict-related disruptions modify the relationship between knowledge, intention, and vaccination behaviour?
5. What evidence-informed strategies can be derived from the cross-national comparison of Ghana, Ukraine, and Syria to address the knowledge–behaviour gap and improve vaccine acceptance among youth in resource-constrained or unstable environments?

3.2.4. Research Design

A comparative, cross-sectional design was adopted to investigate VH, knowledge, and behavioural intentions across diverse populations. Data were collected at single points in time

within each setting, enabling systematic comparison of the psychological, demographic, and contextual determinants of VA. The comparative element allowed identification of both convergent and divergent patterns across countries, while the cumulative thesis structure permitted integration of findings from four interrelated studies into a coherent framework.

Survey methodology served as the principal data collection tool. Surveys provided a standardized and efficient means of capturing information from large populations in each context. Their capacity to measure psychological antecedents (5C model), knowledge levels, attitudes, and self-reported behaviours within a single instrument made them especially suitable for this research. Moreover, the flexibility of survey administration was advantageous under pandemic conditions and crisis settings, where rapid deployment, minimal direct contact, or reliance on trained local facilitators were often required.

The cumulative design was operationalized through four complementary studies, each targeting a specific population while addressing a common set of constructs:

- Study 1 (Ghana – General Population): A national survey of adults to assess knowledge, preventive behaviour, and vaccine acceptance.
- Study 2 (Ghana – University Students): A large-scale student survey examining the knowledge–behaviour gap and the predictive power of psychological antecedents.
- Study 3 (Ukraine – University Students): A study of Ukrainian students exploring the interplay of vaccine hesitancy, conflict-related factors, and institutional trust.
- Study 4 (Syria – University Students): A survey of Syrian students assessing hesitancy in a prolong conflict-affected setting, with attention to complacency, conspiracy beliefs, and collective responsibility.

Together, these studies contribute to an integrated cross-national understanding of the knowledge–behaviour gap. By combining empirical breadth (multiple countries and populations) with analytical depth (psychological, social, and contextual determinants), this research design ensures meaningful insights that extend beyond single-country perspectives.

3.2.5. Study Sites and Populations

Ghana, a lower-middle-income country in sub-Saharan West Africa, has made substantial progress in strengthening its health system through the Ghana Health Service and the National Health Insurance Scheme (NHIS). The country has been a longstanding participant in the EPI, achieving high coverage for routine childhood vaccines such as measles, BCG, and polio [327,328]. Despite these successes, gaps remain in sustaining public trust and ensuring equitable access, particularly across urban–rural divides and among young adults who transition out of paediatric immunization schedules. Ghana's demographic profile is heavily youth-dominated, with over 57% of the population under 25 years [329,330]. This large youth cohort represents both a challenge and an opportunity for public health, as their vaccination decisions influence not only immediate disease prevention but also long-term system resilience. The studies conducted in Ghana therefore targeted both adults in the general population and university students, enabling insights into vaccine behaviour across different age groups.

Ukraine presents a markedly different yet equally complex setting. The country has faced profound socio-political disturbance and conflict, which have strained health service delivery and disrupted vaccination programs [331,332]. During the COVID-19 pandemic, rollout was hindered by delayed procurement, fluctuating supply chains, and widespread institutional distrust [331,332]. Misinformation and conspiracy narratives further eroded vaccine confidence, particularly among university students and young adults, who were highly exposed to digital information streams. Despite increasing international support and targeted campaigns, vaccination rates lagged behind expectations [333,334]. Against this backdrop, the Ukrainian study examined how confidence, collective responsibility, and constraints interacted with conflict-related instability to shape VB among students.

Syria provides a further perspective from a protracted conflict-affected environment, where healthcare systems and vaccination infrastructure have been severely disrupted. The war has displaced millions, undermined routine immunization services, and heightened population vulnerabilities [335–337]. Among university students, COVID-19 VH remained widespread despite broad exposure to information about the disease and vaccines. In particular, non-medical students showed higher hesitancy, often citing complacency, calculation, and mistrust as reasons

for refusal. Structural barriers such as resource scarcity, reduced accessibility to vaccination centres, and political instability compounded these psychological factors. By focusing on over 4,700 Syrian students, the study provided insights into how protracted conflict and systemic fragility amplify the determinants of VH.

3.2.6. Rationale for Focusing on University Students

University students were selected as the primary study population for several reasons. Firstly, they represent a critical segment of the youth demographic, characterized by relatively high educational attainment and access to information. This makes them an especially informative group for analysing the knowledge–preventive behaviour gap, where awareness of vaccine benefits does not always translate into acceptance. Secondly, as future professionals, leaders, and opinion-shapers, students' attitudes and behaviours have the potential to shape broader societal norms and influence public health practices [338,339]. Their decisions can affect not only peer networks but also future communities in which they will serve as educators, health workers, or policymakers.

Thirdly, in Ghana, Ukraine, and Syria, higher education enrolment has grown significantly in recent decades, producing large and diverse student populations that are readily accessible for cross-sectional surveys [340–342]. This accessibility provides a pragmatic advantage for studying determinants of VH within controlled sampling frames while still capturing meaningful variation across gender, discipline, and socio-economic background. Finally, students in conflict-affected or resource-constrained settings such as Ukraine and Syria face additional pressures linked to political instability, institutional distrust, and exposure to misinformation [343,344], which intersect with psychological antecedents to shape VB. By studying university students in both stable (Ghana) and unstable (Ukraine, Syria) contexts, this thesis generates comparative insights into how knowledge, psychological drivers, and structural constraints interact in shaping vaccination intentions and behaviours.

Comparative contextual assessment of the three study sites utilized in the four articles is presented in Table 2.

Table 2. Contextual differences and similarities across study sites

	Ghana	**Ukraine**	**Syria**
Population	~34 million (2023/2024) [345]	~37.9 – 42 million pre-conflict estimates (2024) [346]	~22.1 million (2023, down from 23m pre-war due to displacement) [347]
Youth population	~57% under 25 years; ~33% aged 10-24 [348]	Youth % notable; however, conflict and displacement have shifted demographics [349]	~50% under 25 years; youth disproportionately affected by conflict and displacement [350]
Health expenditure per capita / US$	~US$ 82.32 (2022) [351]	< US$ 300 (pre-war estimates), with actual spending likely much higher but inefficient under war stress [352]	~US$ 34.4 (2022); sharp reductions during conflict [353]
Health spending as % of GDP	~3.7% (2022) [351]	~7.4% (public + private, 2017) [352]	~3.5% (2019 pre-crisis est.) [353]
Stressors / Infrastructure challenges	Rural access, logistics, uneven distribution of facilities; limited healthcare workforce in remote areas [354] .	Major damage from war to facilities; displacement of both population & health workers; supply chain disruptions; soaring costs [355].	Widespread destruction of health facilities; humanitarian reliance; severe vaccine supply disruptions [355]
Hospital beds per 1000 people	~0.7 (2015) [356] regional reports still reflect very low bed-density in many regions (2021) [357]	~6.7 (2018). More recent 8.79 [352].	~1.5 (2019, WHO est.); current capacity reduced due to war [358]

3.3. Sampling Strategy

In this cumulative thesis, four cross-sectional surveys were conducted across Ghana, Ukraine, and Syria, each tailored to the specific population and contextual constraints.

Two distinct surveys were conducted in Ghana. The first targeted the general adult population and employed a multistage sampling approach (i.e., participants were selected in successive stages) to ensure representation across urban and rural settings. Participants were recruited through community networks, health institutions, and local administrative channels, with questionnaires administered both in person and online. A total of 1,560 adults were surveyed. The second survey focused specifically on university students, where a combination of convenience and snowball (participant referrals) sampling was used. Students were reached through university mailing lists, student associations, and peer referrals, facilitating rapid recruitment during the pandemic period. This yielded a final sample of 3,486 students across multiple universities in Ghana.

The survey in Ukraine concentrated on university students and adopted a web-based convenience sampling strategy. Distribution channels included university networks, student organizations, and social media platforms, which allowed wide reach despite ongoing pandemic restrictions and the volatile socio-political environment. Given the challenges of physical fieldwork in a conflict-affected context, online recruitment was the most feasible option. A total of 936 Ukrainian students participated in the survey.

The Syrian survey targeted university students and was conducted across five universities. Due to conflict-related constraints, a convenience sampling approach was used, supported by trained volunteers who facilitated data collection within accessible campuses. To maximize participation, questionnaires were administered in Arabic through both paper-based interviews and structured online formats. A total of 4,722 students participated, making this the largest dataset in the cumulative thesis. Subgroup analyses compared medical and non-medical students, allowing exploration of disciplinary differences in vaccine attitudes.

3.3.1. Inclusion and Exclusion Criteria

Eligibility criteria were consistent across all study sites to ensure comparability. Participants had to be aged 18 years or older**,** currently enrolled as university students (for the student surveys), and provide informed consent. For the Ghana general population survey, adults of any educational background were eligible.

Exclusion criteria included incomplete or substantially missing questionnaires data, responses from individuals younger than 18, and duplicate submissions identified during data cleaning (e.g., repeated online submission). This ensured that only valid, unique, and comparable responses were retained for analysis.

3.3.2. Sample Size Justification

Formal sample size calculations were not performed prior to data collection for these surveys. Instead, recruitment was guided by feasibility considerations and the contextual realities of each study setting. In Ghana, efforts were made to capture population diversity in the adult survey while also ensuring rapid student recruitment during the pandemic. In Ukraine, the conflict situation made conventional field-based recruitment impossible, requiring reliance on online channels and institutional networks. In Syria, participation was shaped by security concerns, restricted mobility, and institutional permissions, but the involvement of trained volunteers and student networks enabled widespread participation.

Although the numbers achieved were determined pragmatically rather than by statistical power estimates, the realized sample sizes were sufficiently large to allow for meaningful analysis. They supported the description of sociodemographic and psychological patterns, the estimation of prevalence rates for vaccine acceptance, hesitancy, and resistance, and the use of regression models to identify predictors of vaccine behaviour. In total, 1,560 adults participated in the Ghana general population survey, 3,486 students in the Ghanaian university survey, 936 students in the Ukrainian study, and 4,722 students in the Syrian survey. While the lack of advance power calculations is acknowledged as a methodological limitation, the scale of data collection provided

robust empirical foundations for the analyses. The large samples enhanced the external validity of descriptive estimates, allowed subgroup comparisons across demographic and psychological variables, and increased the precision of regression models identifying determinants of vaccine attitudes.

3.4. Data Collection Methods

3.4.1. Instruments

Structured self-administered questionnaires were employed in all four studies. The instruments captured sociodemographic characteristics, prior vaccination experience, exposure to misinformation, and self-reported COVID-19 vaccination status or intentions. To measure psychological determinants, each questionnaires incorporated the 5C model of psychological antecedents developed by Betsch et al. (2018). In the Ghana general population survey, additional items on knowledge and preventive practices were included, aligned with WHO and Ghana Health Service recommendations at the time of the study. For the Syrian study, the tool was translated into Arabic and then back-translated to ensure both linguistic accuracy and conceptual validity. Across all sites, instruments were piloted for clarity and adapted to the local context before full administration.

3.4.2. Mode of Distribution

Modes of questionnaire administration differed across settings according to feasibility. In the Ghana general population survey, data were collected through a hybrid approach, with paper-based questionnaires distributed in selected communities and online forms provided for participants with internet access. Among Ghanaian university students, the survey was conducted entirely online using web-based forms disseminated through social media platforms such as WhatsApp and Facebook, alongside distribution via student associations and peer networks. In Ukraine, the university student survey was also implemented exclusively online, reflecting the combined constraints of the COVID-19 pandemic and the volatile conflict situation, with recruitment relying on digital platforms, university mailing lists, and student organizations. In Syria, questionnaires were delivered through a mixed method of paper-based administration on

university campuses, facilitated by trained volunteers, and online forms for students who could access digital platforms. This blended approach accounted for the unequal internet access and security conditions across the country.

3.4.3. Timeline and Context of Data Collection

The four surveys were implemented at different points in the pandemic. The Ghana general population survey took place between September and June 2020, coinciding with the early stages of the national vaccine rollout. The Ghanaian university student survey was carried out between July and October 2022, during targeted vaccination campaigns aimed at young adults. The Ukrainian university student survey was conducted between February and March 2023, shortly before an escalation of armed conflict which further disrupted health services and vaccine distribution. The Syrian university student survey was undertaken between August and October 2022, at a time when prolonged conflict, resource scarcity, and widespread misinformation were strongly shaping vaccination attitudes and behaviours.

3.5. Data Analysis Strategy

3.5.1. Descriptive and Inferential Methods

Data analysis proceeded in two main stages. The first stage involved the use of descriptive statistics to summarize sample characteristics, knowledge levels, vaccination status, and the distribution of the 5C psychological antecedents. Frequencies and proportions were generated for categorical variables, while means and standard deviations were calculated for continuous measures. These descriptive analyses provided a comprehensive overview of the datasets across the four study sites.

The second stage applied inferential statistical methods to test associations and identify predictors of vaccination behaviour. Linear regression and multiple regression models were fitted to examine the relationships between psychological antecedents, sociodemographic characteristics, and vaccine-related outcomes. Logistic regression was employed for binary outcomes such as vaccination acceptance *versus* refusal, while multinomial regression was used

to differentiate between acceptance, hesitancy, and resistance. Model diagnostics and robustness checks, including tests for multicollinearity and goodness of fit, were performed to validate results, with statistical significance set at $p < 0.05$.

3.5.2. Comparative Analysis

To address the cumulative aims of the thesis, cross-national and cross-population comparisons were conducted. Prevalence estimates of vaccine acceptance, hesitancy, and resistance were contrasted not only between Ghana and Ukraine but also extended to Syria, allowing insights from a protracted conflict-affected setting to be included. The Ghanaian dataset further permitted internal comparison between the general adult population and university students, offering a nuanced perspective on how hesitancy manifests across age cohorts.

Regression results were compared across countries to identify both convergent predictors such as the consistent influence of confidence and collective responsibility, and divergent effects shaped by local context, such as the role of constraints in Ukraine under conflict disruption or the heightened impact of complacency and conspiracy beliefs in Syria. This comparative strategy made it possible to systematically interrogate the persistence of the knowledge–behaviour gap across three distinct national contexts, while also highlighting the importance of socio-political conditions in shaping vaccine decision-making.

3.5.3. Statistical Packages

Data were initially entered, validated, and cleaned using Microsoft Excel (version 16.34 or later). All statistical analyses were subsequently conducted in R software (version 4.2.3; R Core Team, 2021) with the support of specialized packages. The car package was used for regression diagnostics and multicollinearity testing; mice facilitated the handling of missing data through multiple imputation; boot was employed for resampling and bootstrapping procedures; and nnet

supported the modelling of multinomial outcomes. The use of these tools enhanced the analytical rigor, transparency, and reproducibility of all four studies.

3.6. Ethical Considerations

Ethical approval was obtained prior to the commencement of each study. In Ghana, the research protocols for both the general population survey and the university student survey were reviewed and approved by the Committee on Human Research, Publications and Ethics (CHRPE) at the Kwame Nkrumah University of Science and Technology, Kumasi. In Ukraine, clearance was granted by the Research Ethics Committee of Danylo Halytsky Lviv National Medical University, in line with institutional and national standards for research involving human participants. In Syria, the study was approved by the Research Ethics Committee of the Faculty of Medicine at Damascus University, with additional administrative permissions obtained from participating universities to facilitate safe on-campus data collection.

All participants received an information sheet describing the study's objectives, procedures, potential risks, and anticipated benefits. Informed consent was obtained electronically for web-based surveys and in written form for paper-based questionnaires. Participation was entirely voluntary, and respondents retained the right to withdraw at any time without adverse consequences. Special care was taken in Ukraine and Syria to emphasize willingness to partake, given the heightened sensitivities associated with conflict settings.

Confidentiality and data protection were rigorously maintained across all sites. No personally identifiable information was collected beyond essential demographic variables, and all datasets were anonymized at the point of entry. Data files were stored in password-protected systems accessible only to the research team, with results presented solely in aggregate form to prevent identification of individuals or institutions.

The conduct of the research adhered to the principles of the Declaration of Helsinki governing ethical research with human participants. For digital data management, precautions were implemented in accordance with General Data Protection Regulation (GDPR) principles,

including transparency, security, and restricted access. Collectively, these measures safeguarded autonomy, minimized risks, and ensured equitable treatment of participants across all four studies, while accounting for the additional ethical complexities of conducting research during a pandemic and in conflict-affected environments.

3.7. Limitations of the Research Design and Thesis

This thesis has several methodological limitations that should be acknowledged. The reliance on cross-sectional surveys restricts the ability to infer causality, since the observed associations between psychological antecedents, knowledge, and vaccination behaviour capture relationships at a single point in time. Although instruments were harmonized across sites, full comparability was limited by contextual differences, including language, cultural framing, and survey administration modes (online versus hybrid approaches), which may have introduced subtle measurement biases.

The generalizability of findings is also constrained by several methodological and contextual factors. Sampling was non-probability-based, and although sample sizes were large, they may not fully represent the broader populations. Online recruitment in Ukraine may have excluded students without reliable internet access, while the paper-based approach used in Ghana and Syria reflected local feasibility but introduced logistical limitations. In Syria in particular, conflict-related displacement likely excluded some of the most vulnerable student groups. Furthermore, the marked socio-political differences across Ghana, Ukraine, and Syria complicate direct cross-country comparison. Even with careful translation, conceptual constructs such as “confidence” and “collective responsibility” may not have been interpreted in precisely the same way across contexts.

Despite these limitations, the thesis demonstrates important strengths. The use of the validated 5C framework provided theoretical robustness and international comparability, while the large sample sizes across all four studies enhanced the reliability of both descriptive and inferential analyses. The combination of adult and student populations in Ghana, alongside student cohorts in Ukraine and Syria, allowed for nuanced within-country and cross-country insights.

Taken together, the cumulative thesis is strengthened by its comparative scope, empirical breadth, and theoretical grounding. By bringing together evidence from sub-Saharan Africa, Eastern Europe, and the Middle East during the COVID-19 pandemic, it offers rare cross-national perspectives on vaccine hesitancy. The findings contribute not only to understanding the knowledge–behaviour gap but also to designing more context-sensitive strategies for improving vaccine uptake in resource-constrained and conflict-affected settings. At the same time, the limitations highlight the need for future longitudinal and probability-based studies to validate and extend these insights beyond the COVID-19 context.

CHAPTER FOUR

4. PRESENTATION OF PUBLICATIONS

4.1. Roll Call of Publications

4.1.1. Informed yet Unvaccinated: Investigating COVID-19 Vaccine Hesitancy among Syrian University Students

Publication: Razouk, A., Skotzke, P., Abdin, A. Y., **Yeboah, P**., et al. (2025). Informed yet Unvaccinated: Investigating COVID-19 Vaccine Hesitancy among Syrian University Students using the 5C framework. COVID, 5(9), 159. https://doi.org/10.3390/covid5090159

Peer-reviewed, open access, indexed in Scopus and Web of Science.

4.1.2. Hesitant Minds in Vulnerable Times: COVID-19 Vaccine Hesitancy among University Students in Ukraine

Publication: **Yeboah, P**., et al. (2025). Hesitant Minds in Vulnerable Times: COVID-19 Vaccine Hesitancy among University Students in Ukraine. COVID, 5(8), 122. https://doi.org/10.3390/covid5080122

Peer-reviewed, open access, indexed in Scopus and Web of Science.

4.1.3. Informed but Unvaccinated: A Cross-Sectional Study among University Students in Ghana

Publication: **Yeboah, P**., et al. (2025). Informed but Unvaccinated: A Cross-Sectional Study among University Students in Ghana. COVID, 5(4), 47. https://doi.org/10.3390/covid5040047

Peer-reviewed, open access, indexed in Scopus and Web of Science.

4.1.4. Knowledge into the Practice against COVID-19: A Cross-Sectional Study from Ghana

Publication: **Yeboah, P**., et al. (2021). Knowledge into the Practice against COVID-19: A Cross-Sectional Study from Ghana. International Journal of Environmental Research and Public Health, 18(24), 12902. https://doi.org/10.3390/ijerph182412902

Peer-reviewed, open access, IF 4.6 (2021), indexed in PubMed, Scopus, and Web of Science.

In three out of the four publications, I served as the first and lead author, responsible for study conception, design, data collection, analysis, and manuscript drafting. My co-authors contributed methodological expertise, contextual insights, and critical feedback throughout the research process.

4.2. Synthesis of Publications

The four peer-reviewed articles presented in this thesis collectively trace a coherent research trajectory on VH and VB. Beginning with the Ghanaian general population, the work identified a persistent knowledge–behaviour gap, where adequate awareness of COVID-19 did not translate into preventive practices or vaccine willingness [359]. The subsequent study of Ghanaian university students confirmed that this gap persisted among the highly educated and demonstrated the importance of psychological antecedents in explaining behaviour [99]. Extending the analysis to Ukraine revealed that similar dynamics were evident in a conflict-affected European setting, though intensified by distrust, ideological divisions, and misinformation [360]. The final study of Syrian university students provided rare evidence from a protracted conflict environment, showing how institutional fragility and disciplinary background shaped vaccine acceptance, with medical students more receptive than their non-medical peers [361].

Synthesised across contexts, the studies converge on three key insights. Firstly, confidence in vaccine safety and institutions consistently predicted acceptance, while exposure to misinformation undermined trust and fuelled hesitancy, reflecting wider global patterns reported

in WHO and UNICEF confidence monitoring [362,363]. Secondly, collective responsibility emerged as a recurring motivator, particularly among student populations, suggesting that prosocial framing and peer norms can be powerful pivot for Vaccine acceptance. Thirdly, contextual differences shaped how hesitancy manifested: in Ghana, concerns about novelty and safety combined with youthful complacency; in Ukraine, active refusal was often ideological, rooted in political distrust and conspiracy beliefs [364]; and in Syria, conflict-driven fragility amplified institutional distrust and widened the gap between medical and non-medical students.

Collectively, the four articles show that while the psychological antecedents of vaccination are broadly consistent, their relative weight and expression are strongly context dependent. The cumulative evidence underscores that VH cannot be explained by knowledge deficits alone but must be understood as a behavioural phenomenon shaped by trust, responsibility, and the socio-political environment [227,259]. This synthesis provides the empirical foundation for the theoretical, methodological, and policy implications discussed in the following chapter.

CHAPTER FIVE

5. DISCUSSION

These investigations provide a cross-national lens on VH, illustrating that it is not confined to any single region or income level but is instead a multifaceted global phenomenon. The collective findings underscore that VH cannot be understood as a simple deficit of knowledge. Across all settings, knowledge of COVID-19 and vaccines were relatively high, yet preventive practices and vaccine acceptance lagged behind. This persistent "knowledge–preventive behaviour gap" reflects a deeper interplay of psychological, social, and structural factors. The studies reveal how trust in institutions, exposure to misinformation, political instability, and cultural contexts influence the 5C psychological antecedents (confidence, complacency, constraints, calculation, and collective responsibility) in ways that shaped VB.

Importantly, the cross-country comparison shows both convergence and divergence. Similarities, such as the central role of confidence and collective responsibility, point to universal behavioural drivers of vaccine acceptance. Differences, such as the amplification of constraints in conflict-affected Ukraine and Syria or the limited role of religion in Ghana, highlight the need for context-sensitive strategies. These findings align with recent global evidence showing that trust erosion, politicization, and structural fragility consistently undermine vaccination uptake, even where biomedical knowledge is widespread [365–367]. This chapter therefore moves beyond individual study results to interpret their broader meaning. It situates the findings within established behavioural theories, examines their implications for policy and practice, the complexities of socio-political context, and reflects on the surprises that complicate conventional assumptions about vaccine decision-making.

5.1. Cross-Cutting Patterns of Vaccine Hesitancy

The four studies point to VH as a shared behavioural challenge that is only partially explained by knowledge. Across Ghana, Ukraine, and Syria studies, a recurring pattern of a knowledge–preventive behaviour gap is observed**.** Interpreting this gap through a behavioural lens suggests three intersecting drivers. Firstly, trust and institutional credibility; where confidence in authorities, health systems, and information sources is weak, the perceived benefits of vaccination

are discounted and the costs (real or imagined) appear larger. Cross-national evidence shows that lower trust in government reliably predicts greater hesitancy, even after adjusting for education and income, which helps explain similar scepticism among university students despite high information access (a hallmark of the "informed sceptic") [368–370].

Secondly, structural and situational constraints**:** conflict, displacement, service disruption, and economic stress, especially prominent in Ukraine and Syria, raise the practical costs of vaccination (i.e., time, travel, safety, continuity of services). Under such pressures, even moderate doubts can tip decisions toward vaccination delay or refusal. Recent global tracking shows how conflict and fragility impede routine immunisation recovery and widen gaps in coverage, reinforcing the role of constraints beyond individual attitudes [371]. Thirdly, social norms and identity dynamics: collective responsibility consistently aligned with greater acceptance in student samples, indicating that prosocial norms remain potent drivers. Yet where political polarisation or contested authorities shape identity, the same social forces can pivot against vaccination. Global surveys during and after the pandemic document declines in vaccine confidence, especially among younger adults, consistent with the student findings from all study countries and with a climate where polarised narratives and online misinformation erode normative consensus [372–374].

Within this triad (i.e., trust/credibility, constraints, and social norms/identity), these dynamics align with and extend established theoretical frameworks. The 5C antecedents, especially confidence**,** constraints**,** and collective responsibility, emerge as the most policy-relevant drivers across all three countries. This aligns with global evidence showing that confidence/trust and barriers/convenience outperform knowledge as predictors of uptake, while also explaining why informational campaigns alone underperform when institutions are contested or logistics are strained [375]. Two comparative insights follow which converge and diverge in different situations. Despite divergent contexts, the same three antecedents repeatedly structure behaviour, suggesting broad applicable intervention targets such as trust-building, barrier reduction, and prosocial framing. The weights on these antecedents are context-sensitive, constraints dominate where health services are disrupted; identity and polarisation weigh more in politicised settings; and among students, calculation (information scanning) can drift into indecision when information signals are confusing. Broader datasets echo these patterns, for example, confidence dipped in a majority of countries post-2020; booster intent fell in many

settings in 2023; and acceptance in LMICs, while often high, still hinges on trusted messengers and barrier-reducing delivery [250].

Unexpected patterns warrant interpretation rather than mere restatement. The finding that complacency distinguishes passive hesitancy from active refusal, for example, suggests that certain subgroups may be more responsive to reduced structural constraints than intensive persuasion efforts. This distinction is particularly relevant for prioritising and tailoring strategies to population segments. Similarly, the association of calculation with greater reluctance in volatile information environments suggests that increased information seeking does not necessarily foster reassurance. In such contexts, the critical intervention target is not message volume but rather the credibility, clarity, and consistency of available information. These specificities are consistent with WHO/SAGE guidance that hesitancy determinants span contextual, individual, and vaccine-specific domains [376]. Hence diagnosis should precede design, and solutions must be tailored to the dominant drivers in each setting.

5.2. Contextual Influences

The comparative dimension of this thesis demonstrates how socio-political contexts shape the significance of psychological antecedents. In Ghana, a history of successful immunisation campaigns has created a cultural baseline of vaccine familiarity [377]. Yet COVID-19 vaccines were uniquely vulnerable to scepticism, amplified by rumours of experimentation and population targeting [378]. Among the general population, radio, community leaders, and religious authorities shaped perceptions, while university students were more strongly influenced by peers and social media [377,378]. These same channels, if strategically harnessed, hold potential as corrective vaccination platforms. Collectively, the Ghanaian findings concord with broader sub-Saharan African trends. A scoping review by Agbozo et al. (2023) reported wide variation in COVID-19 vaccine acceptance across African countries, ranging from 15.5% in Cameroon to 97.9% in Ethiopia. HPV vaccine acceptance was notably lower, with estimates between 6.9% in Nigeria and 39.8% in South Africa [379,380]. These disparities highlight the importance of context in shaping VB and reinforce the argument that acceptance cannot be understood in isolation from socio-political and cultural environments.

By contrast, Ukraine and Syria illustrate how unstable political contexts and conflict exacerbate hesitancy. Both settings were marked by systemic distrust and deliberate disinformation [360] In Ukraine, students who engaged with official information channels were more likely to vaccinate, while reliance on unofficial or conspiracy-based sources predicted resistance. In Syria, mistrust was compounded by fragmented governance and conflict-related narratives, with hesitancy particularly pronounced among non-medical students. These patterns demonstrate how war and political instability magnify the effects of misinformation, further eroding confidence and weakening collective responsibility [361].

The contextual contrasts highlight the necessity of tailoring interventions. In Ghana, messaging must focus on safety reassurance, addressing rumours, and leveraging trusted community leaders. In Ukraine, efforts should prioritise depoliticised peer-led channels and partnerships with neutral international actors to counter institutional distrust. In Syria, strategies must engage both academic and community settings, differentiating between medical and non-medical students, and strengthening health literacy in conditions of limited institutional credibility. The broader implication is that while core determinants of hesitancy (confidence, misinformation, and collective responsibility) appear universally relevant, their influence is contingent on local narratives, traditions, and political realities. Effective responses therefore require both global frameworks and deep contextual adaptation [381].

5.3. Contributions to Social Behaviour

The cumulative evidence demonstrate that vaccine hesitancy is shaped not only by psychological antecedents but also by social identities and cultural dynamics which vary across contexts. Gendered differences in vaccine acceptance, such as those evident in Ukraine, reflect broader public health patterns where men often perceived lower susceptibility to health risks and show reduced engagement with preventive behaviours [360,382]. In Ghana, variations across regional and ethnic lines emphasise the importance of culturally embedded trust networks, where chiefs, religious leaders, and community figures act as critical intermediaries of health information and influence vaccination norms [377]. Similarly, in Syria, differences between medical and non-medical students illustrate how disciplinary training and exposure to scientific knowledge may

buffer against hesitancy, reinforcing the role of professional identity in shaping risk interpretation [361].

These patterns collectively demonstrate that vaccine decisions are mediated by social identity, whether defined by gender, ethnicity, or academic training. Such dynamics underscore the need for targeted, context-specific interventions rather than uniform messaging. Gender-sensitive strategies in Ukraine, culturally grounded approaches in Ghana, and discipline-specific programming in Syrian universities exemplify how tailoring communication and engagement can foster acceptance. More broadly, the findings reveal that social belonging mediates trust in authority and shapes behavioural responses to vaccination. Addressing these dynamics is essential for interventions that resonate across diverse populations and for strengthening the legitimacy of public health systems in both stable and instability settings.

5.4. Theoretical Contributions

The cumulative evidence affirms the utility of the 5C model of psychological antecedents while also suggesting areas of refinements. Across diverse contexts, confidence, constraints, calculation, and collective responsibility consistently structured vaccine attitudes and behaviours, demonstrating the cross-cultural robustness of these dimensions [259,383,384]. Complacency, however, appeared to have limited explanatory power in crisis settings, where the urgency of disease threat and instability overshadowed perceptions of risk. This observation poses theoretical questions about whether all five antecedents retain equal relevance under acute public health emergencies, and whether a context-adapted “4C” framework may better capture behavioural dynamics in such conditions.

The findings also reveal the interdependence of individual-level and contextual determinants. Confidence, for instance, was not solely a matter of personal trust but was deeply conditioned by historical experiences with governance, institutional credibility, and patterns of health communication. This aligns with the WHO SAGE determinants framework, which emphasises the contextual embedding of individual decision-making. Similarly, the persistence of the knowledge–behaviour gap in Ghana supports theories such as the HBM, which stresses the

essence of perceived barriers and cues to action over knowledge alone [385] and with the TPB, which points the role of subjective norms in shaping compliance [194].

A further theoretical contribution lies in differentiating between ambivalence and active refusal. Many individuals across contexts did not fall clearly into "acceptant" or "resistant" categories but occupied intermediate states of contemplation or indecision [386]. This has significant theoretical implications, as recognising this spectrum challenges the tendency to treat hesitancy as homogeneous and calls for models that account for gradations of reluctance. Recent studies covering types of vaccine hesitancy, such as the segmentation of hesitant populations into "the watchful" and "the system distrusters" [387] align with this thesis's findings and offer a more granular lens for intervention design.

Collectively, these contributions suggest that existing behavioural frameworks remain highly relevant but require refinement to capture context-sensitivity, the interaction of structural and individual determinants, and the heterogeneity of hesitant populations. By integrating the 5C model with complementary frameworks such as HBM, TPB, and the SAGE matrix, this thesis advances a more comprehensive theoretical approach to understanding vaccine decision-making across both stable and unstable contexts.

5.5. Policy and Practical Implications

A central implication of this thesis affirms the notion that knowledge-oriented campaigns, though necessary, are insufficient to shift vaccination behaviour. The persistence of hesitancy despite widespread awareness demonstrates that interventions must address trust deficits, structural barriers, and social norms if they are to achieve sustainable impact.

From a practical standpoint, the findings point to several strategies for enhancing vaccine acceptance, with three areas emerging as priorities. Firstly, building trust and transparency is paramount. Communication on vaccine development, safety monitoring, and adverse events, must be clear, open, and contextualized in ways that relates locally. Relatable statistics, peer voices, and trusted figures provide credibility where official messaging alone may falter. Evidence from

behavioural science supports the use of inoculation theory, where pre-emptive exposure to misinformation alongside refutations can increase resilience to conspiracy narratives [388]. Secondly, structural and logistical constraints require systematic reduction. Expanding access through mobile clinics, workplace and university-based delivery, extended clinic hours, and integration into community hubs can normalise vaccination and reduce opportunity costs. In unstable settings, embedding vaccination within emergency assistance frameworks and relying on neutral international partners, such as the WHO or Red Cross, can both extend reach and strengthen credibility. Targeted incentives, whether transport subsidies, food packages, or data bundles, can further ease barriers for younger populations and students without undermining voluntariness.

Thirdly, framing vaccination as a collective responsibility remains a powerful behavioural mechanism. Campaigns that emphasise protection of peers, families, and communities can activate prosocial motivations and counteract individual hesitancy. Publicising coverage rates within peer groups or embedding vaccination drives in social and academic events reinforces social norms and positions acceptance as the expected behaviour. Community vaccination events integrated with social gatherings can also reinforce collective responsibility via publicizing high acceptance rates among valued peer groups (e.g., "70% of final-year students vaccinated"). Differentiated strategies are critical: appeals to personal vulnerability may resonate with those who are complacent, while empathetic engagement is essential for individuals whose hesitancy is rooted in distrust. Finally, tailoring interventions to specific social groups is indispensable. Student populations, for example, represent both a high-risk group for hesitancy and a future generation of influencers. University-based health literacy programmes, peer-led campaigns, and youth-driven social media content are particularly well placed to reshape norms in this demographic.

These practical implications extend beyond COVID-19. Routine immunization programmes encounter similar psychological and structural barriers, meaning that investments in school-based health literacy, digital media resilience, and sustained community engagement are vital to safeguard broader vaccination agendas. Collectively, these strategies point toward a multi-layered approach that integrates trust-building, accessibility, and social norm reinforcement. Such integration is essential to address vaccine hesitancy more effectively in both stable and fragile

contexts. These Suggested interventions capable of leading to actionable positive vaccination behaviour are summarized in Figure 3.

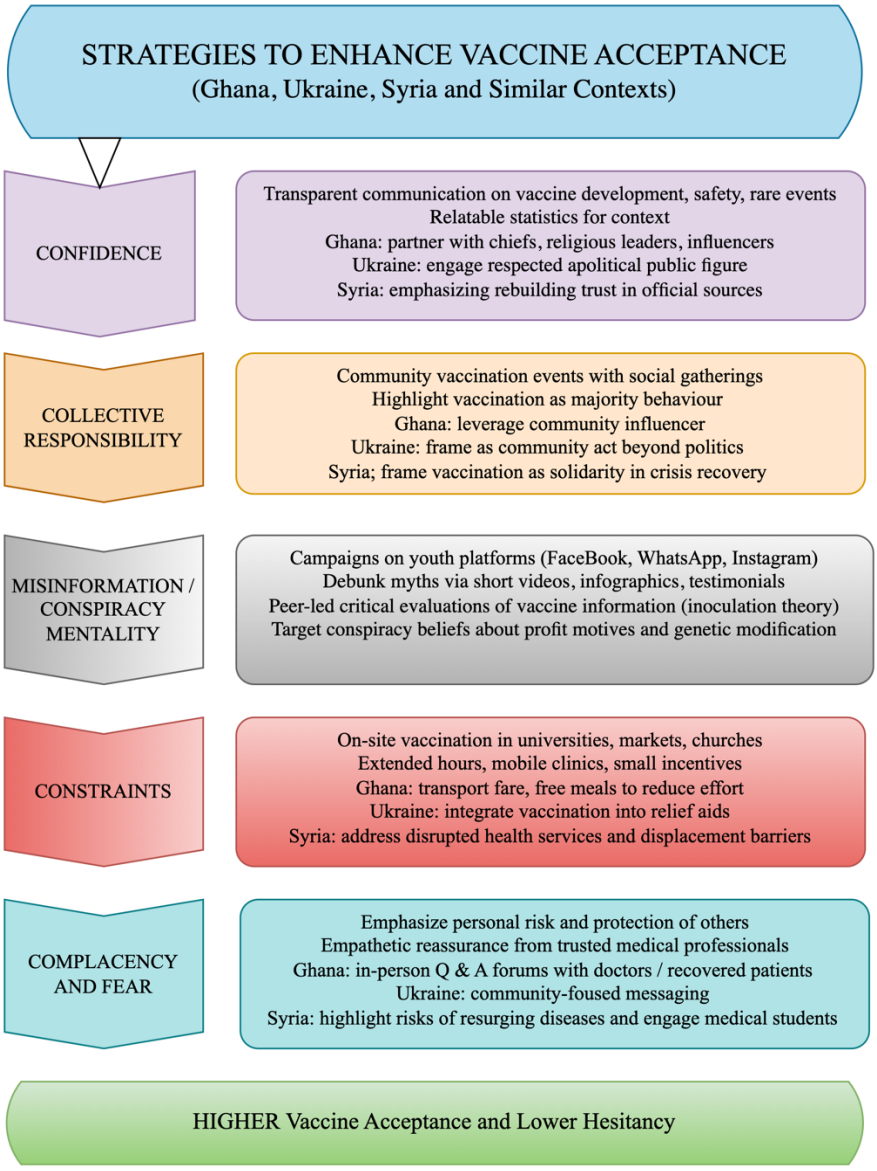

Figure 3. Infographic of evidence-based strategies to enhance vaccine acceptance in Ghana, Ukraine, Syria, and comparable contexts.

Eventually, the findings presented in this thesis provide actionable insights for policy and practice. The thematic synthesis mitigates this, integrated modelling of country-context interactions remains a future research opportunity. Future research should build on this foundation

through longitudinal designs, triangulation with verified vaccination records, and broader application beyond COVID-19 to encompass other immunisation priorities.

CHAPTER SIX

6. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

6.1. Conclusions

This study has examined vaccine hesitancy through the lens of four cross-sectional studies conducted in Ghana, Ukraine, and Syria, spanning diverse socio-political and cultural contexts. Collectively, the evidence demonstrates that vaccine hesitancy is not simply a consequence of inadequate knowledge, but a multidimensional behavioural phenomenon shaped by psychological antecedents, social identities, and structural realities. Across diverse contexts - sub-Saharan Africa (Ghana), Eastern Europe (Ukraine), and the Middle East (Syria), this thesis demonstrates a consistent paradox: knowledge about infectious diseases and vaccines, though widespread, is not sufficient to ensure acceptance. In each setting, hesitancy persisted despite high knowledge, revealing that vaccine decision-making is shaped as much by psychology, trust, and context as by factual information.

The cross-national application of the 5C model underscores its explanatory strength and flexibility. Confidence in vaccine safety and institutions repeatedly emerged as the most influential driver of acceptance, while collective responsibility highlighted the importance of social norms. Structural and psychological constraints operated as persistent barriers, while complacency and calculation exerted variable influence, sometimes tempering resistance, at others amplifying scepticism in environments saturated with conflicting information. These studies collectively confirm that VH is inherently contextual. Its drivers differ across political, cultural, and economic environments, yet the underlying behavioural mechanisms show broad universality. This interplay of local variation within global consistency explains why interventions must be both evidence-based and context-sensitive.

The policy implications are clear: effective vaccination strategies cannot rely on knowledge dissemination alone. They must address the human factors that govern compliance: trust, identity, accessibility, and social responsibility. Strengthening immunization systems therefore requires transparent communication, participatory community engagement, and interventions designed to address both structural constraints and socio-cultural realities. Ultimately, vaccination is not only a scientific achievement, but also a behavioural challenge. Bridging the gap between knowledge

and action demands sustained investment in the social fabric in which vaccines are received. Only by embedding trust, convenience, and collective responsibility into routine immunization and crises response, can societies unlock the full life-saving potential of vaccines and strengthen preparedness against future public health emergencies.

6.2. Future Research Directions

Despite the contributions of this thesis, further research is required to deepen understanding of VH and to strengthen the evidence base for effective interventions across diverse contexts. Firstly, longitudinal studies, in which same individuals/groups are observed repeatedly over time, are urgently needed to track how psychological antecedents such as confidence, constraints, and collective responsibility evolve over time and influence vaccination outcomes. Longitudinal designs are particularly valuable in unstable environments, where shifting political and conflict dynamics may reshape trust and attitudes, thereby predicting acceptance or refusal months or even years later [321]

Secondly, mixed-methods research should complement large-scale quantitative surveys with qualitative depth to explore the cultural explanations and contextual dynamics that numbers alone cannot reveal. For instance, In-depth interviews and focus groups could illuminate the role of institutional credibility, community authority structures, or disciplinary training in shaping vaccine behaviour. Such perspectives provide essential nuance for interpreting statistical patterns and designing culturally sensitive interventions.

Thirdly, future research must systematically examine the digital dimensions of the infodemic. Evidence shows that misinformation on social media undermines vaccine confidence, mental health, and healthcare decisions [389,390]. Comparative digital studies across regions could assess how algorithm exposure, digital literacy, and the effectiveness of counter-messaging strategies differ, and which approaches most effectively enhance resilience against misinformation. Fourthly, integrative modelling should align individual-level psychological frameworks with structural perspectives. While the 5C model captures behavioural antecedents, it omits systemic factors such as supply chain disruptions or weak health infrastructures. Combining

the 5C psychological model with the WHO SAGE determinants matrix would provide a more holistic account of hesitancy, integrating psychological and contextual barriers [391].

Eventually, translational and applied intervention research is required to move beyond theoretical insight toward practical solutions. Pilot programmes and controlled trials testing peer-led confidence campaigns, university-based health literacy initiatives, mobile vaccination services, or digital literacy interventions should not only measure effectiveness but also assess feasibility, scalability, and sustainability across health systems. Here, approaches drawn from knowledge translation research, and real-world programme evaluation can help ensure that strategies proven effective in one setting can be adapted and sustained in others. Early evidence already suggests that media literacy interventions reduce vulnerability to misinformation but systematic testing in fragile contexts remains a crucial next step [392].

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8. PERSONAL RESUME

PRINCE YEBOAH

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EDUCATION

PhD Student November, 2018 - Present

School of Pharmacy, Saarland University, Saarbruecken, Germany

Title: Public Health at a Crossroad: Vaccine Hesitancy and the Knowledge–Behaviour Gap among University Students across Diverse Contexts

Master of Philosophy | MPhil May, 2016

Department of Pharmaceutical Chemistry, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Title: The use of surrogate reference standards in quantitative HPLC; a case study of the analysis of Amlodipine and Lisinopril tablets

Bachelor of Pharmacy | BPharm June, 2012

Faculty of Pharmacy, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

RESEARCH INTERESTS

Infectious Diseases Epidemiology, Social Epidemiology, Pharmacoepidemiology, and Vaccinology.

RESEARCH EXPERIENCE

PhD | Student Investigator November, 2018 – Present

Unit Pharmasophy, School of Pharmacy, Department of Bioorganic Chemistry, Saarland University, Germany

- Designed cross-sectional studies on various public health topics and performed statistical analyses (linear and multiple logistic regression models) using R.
- Collected field survey data using self-designed and validated research questionnaires.
- Conducted various literature reviews including narrative, integrative and systematic literature reviews.

- Undertook extensive literature reviews in multiple peer-reviewed journals on various research topics and developed manuscripts.
- Collaborated with colleagues and other researchers across different disciplines on diverse public health research projects.
- Authored and contributed to publications in peer-viewed public health journals.

Graduate Student | Research Assistant September, 2013 – May, 2016

Department of Pharmaceutical Chemistry, Kwame Nkrumah University of Science and Technology, Ghana

- Conducted comprehensive literature reviews, analysed data, and wrote a thesis evaluating the use of surrogate reference standards in quantitative HPLC.
- Performed literature searches in multiple peer-reviewed journals, conducted laboratory experiments and developed a dissertation for a master of philosophy degree in pharmaceutical chemistry.
- Taught undergraduate level classes on pharmaceutical chemistry and guided students to develop appropriate research questions and study designs.

Graduate and Undergraduate Intern July – September, 2015; June – August, 2010

Institute for Pharmacy, University of Leipzig; Institute for Pharmacy, Martin Luther University, Halle, Germany

- Assisted PhD students with drug discovery laboratory tasks such as reagent preparation and review of protocols.
- Performed mini projects and reported research outcomes on synthesis of active biological agents.

PROFESSIONAL EXPERIENCE

Staff Support | volunteer March, 2021 – November, 2022 Department of Pharmacy Practice, Kwame Nkrumah University of Science and Technology, Kumasi

- Supported lecturers in general oversight of clinical trainings, tutored and aided undergraduate students.
- Facilitated discussions, group projects, and assessed student performance using exams, assignments, and presentations.
- Provided guidance on designing research projects or protocols to graduate and undergraduate students.
- Involved in collecting and analysing data, and interpreting findings for graduate and undergraduate students.

TECHNICAL SKILLS

- Programming languages and Statistical Packages: R- RStudio, SPSS, SQL, GraphPad, Tableau
- Microsoft Office suite: Excel / Spreadsheet
- Windows OS, Mac OS
- Data analytics

9. LIST OF PUBLICATIONS

Number of citations: 232 and H-index: 4, according to Google Scholar September 2025. First publication: 2020.

1. Razouk, A.; Skotzke, P.; Abdin, A.Y.; **Yeboah, P**.; Pitsch, W.; Wakkaf, M.; El-kour, T.; Rajab, M.; Nasim, M.J.; Jouma, M.; et al. Informed Yet Unvaccinated: Investigating COVID-19 Vaccine Hesitancy Among Syrian University Students Using the 5C Framework. *COVID* 2025,*5*, 159. https://doi.org/10.3390/covid5090159

2. **Yeboah, P**.; Razouk, A.; Skotzke, P.; Pitsch, W.; Chubuchna, O.; Serhiyenko, V.; Slyvka, N.; Holota, S.; Nasim, M.J.; Abdin, A.Y.; et al. Hesitant Minds in Vulnerable Times: COVID-19 Vaccine Hesitancy Among University Students in Ukraine. COVID 2025, 5, 122. https://doi.org/10.3390/covid5080122

3. **Yeboah, P**.; Abdin, A.Y.; Gyasi, T.O.; Anyimiah, P.; Osafo, N.; Skotzke, P.; Pitsch, W.; Brobbey, M.O.; Panyin, A.B.; Razouk, A.; et al. Informed but Unvaccinated: A Cross-Sectional Study Among University Students in Ghana. COVID 2025, 5, 47. https://doi.org/10.3390/covid5040047

4. **Yeboah, P**., Daliri, D. B., Abdin, A. Y., Appiah-Brempong, E., Pitsch, W., Panyin, A. B., Adusei, E. B. A., et al. (2021). Knowledge into the Practice against COVID-19: A Cross-Sectional Study from Ghana. International Journal of Environmental Research and Public Health, 18(24), 12902. MDPI AG. Retrieved from http://dx.doi.org/10.3390/ijerph182412902

5. Razouk, A., Abdin, A. Y., **Yeboah, P**., Pitsch, W., Nasim, M. J., Maarouf, M., Jacob, C. (2021, October). Corona in the Time of War: A Cross-Sectional Study from Syria. Paper presented at the UNESCO Social Sciences and the COVID-19 Pandemic – State of Knowledge and Proposals for Action, Paris, France. UNESCO Digital Library {https://unesdoc.unesco.org/ark:/48223/pf0000379455}

6. Alnahas, F., **Yeboah, P**., Fliedel, L., Abdin, A. Y., & Alhareth, K. (2020). Expired Medication: Societal, Regulatory and Ethical Aspects of a Wasted Opportunity. International Journal of Environmental Research and Public Health, 17(3), 787. https://doi.org/10.3390/ijerph17030787

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8. Abdin, A. Y., **Yeboah, P**., & Jacob, C. (2020). Chemical Impurities: An Epistemological Riddle with Serious Side Effects. International Journal of Environmental Research and Public Health, 17(3), 1030. https://doi.org/10.3390/ijerph17031030

9. **Yeboah, P**. (2016). The use of surrogate reference standards in quantitative HPLC; a case study of the analysis of Amlodipine and Lisinopril tablets (Corpus ID: 78554434) Master's thesis, Kwame Nkrumah University of Science and Technology. URL= {https://api.semanticscholar.org/CorpusID:78554434

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Informed Yet Unvaccinated: Investigating COVID-19 Vaccine Hesitancy Among Syrian University Students Using the 5C Framework

Afraa Razouk, Philip Skotzke, Ahmad Yaman Abdin, Prince Yeboah, Werner Pitsch, Modar Wakkaf, Tatyana El-kour, Mazen Rajab, Muhammad Jawad Nasim, Mouhiadien Jouma et al.

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Informed Yet Unvaccinated: Investigating COVID-19 Vaccine Hesitancy Among Syrian University Students Using the 5C Framework

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Abstract

Background: Vaccine hesitancy (VH) remains a pressing global health concern, particularly in low-resource settings, where vaccination remains the primary means of protection against infection. The urgency of this issue became evident during the COVID-19 pandemic. The present study aimed to elucidate the determinants of vaccine hesitancy among university students in medical and non-medical fields in Syria by utilizing the 5C framework (confidence, complacency, constraints, calculation, and collective responsibility). Methods: A structured interview-administered questionnaire collected responses from 4722 students at five universities in Syria. The questionnaire assessed sociodemographic factors, COVID-19 vaccination status, vaccination experience, sources of information, beliefs in vaccine-related conspiracies, attitudes toward vaccine policies and attributes, and the 5C psychological antecedents. Internal consistency and factor analysis of the Arabic 5C scale were performed to ensure construct validity. Statistical analyses included descriptive statistics, logistic regression, and multivariate multiple regression. Results: Our findings revealed that 64% of participants had not received the COVID-19 vaccine, with official sources (e.g., WHO, Ministry of Health) being the most trusted. The highest 5C score was for calculation (5.86, sd = 1.21), followed by confidence (5.29, sd = 1.26). Belief in vaccine conspiracies was common, particularly regarding profit motives and genetic modification. Only three of the 5C—complacency, calculation, and collective responsibility—significantly, predicted vaccination behavior, while all the 5C were influenced by contextual factors. Non-medical students showed significantly higher hesitancy (OR = 1.60, 95% CI [1.39–1.84, $p < 0.001$]) compared to their medical counterparts. Hesitant respondents displayed significantly, higher complacency, increased calculation, and reduced collective responsibility scores. Conspiracy beliefs eroded confidence and magnified perceived barriers, whereas trust in official sources and favorable views of the vaccine's attributes strengthened collective responsibility and acceptance. The regression models explained 2.8% to 11.2% of variance across the 5C, with collective responsibility showing the highest explanatory power (adjusted R^2 = 0.112). Conclusions: Despite high self-reported knowledge, significant

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VH persisted—a paradox that highlights the limits of information alone. Given the cross-sectional design and the modest explanatory power of the models, these recommendations are tentative. These findings highlight the need for trust-based interventions targeting populations in conflict-affected areas.

Keywords: COVID-19 vaccine hesitancy; 5C psychological model; conflict-affected settings; conspiracy beliefs; information sources; public health interventions

1. Introduction

Vaccination serves as one of the most vital and successful health approaches used to combat serious infectious diseases and stop their spread worldwide as a preventive measure [1]. However, the World Health Organization has acknowledged that one of the top ten significant global health obstacles undermining immunization efforts—especially in areas facing complex crises—is vaccine hesitancy (VH) [2]. Studies have confirmed the role of VH as an obstacle in the fight against the outbreaks of infectious diseases [3–6]. International attention to this problem has intensified after the COVID-19 pandemic in 2019, where people's reluctance to take the available vaccines resulted in a noticeable increase in fatality rates [7].

While VH is a global issue, it presents unique risks in conflict-affected settings like Syria, where systemic health failures intersect with social distrust [8]. Syria offers a particularly compelling case for studying people's reluctance toward vaccines, due to its dramatic change from a previously strong healthcare system to one facing unprecedented challenges [9–13]. Syria's healthcare situation has undergone a profound deterioration over the past decade and a half. Before 2011, the country's pharmaceutical industry was able to meet national needs [14]. This capacity has fallen sharply to less than 10%, severely affecting the availability and affordability of medicines. The war that started after the Syrian revolution and the destruction of most health sector facilities have made the country unable to deal with infectious diseases [14]. Moreover, the forced displacement of people and healthcare workers from major cities such as Aleppo, Hama, Deir ez-Zor, and Homs has caused a severe shortage of trained staff necessary for effective vaccination and health education programs [9,15,16].

During the COVID-19 pandemic in 2021 and the conflict in Syria, the governance of vaccination was fragmented. In government-controlled areas such as Damascus, Aleppo, Hama, Lattakia, and Homs, which also received internal migration from other governorates, the Ministry of Health coordinated campaigns with WHO and UNICEF [17,18]. In opposition-held areas, local health directorates, NGOs, and international partners played central roles. This fragmentation complicated trust in authorities, which varied regionally [17]. Consequently, this structural collapse means that even routine vaccination campaigns now face extraordinary logistical and personnel shortages.

The economic impact of the conflict and sanctions has been severe, as the country went through complete economic collapse for years. These economic pressures have forced the population below the poverty line, directly affecting access to healthcare and the ability to afford vaccines [19]. Above all these challenges, in February 2023 an earthquake affected the entire country, especially the already devastated and isolated northern regions (Aleppo, Idlib, AL Raqqa, Deir Al Zour, and others). This disaster further damaged the collapsed healthcare system and also killed over 50 healthcare providers, triggering a public health crisis [20–22]. These combined factors have led to a fragile health system that cannot bear the additional burden of VH, which remains the only available method to stop a disease if it

spreads throughout the country [23,24]. This was clearly highlighted by the United Nations in recent analyses emphasizing Syria's ongoing transition challenges and the critical need for strengthening the Syrian health sector [24].

Recent surveillance information reveals the consequences of these disruptions, with the reappearance of previously re-emerging infectious diseases and outbreaks, including acute watery diarrhea (AWD)/cholera, measles, and tuberculosis [25–28]. Additionally, between 2013 and 2024, Syria experienced a resurgence of polio after a long period without any reported cases [29–31]. Infant vaccination coverage in Syria has been substantially affected by the ongoing conflict. According to WHO and UNICEF estimates (2021 revision), coverage among children aged 12–23 months was around 91% for BCG, 91.7% for DTP1, 91% for DTP3, and 90.7% for HepB3. However, these national averages mask significant regional disparities, with war-affected areas experiencing considerably lower coverage due to disrupted health services, population displacement, and insecurity [32,33].

In 2021, the WHO-supported Early Warning, Alert, and Response System (EWARS) in Syria reported 158,912 consultations across the governorates for various infectious diseases. The most common morbidities were influenza-like illness (92,765 cases, 58.4%) and acute diarrhea (32,303 cases, 20.3%) [34]. Additional reported conditions included leishmaniasis (10,495 cases), severe acute respiratory infections (10,115 cases), and chickenpox (3597 cases). Furthermore, 77 suspected measles/rubella cases and 13 cases of acute flaccid paralysis were also reported, highlighting the re-emergence of vaccine-preventable diseases [34]. Despite having a network of more than 1200 health facilities in 14 governorates, the Syrian healthcare system continues to struggle to deliver services consistently. The COVID-19 pandemic has exposed these vulnerabilities more due to limited testing capacity and logistical challenges for vaccination. As the latest reported number for the COVID-19 vaccination rate in Syria was only 18.34% by March 2023 [35]. Such low coverage heightens the risk of variant emergence, threatening not only Syria but the wider Middle East and North Africa (MENA) region and other low- and middle-income countries (LMICs).

Social, religious, and cultural elements further complicate vaccine acceptance [4,36,37]. The spread of misinformation, social stigma, and beliefs—such as viewing disease as divine anger or vaccines as lethal—create additional barriers. Economic hardship compounds these attitudes by limiting access to basic preventive tools.

Considering these challenges, our 2021 survey—conducted during the most intense COVID-19 wave and before vaccines became available—assessed knowledge, attitudes, and practices among Syrians. Surprisingly, half of the 2860 well-educated respondents said they would decline a future COVID-19 vaccine [38]. While past investigations have mapped vaccine knowledge and attitudes in Syria, few have applied a validated psychological framework to reveal deeper drivers of hesitancy, particularly among educated groups. This unexpected level of VH among educated individuals showed a critical knowledge–behavior gap and underscores the need to identify the psychological antecedents of refusal.

To bridge this gap, our investigation focuses on university students from both medical and non-medical disciplines, future influential community voices. By exploring vaccine hesitancy in these educated groups, we seek to uncover the psychological, social, and contextual factors affecting VH even when information is accessible. Guided by the 5C model—confidence, complacency, constraints, calculation, and collective responsibility—we consider how prolonged economic hardship, a deteriorated healthcare system, and complex sociocultural norms uniquely shape each dimension in Syria [39]. As part of the 5C model's 'confidence' dimension, participants were specifically asked about their trust in vaccine safety, effectiveness, and whether the ministry makes decisions in the community's best interest to assess trust in health authorities during pandemics.

Findings from this work will equip health authorities and humanitarian organizations with culturally sensitive, peer-led, and trust-based strategies to enhance vaccine acceptance and strengthen public health recovery in Syria and other conflict-affected low- and middle-income countries.

2. Materials and Methods

2.1. Questionnaire

The standardized 52-item questionnaire consisted of three main sections to cover the purpose of the study and understand the reasons behind VH (available together with all other Supplementary Material on OSF: https://osf.io/ekmd8/, accessed on 16 September 2025). The first part covers the demographic data of the study participants, such as (age and gender, etc.). The second part covers information related to previous experiences with vaccines (e.g., COVID-19, polio, and tetanus, etc.) and questions to determine the impact of conspiracy mentality. The third part covers several sections, including (1) a section assessing the psychological factors influencing vaccination decisions, (2) a section studying the influence of the source of information on vaccination, (3) a section on the influence of the source or manufacturer of the vaccine, and (4) a section related to studying people's opinions about the compulsory travel document).

The section on assessing the psychological factors influencing the decision to vaccinate includes a translated version of a scale that covers the (5C): Confidence, trust in the effectiveness and safety of vaccines as well as trust in the procedures implemented by the governments and health authorities for vaccination [5], Complacency, which refers to not taking the disease seriously and therefore not vaccinating against it [39], Constraints, which relates to factors that may hinder the vaccination process, such as inability to afford the cost, availability of vaccines or geographical access to the place of vaccination [40], Calculation, which refers to the extent to which individuals seek information about the vaccine, which as a result of incorrect sources may lead to non-vaccination [41], Collective responsibility, which reflects the extent to which individuals are willing to protect others by vaccinating to reduce infection [41], adopted from Betsch et al. 2018 [39]. Each of the 5 C's was assessed with 3 questions. Responses were rated on a seven-point Likert-type scale, ranging from 1 (strongly disagree) to 7 (strongly agree). Average scores were calculated for the items within each sub-scale, with higher scores indicating a stronger level of agreement with the corresponding psychological factor. The calculation of a total score does not reflect an absolute state of the sample's indecision towards vaccines but allows the 5C scale to be used to give an assessment of the psychological factors that influence the decision to vaccinate.

The remaining parts of the questionnaire include the sources of information used to find information about vaccines, whether official or unofficial. In addition to three questions about the extent to which the source of the vaccine or the manufacturer influences the decision to vaccinate, responses are measured on a seven-point Likert-type ascending scale, where 1 represents "No influence at all" and 7 "Strong influence".

Finally, the last part includes two questions regarding the extent to which Syrians accept the imposition of the mandatory travel document 24 h before the flight, which consists of a PCR test exclusively at centers approved by the Ministry of Health. Note that although the questionnaire included 51 items, only data related to 45 items were processed and presented in this study.

2.2. Study Design and Sampling

For data collection, interviews were conducted in five universities located in four different Syrian governorates: Damascus University, Aleppo University, Hama Univer-

sity, International University for Science and Technology (IUST), and Arab International University (AIU), as shown in Figure 1.

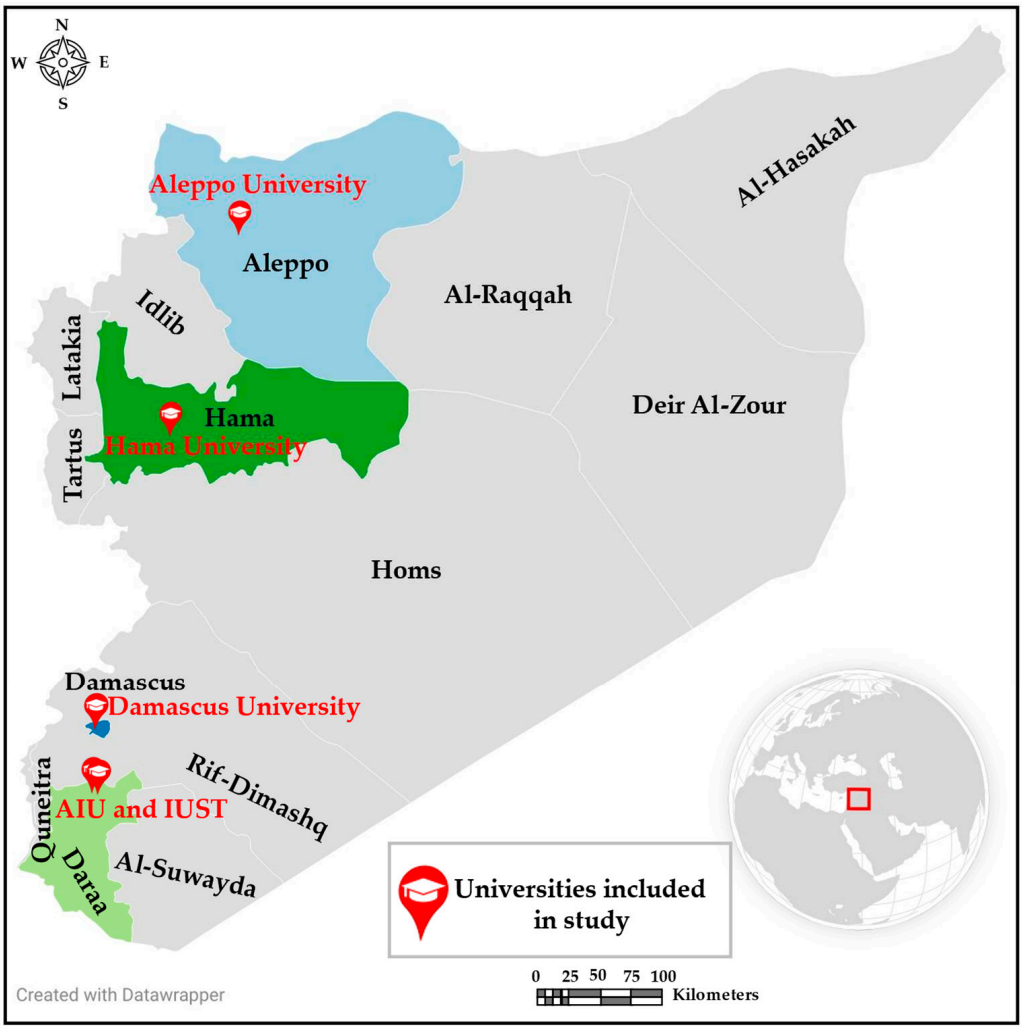

Figure 1. A map of Syria showing the different locations of data collection.

The random sampling technique was unable to be used due to limited mobility and access. Instead, the research team was instructed to use convenience sampling in specific safe locations to avoid unnecessary risks. On-site data was collected by the principal investigator and 50 trained volunteers daily (from 8:00 am to 4:00 pm) between 19 August 2022 and 30 October 2022, using the Kobo collect app. The questionnaire was originally developed in English and translated into Arabic by a sworn translator. Back-translation from Arabic to English was performed by an independent bilingual translator to ensure accuracy and cultural appropriateness. At each of the five locations, the faculties and departments were classified by their scientific specialties as either medical or non-medical. Faculties and departments were selected through a lottery. After selecting a college or department, the principal investigator and trained volunteers visited the site and distributed the questionnaire through convenient sampling in lecture halls and campuses to conduct interviews and fill out the forms one-on-one with a volunteer under the researcher's supervision.

Although pragmatic under security constraints, convenience sampling may over-represent students from relatively accessible urban campuses and under-represent those from rural or highly insecure areas. Consequently, the reported "constraints" results may be underestimated due to recruitment primarily from urban/safer campuses. Thus, caution should be exercised when interpreting the prevalence estimates and correlations reported

here when generalizing them to the entire Syrian university student population. Future studies using probabilistic designs or multistage cluster designs, when conditions permit, are necessary to validate and extend these findings to rural and university campuses in devastated areas.

2.3. Ethical Considerations

The study was approved by the Committee of Human Research, Publications, and Ethics by 18 July 2022, Committee of the Faculty of Pharmacy, Arab International University (AIU), with reference number 2022-PSR-17/O.

2.4. Data Preparation

For details on variable creation and data preparation procedures, please refer to the section "Data preparation—creating new variables" in the Supplementary File on OSF (https://osf.io/ekmd8/, accessed on 16 September 2025). This section outlines how composite variables such as the 5C psychological antecedents, conspiracy mentality scores, information sources, and vaccine-related variables were constructed and processed prior to analysis.

2.5. Statistical Analysis

The raw data was transferred to Microsoft Excel version 16.78.3 (2019), where it was validated qualitatively, checked, and cleaned. After that, all statistical analyses were performed using R (version 4.4.1, R Core Team, 2024) in RStudio (RStudio Team, 2024) at the Department for Economics and Sociology of Sports, Faculty of Economics and Empirical Human Sciences, Saarland University, Germany. University students were interviewed in person using a questionnaire-based structured interview. n = 5060 students participated. Participants were excluded from the analysis when they answered (1) "prefer not to say" for gender (n = 36), (2) "don't know" for the question if they got the COVID-19 vaccine (n = 296), and (3) if their age was > 45 years (n = 6). A total of n = 4722 observations are included in the study.

After establishing the psychometric properties of the translated 5C questionnaire (see Supplementary File), a logistic regression was used to investigate the effect of sociodemographic variables (gender: male/female) and study program (medical/non-medical) as well as the 5C on COVID-19 vaccination behavior. Assumptions were checked using typical procedures. Odds ratios with their 95% confidence intervals (CIs) and Nagelkerke's pseudo-R^2 were computed to quantify explained variance (more accurately as improvement from null model to fitted model) [42].

In a second step, the influence of further variables on the multivariate construct of VH measured using the 5C was investigated using multivariate multiple regression. Included independent variables are gender (male/female), study program (medical/non-medical), information status about previous vaccines, conspiracy mentality, official as well as unofficial sources of information, vaccine attributes, and vaccine passport. For variables that show an overall significant effect on the 5C, univariate analyses were performed to investigate the strength and direction of the effect. Regression coefficients (beta), *CIs*, and p-values are reported. Adjusted R^2 values give an indication of explained variance. Assumptions were checked following standard procedures.

The significance level was set to $p < 0.05$ for all analyses. The full report of all analyses performed can be found in the Supplementary Files on OSF (https://osf.io/ekmd8/, accessed on 16 September 2025).

3. Results

3.1. Descriptive Statistics

3.1.1. Sociodemographic Indicators

The median age of the participants was 21.9 years, with an interquartile range (IQR) of 20.85–30.75 years. The gender distribution showed a higher proportion of males (59.2%) compared to females (40.8%). Geographically, most participants were from the capital, Damascus, with fewer respondents from other governorates. In terms of academic background, the study participants were predominantly from non-medical-related study disciplines compared to medical-related disciplines. The overall characteristics of the study are summarized in Figure 2.

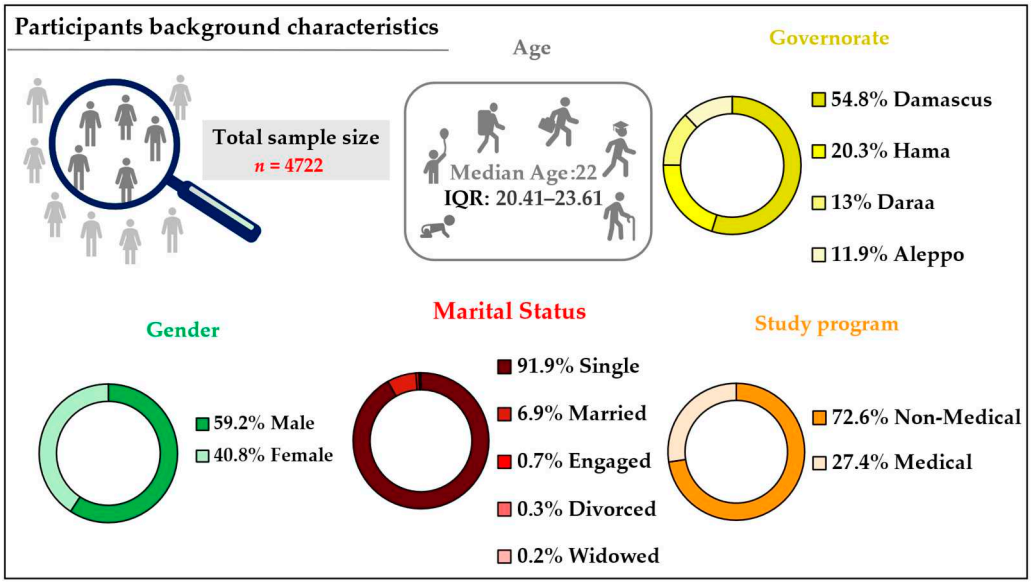

Figure 2. Sociodemographic of participants.

3.1.2. Factors Influencing Vaccination

Vaccination experience was assessed by asking the respondents about their COVID-19 vaccination status, considered as the reference of vaccination behavior, and other vaccine-preventable diseases. The overall vaccination experience (EXP) was high, with a mean score of 0.78 (sd = 0.11). Examination of COVID-19 vaccination status among the total participants (n = 4722) revealed that 64% (n = 3022) had not received the COVID-19 vaccine. Among those who refused vaccination, the majority were fully informed, accounting for 70% (n = 2114), and 30% were partially informed. Detailed results of vaccination experience are presented in Figure 3.

When asked which sources influenced their willingness to be vaccinated, participants indicated that official sources were the most influential. Governmental institutions and international health agencies (e.g., WHO, USAID, CDC, and UNICEF, etc.) were among the leading sources. Scientific literature on vaccines (such as articles, books, and journals, etc.) also played a moderate role. Conversely, respondents also valued social media, family and friends, and media outlets, though social influencers were less impactful. The summarized results for each information source are represented in Figure 4.

Given the widespread conspiracy theories about vaccines—especially COVID-19 vaccines—respondents were asked to share their opinions on these beliefs. Most of them believe that COVID-19 vaccines do not work and are made for profit. While one-third, approximately, believe vaccines influence their genetic material. The conspiracy mentality results are represented in Figure 5.

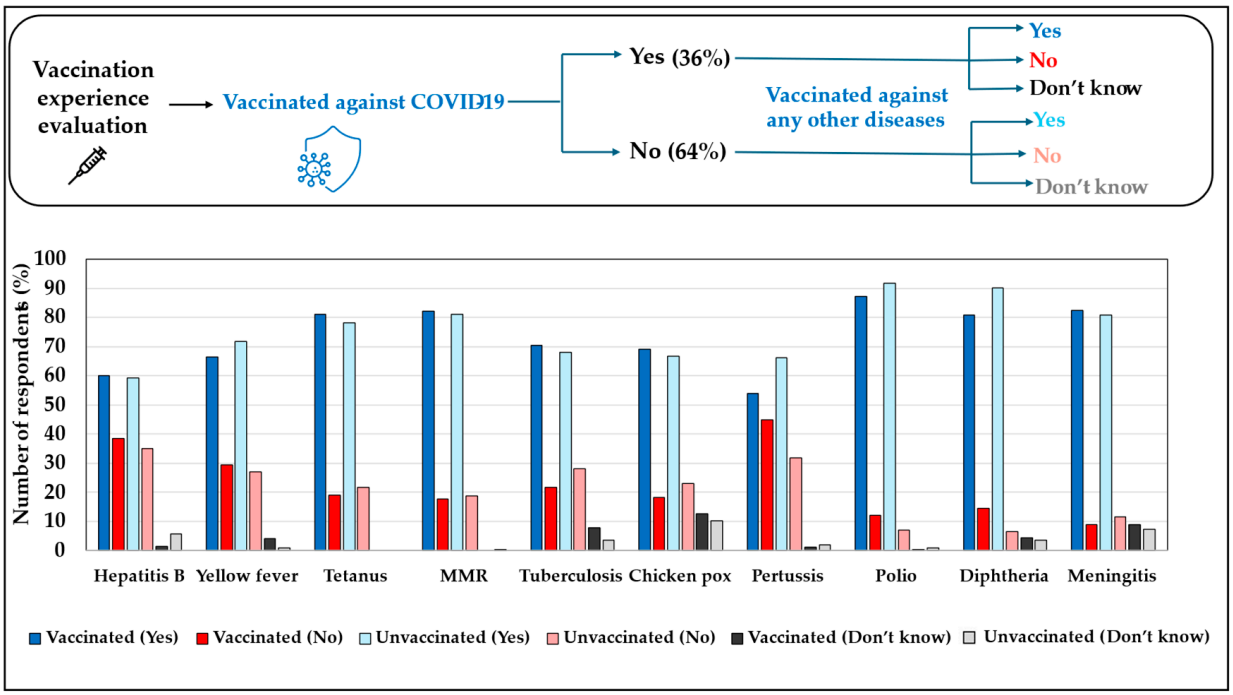

Figure 3. Distribution of participants' responses based on previous vaccination experience. "Vaccinated" refers to individuals who received the COVID-19 vaccine, while "Unvaccinated" refers to those who did not. "Yes" indicates participants who had received vaccines for other vaccine-preventable diseases, while "No" means they had not, and "Don't know" refers to participants who were unsure or could not recall their vaccination history.

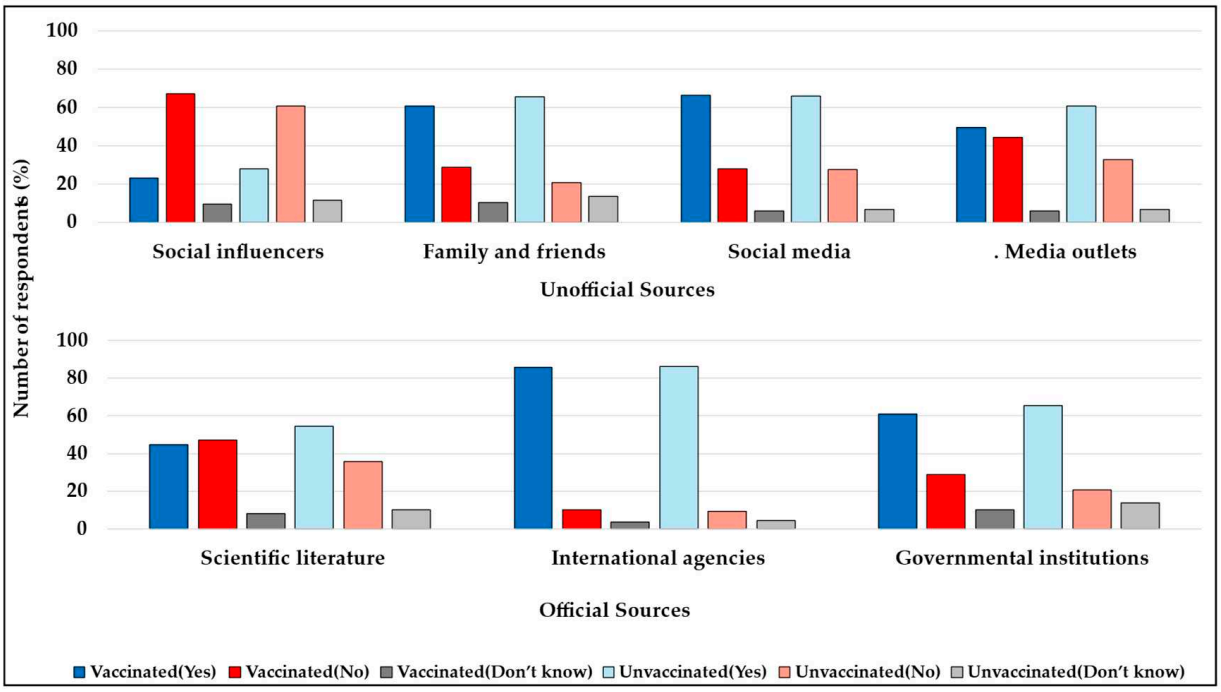

Figure 4. Information source preferences among study respondents. "Vaccinated" indicates individuals who received the COVID-19 vaccine, while "Unvaccinated" denotes those who did not. Additionally, "Yes" indicates that the information source was preferred, "No" indicates t it was not, and "Don't know" refers to participants who were unsure about their preference.

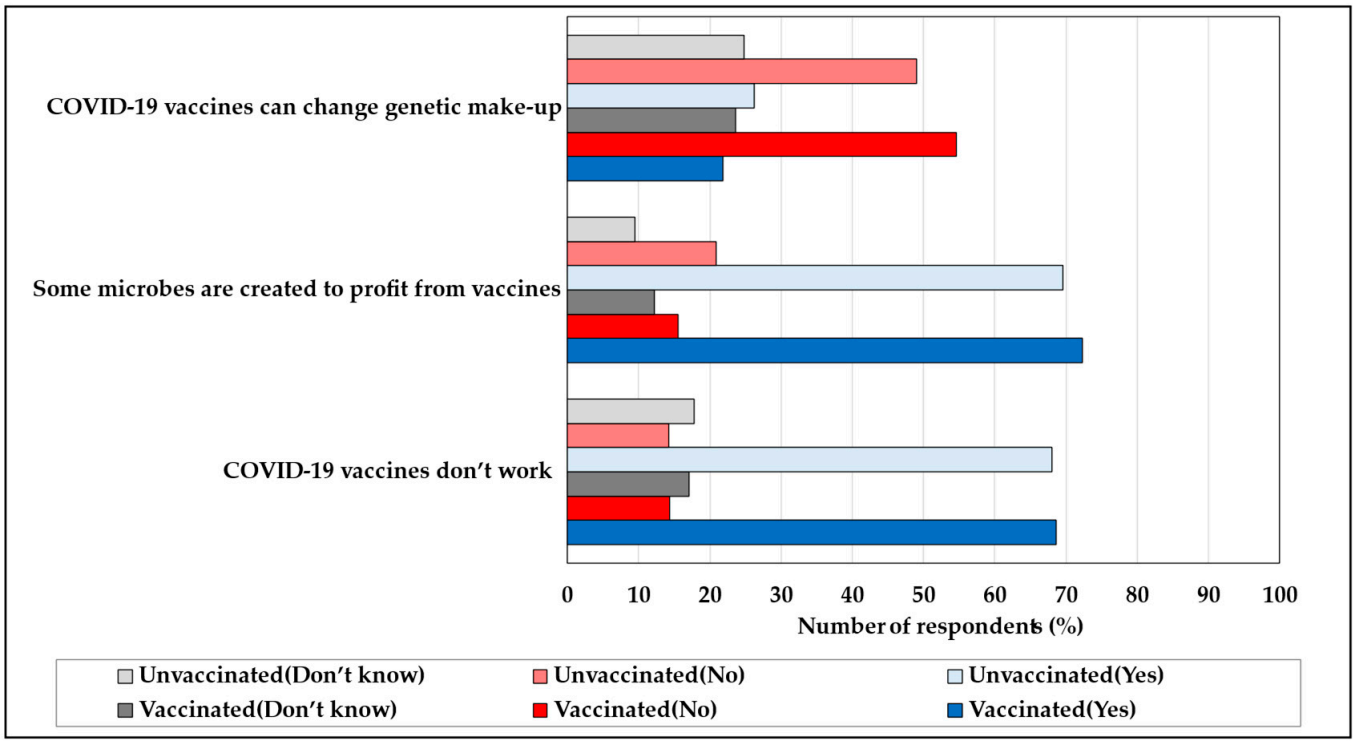

Figure 5. Prevalence of conspiracy mentality beliefs among study participants. "Vaccinated" denotes those who received the COVID-19 vaccine, while "Unvaccinated" refers to those who did not. Additionally, "Yes" participants who supported conspiracy mentality beliefs, 'No' indicates those who did not, and 'Don't know' refers to those who were unsure.

To understand whether vaccine attributes have an effect, respondents were asked about their importance. The mean score was 0.64 (sd = 0.23) across all participants. The results for vaccine attributes are represented in Table 1.

Table 1. Vaccine attributes of study respondents.

Characteristic	Overall (n = 4722)	Unvaccinated (n = 3022)	Vaccinated (n = 1700)
Vaccine Attributes (Overall Score) [1]	0.64 (0.23)	0.64 (0.23)	0.64 (0.23)
Manufacturer/Country of Origin [2]	5 (4, 6)	5 (4, 6)	5 (4, 6)
Brand Name [2]	5 (3, 6)	5 (3, 6)	4 (3, 6)
Availability of Popular Brand [2]	5 (3, 6)	5 (3, 6)	5 (3, 6)

[1] Mean (SD); [2] Median (Q1, Q3); "Vaccinated" denotes those who received the COVID-19 vaccine, while "Unvaccinated" refers to those who did not.

As vaccine passports were mandatory in Syria during the COVID-19 pandemic and served as a travel document to cross country borders, the study also assessed respondents' opinion on vaccine passports. The results showed a mean score of 0.57 (sd = 0.42), indicating moderate overall support among respondents. However, opinions were evenly divided (50–50) on limiting mobility of unvaccinated individuals as a strategy to increase vaccination rates. Interestingly, unvaccinated participants showed slightly higher support for both policies compared to vaccinated individuals, as represented in Table 2.

Table 2. Vaccination policy.

Characteristic		Overall (n = 4722)	Unvaccinated (n = 3022)	Vaccinated (n = 1700)
Mandatory Vaccination [1]	Score	0.57 (0.42)	0.58 (0.42)	0.54 (0.42)
Do you agree that limiting the mobility of people who are not vaccinated is an effective way to increase the vaccination rates? [2]	Yes	50.0	51.2	47.9
	No	50.0	48.8	52.1
Do you agree with vaccines being a permissible factor to travel or visit public place of interest? [2]	Yes	63.2	65.3	59.6
	No	36.8	34.7	40.4

[1] Presented as Mean (SD); While [2] presented as (%); "Vaccinated" denotes those who received the COVID-19 vaccine, while "Unvaccinated" refers to those who did not.

3.1.3. Distribution and Mean Scores of the Psychological Antecedents of Vaccination (5C)

The results, interpreted on a seven-point Likert-type scale from 1 (strongly disagree) to 7 (strongly agree), are presented as mean scores and standard deviations. The highest score was found for calculation, followed by confidence, collective responsibility, and complacency while constraints were the lowest. The results are represented in Table 3.

Table 3. 5C of the Syrian students.

5C	Mean	SD
Confidence	5.29	1.26
Complacency	4.90	1.44
Constraints	3.68	1.49
Calculation	5.86	1.21
Collective responsibility	4.98	1.20
Overall collective mean score	4.94	0.59

3.2. Inferential Statistics

3.2.1. Evaluation of VH

A logistic regression model revealed significant predictors of COVID-19 vaccination behavior among university students. Study program emerged as the strongest predictor, as non-medical students were 1.6 times more likely (OR = 1.60, 95% CI [1.39–1.84], $p < 0.001$) to be unvaccinated compared to students from medical backgrounds. Among the 5C, only three components (complacency, calculation, and collective responsibility) showed a significant association with vaccination behavior, while confidence and constraints were not significant predictors. Higher complacency was associated with increased odds of being unvaccinated (OR = 1.11, 95% CI [1.06–1.16], $p < 0.001$), as was higher calculation—indicating that extensive deliberation about vaccination benefits and risks was linked to VH (OR = 1.06, 95% CI [1.01–1.12], $p = 0.022$). Conversely, higher collective responsibility was associated with decreased odds of being unvaccinated (OR = 0.90, 95% CI [0.86–0.96], $p < 0.001$). Confidence, perceived constraints, and gender showed no significant effect on vaccination behavior. Overall, the model explained a modest but meaningful portion of variance in vaccination behavior (Nagelkerke pseudo-R^2 = 0.023). The results of logistic regression are represented in Figure 6.

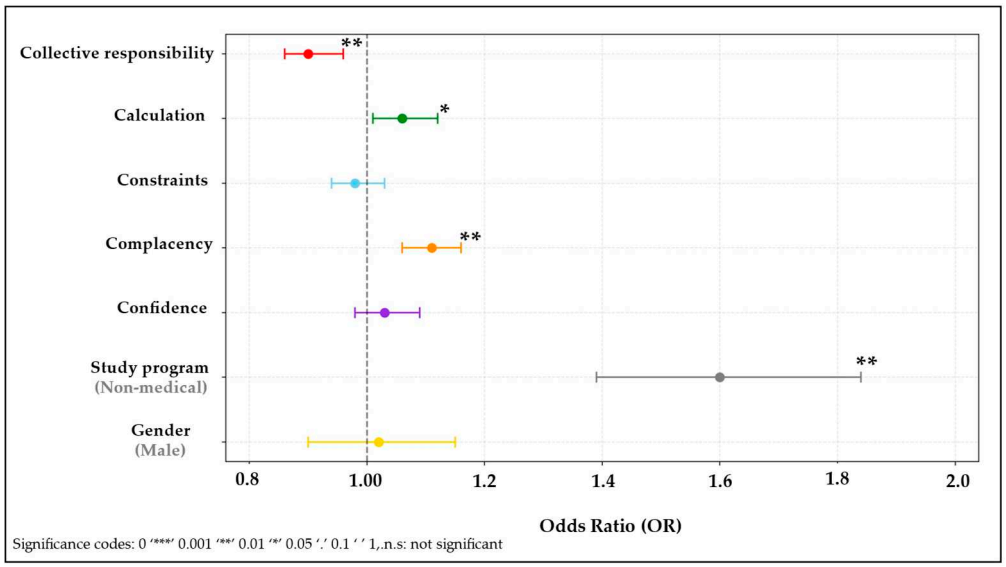

Figure 6. Predictors of COVID-19 vaccination behavior among Syrian university students. Logistic regression model, demonstrating the correlation of socio-demographic and psychological factors (5C) on vaccination behavior. This model explains vaccination behavior from key predictor variables by (R^2 = 0.023).

3.2.2. Multivariate Multiple Regression Model to Investigate Which Factors Influence the 5C

After examining the effects of 5C on vaccination behavior, a multivariate multiple regression model was conducted to go deeper into the 5C and understand what affects each of them and reflects on VH. All independent variables showed an overall significant effect on the 5C, allowing us to investigate their influence on the individual 5C in univariate models, separately from their effects on vaccination behavior.

First, for confidence significant positive predictors were official information sources (β = 0.28, 95% CI [0.14–0.42], p = 0.001), vaccine attributes (β = 0.78, 95% CI [0.62– 0.94], $p < 0.001$), and vaccine passports (β = 0.33, 95% CI [0.24–0.41], $p < 0.001$), while conspiracy beliefs showed a negative association ($\beta = -0.29$, 95% CI [−0.43–−0.16], $p < 0.001$).

Second, complacency was positively influenced by official sources (β = 0.50, 95% CI [0.33–0.66], $p < 0.001$) but negatively associated with conspiracy beliefs ($\beta = -0.33$, 95% CI [−0.48–−0.17], $p < 0.001$), unofficial sources ($\beta = -0.51$, 95% CI [−0.67–−0.35], $p < 0.001$), and studying a non-medical program ($\beta = -0.35$, 95% CI [−0.45–−0.26], $p < 0.001$).

Third, constraints that negatively affect vaccination decisions were positively associated with studying a non-medical program (β = 0.38, 95% CI [0.28–0.48], $p < 0.001$), information status about one's own vaccinations (β = 0.13, 95% CI [0.04–0.23], p = 0.005), conspiracy beliefs (β = 0.55, 95% CI [0.39–0.71], $p < 0.001$), and unofficial sources (β = 0.42, 95% CI [0.26–0.59], $p < 0.001$). Conversely, constraints were negatively associated with the use of official sources of information ($\beta = -0.66$, 95% CI [−0.83–0.50], $p < 0.001$) and vaccine passport support ($\beta = -0.42$, 95% CI [−0.53–−0.32], $p < 0.001$). These associations indicate factors affecting the perception of constraints rather than directly predicting vaccination behavior.

Fourth, calculation was increased by being fully informed (β = 0.20, 95% CI [0.13–0.28], $p < 0.001$]) and vaccine attributes (β = 0.43, 95% CI [0.28–0.59], $p < 0.001$), but decreased by unofficial sources ($\beta = -0.74$, 95% CI [−0.87–−0.61], $p < 0.001$) and vaccine passport support ($\beta = -0.23$, 95% CI [−0.31–−0.15], $p < 0.001$).

Finaly, collective responsibility was associated positively with official sources (β = 0.87, 95% CI [0.74–1.0], $p < 0.001$), vaccine attributes (β = 0.86, 95% CI [0.71–1.0],

$p < 0.001$) and vaccination passport support ($\beta = 0.23$, 95% CI [95% CI [0.15– 0.31], $p < 0.001$), but negatively by studying in a non-medical program ($\beta = -0.15$, 95% CI 95% CI [−0.22–−0.07], $p < 0.001$), being fully informed ($\beta = -0.29$, 95% CI [−0.36–−0.22], $p = 0.001$), and the use of unofficial sources of information ($\beta = -0.18$, 95% CI [−0.31–−0.06], $p = 0.004$). The adjusted R^2 values for the 5 regression models indicate the proportion of variance in each 5C explained by the included predictors, reflecting how well these factors account for differences in the 5C components, independently of vaccination behavior. Calculation and collective responsibility reported the highest adjusted R^2 values and lower for the rest. The results are comprehensively presented in Figure 7.

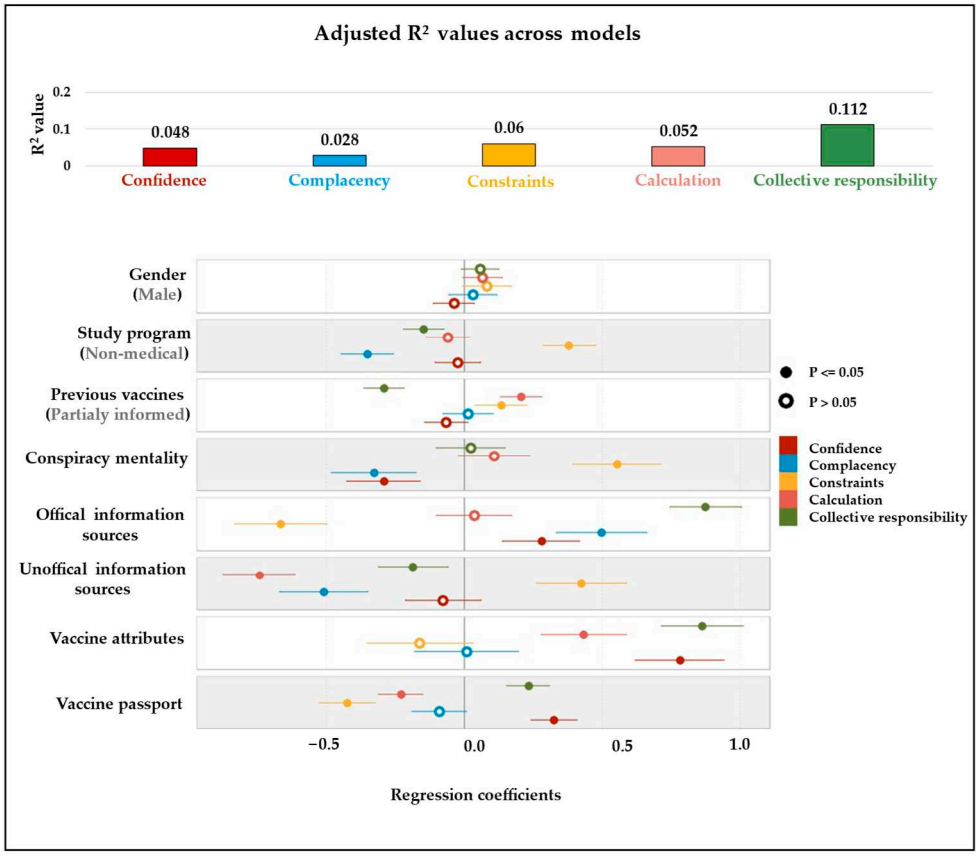

Figure 7. Multivariate regression models examining the association between social determinants of vaccination and 5C psychological constructs. Models demonstrate the variance explained by predictor variables in confidence, complacency, constraints, calculation, and collective responsibility, respectively.

4. Discussion

This study aims to assess the psychological, social, and contextual factors influencing COVID-19 vaccine hesitancy among Syrian university students in war-affected areas. Among the study respondents ($n = 4722$), 64% refused the COVID-19 vaccines. 70% of them were fully informed about their vaccination status. This gap indicates that possession of information about vaccines does not automatically translate into uptake.

In exploring where students look for guidance, we found that study participants predominantly relied on international health agencies as their primary sources of information, indicating a strong preference for official sources. Many students sought guidance from family and friends, 73% ($n = 3017$). This high proportion indicates a preference for personally close sources of unofficial information. The participants used governmental agencies and social media more than media outlets (TV and radio) and social influencers, as shown in Figure 4. Suggesting that official and informal narratives are both present and

may obscure otherwise authoritative messages [43]. Previous work supports this tension: Yue et al. demonstrated that trust in the WHO promotes vaccine confidence, while parallel informal channels can simultaneously foster hesitancy [43]. A 2022 Syrian web-based study also documented significant use of social media for health information but—unlike our cohort—reported no significant associations between online information searching and vaccination status, indicating how the influence of the same channel can differ by sample and context [44].

Interpreting the psychological antecedents through the 5C framework allows for a more complex interpretation. The overall mean score of 4.94 (sd = 0.59) represents moderate hesitation; however, the internal pattern is different. Calculation had the highest mean, underscoring intense risk–benefit deliberation, while complacency also increased the odds of refusing vaccination. Conversely, constraints had the lowest score and were non-significant in multivariable models, suggesting that physical access or even costs were not the main barriers. Confidence and collective responsibility occupied the mid-range, pointing to baseline trust in vaccine safety and a willingness to protect others, yet not at a level that would ensure uptake. This pattern aligns only partly with other vaccine hesitancy studies. For example, both European and Chinese studies report the same case—high calculation and complacency but protective collective responsibility—whereas a 13-country Arab study including Syria barriers were low confidence and high constraints [45–47].

A consolidated comparison with Ghana, where the same 5C-based survey instrument was administered, underscores contextual variability [48]. In the Ghana cohort of 3486 students, fully adjusted models explained 11% to 34% of the variance in vaccination intention and behavior—well above the ≈10% captured in Syria [48,49]. Four 5C dimensions—confidence, constraints, calculation, and collective responsibility—remained significant in Ghana, whereas complacency lost significance after adjustment; by contrast, all 5C retained explanatory weight in Syria [48]. Among Syrian students, the strongest effect on vaccination behavior was study program, followed by small effects of complacency, calculation, and collective responsibility, whereas confidence, constraints, and gender had no effect. Sociodemographic patterns also diverged: reluctance in Syria clustered among non-medical students, while the Ghana analysis highlighted gender, study program, and ethnicity. Yet both settings converged on one critical point: conspiracy beliefs and heavy reliance on unofficial information consistently magnified hesitancy, underscoring a universal challenge of misinformation that transcends national and cultural contexts [48].

More recently, a study conducted in Ukraine—yet another context of conflict—using the same 5C survey among university students revealed additional insights where collective responsibility was the strongest positive predictor of vaccine acceptance [50]. Interestingly, complacency was found to reduce resistance—indicating that passive hesitancy and active refusal can create a difference in the context of a crisis. While in Syria, unofficial sources and conspiracy beliefs showed strong effects on the 5C, vaccine attributes and official sources had the largest positive impact on psychological determinants of vaccination. As in Syria, unofficial sources and conspiratorial beliefs in Ukraine promoted hesitancy in the context of war, indicating the complexity of these areas when trying to understand what leads to vaccine hesitancy [50].

A detailed multivariate multiple regression was conducted to explore the influence of the significant factors affecting the 5C, as shown in (Figure 7). Among the 5C, collective responsibility and calculation had the highest explained variance, indicating stronger effects, while confidence, complacancy, and constraints showed lower levels of explained variance. Positive perceptions of vaccine attributes enhanced confidence, calculation, and collective responsibility. Support for vaccine passports increased confidence, although it reduced complacency, constraints, and calculation, mirroring findings from the United

Kingdom that endorsement of mandates can temper hesitancy by lowering perceived barriers [51]. Reliance on official sources increased confidence and collective responsibility while lowering constraints, whereas unofficial sources had the opposite impact and facilitated conspiracy thinking, which in turn diminished confidence and increased perceived barriers—patterns aligning with reports from Zambia and a survey with 24 nations on conspiracy mentality [52–54].

Taken together, these findings represent the first 5C assessment in a prolonged-conflict LMIC to reveal a calculation-plus-complacency profile with moderate levels of confidence and low structural barriers [55–57]. By integrating effect sizes, it is evident that the study program had the largest direct effect on vaccination behavior, while factors such as vaccine attributes and information sources (official and unofficial) had strong effects on the 5C, and other factors like being fully informed had a moderate to small effect. By challenging the prevailing narrative from studies in the MENA region that low confidence or limited supply dominates, this study extends existing literature and stresses the decisive role of psychological and informational factors even when vaccines are available. From a policy standpoint, several actions follow logically. Peer-to-peer education in which medical students deliver concise, evidence-based sessions can address calculation and complacency directly among non-medical peers. Complementary official campaigns should publish transparent risk-versus-benefit data through channels already trusted by students, reinforcing baseline confidence. In parallel, publicly televised vaccination by respected local influencers or religious leaders can model collective responsibility and counter conspiracy narratives, an approach validated by Loomba et al. [58]. Furthermore, mobile vaccination clinics on insecure or remote university campuses can help ensure that any rise in vaccination willingness translates into actual uptake, a crucial step in conflict-affected settings where static services remain vulnerable to disruption.

5. Conclusions

This study has examined vaccine hesitancy in Syrian university students, using the 5C psychological model. Our findings indicate that a large number of students, particularly students, remain unvaccinated and hesitant toward COVID-19 vaccination. Important psychological and information factors associated with vaccine hesitancy were low confidence, high complacency, more calculation, lower collective responsibility, conspiracy thinking, and relying on unofficial information. Conversely, trust in official information and positive perceptions of vaccine attributes were associated with greater vaccine acceptance. These findings serve as a basis for targeted, evidence-based interventions and evidence-based communication to target the factors that were associated with vaccine hesitancy in a conflict-affected context and resource-constructed context.

6. Limitations of the Study

Various points should be considered when interpreting these results. First, the cross-sectional design does not allow for conclusions about causality between the identified factors and vaccine hesitancy. This prevents inference of temporal or causal relationships. Second, this study is the first to use the 5C questionnaire in Syria. We established the psychometric properties of the translated scale and found that, while the Arabic questionnaire was able to capture the 5C construct reasonably well, the items for collective responsibility may be suboptimal and should be further developed for future applications (see Supplements for details). Third, students from rural campuses and high-insecurity areas were likely under-represented due to convenience sampling being restricted only to accessible universities. Consequently, the reported “constraints” results may be underestimated due to recruitment primarily from urban/safer campuses, introducing a potential sampling

bias. This may have introduced selection bias, as it may affect the representativeness of the sample and limit the generalizability of findings to the entire Syrian university student population. Moreover, security and safety issues limited the mobility of volunteers and inclusion of other universities. Furthermore, the rapidly evolving nature of the COVID-19 pandemic and related information may have influenced participants' attitudes at the time of data collection, limiting the temporal generalizability of the findings [59]. Finally, there may also be unmeasured variables, and the explanatory power of the models, while informative, indicates that other factors not captured in this study also contribute to vaccine decision-making.

Supplementary Materials: The following supporting information can be downloaded at: https://osf.io/ekmd8/, accessed on 16 Septermber 2025.

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Hesitant Minds in Vulnerable Times: COVID-19 Vaccine Hesitancy Among University Students in Ukraine

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Abstract

COVID-19 vaccine hesitancy (VH), like attitudes towards other vaccines, is a critical global public health concern. Despite numerous studies covering psychological, sociodemographic, and other determinants of vaccine acceptance, resistance, and hesitance, few studies have reported these factors among students, particularly in politically unstable settings like Ukraine. This cross-sectional, descriptive, and quantitative study assesses hesitancy towards COVID-19 vaccines, utilizing the 5Cs Model. Among 936 respondents surveyed in 2023, 64% received at least one shot of the COVID-19 vaccine (acceptant), 11% were still considering getting vaccinated (hesitant), and 25% refused vaccination (resistant). Vaccination behavior is significantly associated with the 5Cs. Higher collective responsibility significantly increased acceptance and reduced resistance, while higher constraints lowered the chances of being either acceptant or resistant. Confidence protected against resistance. Complacency, counterintuitively, reduced odds of resistance, pointing to differences between passive hesitancy and active refusal. Male gender and sources of information and misinformation influenced confidence. Collective responsibility was positively associated with official sources and negatively with conspiracy beliefs. Complacency increased with official sources, while constraints and calculation were least explained by predictors. Practical barriers should be tackled through improved accessibility and fostering collective responsibility via targeted communication strategies. These findings provide actionable insights for policymakers, healthcare providers, and academic institutions to enhance vaccine uptake among university students, particularly in crisis settings.

Keywords: conspiracy theories; COVID-19 vaccines; health communication; health knowledge; attitudes; practice; information sources; misinformation; psychological antecedents; students; vaccine hesitancy

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1. Introduction

Vaccine hesitancy continues to be a critical public health concern globally and in Ukraine, where the current sociopolitical instability, the circulation of misinformation, and conspiracy theories about vaccines have undermined vaccination campaigns [1–3]. Despite the availability of effective vaccines, COVID-19 vaccination uptake in Ukraine has lagged [4,5]. Prior to the pandemic, Ukraine had some of the lowest full vaccination rates in Europe (about 14–16%), up to the WHO declaring an end to the COVID-19 pandemic as a public health emergency in May 2023 [1,5,6], partly attributable to widespread misinformation and historical public distrust in healthcare institutions [5,7,8]. In addition, vaccine hesitancy has intertwined with political and social dynamics, contributing to rising vaccine refusal rates both in the United States and Europe [9]. Hesitancy, orchestrated and promoted by political unrest and political leaders, could cause many people to develop negative opinions, not only toward COVID-19 vaccines but also other vaccines [10,11]. This is as a result of eroded trust in public health institutions for promoting vaccinations globally [12–14].

Recent studies indicate a growing trend of vaccine hesitancy across diverse populations, including healthcare professionals. For instance, 12–66% booster hesitancy has been reported among healthcare workers across continents [15,16]. Studies on medical professionals and students revealed varied levels of vaccine acceptance due to access to scientific information, field of study, or perceived personal risk. Published studies from Poland, Italy, and Greece, for instance, show that even among medical students and professionals, VH can be high due to exposure to misinformation or sociocultural dynamics [17–19]. In a politically unstable and conflict-affected state like Ukraine, the phenomenon of COVID-19 VH, with its intricate determinants, may present different dynamics in terms of strategies to address it. The ongoing war against Ukraine, along with displacement of people, including students, has also disrupted COVID-19 vaccination efforts, breaking down routine immunization infrastructure and stopping rollout campaigns [20,21]. These war-induced interruptions of public health services and routine surveillance have further culminated in a stifled vaccine delivery and uptake, especially among the young, higher-educated population [21,22].

These vaccination impediments, compounded by the war, translated into the COVID-19 era, as demonstrated in literature. For example, studies showed that only about 35% of the Ukrainian population had completed a full COVID-19 vaccination course as of late 2022, compared to 42% by December 2023 [5,23–25]. Surveys during the pandemic found that over half of Ukrainian adults were reluctant to get vaccinated, and about 43% were strongly opposed to COVID-19 shots [5,26]. The reasons outlined for the observed hesitancy were multifaceted; a lack of confidence in vaccine safety and efficacy, low trust in government and the medical system, and gaps in health literacy have all been highlighted as key factors in Eastern Europe. In Ukraine specifically, public fears have been fueled by historical distrust, pervasive misinformation, and concerns about side effects of vaccines. Indeed, conspiracy theories and myths ranging from absurd claims about vaccines "blocking the soul's sensor" to fears of DNA alteration circulated widely on social media, reflecting an atmosphere of confusion and fear surrounding vaccination. While direct research on Ukrainian university students is limited, evidence from Eastern Europe suggests that mistrust in media significantly contributes to vaccine hesitancy in this group. Specifically, students who distrust media sources are up to twice as likely to exhibit COVID-19 vaccine hesitancy [27,28]. A UNICEF report showed that about 40% of Ukrainian healthcare workers were vaccine hesitant during the COVID-19 pandemic [29].

The present study applies the 5Cs model of the psychological antecedents of vaccination as a guiding framework. The 5Cs model describes five key determinants of

vaccine hesitancy and acceptance: Confidence: trust in the vaccine's safety and effectiveness and in the health system; Complacency: perceiving the disease as low risk, hence vaccination is seen as unnecessary; Constraints: structural or psychological barriers to vaccination; Calculation: engagement in extensive information gathering and deliberation about the vaccines; and Collective responsibility willingness to vaccinate for the benefit of others [30–32]. Each of these factors has been shown to play a role in explaining vaccination behavior. The 5Cs scale, a validated questionnaire measure of these antecedents, has demonstrated good psychometric properties and ability to predict vaccination uptake in various populations [32,33].

Against the afore-stated backdrop, this study seeks to address a critical research gap in applying the 5Cs model to grasp vaccine hesitancy in post-Soviet, politically distressed, and war contexts like Ukraine, especially among university students. University students, though instinctively assumed to be health savvy and socially active, remain vulnerable to conspiracy theories and are an essential target group for promoting vaccination coverage. The research was set to achieve two primary objectives: (1) to identify predictors of COVID-19 vaccination behavior (categorized as vaccine-acceptant, vaccine-hesitant, or vaccine-resistant) and (2) to explore how sociodemographic and informational factors relate to the 5Cs psychological antecedents of hesitancy. By integrating descriptive analysis with inferential modeling, we aim to shed light on the drivers of vaccine acceptance or hesitancy among young Ukrainians and to inform tailored strategies to improve vaccine uptake, particularly in crisis settings. Grounded in these aims, this study tests three key hypotheses: (1) each of the 5Cs is significantly associated with vaccination behavior; (2) higher confidence and collective responsibility predict vaccine acceptance, while higher constraints are associated with hesitancy or resistance; and (3) exposure to misinformation and low trust in official sources significantly shape confidence and complacency.

2. Materials and Methods

2.1. Questionnaire

The 48-item questionnaire consisted of four main parts. The first part documented the sociodemographics of participants, including age, gender, marital status, level of education, faculty (medical/non-medical), and study site (university). The second part probed basic information about participants and vaccines, that is, their medical history (suffering from chronic diseases and previous infection of COVID-19) and their COVID-19 vaccination status, that is, whether they received two doses and at least one booster shot, one or two doses only, and were still considering getting vaccinated or were not willing to get vaccinated. Additionally, this part also recorded their vaccine experience based on whether participants previously received nine specific vaccines, such as those against MMR, flu, and tetanus. The third part of the questionnaire was dedicated to evaluating the psychological antecedents regarding the COVID-19 vaccine. Here, the participants' responses to the 5Cs (Confidence, Complacency, Constraints, Calculation, and Collective responsibility), adopted from Betsch et al. (2018) as a guide, were assessed [32]. Each antecedent of the 5Cs was measured via three items. It should be noted that one extra item was added, "If it is 2023, please choose answer number «2»", to enhance the quality of data during collection and credibility of responses. The fourth part covered sources of information respondents rely on when deciding to get vaccinated against COVID-19, which included governmental agencies, social influencers, and/or scientific literature, as well as items measuring their level of misinformation (conspiracy mentality regarding the COVID-19 vaccine, which was common around the time of the pandemic in Ukraine, such as the vaccine leading to sterility, affecting spirituality and relationship with God, or being produced as a harmful weapon). Here, once again, one item exploring misinformation about vaccines was true, "vaccines

sensitize the body and offer protection against diseases", and was included to improve data quality. The questionnaire, together with the collected data, is openly available on OSF (https://doi.org/10.17605/osf.io/y8nha, accessed on 20 May 2025).

The questionnaire included categorical and ordinal variables. Gender, marital status, educational level, faculty (health or non-health related), university name, presence of chronic diseases, previous COVID-19 infection, COVID-19 vaccination status, and vaccine experience were recorded as categorical variables. For vaccine experience, participants initially indicated their familiarity with nine specific vaccines by responding "Yes", "No", or "I do not know". By adding up the number of "I do not know" answers for all vaccines asked, these categorical variables were transformed into the ordinal variable "vaccine experience" using the 33rd and 66th percentiles, thus resulting in three equally sized groups: nearly "uninformed" (participants above the 66th percentile, showing predominantly uncertainty or lack of knowledge), "moderately informed" (participants between the 33rd and 66th percentiles), and nearly "fully informed" (participants below the 33rd percentile, demonstrating clear and comprehensive awareness of their vaccination status). As for the ordinal variables, the 5Cs antecedents of vaccine hesitancy, influence of sources of information, and level of misinformation (conspiracy mentality) were measured on a seven-point Likert-type scale from 1 (strongly disagree) to 7 (strongly agree).

2.2. Study Design and Data Collection

This cross-sectional study employed a questionnaire, which was distributed digitally via a link or a QR code from February to March 2023 by researchers and trained volunteers using emails and posts on student-group platforms, such as WhatsApp and Facebook, aiming to reach as many university students as possible. The prepared scale (the 5Cs), which was piloted, pretested, and validated as a measurement applied in our previous study in Ghana, was utilized in this cohort. Initially, this study targeted specific institutions, including Bukovinian State Medical University (BSMU), Danylo Halytsky Lviv National Medical University (LNMU), Ivano Frankivsk National Medical University (IFNMU), Karazin Kharkiv National University (KKNU), Lesya Ukrainka Volyn National University (LUVNU), Lutsk National Technical University (LNTU), Lviv Medical Institute (LMI), and Ternopil Volodymyr Hnatiuk National Pedagogical University (TVHNPU). Study locations are represented in Figure 1.

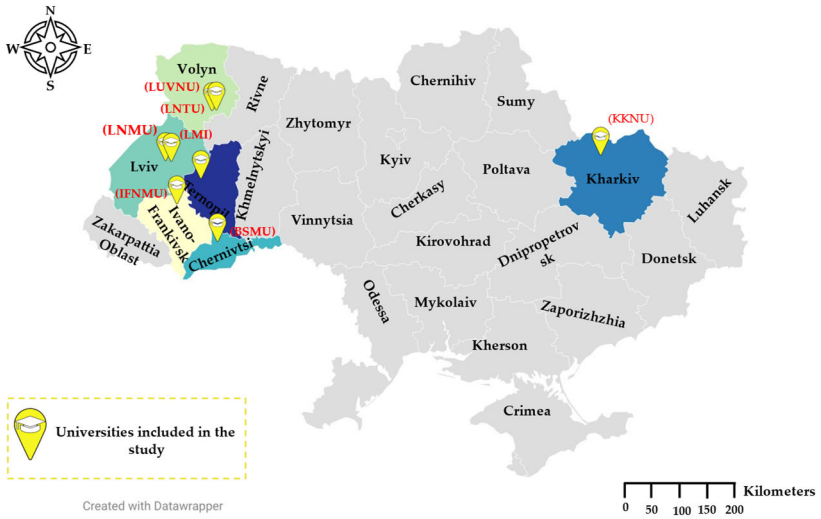

Figure 1. A map of Ukraine showing the different locations of data collection.

Due to logistical challenges associated with the ongoing conflict, however, the inclusion criteria were adjusted to encompass (1) students from any Ukrainian university

(Ukrainian territory not under Russian occupation), broadening the scope to ensure adequate participant recruitment; (2) Ukrainian university students outside Russian-occupied territories due to the war; and (3) all levels of university studies. The following were excluded: (1) acutely ill persons and (2) all non-university individuals. After acquiring consent, the questionnaire was self-administered by participants. This study did not assume the sample to be representative of the university student population due to the study site being a war-torn country with blockages and no internet. We, however, tried to reach as many people as possible given the circumstances. The data were collected through Google Forms and stored in a password-protected electronic format.

2.3. Statistical Analysis

The raw data were transferred to Microsoft Excel version 16.78.3 (2019), where they were validated qualitatively, checked, and cleaned. All subsequent analyses were conducted using R (R core team, 2021), including the packages boot [34], car [35], and nnet [36], at the Department for Economics and Sociology of Sports, Faculty of Economics and Empirical Human Sciences, Saarland University, Germany. A total of 1197 participants responded to the questionnaire. After excluding one participant who stopped answering in the first part, eight participants who chose a "Gender" other than male or female, eight participants with age > 47, two who chose a "Prefer not to say" when asked about previous infection with COVID-19, 114 participants who chose Ph.D. or professor as the highest level of education attained, 61 participants who chose "Prefer not to say" when asked about their COVID-19 vaccination status, and 67 participants who answered the quality control item in the 5Cs wrong, the total number for the statistical analysis was $n = 936$.

As for the inferential statistics, two models were employed. The first model utilized multinomial logistic regression to predict COVID-19 vaccination behavior (VB), based on the participants' vaccination status against COVID-19 as a dependent variable categorized into three groups: "Acceptant" (participants who received at least one dose of the vaccine), "Hesitant" (participants still considering vaccination), and "Resistant" (participants who decided not to get vaccinated). The "Hesitant" category was selected as the baseline group for comparison. Independent variables included gender (binary: male/female), study program (binary: health/non-health), and the 5Cs psychological antecedents, namely, Confidence, Complacency, Constraints, Calculation, and Collective responsibility, as continuous predictors. This was carried out to quantify how participants from the "Hesitant" category differ from either the "Acceptant" or "Resistant" participants based on changes in these predictors. Odds ratios greater than 1 (OR > 1) suggest factors that are associated with a higher probability of being acceptant (or resistant) compared to hesitant, while OR less than 1 (OR < 1) suggest factors that are negatively associated with differences between the groups. Meaning, they could be interpreted as either reducing the chances of firm resistance or as insufficient to encourage acceptance.

The second model aimed to explain vaccine hesitancy (VH) by deploying a multivariate regression method having the 5Cs as multivariate dependent variables, which were scrutinized using five different univariate sub-models. This multivariate multiple regression model included the following independent variables: gender (male or female), study program (health or non-health), marital status, vaccination experience (informed, moderately informed, or uninformed), sources of information (official or unofficial), and vaccine misinformation (conspiracy mentality). The analysis provides the following statistical information about factors influencing hesitancy: For the multinomial logistic regression ORs with non-parametric bootstrapping confidence intervals (CI), as well as the Nagelkerke pseudo R^2, are reported. When the CI did not include 1, the influence of the variable was considered significant. For the multivariate regression model, adjusted R^2 values for

each sub-model, regression/beta coefficients indicative of the strength and direction of the association between the predictors and the outcome when holding other variables constant, and *p*-values are reported. The level of significance was set to $\alpha = 0.05$. Additional information, including *t*-values showing if the regression/beta coefficients significantly differ from zero, is also reported; see OSF (https://doi.org/10.17605/osf.io/y8nha, accessed on 20 May 2025).

3. Results

3.1. Descriptive Statistics

3.1.1. Sociodemographic Indicators

A total of 936 university students were included in the analysis. The participants are mostly young (94% within the [18–27] age group), female (85%), single (49%), and studying a medical-related program (58%), which represent common features in health-related survey responses. Around 64% of the participants report receiving at least one dose of the vaccine against COVID-19, while only 11% were hesitant (still considering) and 25% were resistant (no intention). The overall sociodemographic characteristics of participants, along with basic medical information, are summarized in Figure 2.

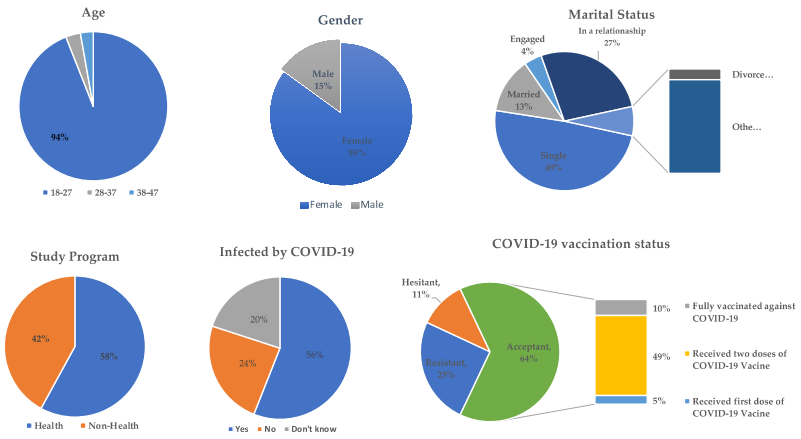

Figure 2. Sociodemographic and basic information about the COVID-19 vaccine of respondents.

3.1.2. The 5Cs Antecedents, Sources of Information, and Conspiracy Mentality

The mean values of the 5Cs scores of participants are presented in Table 1 together with the mean values for the influence of sources of information and misinformation/conspiracy mentality. The results are to be interpreted on a seven-point Likert-type scale from 1 (strongly disagree) to 7 (strongly agree) and presented as mean and standard deviations in Table 1.

Table 1. Mean scores and standard deviations for the 5Cs and factors influencing vaccination. Results were measured on a seven-point Likert-type scale from 1 (strongly disagree) to 7 (strongly agree).

Characteristic	Overall N = 936	COVID-19 Status		
		Acceptant *n* = 600	Hesitant *n* = 101	Resistant *n* = 235
Confidence	4.37 (1.59)	4.81 (1.40)	4.79 (1.21)	3.05 (1.43)
Complacency	4.67 (1.49)	5.05 (1.37)	4.89 (1.20)	3.58 (1.36)
Constraints	2.25 (1.24)	2.12 (1.16)	2.80 (1.35)	2.35 (1.33)
Calculation	5.66 (1.37)	5.57 (1.41)	5.65 (1.34)	5.91 (1.27)
Collective responsibility	4.95 (1.45)	5.42 (1.23)	5.09 (1.26)	3.68 (1.27)
Official vaccine information sources	4.76 (1.37)	5.04 (1.23)	4.95 (1.21)	3.98 (1.47)

Table 1. *Cont.*

Characteristic	Overall N = 936	COVID-19 Status		
		Acceptant *n* = 600	Hesitant *n* = 101	Resistant *n* = 235
Unofficial vaccine information sources	3.94 (1.39)	4.06 (1.39)	4.15 (1.07)	3.53 (1.45)
Misinformation (conspiracy mentality)	2.62 (1.19)	2.35 (1.01)	2.39 (1.09)	3.43 (1.29)

3.2. Inferential Statistics

3.2.1. Factors Influencing Hesitancy Toward COVID-19 Vaccination

A multinomial logistic regression model was utilized to examine which factors are different between hesitant individuals and those who are either acceptant or resistant. The model demonstrates that none of the sociodemographic variables significantly influence being in either the acceptant or resistant group ($p < 0.05$). Perceiving a higher level of constraints was associated with being less likely to be "acceptant" (OR: 0.68, CI: [0.57, 0.79]) or "resistant" (OR: 0.74, CI: [0.59, 0.89]). Higher acceptance is significantly associated with a higher sense of collective responsibility, OR: 1.37, Cl: [1.08, 1.78] and OR: 0.69, CI: [0.50, 0.91] when transitioning from hesitant to acceptant and hesitant to resistant, respectively. Being more resistant was significantly associated with having lower confidence, OR: 0.60, CI: [0.47, 0.75]. Interestingly, complacency is found to reduce the odds of being resistant, OR: 0.70, Cl: [0.54, 0.87]. The results are visualized in Figure 3.

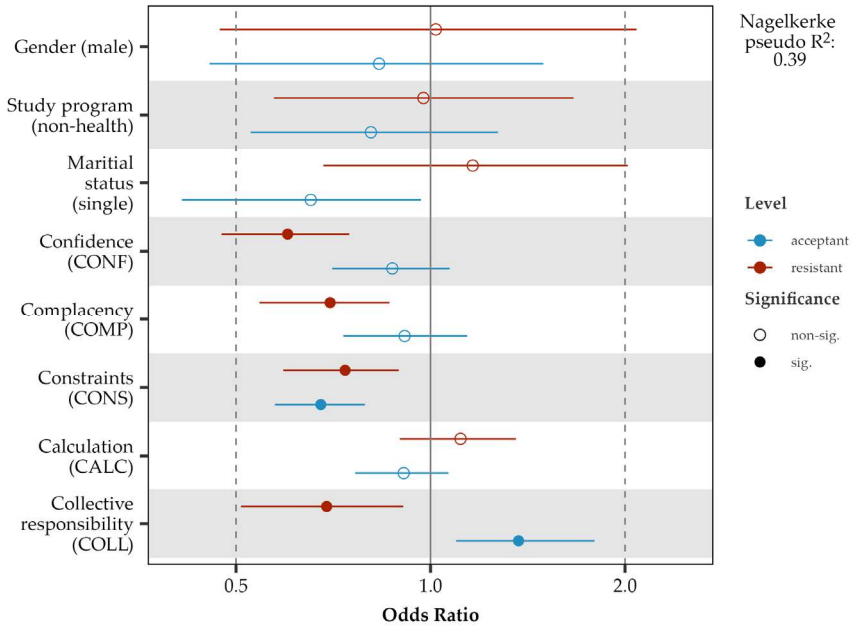

Figure 3. The multinomial logistic regression model shows the influence of 5Cs and sociodemographic variables on VB. The baseline category is "hesitant". Note that a variable was considered significant when the non-parametric bootstrapping interval does not overlap with 1. The multinomial model had a good fit (Nagelkerke pseudo-$R^2 \approx 0.3900$).

3.2.2. Factors Influencing the 5Cs Antecedents of Hesitancy Toward COVID-19 Vaccine

The multivariate regression model identifying factors associated with each of the 5Cs is shown in Figure 4. Higher confidence in the COVID-19 vaccine is associated with being male (β: 0.47, Cl: [0.27, 0.67], $p < 0.001$), being informed from both official channels (β: 0.31, Cl: [0.24, 0.37], $p < 0.001$) and unofficial channels (β: 0.12, Cl: [0.06, 0.18], $p < 0.001$) for information, and having lower levels of misinformation/conspiracy mentality (β: −0.67, Cl: [−0.74, −0.61], $p < 0.001$). Being complacent about the severity of COVID-19 and

the importance of its vaccine is positively associated with relying on official sources of information (β: 0.13, CI: [0.06, 0.21], $p < 0.001$) and negatively with having higher levels of conspiracy mentality (β: −0.58, CI: [−0.66, −0.50], $p < 0.001$). Perceiving higher constraints to be vaccinated is positively associated with relying more on both official (β: 0.08, CI: [0.00, 0.15], $p = 0.040$) and unofficial sources of information (β: 0.07, CI: [0.00, 0.14], $p = 0.040$) and having higher conspiracy mentality (β: 0.28, CI: [0.21, 0.35], $p < 0.001$). Being more immersed in seeking out information about the COVID-19 vaccine and weighing its benefits over risks (calculation) is negatively associated with being male (β: −0.38, CI: [−0.2, −0.13], $p = 0.003$) but positively associated with relying on official channels of communication (β: 0.17, CI: [0.09, 0.26], $p < 0.001$) as well as having a higher level of conspiracy mentality (β: 0.09, CI: [0.01, 0.17], $p = 0.030$). Having a higher sense of collective responsibility (i.e., willingness to get vaccinated to protect others) is positively associated with relying on official channels of information about the vaccine (β: 0.29, CI: [0.23, 0.36], $p < 0.001$) and negatively associated with having higher levels of conspiracy mentality (β: −0.57, CI: [−0.63, −0.50], $p < 0.001$). The multivariate model is summarized in Figure 4.

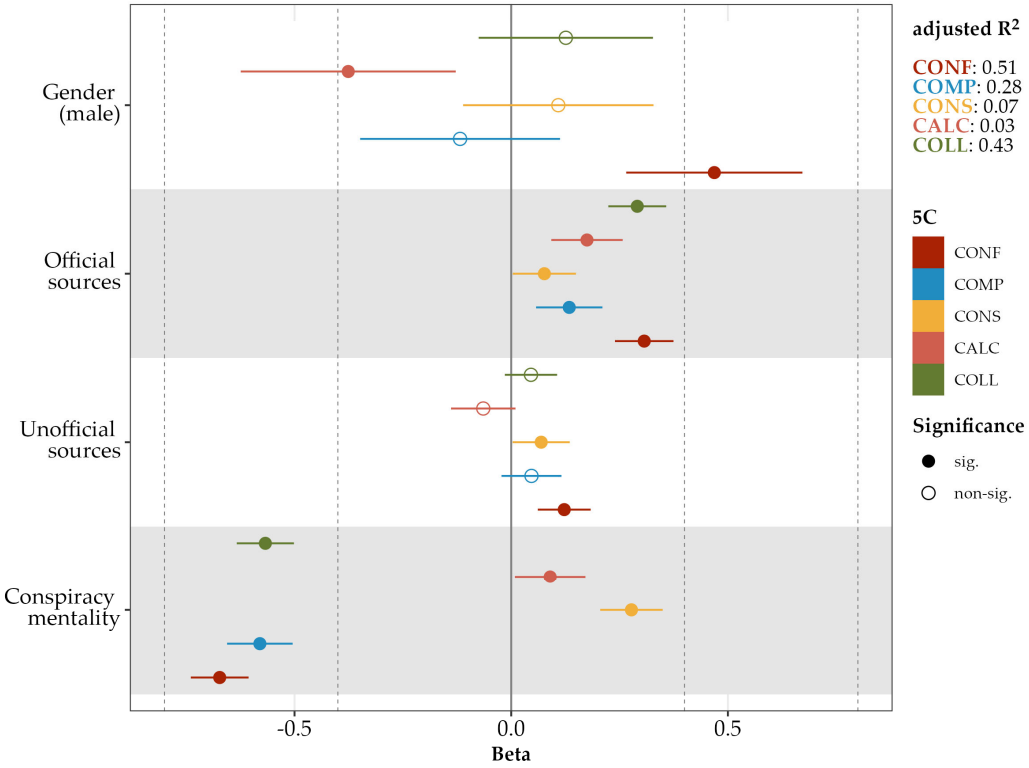

Figure 4. Multivariate multiple regression analysis to predict the influence of different variables on the 5Cs.

Amongst all the 5Cs, the variance in confidence among the participants is best explained by the predictors, followed by collective responsibility with adjusted R^2 values of 51% and 43%, respectively. While the variance observed in complacency is appreciably explained by the model (adjusted R^2 = 28%), the least variance could be explained in calculation (adjusted R^2 = 3%) and constraints (adjusted R^2 = 7%).

4. Discussion

We investigated the psychological and sociodemographic predictors of COVID-19 vaccination behavior among university students in Ukraine. The relationship between the five psychological drivers (5Cs) of VH and informational and demographic variables was examined. Our findings amplify the significant roles of collective responsibility and

practical constraints as key determinants of COVID-19 vaccine uptake among this cohort. Complacency, interestingly, demonstrated a counterintuitive association by reducing the likelihood of active resistance, indicating that passive indecision and deliberate refusal may reflect distinct psychological processes. This study also revealed psychological antecedents of vaccine hesitancy, particularly confidence and collective responsibility, to be strongly shaped by information sources and misinformation. Generally, official sources promote trust, while unofficial or conspiratorial thinking increases hesitancy. Notably, higher constraints were unexpectedly linked to both official and unofficial information reliance. Calculative behavior was paradoxically associated with both trust in official sources and susceptibility to misinformation, stressing the complex interplay between information-seeking and belief systems.

This study of 936 university students revealed that 36% had not received COVID-19 vaccines, which makes attainment of herd immunity difficult and puts the population at risk of the infection. This is in line with published studies that reported over half of the Ukrainian population to be vaccine hesitant and 43% opposed to COVID-19 shots [5,23,26]. Sociodemographic variables showing no significant influence on vaccination behavior (VB) (i.e., acceptant, hesitant, and resistant) align with broader research suggesting that psychological variables, rather than demographic factors, drive vaccine decisions, especially during conflict disruptions [37]. In the context of Ukraine, the war has intensified disinformation campaigns and heightened reliance on psychological defenses, possibly diminishing the influence of traditional demographics on vaccination choices [38]. The prolonged armed conflict in Afghanistan, for example, has intensified disinformation and reinforced psychological resistance to vaccination, thereby diminishing the influence of conventional sociodemographic factors and shifting vaccine decision-making toward mistrust-driven and ideologically rooted behaviors [39]. These findings add on to existing literature by showing that in conflict-affected and high-misinformation environments, interventions should pivot from demographic targeting toward addressing cognitive and informational factors. This is possible via improving trust, countering misinformation, and reinforcing social responsibility to effectively tackle vaccine hesitancy.

Our research outcomes align with prior literature and also introduce novel insights. Specifically, the positive influence of collective responsibility on vaccine acceptance supports previous research, demonstrating its role as a strong motivator of VB [40–43]. However, the unexpected negative association between complacency and resistance contradicts conventional studies linking complacency to increased vaccine refusal [44,45]. This finding might show that people stick to their usual habits instead of actively refusing vaccines. According to psychological theories, when people think a risk is low, they tend to make quick, automatic decisions rather than carefully thinking things through [46]. Indecisive vaccine attitudes, similarly, link low-risk perception with uncertainty, not resistance [47]. The divergence may also likely reflect a critical distinction in conflict-stifled Ukraine, where there is passive hesitancy, driven by the perceived irrelevance of vaccination amid more immediate threats, versus active resistance rooted in skepticism. Furthermore, the finding that perceived constraints reduced both acceptance and resistance parallels evidence from crisis contexts where logistical barriers suppress behavioral extremes, pushing individuals toward indecision [48,49].

Our finding that lower confidence in the COVID-19 vaccines was a significant predictor of resistance reinforces the central role of the psychological constructs, particularly trust, in shaping vaccination behavior. It aligns with studies in Ghana and others, where low trust in vaccine safety was a key driver of hesitancy [45,50–52]. These results suggest that in both stable and unstable contexts, boosting vaccine confidence is critical to reducing resistance and improving uptake. Unofficial sources and misinformation, though

untrusted, seem to suggest an unusual influence on the 5Cs' psychological antecedents. This can possibly be explained by studies postulating conflicts throwing persons into a state of uncertainty—not knowing which source has their best interest, and thus, ultimately, increasing one's hesitancy or resistance levels towards vaccinations [53,54]. First, our results discuss the association between higher vaccine confidence and use of unofficial information sources. Second, our results suggest that the negative influence of conspiracy mentality/misinformation on complacency contradicts traditional concerns that unofficial sources and misinformation promote hesitancy. Recent studies suggest that, in conflict settings, individuals may turn to peer networks, independent influencers, or community channels that, though unofficial, can sometimes disseminate accurate or reassuring information [55–58]. Third, our results explain the observed positive influence of official sources on greater complacency, perceived constraints, and calculation. This pattern may also reflect information fatigue, where continuous exposure to official COVID-19 messaging may fail to engage students who feel saturated or disconnected from state-level messaging during prolonged crises [59,60]. Moreover, this aligns with recent research showing that conspiracy believers may still perceive the disease as serious but reject vaccines due to institutional distrust, not a lack of concern about the virus itself [61,62]. Winter et. al. (2021) also postulate that subjective norms (perceptions of close persons beliefs) moderate the link between conspiracy mentality and vaccination intentions and thus mitigate the negative impact of misinformation on vaccination acceptance [63].

Male students showed higher confidence in COVID-19 vaccines but were less likely to engage in detailed information seeking, consistent with prior evidence [52,63–66]. This suggests the male gender exhibits greater baseline trust in vaccines, likely influenced by cultural norms and gender-centric expectations like risk tolerance and social health responsibilities, while women engage in critical information processing before making health decisions. These findings project the need for gender-sensitive vaccine communication strategies. Confidence in COVID-19 vaccinations increased with reliance on official sources and declined in the presence of misinformation/conspiracy beliefs. A pattern supported by recent studies showing that trust in health institutions and conspiracy mentality shape vaccine acceptance [4,66]. Conversely, perceived constraints were elevated among individuals who depended on unofficial sources and those with a stronger conspiracy mentality, a finding consistent with research showing misinformation exacerbates psychological and logistical barriers [67,68]. Furthermore, the positive relationship between collective responsibility and the use of official information sources, along with its inverse association with conspiracy beliefs, allies with evidence that positive vaccination behaviors thrive in environments of trusted information and diminish under conspiracy influence [32,69,70]. Among the 5Cs, confidence and collective responsibility showed the highest explained variance. Mirroring patterns observed in large-scale pre-, during-, and post-pandemic studies using the 5Cs model [41,44]. It also supports existing literature showing that these two constructs are the strongest predictors of vaccination intentions and behaviors across diverse populations [52]. In contrast, calculation showed the lowest explanatory power, which reflects findings that this construct is often influenced by complex (i.e., unmeasured structural or emotional factors) and context-specific dynamics [32].

Our findings are particularly relevant within the Ukrainian context, where the war has contributed to a systemic burden on healthcare services, limiting access to routine immunization and reducing institutional outreach capacity. This strain worsens existing logistical constraints and disrupts continuity in health communication, further undermining vaccine uptake. The results highlight the intricate interplay of psychological, informational, and structural factors in shaping vaccination VB during wartime. It also suggests that interventions should address both cognitive motivations and passivity driven by fatigue,

displacement, or competing priorities (practical access issues) in populations under duress. Healthcare providers should address practical barriers by improving the accessibility and convenience of vaccination services, particularly for students balancing academic demands. Policymakers could strengthen public messaging that emphasizes community protection, using trusted and diverse channels to counter misinformation. University administrators are advised to embed evidence-informed strategies into campus life through curricula, peer-led initiatives, and student support services to cultivate informed vaccine acceptance within the university community. Interventions should also distinguish between active resistance and passive disengagement, using emotionally and cognitively accessible messaging to re-engage complacent individuals with risk awareness and civic responsibility.

Limitations of Study

As with all cross-sectional designs, our study is limited in its ability to establish causal relationships between predictors and vaccination behavior. Temporal ordering cannot be determined, and associations should be interpreted with caution. The use of self-reported vaccination status may have introduced social desirability bias, especially in the context of public health norms and institutional expectations, possibly leading to overreporting of vaccine acceptance. Additionally, items measuring complacency may have been interpreted differently by vaccinated individuals, whose retrospective perception of COVID-19 risk may have biased their responses.

The exclusive use of digital data collection poses further limitations, as students with limited internet access, low digital literacy, or those displaced by the war may have been excluded (groups potentially more hesitant or resistant to vaccination). This introduces selection bias and limits the representativeness of the sample. Moreover, this study focused only on students in non-occupied Ukrainian territories, restricting generalizability to those in conflict zones or non-university populations. Non-response bias is also possible, as students with strong vaccine attitudes may have been more likely to participate, potentially skewing results.

We recommend future research to incorporate longitudinal and mixed-methods designs to better capture changes in vaccine attitudes over time. Further studies are needed to enhance causal inference and reach underrepresented subgroups.

5. Conclusions

Our study offers critical understanding into the psychological and informational determinants of COVID-19 vaccine hesitancy among Ukrainian university students during a time of war. It confirms that the 5Cs psychological antecedents (except calculation) are significantly associated with COVID-19 VB (i.e., acceptant, hesitant, and resistant). Higher confidence and collective responsibility predicted acceptance, while greater constraints were linked to hesitancy and resistance. These associations project the need to address both belief-based and structural barriers to vaccinations. Notably, low trust in official sources and high exposure to misinformation significantly eroded confidence and increased complacency, reinforcing global evidence on the damaging role of misinformation, yet contextualized here within a conflict-affected population.

Unexpectedly, reliance on official information sources positively influences increased levels of complacency, perceived constraints, and calculation, which suggests information fatigue may hinder intended public health outcomes. Additionally, higher vaccine confidence was also associated with the use of unofficial sources, such as peer networks and independent influencers, indicating that informal mediums may convey contextually resonant health information. The inverse relationship between conspiracy mentality and complacency challenges the prevailing view that conspiratorial beliefs promote hesi-

tancy in the context of war. Sociodemographic variables showed limited predictive power, highlighting a greater influence of psychological and informational variables in shaping vaccination decisions.

These study outcomes point to the importance of context-sensitive public health interventions that go beyond demographic targeting to focus on rebuilding confidence and reducing both cognitive and practical barriers. Finally, communication strategies such as effective public health messaging in war settings need rethinking beyond institutional channels and engaging with informal networks to rebuild trust and relevance.

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Informed but Unvaccinated: A Cross-Sectional Study Among University Students in Ghana

Prince Yeboah, Ahmad Yaman Abdin, Trudy Osei Gyasi, Priscilla Anyimiah, Newman Osafo, Philip Skotzke, Werner Pitsch, Mahmood Oppong Brobbey, Anto Berko Panyin, Afraa Razouk et al.

MDPI

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COVID

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Article

Informed but Unvaccinated: A Cross-Sectional Study Among University Students in Ghana

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Abstract: During the COVID-19 pandemic, vaccination hesitancy (VH) posed an equally unexpected and significant obstacle to the effectiveness of public health interventions. VH has not only the potential to stir up public unrest, but it may also impede the success of entire immunization programs and thus prevent the attainment of herd immunity. This cross-sectional, quantitative, and descriptive study examined VH and vaccination behavior (VB) among 3486 university students in Ghana, using a standardized self-administered questionnaire based on the 5Cs model among other relevant variables. The findings confirm a significant VH and a VB influenced by both sociodemographic factors, such as gender (OR: 1.45; [CI: 1.26–1.67]), study program (OR: 0.55; [CI: 0.47–0.64]), and ethnicity (OR: 1.31; [CI: 1.12–1.52]) and also four of the 5Cs, i.e., Confidence (OR:1.56; [CI: 1.45–1.68]), Constraints (OR: 0.83; [CI: 0.78–0.87]), Calculation (OR:0.85; [CI: 0.78–0.92]), and Collective Responsibility (OR:1.27; [CI: 1.16–1.38]), yet not Complacency, nor religion. Notably, VH was further shaped by previous vaccine experience, information sources, vaccine attributes, stance on vaccine passport, and conspiracy beliefs, with misinformation from unofficial sources playing a key role. The multiple regression models explained 11% to 34% of the variance in the 5Cs, indicating varying degrees of explanatory power for each factor influencing VB and eventually also VH. This study highlights the urgent need for targeted public health interventions, such as integrating vaccine education into university orientation programs, streamlining vaccination processes, and leveraging influencers for trust-building campaigns.

Keywords: health attitudes; herd immunity; immunization programs; misinformation; psychological models (5Cs model); public health interventions; vaccination hesitancy; vaccinations; vaccines

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1. Introduction

Although the COVID-19 pandemic of about five years ago has been superseded in the news by war and other natural and manmade disasters, this viral outbreak has claimed over 6 million lives worldwide [1,2]. In many countries of the Global South, such as Ghana, the effects of COVID-19, combined with other infections, continue to be significant, exacerbating a constant strain on the healthcare system and the economy [3–5]. Confronted by other infectious diseases, such as Ebola, influenza, malaria, cholera, meningitis, HIV/AIDS, and a very recent outbreak of Mpox, vaccination in these countries is as important as ever and indeed the most effective antidote to future epidemics and pandemics.

Yet, despite modern research and the development of effective and safe vaccines for many of these infectious diseases, vaccination is not simply an automatism. Even during the COVID-19 outbreak, large sections of populations in many countries worldwide have refused to take the vaccines available [6,7]. In some countries, such as Germany, this has even led to protests, riots, and new political parties ready to fight for the "right" to not be vaccinated [8,9]. Indeed, the underlying behavior, known as "vaccination hesitancy" (VH), and defined by the Strategic Advisory Group of Experts on Immunization (SAGE) affiliated with the WHO as "the refusal or a delay in accepting vaccines despite their availability" [10,11], remains a major hindrance to achieving herd immunity in many countries [12]. Studies have confirmed that vaccination hesitancy poses a major obstacle in the fight against the outbreaks of infectious diseases, which may lead to epidemics and eventually to pandemics [13–17]. In some cases, such as cholera and meningitis, VH—and not limited access to or effectiveness of modern, adequate vaccines—may even turn out to be the main factor behind those outbreaks [18].

Ghana stands out among the African countries not only because of the devastating impact of COVID-19 on its society, but it was also the first country to receive COVID-19 vaccines through the COVID-19 Vaccines Global Access (COVAX) Facility on 24 February 2021. Yet, despite this "early" access to COVID-19 vaccines, only 16% of Ghanaians were fully vaccinated by March 2022, with 71% not receiving the second dose [19–21]. Even in 2023, Ghana's COVID-19 vaccination rate was still less than 32% and thus behind many African countries such as Rwanda and Mozambique [22]. Indeed, published studies have reported some possible reasons, including concerns about vaccine safety, origins, limited funds, and logistical requirements with the limited shelf-life of vaccines [23,24].

Low vaccination willingness remains a major issue to this day, especially among highly educated young adults. At first, this may be rather surprising as one often instinctively associates the educated "informed citizen" with rational decisions and choices. Nonetheless, our previous study already reported a mismatch between high levels of knowledge about infectious diseases including influenza, cholera, and COVID-19 on the one side and a surprisingly low, often irresponsible practice of preventive measures on the other, including, indeed, a low willingness to be vaccinated [25]. This poses the question of why educated and informed young adults exhibit such a pronounced hesitancy towards being vaccinated despite obviously "knowing it better". In that study [25], higher levels of knowledge about infectious diseases correlated positively with higher levels of education and younger adults. Indeed, the decision to accept or to refuse a vaccine is influenced by an individual's psychological factors which may not always follow a predictable or definite pattern. This choice may come after an intricate deliberation process possibly affected by a myriad of personal and social factors [26].

The 5Cs model developed and validated by Betsch et al. (2018) and built upon established theoretical frameworks, such as the Health Belief Model and the Theory of Planned Behavior, is widely adopted and accepted in the literature for predicting hesitancy behav-

ior [27]. It employs five psychological constructs, called "antecedents of vaccinations", namely Confidence, Complacency, Constraints/Convenience, Calculation, and Collective Responsibility. These constructs, in turn, may be influenced by various environmental factors subsumed under the so-called "epidemiological triad of the environment", composed of (a) social determinants, such as public health policies, messages spread by media, and social factors, (b) the vaccine and disease itself (perception of vaccine safety, effectiveness, and perceived susceptibility to the disease), and (c) the host (i.e., knowledge, previous experience, and educational level) [10,27–32]. The five antecedents and their predictive roles in influencing VH are presented in Figure 1.

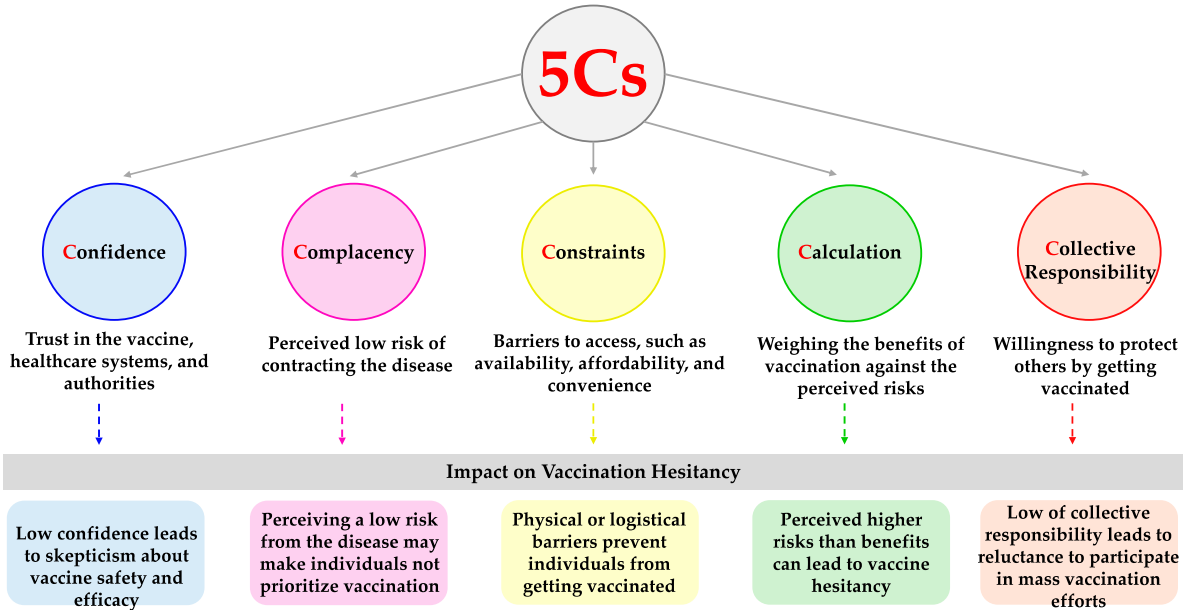

Figure 1. Schematic representation of the '5Cs psychological antecedents' and their predictive influence on VH.

Is it possible to identify the factors underlying this VH and thus develop strategies to influence them in order to minimize VH and increase the success of vaccination campaigns? This study therefore aims to assess VH among university students in Ghana, utilizing the 5Cs model, in order to examine the influence of each of the 5Cs psychological antecedents of vaccination behavior and to explore the impact of multiple external, environmental variables, such as vaccination experience/history, conspiracy mentality/misinformation, sources of vaccination information (official and unofficial), vaccine passport and vaccine attributes on these 5Cs, and subsequently the individual inclination towards vaccination.

2. Materials and Methods

2.1. Questionnaire

The standardized 51-item questionnaire consisted of three main sections (https://doi.org/10.17605/OSF.IO/AFUP7, accessed on 25 March 2025) The first section probed sociodemographic information of participants including age (year of birth), gender, religion, ethnicity, and study program. The second section included participants' information regarding vaccines, that is, their vaccine experience (whether they have previously received eight specific vaccines such as against COVID-19, polio, and yellow fever), sources of information about vaccines such as governmental agencies, social influencers and/or scientific literature, and misinformation about vaccines (conspiracy theories regarding vaccines which were common around the time of this study and featured in local news or social media platforms such as vaccines being ineffective, causing infertility, or

simply produced for financial gain). It should be noted that one item exploring misinformation about vaccines was true, "Vaccines sensitize the body and offer protection against diseases", and was included to enhance quality during data collection. The third section was dedicated to evaluating psychological antecedents regarding vaccines. Here, the participants' responses to the 5Cs (Confidence, Complacency, Constraints, Calculation, and Collective Responsibility), adopted from Betsch et al. (2018) were assessed [26]. Each antecedent of the 5Cs was measured through three items; the long version of the model, consisting of 15 items, was employed. Afterwards, the influence of attributes related to vaccines (origin, brand name, and popularity) on participants' willingness to accept such vaccines, as well as participants' perception of the effectiveness and acceptability of vaccine passports was each measured with one item. It should be noted that, despite the questionnaire consisting of 51 items, only data pertaining to 45 items were processed and presented in the current study.

2.2. Study Design and Data Collection

The questionnaire was distributed physically (paper form) and digitally (sharing of link or scanning of a QR code) between July 2022 and October 2022 by the principal investigator and trained volunteers at the designated locations, Kwame Nkrumah University of Science and Technology (KNUST), University of Ghana (UG), and University of Cape Coast (UCC), after acquiring consent, and the questionnaire was self-administered by participants (https://doi.org/10.17605/OSF.IO/AFUP7, accessed on 25 March 2025). The digital data were collected through Google Forms and stored in a password-protected electronic format. Ethical clearance for this study was granted by the Ethics Committee on Human Research Publication and Ethics, School of Medicine and Dentistry, KNUST, Kumasi, Ghana (Ref#: CHRPE/AP/345/22). The purposively selected locations, (i.e., KNUST, UG, and UCC), satisfied this study's criteria of having health and non-health-related study programs and also having a student population of no less than 25,000. These criteria were set by the researchers to account for variability and improve the generalizability of this study's outcomes.

Faculties and departments at each of the three study sites were classified and structured based on scientific discipline as being either medical (fields of study related to health, disease prevention, treatment, and healthcare systems) or non-medical and were selected upon balloting. Once a faculty or department was balloted, the principal investigator and trained volunteers visited the location and distributed the questionnaire through convenience sampling at lecture halls and campuses and asked participants to share the link to the questionnaire on electronic group-study platforms, such as WhatsApp, to reach as many students as possible.

2.3. Statistical Analysis

The raw data were transferred to Microsoft Excel version 16.78.3 (2019) where it was validated qualitatively, checked, and cleaned. All subsequent analyses were conducted using R (R core team, 2021) including the packages car [33], and mice [34] at the Department for Economics and Sociology of Sports, Faculty of Economics and Empirical Human Sciences, Saarland University, Germany. All items in the questionnaire were collected as categorical variables (Yes/No/Prefer not to say/Don't know) apart from year of birth, which was afterwards converted to age (ordinal scale), the 5Cs antecedents, and vaccine attributes which have been measured based on a Likert-type scale from 1 (strongly disagree) to 7 (strongly agree). A seven-point scale was to increase granularity leading to the enhanced robustness and reliability of the measurement. The religion variable, which consisted of six categories, ethnicity variable, which had 13 categories, and study program

were dichotomized and reduced to Christians/non-Christians, Akans/non-Akans, and medical/non-medical, respectively, for convenience. Furthermore, for vaccine experience, misinformation (conspiracy mentality), vaccine attributes, and vaccine passport, the answers were summed up and divided by the number of the items in each part resulting in a score ranging from 1 to 0. In the case of vaccine experience which had 8 items, for example, "No" answers were coded as having the value of 1, while "Yes" answers were 0. The sum was then divided by 8 and, therefore, a score closer to 0 indicates a higher number of vaccines received. In the case of misinformation (conspiracy mentality), which consisted of 4 items, values closer to 0 indicate a higher level of misinformation about vaccines.

A total of 4126 individuals participated in this study. This included university students at different levels of their studies, non-student university community members, and others. The data set was filtered to include only students, i.e., undergraduates and postgraduates, eventually resulting in a data set: n = 3486. As for missing data, multiple imputation (100 iterations) was performed for participants who answered "Prefer not to say" or "Don't know", to deal with item non-responses. Missing data accounted for 16.9% cases. In the regression analysis, two models were employed. The first model applied binary logistic regression to predict adulthood vaccination behavior (VB) using acceptance of the COVID-19 vaccine as a dependent variable. Here, the starting model, Basic Model, included only the sociodemographic variables (age, gender, religion, ethnicity, and field of study) as independent variables. The Extended Model to explain VB further included the 5Cs antecedents as additional predictors. As for reference categories, in gender it was "female", "Akan" in ethnicity, "Christian" in religion, and "non-health students" in study program. The assumptions of multicollinearity were tested, and heteroscedasticity was assessed using the Goldfeld–Quandt t-test. There were no repeated observations in the data and the observations were random and without biases. Due to the multiple imputation technique, t-tests were employed to compare the Akaike Information Criterion (AIC) and Nagelkerke R-squared distributions between the Basic Model and the Extended Model. Additionally, to confirm the improved prediction by the Extended Model, two-way ANOVA was used to evaluate differences between the models. For all statistical tests, the level of significance was 5%.

The second model aimed to explain vaccine hesitancy (VH) deploying a multivariate regression method having each of the 5Cs as dependent variables, hence resulting in five different sub-models. This multivariate multiple regression model included the following independent variables: gender, religion, ethnicity, study program, vaccination experience, vaccine misinformation, information sources, vaccine attributes, and the respondent's stances towards a vaccine passport. The analysis provides the following statistical information about factors influencing hesitancy: regression/beta coefficients indicative of the strength and direction of the association between the predictors and the outcome when holding other variables constant, odds ratios (OR) with 95% confidence intervals as measures of the impact of predictors on outcome, and p-values as appropriate. Additional information, including t-values showing if the regression/beta coefficients significantly differ from zero, pseudo R-squared values measuring the proportions of variance in the outcome explained by the predictors, and F-statistics assessing the overall significance of the models are also provided in the results and in analytical documentation (https://doi.org/10.17605/OSF.IO/AFUP7).

3. Results

Among the total participants, about 40% had not taken the COVID-19 vaccine (the reference vaccine for VB) out of which 71% were non-health subject students. The findings also support the notion that the 5Cs are crucial for assessing VB and VH, as four of the

5Cs, namely Confidence (OR = 1.56 [1.44–1.68), Constraints (OR = 0.83 [0.78–0.97]), Calculation (OR = 0.85 [0.78–0.87]) and Collective Responsibility (OR = 1.26 [1.16–1.38])—not Complacency—significantly predicted VB ($p < 0.001$). Notably, the 5Cs themselves seem to be significantly influenced by several factors. Vaccine attributes, for example, had a significant influence on all the 5Cs. This is also the case for misinformation (conspiracy mentality). In the next subsection, the sociodemographic details of the participants are first presented, followed by the descriptive statistics on participants' information regarding vaccines and their psychological antecedents. Later on, results from the inferential statistics are demonstrated to attempt at explicating first the vaccine behavior (VB) and then vaccine hesitancy (VH) based on the 5Cs.

3.1. Descriptive Statistics

3.1.1. Sociodemographic Information

The sample included in the statistical analysis was $n = 3486$. The median age of the participants was 21 years, with an interquartile range (IQR) of 19–28 years. Most of the participants were males (55.8%), Christians (92.2%), and Akan (64.3). The study participants were predominantly from non-medical-related study disciplines (62.4%) compared to medical-related disciplines. The overall characteristics of this study is summarized in Figure 2.

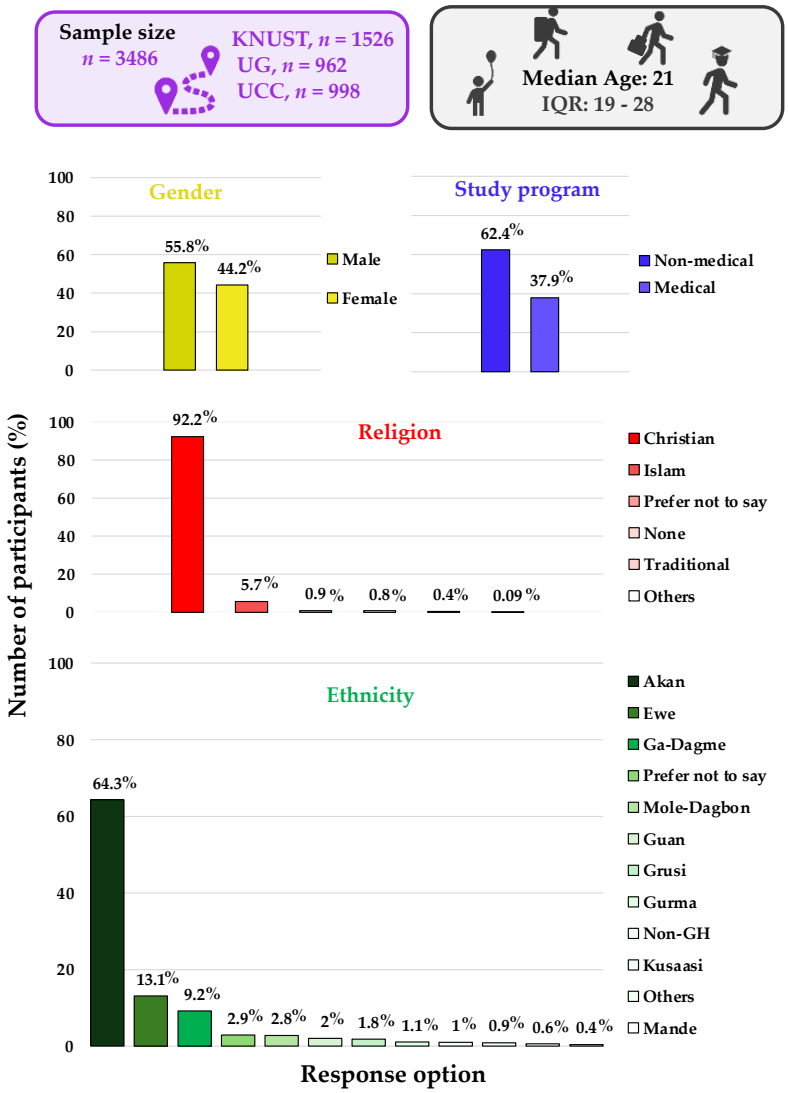

Figure 2. Sociodemographic of participants.

3.1.2. Factors Influencing Vaccination

In this subsection, the results pertaining to mean values and standard deviations of participants' vaccine experience, conspiracy mentality (misinformation), and vaccine attributes are presented. See Table 1.

Table 1. Mean scores and standard deviations for factors influencing vaccination.

Vaccination-Related Factors	Valid	Mean	SD
Vaccine Experience	1878	0.64	0.30
Conspiracy Mentality	1797	0.7	0.24
Vaccine Attributes	3486	0.2	0.23

Score ranges: vaccine experience: 0 (highest) and 1 (lowest); conspiracy mentality: 0 (highest) to 1 (none) and vaccine attributes: 0 (no importance) to 1 (high importance).

When participants were asked about vaccine information sources influencing their vaccination decision, official sources were the most utilized. The scientific literature on vaccines (articles, books, journals, etc.) and international agencies on health (e.g., the WHO, USAID, CDC UNICEF, etc.) were leading sources with 2545 and 2491 respondents, respectively. Unofficial sources, such as family and friends, were also preferred by about two-thirds of the respondents. Governmental agencies and traditional media outlets had a notable influence, while social media and influencers were less preferred, as represented in Figure 3a.

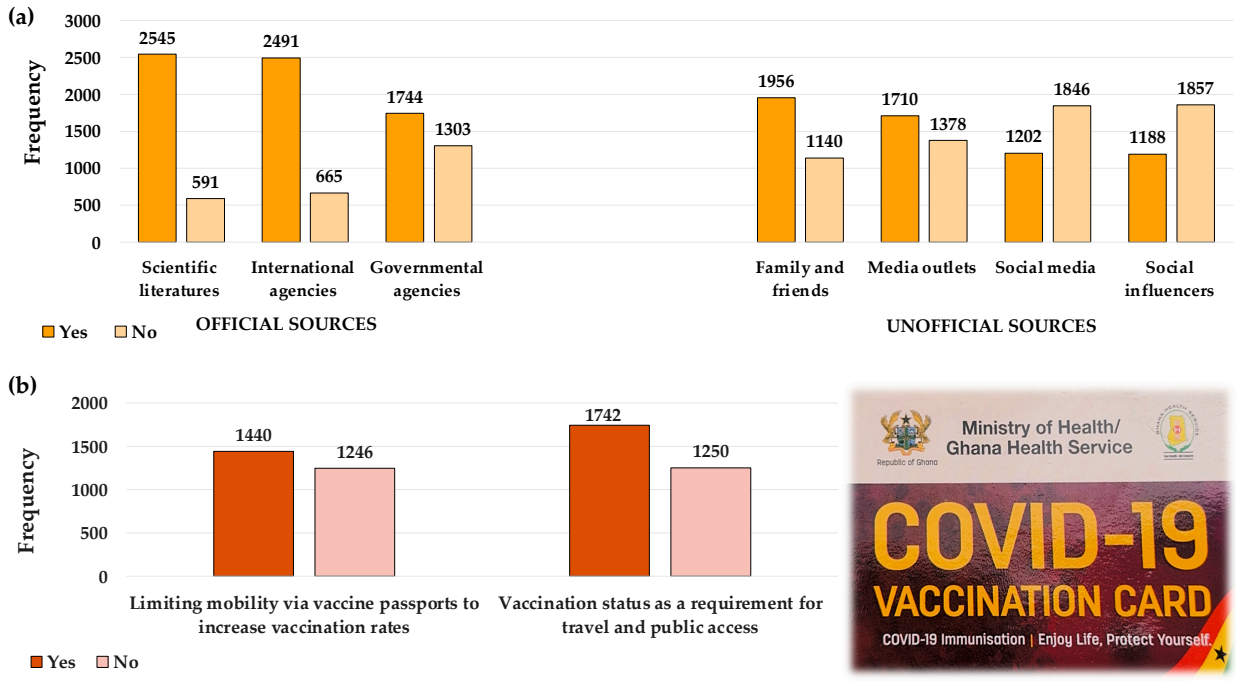

Figure 3. The influence of vaccine information sources and vaccine passport on vaccination. (**a**) Distribution of preferred sources for vaccine information among respondents; (**b**) respondents' stances on vaccine passports, alongside Ghana's COVID-19 vaccination card (photograph by author).

As vaccine passports were mandatory in Ghana, this study assessed respondents' opinions on vaccine passports and their influence on vaccination. The results showed that 1440 respondents supported them. Whilst a small majority supported the use of vaccination status as a criterion for accessing public places such as restaurants, tourist sites, and universities, a notable number of respondents were against this, as represented in Figure 3b.

3.1.3. Distribution and Mean Scores of the 5Cs

The results interpreted on a seven-point Likert-type scale from 1 (strongly disagree) to 7 (strongly agree) are presented as mean and standard deviations of the 5Cs construct in analytical documentation (https://doi.org/10.17605/OSF.IO/AFUP7, accessed on 25 March 2025) Table 2.

Table 2. 5Cs of the Ghanaian university students.

5Cs	Mean	SD
Confidence	2.30	1.31
Complacency	4.40	1.79
Constraints	3.88	1.95
Calculation	1.98	1.09
Collective Responsibility	2.88	1.19

3.2. Inferential Statistics

3.2.1. Evaluation of Factors Influencing Vaccination Behavior

A logistic regression model was employed to investigate vaccination behavior (VB) (whether the participant has received the COVID-19 vaccine or not) of participants. Initially, a Basic Model based on sociodemographic predictors was calculated (https://doi.org/10.17605/OSF.IO/AFUP7). According to this Basic Model, all the sociodemographic predictors provided a significant correlation with VB ($p < 0.001$). The results revealed that religion (non-Christian), gender (male), ethnicity (non-Akans), and study program (non-medical student) significantly correlated with VB in a negative manner with OR values of 1.72 [1.31–2.26], 1.45 [1.26–1.67], 1.31 [1.12–1.52], and 0.548 [0.47–0.64], respectively. The male population exhibited higher odds of not being vaccinated compared to the female population. Moreover, the participants of non-medical programs showed lower odds of being vaccinated than students from courses related to health and medicine. This model explains only 5% of the variability in VB by the sociodemographic data, indicating that these factors could have a limited ability to predict vaccination behavior. Subsequently, when extending the Basic Model by adding the 5Cs, the significant influence of sociodemographic variables persists except for the influence of religion. Beyond sociodemographic determinants, the Extended Model highlights an influence of Confidence on vaccines, Constraints on vaccination, Calculation (i.e., risks–benefits assessment of vaccines), and sense of Collective Responsibility on an individual's VB, as indicated in Figure 4.

Odd ratios of 1.56 [1.45–1.68] and 1.27 [1.16–1.38] for getting vaccinated have been estimated for Confidence and Collective Responsibility, respectively, making these two antecedents stand out positively and show that participants high in these antecedents are more likely to be vaccinated. Constraints (OR = 0.83 [0.78–0.87]) and Calculation (OR = 0.85 [0.78–0.92]) show a decreased likelihood of being vaccinated among the cohort high in these antecedents, and Complacency has no significant influence. Notably, the Extended Model including the 5Cs explains about 20% of the variance in VB. Comparison of the two models showed that adding the 5Cs significantly improves the explanation of variance in VB compared to the Basic Model.

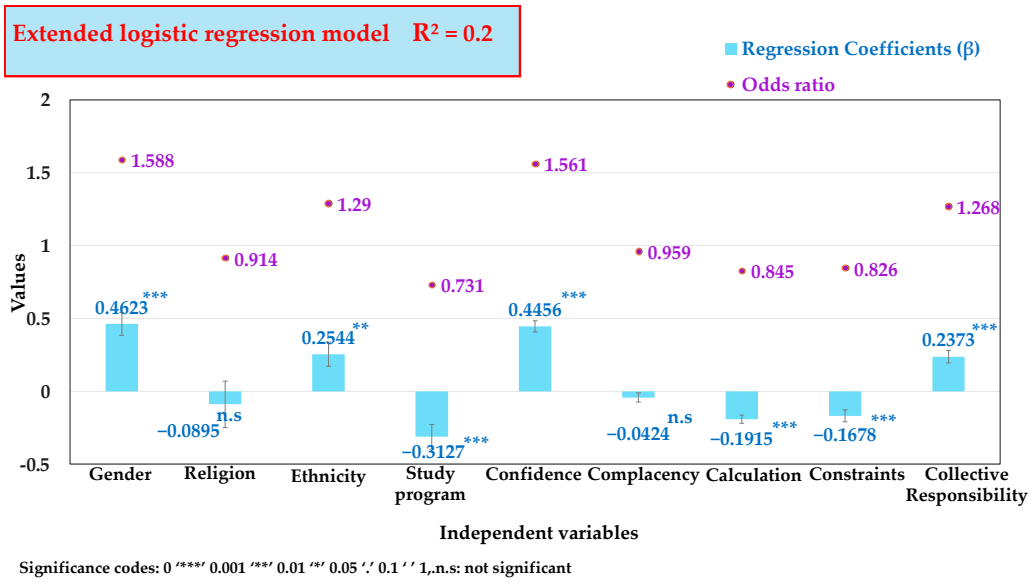

Figure 4. Extended logistic regression model illustrating the influence of sociodemographic variables and 5Cs constructs on VB. This model explains the variance in VB by 20% by (R^2 = 0.20).

3.2.2. Multivariate Regression Explicating the 5Cs Model for Vaccination Hesitancy

In order to evaluate factors influencing vaccination hesitancy, a multivariate regression model was employed to explore the impact of different factors on each of the 5Cs. This model was built to analyze the impact of sociodemographic (study program [medical] and religion [non-Christians]), vaccine experience, conspiracy mentality/misinformation, vaccine information sources, vaccine attributes, and vaccine passport/policies on the 5Cs psychological antecedents. The influences of the different factors on each of the 5Cs are presented in Figure 5.

Amongst all the 5Cs, the variance among the participants in their Confidence (sub-model a) was best explained by the predictors, followed by Collective Responsibility with adjusted R-squared values of 0.339 and 0.200, respectively. Complacency and Constraints were explained to a similar level with adjusted R-squared values of 0.151 and 0.144, respectively, whilst variance in Calculation could be explained the least with an adjusted R-squared value of 0.110.

Conspiracy mentality and unofficial (mis-)information consistently showed a negative impact on the (positive) vaccination traits across each of the antecedents studied, while (reliable) official information sources and vaccine attributes had positive effects on the 5Cs variance. Conspiracy mentality, for instance, negatively impacts the Confidence ($\beta = -1.476$), Complacency ($\beta = -1.607$), and Collective Responsibility ($\beta = -1.135$) and positively influences the Constraints ($\beta = 1.578$), contributing to an overall significant VH among the educated population. Reliable official information sources and vaccine attributes had positive effects on the 5Cs, with vaccine attributes significantly contributing to the explaining the variance in Confidence ($\beta = 2.258$, $p < 0.001$), Calculation ($\beta = 1.655$, $p < 0.001$), and Collective Responsibility ($\beta = 0.734$, $p < 0.001$).

On one hand, unofficial sources of vaccine information had significantly increased the level of Constraints in individuals ($\beta = 0.890$, $p < 0.001$), while on the other hand, decreased the level of Complacency ($\beta = -0.850$, $p < 0.001$), thus, significantly promoting VH. Official information ($\beta = 1.099$, $p < 0.001$ for Complacency; $\beta = 0.602$, $p < 0.001$ for Collective Responsibility) and studying a medical-related subject ($\beta = -0.646$, $p < 0.001$ for Complacency) may directly, via increased knowledge or indirectly via the 5Cs, guard against the influence of unofficial vaccine information sources. Additionally, vaccine

passports were reported as a significant influence on a positive prediction for Confidence ($\beta = 0.508$, $p < 0.001$) and Collective Responsibility ($\beta = 0.545$, $p < 0.001$).

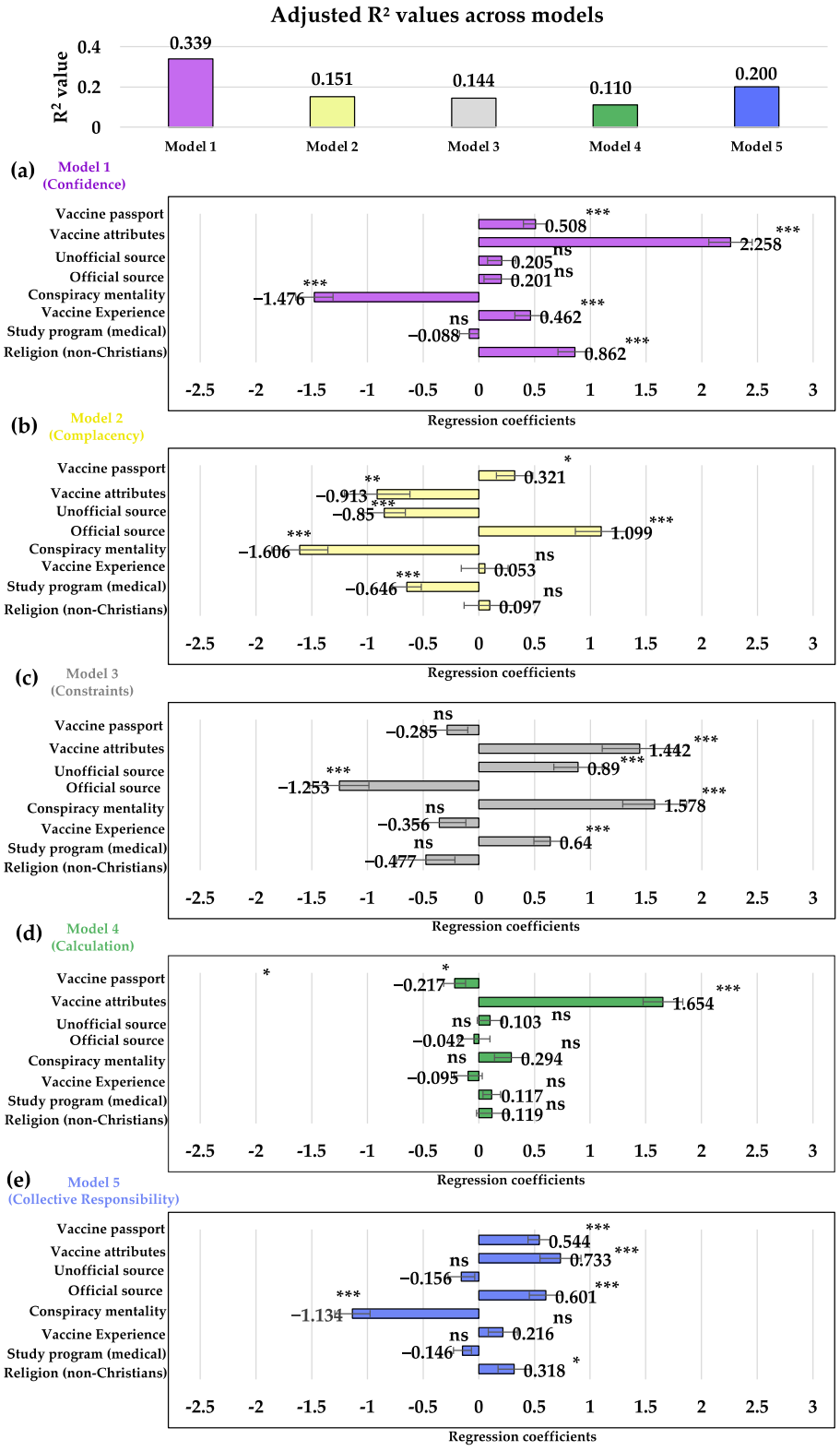

Figure 5. Multivariate regression analysis predicts the influence of different factors on the 5Cs psychological antecedents. Sub-models (**a**–**e**) explicate the proportion of the explained variance in confidence, complacency, constraints, calculation and collective responsibility by the predictors. SE = error bar.

4. Discussion

This study contributes to the existing body of research by examining factors influencing vaccination behavior as well as vaccination hesitancy among highly educated individuals in Ghana. It provides insights which can inform targeted healthcare strategies and policies to enhance vaccination uptake. This study confirms VH among university students, where 40% of the sample remained unvaccinated against COVID-19 with 71% of them who studied non-health disciplines. Confidence and Collective Responsibility increased vaccination likelihood, whilst Constraints and Calculation decreased it. The study also showed that gender (males), ethnicity (non-Akans), and study discipline (non-medical students) exhibited higher VH. Official vaccine information sources were the most trusted, whilst misinformation/conspiracy beliefs increased VH. Vaccine passports encouraged vaccination and the addition of the 5Cs model improved the prediction of VB, accentuating the role of trust, policy, and vaccine information sources in shaping VB.

Our findings among 3486 highly educated young persons in Ghana are in line with recent studies, for instance by Yeboah et al. (2020) [25,35], which reported VH among educated populations. Indeed, this study unveiled a substantial gap between high educational backgrounds and the actual practice of preventive measures against infectious diseases, including vaccinations. In addition, Arko AB, 2023 [36] also reported VH among similar young and highly educated cohorts with 'supposed' access to considerable information on health and health-related issues. Indeed, it is more likely that psychological antecedents of vaccination shape vaccination behavior and in doing so are often themselves influenced by other environmental factors, such as sociodemographic factors and (mis)information via official and unofficial vaccine information sources. These relationships not only expose a set of potential obstacles towards effective vaccination campaigns. They also provide impetus to deal with some of these issues openly and effectively, for instance by addressing possible concerns on the one side and building on existing strengths on the other.

The 5Cs assessment reveals contributive elements of VH among the participants (as shown in Table 2, Figures 4 and 5). Notably, similar to a study conducted in the USA [37], Confidence—or lack thereof—is likely the most significant driver of VH, followed by Collective Responsibility. The analysis of statistical means showed that Complacency, Constraints, and Calculation exhibited patterns indicating either no significant effects or positive association with VH. However, further analysis showed significant influence on VB and thus, VH. The strong associations between VB, gender, ethnic groupings, and VH factors, for instance, point to the need for individually tailored and more targeted public health strategies [38,39]. On a gender-specific note, male-tailored education and vaccination campaigns can alleviate the gender disparity towards vaccination. In Ghana, ethnic variations, including geographical location, socioeconomic status, educational level, religious beliefs, and cultural or traditional systems between Akans and non-Akan groupings impact VH determinants. These factors are reported in many studies to be significantly associated with VB and thus VH [40–42], concurring with our studies where non-Akans are more likely to not get vaccinated compared to Akans. For instance, Akan communities, by virtue of their geographical locations in more developed regions, have more economic opportunities [43,44], hence increasing their ability to afford and access vaccines in contrast to non-Akans who are mostly in less economically developed regions and face financial and logistical constraints to vaccination.

Ethnic-centric vaccination campaign strategies and policies in light of the aforementioned ethnic differences are pivotal to addressing unique vaccination concerns. In addition, since ethnic groupings are mostly localized to specific regions in Ghana, the training and involvement of localized leadership including traditional leaders (i.e., kings, chiefs, and queen mothers), religious leaders, opinion leaders, or people of influence in public health

promotions is imperative as reported in other studies [45,46]. Moreover, with the reported levels of Constraints and its significant influence on VB, policies to reduce vaccination constraints including lack of access, affordability, and availability should be top of the agenda in public health interventions.

On the upside, this study also shows that a higher sense of Collective Responsibility actually increases the likeliness to get vaccinated, similar to findings from a study conducted in Kenya [47], and thus social responsibility should be promoted and rewarded, also in public. At the same time, governments and public health institutions in charge of vaccinations should formulate policies and direct education that increases vaccine confidence via official, trustworthy communication. It would be easy, for instance, to introduce relevant seminars at the three Universities involved in this study and beyond, recruiting medical students to inform non-medical students about infectious diseases, vaccines, and vaccination. Similarly, non-governmental public influencers and political leaders themselves taking the vaccines could play a positive role.

This "role model" approach has already shown to be highly beneficial during the COVID-19 pandemic to boost interest in vaccination and may also safeguard against misinformation which has a distinctly negative influence on VB [48,49]. Whilst misinformation concerning vaccine safety, efficacy, or ingredients can promote doubt and fear, they are further exacerbated by conspiracy theories that suggest vaccines are part of a larger, nefarious agenda [50,51]. Furthermore, the influence of misinformation on 5Cs and thus VH, align with the findings of a study conducted in six Asian and African regions [35] where there was a significant positive correlation between conspiracy beliefs and vaccine hesitancy. Official sources, such as government health agencies, international organizations like the WHO, and healthcare professionals, generally enhance public confidence in vaccines [52]. These sources are often trusted due to their perceived expertise, authority, and commitment to public health and, together with accurate, transparent, and consistent communication from official sources may reassure the public about vaccine safety and efficacy, thus advancing confidence and reducing VH.

The findings presented in this study demonstrate vaccine hesitancy among university students in Ghana as a complex issue requiring integrated clinical and public health approaches. The significant role of psychological factors, such as low confidence, high complacency and constraints, and sociodemographic influences among male, non-Akan, non-medical students, and conspiracy mentality suggests the need for targeted interventions at several levels. Public health policymakers may benefit from adopting behavioral science methods, which include peer testimonies, transparent communication about vaccine safety, and perhaps small incentives, e.g., "thank you" certificates or vaccination pins, to foster trust and collective responsibility. Traditional vaccination campaigns could introduce focused vaccine education and practical tools such as an Email or SMS reminders to simplify vaccination access. Healthcare providers, including campus clinics, can empathetically discuss individual concerns, communicate early and clearly about vaccine efficacy, and possible side effects, and thus, positively shape vaccination attitudes. These coordinated efforts, informed by this study's results, can meaningfully improve vaccine uptake and strengthen community readiness for future health challenges.

5. Limitations of This Study

Our study is limited in generalizability as it has only been carried out on young university students with no prior specific sample size calculations being made and participants sampled by convenience. However, a larger and more varied sample may in part minimize this limitation and improve external validity.

Like any other survey study, our research was partly limited by a social desirability bias [53]. This bias mostly affects the measurement of vaccination behavior and the 5Cs and was not directly addressed by adding a social desirability scale [54]. Nevertheless, the sample is characterized by a broad variety of ethnic and religious groups and study courses. These differences may well concur with different (sub-) cultural social norms and thus, this bias in individual answers may well be assumed to (partly) level out on the collective level.

Another shortcoming of our approach results from the operationalization of vaccination hesitancy only as the contrary of positive vaccination behavior. Besides vaccination hesitancy, vaccination behavior may well be influenced by other circumstances like legal or contractual requirements for certain occupations. Additionally, not being vaccinated may as well depend on other issues than mere hesitancy like chronic illnesses or lacking access to vaccines. Future research may account for this by not only measuring vaccination behavior but also addressing such factual reasons both for being vaccinated or not vaccinated.

While these limitations may be overcome in future research on VB/VH, we trust that our study, nevertheless, provides valuable basic insights into the relevant determinants of VB/VH.

6. Conclusions

Our study on highly educated young respondents in Ghana has confirmed varying levels of VH in this section of society and shown that both sociodemographic factors and the 5Cs significantly influence VB. These findings also provide renewed impetus for addressing some of the influences, concerns, and mechanisms that determine individual's VB and possibly lead to VH. Males, non-Akans, and those enrolled in non-health study programs were less likely to be vaccinated and thus may require tailor-made, community-specific information campaigns to overcome their inherent VH. Greater Confidence and a sense of Collective Responsibility increase the likelihood of vaccination. Additionally, open and transparent discussions about diseases, available vaccines, and the benefits of vaccination for individuals and society are essential for overcoming misinformation. This may also remediate higher Constraints and (negative outcomes of) Calculation, which lead to a decrease in the likelihood of vaccination. Notably, context-specific health interventions augmenting policymakers and healthcare professionals in advancing vaccine up-take and achieving community herd immunity against vaccine-preventable diseases should therefore be promoted. Together, these measures are important to enhance the preparedness for potential future epidemics or pandemics, especially in countries of the Global South.

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Abstract: The COVID-19 pandemic has affected populations globally, including Ghana. Knowledge of the COVID-19 disease, and the application of preventive public health interventions are pivotal to its control. Besides a lockdown, measures taken against the spread of the virus include the wearing of face masks, social distancing, regular hand washing with soap and, more recently, vaccination against the virus. In order to establish a possible link between the knowledge of the disease and compliance with preventive measures, including vaccination, a cross-sectional study employing an interview-structured questionnaire was conducted in six regions of Ghana (n = 1560). An adequate level of knowledge of COVID-19 (69.9%) was reported. The linear multiple regression analysis further explicated the differences in the knowledge of COVID-19 among the respondents by their knowledge of cholera and influenza (adjusted R-Square = 0.643). Despite this profound knowledge of the illness, two thirds of the respondents were unwilling to follow basic preventive measures and only 35.3% were willing to be vaccinated. Amazingly, neither knowledge of COVID-19 nor the socio-demographic characteristics had any meaningful influence on the practice of preventive measures. Personal attitude leading to efficient public compliance with preventive measures, therefore, is a critical issue demanding special attention and effective interventions by the government and locals with authority to curb the spread of the pandemic which surpasses the traditional channels of public health communication. This includes a roll-out of persuasion, possibly including public figures and influencers, and in any case, a balanced and open discussion addressing the acceptance of the COVID-19 vaccine in order to avoid new variants and comparable problems currently facing many countries of Western Europe. Indeed, a profound hesitancy against vaccination may turn African countries such as Ghana for many years into hotspots of new viral variants.

Keywords: attitudes; COVID-19; Ghana; knowledge of COVID-19; linear multiple regression analysis; practices against COVID-19; preventive measures; public health; socio-demographics; vaccination

1. Introduction

Since its first appearance in December 2019, COVID-19 has become a global pandemic and the virus is also increasingly affecting countries in Africa, which have witnessed viral and bacterial outbreaks, such as H1N1 influenza and cholera, before. On February 2020, researchers projected that developing countries, such as the ones in sub-Saharan Western and Central Africa, may be unable to mount an adequate response in terms of infection control and disease management, owing to a poor healthcare structure and lack of resources [1,2]. Although the outbreak of Ebola in countries, such as Nigeria, Liberia and the Democratic Republic of Congo in 2014–2016, may have highlighted the necessity to prepare the regional defenses against such pandemics, few concrete measures had been taken since. Indeed, the recent COVID-19 outbreak indicates that these limited efforts have been confronted off-guard and put to the test [3].

Nonetheless, the impact of COVID-19 in Africa has been country specific and often surprisingly contained [4,5]. While countries such as South Africa have suffered an outbreak eventually leading to new variants of SARS-CoV-2, in sub-Saharan African countries such as Ghana, with a population of 30 million, the impact of the virus has been so far relatively modest [6]. Ghana recorded her first two cases of COVID-19 in March of 2020, comparatively late in the early days of the pandemic. Since March 2020, there has been a gradual and occasional sharp increase in the number of confirmed cases. As of November 2021, Ghana has recorded a total of 131,000 confirmed cases of COVID-19 and 1208 fatalities, while Poland, a European country with a similar population, suffered 3.38 million confirmed cases and 81,228 fatalities.

In fact, despite issues of inadequate medical resources and preparedness, the official response to the pandemic in African countries such as Ghana has been quite timeous and progressive [7]. These measures so far have included lockdowns in high-risk areas, isolation of infected persons and contact tracing, advocating personal preventive practices, such as wearing face masks, using alcohol-based sanitizers, hand washing with soap, and social distancing [8,9]. Testing facilities have been in place early in Ghana and an infectious disease center has been built in the capital city Accra and completed during the ongoing COVID-19 pandemic [10].

In parallel, public health campaigns to curb the spread of the ongoing COVID-19 pandemic have been in place. The knowledge of the population with regard to the nature, symptoms, transmission, and prevention of an infectious disease is often considered pivotal in influencing the attitudes and practices towards tackling a pandemic. Nonetheless, knowledge alone may not suffice to convince the population to implement preventive measures or to become vaccinated as some of the recent shocking news from across Europe have demonstrated [11–14].

We have therefore carried out a cross-sectional study to characterize the knowledge of the Ghanaian population related to COVID-19 and to investigate the postulated link between this knowledge on the one side and the implementation of preventive measures in practice on the other. Such cross-sectional studies reporting the knowledge and practice of different populations are conducted routinely to evaluate and better design public health campaigns and interventions [15]. In this context, we also have elucidated whether there are any socio-demographic factors influencing either the knowledge or compliance with the preventive measures. One may, for instance, expect that higher levels of knowledge related to COVID-19 along with certain socio-demographic factors such as age, education, occupation and/or type of community, may be valuable determinants of better compliance with preventive measures including personal hygiene and willingness to become vaccinated.

2. Materials and Methods

2.1. Preparation of the Questionnaire

To address these issues of information about COVID-19 and implementation of measures against it among the wider population across Ghana, a questionnaire was developed, pretested, and validated as shown in Supplementary-Section S5. The questionnaire was

also translated from English to local languages of participating communities, including Twi, Ewe, Ga, Gonja, Kussal, and Buli by professional linguists for the few participants who could not understand English. Their answers were translated back to English. In the field, the principal investigator and trained research assistants then read the 26-item questionnaire to the respondents and collected their answers.

As for the questionnaire itself, it is divided into three main sections, namely, socio-demographics, knowledge, and practice of preventive measures. The socio-demographics collects information on age, gender, marital status, educational level, occupation, religion, and type of community. The knowledge section consists of four subsections. The first subsection has two categorical items addressing general knowledge of infectious diseases. The following two subsections address the knowledge of the respondents on cholera and influenza. The last subsection assesses the knowledge of the respondents of COVID-19 with nine categorical items. By the term knowledge we aim to capture the facts, awareness, or information obtained through experience or education related to the COVID-19 pandemic. The WHO recommendations on preventive practices to stop the spread of COVID-19 are used as a standard in evaluating the practices of the respondents, such as wearing a face mask, practicing social distancing, regular hand washing with soap, and willingness to receive the vaccine.

It should be noted that the topics of the questionnaire are highly specialized, ranging from knowledge of infectious diseases, symptoms, and modes of transmission to different preventive practices. These questions are addressed to the broad public excluding healthcare professionals.

2.2. Study Design and Data Collection

The cross-sectional study employing an interview-structured questionnaires (n = 1560) was carried out in six different regions of Ghana, including Upper East, Savannah, Ashanti, Western, Greater Accra, and Volta regions, Figure 1a.

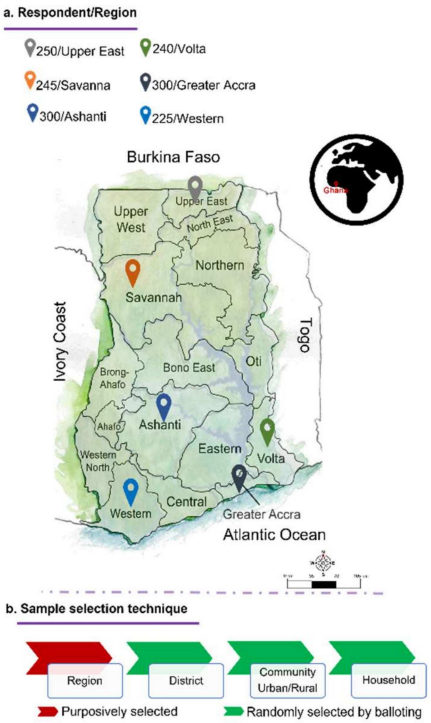

Figure 1. (**a**) Geographic locations of sampling within Ghana on the right and, (**b**) a scheme of sampling technique (sketch provided by Leja Nessis).

The study followed a multistage sampling technique, Figure 1b. The six regions for the study were selected to represent the northern, middle, south-western, and south-eastern parts of the sixteen regions in Ghana. On the district, community, and household level the sampling technique was randomized. The study was carried out from September 2020 to December 2020. Data collection was completed on Saturdays and Sundays as most respondents should be at home then. During sampling, the interviewers and the participants adhered to the COVID-19 preventive measures.

Health-care workers were excluded as they are likely to be trained in disease-related countermeasures. As the study was based on an anonymous survey and did not include human or animal specimens, ethical clearance was addressed to the relevant authorities and obtained from the Ethics Committee on Human Research Publication and Ethics, School of Medical Sciences, KNUST Kumasi, Ghana. Moreover, informed consent forms were obtained from each of the respondents. In the case of participants below 18 years of age, consent was sought from their guardians. The questionnaires were completed by these volunteers and collected on the spot, checked manually for completeness, and then taken to Kwame Nkrumah University of Science and Technology (KNUST) for processing.

2.3. Statistical Procedure

The raw data were entered in Microsoft Excel version 16.34 (2019) where data cleaning, validation, and quality checks were carried out. The analysis of the data employed linear multiple regression models and was conducted using *R* (*R* core team, 2021) including car [16] and boot packages [17] at the Department for Economics and Sociology of Sports, Faculty of Economics and Empirical Human Sciences, Saarland University, Germany.

The data were tested (Chi-squared test) for representativeness of both the regional and overall population in Ghana, Supplementary Section S6. The sample in this study was found to be not representative, as a result, descriptive statistics were calculated as weighted means. The weights were calculated from the univariate marginal distributions, thus assuming that age, gender, and region were independent. Therefore, age, gender, and region were included in the statistical models as instrumental variables (IV) to control for error variance and confounded results from unequal cross-distributions, see Supplementary Section S1.

As for the linear multiple regression analyses, gender was reduced to binary (male/female), region was dummy-coded to provide significance tests for contrasts between each region and the capital region Accra and age was recoded into three groups (15–24), (25–54), and (55+), and was dummy-coded to provide significance between the younger group and the two older groups. The remaining sample for the regression analysis was $n = 1516$. Only weak multicollinearity assessed via the intercorrelation matrix models and the variance inflation factor VIF, was observed throughout. The Shapiro–Wilk Test and also skewness and kurtosis were assessed for normality in the distributions of variables. In the case of deviation from normality, a bias-corrected and accelerated bootstrap interval, and 2000 bootstrap-replications of the designated regression coefficients were computed. *t*-values, *beta* coefficients, and adjusted *R*-squared values were reported, as appropriate. A test for the independence of errors (Durbin–Watson Test), outliers and inferential cases, and one-sided 5% Bootstrapped Confidence intervals were reported when applicable, see Supplementary Section S2.

Scores weighted to represent the sample at the regional level are reported, when applicable, are provided in Supplementary Sections S2–S4. The scores were calculated via the mean number of correctly ticked answers and correctly unticked answers, and hence a higher accuracy of the measurement was achieved due to the higher number of items per domain.

3. Results

In general, the data obtained confirm that there is a good level of knowledge within the communities in Ghana about the SARS-CoV-2 infection and the pandemic caused by this virus. This knowledge of COVID-19 may indeed be the result of a general alertness due

to other outbreaks having affected Ghana in the past (influenza and cholera). Despite this level of knowledge, there was a certain low willingness to comply with the COVID-19 preventive practices/measures to counteract the pandemic and also a low inclination for vaccination. Furthermore, though the linear multiple regression analysis demonstrated that the knowledge of COVID-19 associated positively with the practice of preventive measures, the level of explained variance of the model was as low as 6.9%. There was no substantial influence of any of the socio-demographic characteristics surveyed on the practice of the preventive measures.

In what follows, we first present the descriptive statistics of the sample. In the knowledge and practice sections, the results are presented as weighted mean numbers and standard deviations of the scores from our sample to represent the Ghanaian population.

3.1. Descriptive Statistics

3.1.1. Socio-Demographic Indicators

The socio-demographic characteristics of the 1560 respondents in the survey and regional data are summarized in Figure 2.

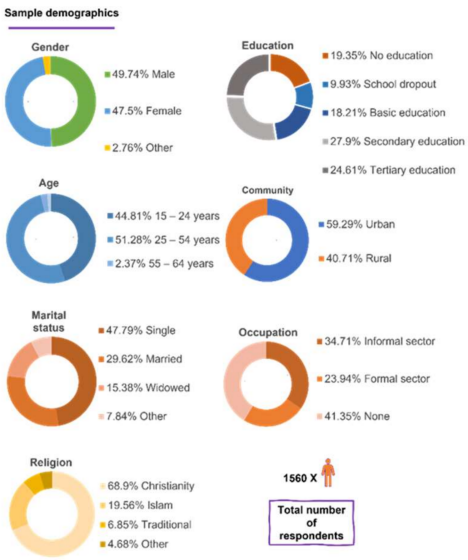

Figure 2. The socio-demographic characteristics of the 1560 respondents of the study.

3.1.2. Data Obtained from the Knowledge Section

The scores of the population sampled in the knowledge section are presented as weighted mean numbers and standard deviations in Table 1.

Table 1. The level of knowledge of the Ghanaian population on existing infectious diseases and COVID-19.

	Mean	SD
General Knowledge of infectious diseases	0.654	0.188
Influenza	0.579	0.240
Cholera	0.752	0.222
COVID-19	0.699	0.190
Summative score	0.671	0.177

The average result in the general knowledge of infectious diseases was 65.4%. The average knowledge scores of COVID-19 obtained were also close to 70%, implying that many respondents questioned held an adequate level of knowledge about infectious diseases and the COVID-19 pandemic. An average summative score of 67.1% was obtained in the knowledge section of the questionnaire, as shown in Supplementary Section S1.

3.1.3. Data Obtained from the Practice Section

Only about 31% of the estimated population indicated positive responses to the practice of preventive public health measures. With regards to vaccination against COVID-19, which has been on the roll-out in Ghana since March 2021, only around 35% of the population showed willingness towards getting vaccinated, Table 2.

Table 2. Responses to the different preventive practices/measures presented as average weighted mean numbers.

Preventive Practice	Response (%) Yes
Wearing of face mask	28.7
Regular hand washing	31.7
Social distancing	28.0
Willingness to be vaccinated	35.3

3.2. Linear Multiple Regression Analysis

3.2.1. Influences on the Knowledge of COVID-19

From the scores obtained in the knowledge section, one may hypothesize that prior knowledge on previous outbreaks other than COVID-19, such as cholera and influenza, may sensitize the population for pandemics. Figure 3 indicates significant positive associations between having good general knowledge of infectious diseases along with more specific knowledge of existing infectious diseases, cholera, and influenza, on the one side and knowledge of COVID-19 on the other.

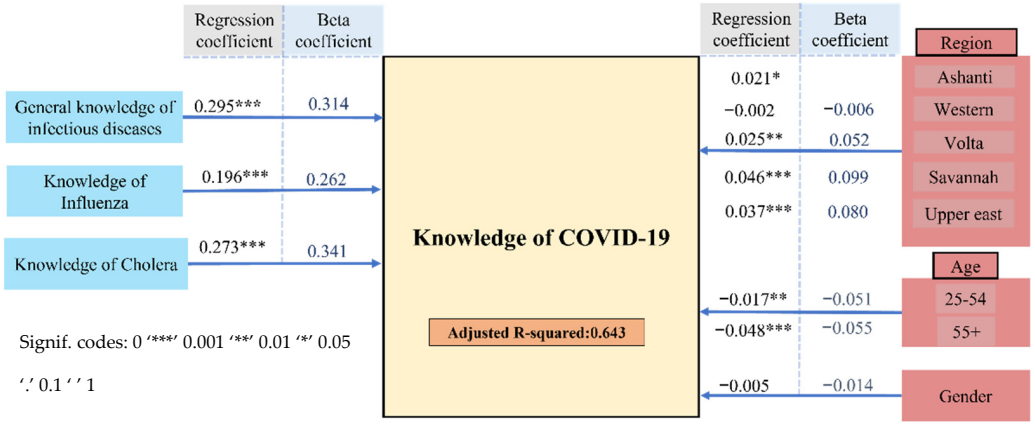

Figure 3. The knowledge of COVID-19 Model (KCM) which was employed to assess the influences of the other domains of knowledge surveyed on the knowledge related to COVID-19. The results are shown in terms of regression coefficient estimates (non-standardized coefficient) and *beta* coefficients (standardized coefficient).

The values of the regression coefficient (unstandardized coefficient) and *beta* coefficient (standardized coefficient), which have values ranging from −1 and +1, represent the mean change in the response given a one unit change in the predictor. So, for instance, an increase of one unit in the respondent's knowledge related to cholera, would lead to an increase of 0.273 in their knowledge related to COVID-19. However, when the variance between their knowledge related to COVID-19 and cholera is standardized, the increase would be 0.341. Furthermore, the adjusted R-square value for this model was 0.643. This means that the difference in the knowledge of COVID-19 among the population can be explained by their knowledge related to influenza and cholera while considering age, gender, and region by a level of more than 64%.

The model was extended stepwise to assess for the influence of other socio-demographic characteristics of the sample. The type of community, whether rural or urban, affected the

variance in the knowledge of COVID-19 variable only slightly, and the explained variance rose insignificantly from 64.4% to 65.4%. As anticipated, education and occupation also increased the explained difference in knowledge of COVID-19 from 65.4% to 70.3%, which is significant at $p = 0.001$, implying a significant influence of education and occupation on knowledge of COVID-19. Apart from that, accounting for religious differences slightly influenced knowledge of COVID-19, as it increased the level of explained variance by 0.6%; final adjusted R-squared = 0.709, Figure 4, Supplementary Section S3.

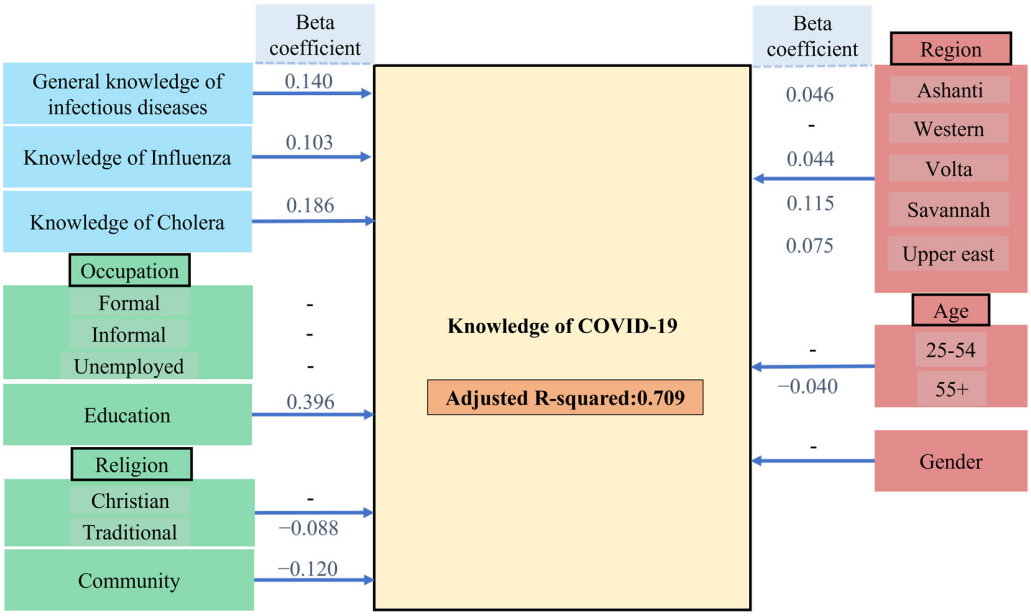

Figure 4. The extended knowledge of COVID-19 model (E-KCM) employed to assess the influences of the socio-demographic characteristics on the knowledge of COVID-19. The results are shown in terms of regression coefficient estimates and *beta* coefficients. The level of explained variance in the results of this model was 70.9%.

It should be noted that in this model, the Akaike information criteria (AIC) demonstrated that education—given the non-significant contribution of occupation—adds substantially to the explanation of the differences in the knowledge of COVID-19 among the respondents, Supplementary Section S3.

3.2.2. Knowledge onto Practice

A significant although weak association was also found between the knowledge of COVID-19 and the practice of preventive measures against it, Figure 5.

Unexpectedly, the linear regression model explicated just 6.9% (adjusted *R*-square = 0.069) of the relationship between the level of knowledge related to COVID-19 and the low compliance with preventive measures. This implied no substantial influence of knowing about COVID-19 and practicing of preventive measures, Supplementary, Section S4.

This model was extended by stepwise addition to assess the influence of the type of community, level of education, occupation, and religion of the respondents on their practice of preventive measures against COVID-19. Being employed in the formal sector significantly associated with better practice but comparing the AICs of the models showed that the increase in explanatory power was nearly neutralized by the increased complexity of the model. The Bayesian information criterion (BICs), showed that the more complex model would be classified as worse than the basic model. In other words, none of the socio-demographic characteristics meaningfully changed the level of explained variance of the practice of the respondents against COVID-19, ultimately contributing just 3.7% of the level of explained variance. This indicates that there was no substantial influence of either gender, age, religion, education, occupation and, indeed, the type of community one

resides in, on the practice towards preventing the SARS-CoV-2 infection and the pandemic as detailed in the statistical model, Supplementary Section S4.

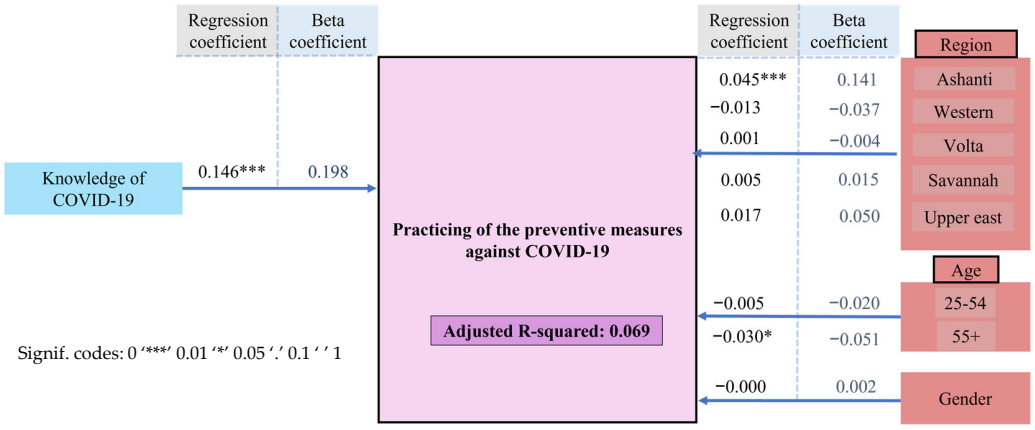

Figure 5. The practices against COVID-19 model employed to assess the influences of knowledge related to COVID-19 and the practicing of preventive measures recommended by the WHO. The results are shown in terms of regression coefficient estimates and *beta* coefficients.

4. Discussion

In general, the data suggest that in Ghana the campaign to inform the wider population about the SARS-CoV-2 pandemic and its risks has been successful. This campaign has reached virtually every sector of the Ghanaian society, in bigger cities and also in the remote countryside. Although this is very encouraging, the limited readiness of the same individuals to protect themselves, for instance, by wearing face masks, washing hands with soap, or maintaining social distancing is worrisome and may require further action, especially in the context of the vaccination program. These issues are now discussed in more detail.

Firstly, our study suggests that public knowledge of COVID-19 in Ghana is generally good, as the overwhelming majority of the 1560 respondents questioned, in cities and also in the countryside scored an average of 69.9%. These results are indeed comparable to studies from neighboring countries such as Côte d'Ivoire, Burkina Faso, Nigeria, Uganda, and Gambia [18–20]. These findings may be explained with prior exposure and experiences of the population to and with similar infectious outbreaks, for instance, cholera, which accounts for 3.8% of fatalities in Ghana each year [21]. Indeed, knowledge of COVID-19 at 69.9% was associated positively with knowledge of other existing infectious diseases—cholera and influenza, with a 64.3% level of explained variance among the population. Knowledge related to these two infectious diseases, along with the socio-demographics surveyed accounted to more than 70% of the difference among the knowledge of the population about COVID-19, Figures 3 and 4.

Secondly, and this may be the most astonishing finding of the entire study, this generally adequate knowledge does not translate into a general compliance with the personal preventive public health measures. These basic preventive measures are only followed by around 30% of the population, as presented in Table 2. Knowledge related to COVID-19, being of a younger age and living in the capital city Accra associated positively with practicing the preventive measures. Nonetheless, the differences among the population, even after including further socio-demographic variables, remained indeed high and were barely explained by the regression model presented in Figure 5 and Supplementary Section S4. Therefore, the question of why the population is not practicing the preventive measures remains open. Here, an interplay between economic, social, psychological, and environmental structural factors, operating on individuals and also on groups, might be considered to be hindering acceptability, accessibility and availability of such preventive measures in

Ghana [22,23]. In this sense, the effect of knowledge onto practice could be moderated by other factors beyond the scope of this study [24–26].

In our study, for instance, only about 29% of the respondents were willing to wear a face mask. While the individual daily average living wage in Ghana is around GHC 30 (USD 4.89), locally produced face masks cost between GHC1 (USD 0.17) and GHC 7 (USD 1.20). In contrast, the price of N95 masks is around GHC 25 (USD 4.37) per mask [27,28]. Since wearing a face mask on public transportation was rendered mandatory in Ghana, in April 2020, the accumulating costs, amplified, perhaps, by low perceived benefits of the face mask on a hot day in public transport, may indeed lower the acceptability of face masks [28]. In the same breath, unwillingness to regular hand washing can also be viewed as a consequence of the customs and traditions of the population [29]. Notwithstanding, the *Veronica bucket*, a revolutionary, simple and local invention which became popular in 2020 in response to the pandemic and has rendered washing hands with soap and water available to the population at many public places [30]. It should also be noted that the collective and inclusive social structures in Ghana, such as the crowded local, informal markets, in which the majority of the population earn and shop, added to the household structure, which is reported to be congested with individuals of varying ages could also hamper the compliance with the preventive measures [8,31].

Furthermore, investigating and addressing psychological factors on the attitudinal level, such as stigma, self-efficacy, group-efficacy, perceived severity of disease, and perceived barriers could also explain the discrepancy between knowledge on the one side and individual attitude and adeptness to follow the preventive measures and vaccination on the other [32–34]. Several such structural factors, belonging to different settings and contexts have been addressed as part of this special issue, Reducing Health Inequities: Social Epidemiology Insights for Public Health and Social Policy [35–39].

In the case of willingness to receive the vaccination, our findings agree with the ones provided by the so-called Afro barometer survey conducted in March 2021 in five African countries, namely Benin, Liberia, Niger, Senegal, and Togo. The survey reported that only 4 in 10 respondents (n = 1200) were likely to take the vaccine [40]. The rates of willingness to be vaccinated presented in Figure 6 indeed elicit wider issues with compliance in many countries in Africa and globally which do not necessarily simply rely on sufficient information about the disease and the countermeasures in place [40–42]. In fact, misinformation about the COVID-19 vaccines and their benefits is common, especially on social media, and has already resulted in hesitancy towards vaccination [43,44]. In fact, one of our previous studies conducted in Ghana has already documented a cultural element regarding the choice of antimalarial drugs [45]. In this study, the recommendation by friends guided the choices of 93.6% of the respondents in Ghana on the preference of herbal medicines used against malaria. In any case, these findings also define a potentially major problem for the next couple of years, as producing and providing vaccines alone may not be sufficient unless there is a general willingness to be vaccinated.

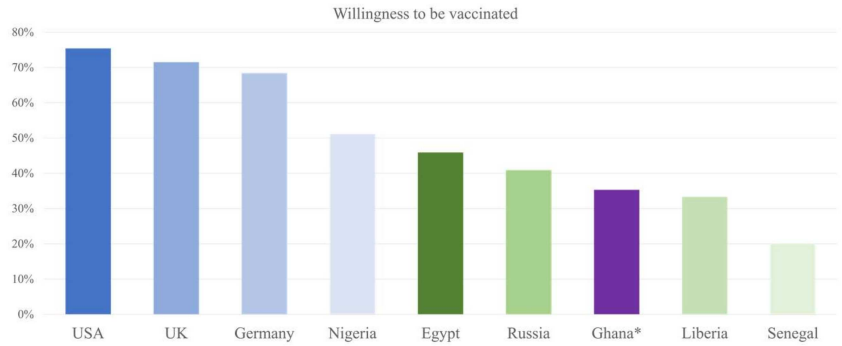

Figure 6. The readiness to receive vaccines against COVID-19 in different countries compared to Ghana. * Results reported in our study.

Indeed, whilst developed countries such as Austria, Germany, and the Netherlands should be close to achieving protection by vaccination, countries such as Ghana, where only about 3% of the population is fully vaccinated to date might allow COVID-19 to linger on and also to produce new and more dangerous variants [44–46]. This may not only be due to a lack of availability of vaccines but also the acceptance from the population. The willingness of the respondents to be vaccinated resided at 35.3%, which might indicate that availability of the vaccine alone might not be the problem. For instance, some individuals may distrust the sources of the vaccines and develop fear of possible side effects. Here, remembering the deleterious Tuskegee study of untreated syphilis in African American males in 1932 may contribute to the reluctance [47]. The prognosis of failing to wisely promote the vaccines could lead to a huge humanitarian crisis on an international scale [48].

Africa and indeed the world at large, may therefore provide new hotspots of new variants of the virus as, indeed, has been the case with the new variants isolated in South Africa, Brazil, and, recently, India [45,49]. As this low level of compliance is almost independent of socio-demographic indicators, such as gender, age, education, occupation, religion, community, and region, simply running more public campaigns in different groups of the population and different areas of Ghana may not resolve this problem. Additional approaches should include a consistent and proper communication between the public and governmental bodies involved in the procurement of the vaccine [41]. The recent experience of Ebola vaccination across several African countries demonstrates strong social and political hesitancy to the introduction of new vaccines [40,43,45,46,48,50]. Campaigns of public awareness and interpersonal engagements involving health practitioners and trained vaccination assistants from and within the communities should be put in place and encouraged. This may help achieve an incremental uptake of the vaccine in the country, as aimed at by the government of Ghana. Furthermore, household elders, traditional, religious, academics and other opinion leaders, in modern English often referred to as "social influencers", may serve as channels of communication, in public and also in the social media. Vaccinating these formal and informal leaders and influencers, perhaps in the open as often exercised by politicians, may help to relieve and to reduce the skepticism. As for scientists, it is imperative for Ghana, Africa, and the global community to study the challenges with compliance in order to put measures in place, as willingness to become vaccinated, rather than availability of a suitable vaccine, may soon become a major obstacle in the fight against the virus.

5. Conclusions

To conclude, our study involving respondents from various subgroups of, and locations in, Ghana confirms that the population is by large properly informed about the SARS-CoV-2 pandemic. Nonetheless, compliance with preventive measures and willingness to take the vaccine is low. We could not find any meaningful correlations between this low readiness to follow the precautionary measures on the one side and common socio-demographic parameters on the other. The manifestation of this mismatch between knowing about COVID-19 and non-complying with its preventive measures is not limited to Ghana, as major demonstrations against COVID-19 measures and vaccination on the streets of major European countries, such as Amsterdam, Berlin, and Vienna, demonstrate [11–14,51,52]. Indeed, attempts to enforce preventive measures and vaccinations by the governments in these countries already have led to riots and political unrest. In fact, some of the findings of our study conducted in the second half of 2020 have already heralded these developments, including a perhaps initially suspected resistance of the virus against the vaccines and its ability to result in further outbreaks and more dangerous variants, such as the Omicron variant. It is therefore pivotal to discuss and address additional factors such psychological, social, political, economic, and environmental attitudes and influences.

Considering these rather distressing findings of our present study together, effective measures need to be put in place to convince the population in Ghana of the necessity and benefits of adopting precautionary measures, including vaccination against the virus. Therefore, once vaccines become available more widely, a campaign must be in place to convince and educate the wider population to the benefits of these vaccines. This task may be shouldered by the government and should be supported by the traditional and modern influencers on the ground, in public, and possibly also on social media. A qualitative study to unravel why, despite the adequate level of knowledge on infectious diseases and COVID-19, only a few individuals are willing to take precautionary measures and be vaccinated should be carried out to drive policy directions. Informed policy, would indeed avoid unrest, similar to what occurred in Europe, and to avoid turning Africa into the home of new and perhaps more dangerous variants.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijerph182412902/s1, Supplementary Section S1: Descriptive statistics, Section S2: Inferential statistics, Section S3: Linear Multiple Regression Analysis: Influences on the Knowledge of COVID-19, Section S4: Linear Multiple Regression Analysis: Influences on the practice against COVID-19, Section S5: Questionnaire, Section S6: Test for Representativeness.

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