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About Mankind Quarterly

Mankind Quarterly was founded as a quarterly journal of anthropology, in the broadest sense of "the science of man," in 1961. This was a time when the study of man had already diversified into physical anthropology, ethnography, quantitative cross-cultural research, archaeology and other subspecialties.

These developments took place against the background of a widening gulf between the biological and social sciences. Following the leading dogma of the day, cultural and social anthropologists in academe had begun to deny the importance of biology for behavioral and cultural phenomena. Conversely, biological (physical) anthropologists aligned themselves with the "hard" sciences, many describing themselves as human biologists rather than anthropologists in an attempt to distance themselves from a social anthropology that they no longer saw as scientifically sound. In many places, these divisions persist to the present day. *Mankind Quarterly* was founded as a response to these centrifugal trends. Its founders believed in the interdependence of human biology, behavior and culture, and they understood biological and cultural diversity as the outcomes of evolutionary, ecological, and historic processes.

In short, *Mankind Quarterly* was established as a journal for those scholars who still believed in a unified "science of man" that studies the interactions between biological and cultural diversity. It was first published in Edinburgh, Scotland in 1961, and then, from 1979 to 2014, by the Council for Social and Economic Studies (chaired by Roger Pearson) in Washington, D.C. In January 2015, publication was transferred to the Ulster Institute for Social Research, a non-profit organization in London, England. Throughout its existence, *Mankind Quarterly* has maintained its character as a journal devoted to the interdisciplinary study of man. New developments in the field were reflected in the journal early on. When first sociobiology and then evolutionary psychology developed descriptions of human nature and explanations for cultural universals, the new developments found expression in the journal. The same happened with behavioral genetics, which like sociobiology saw major advances during the last three decades of the 20^{th} century.

Today the editorial board includes scholars from 12 countries who represent a wide variety of disciplines including primatology, physical anthropology, archaeology, cultural anthropology, human genetics, differential psychology, sociology, and history. Despite their varied expertise and views, the editors share a common interest in the evolutionary and historical processes that generate human diversity, and in the universal features of human nature that constrain this diversity. Because history and biological evolution are ongoing processes, this includes an interest in the social, cultural, demographic and biological changes that are taking place in modern societies.

Some of the articles the journal publishes deal with the evolutionary and historic processes that have created the racial, ethnic, linguistic and cultural diversity we see today. Others describe present-day cultural diversity and ongoing trends, especially at the psychological level. During the last years, intelligence and its change over time have been especially active research areas, and a substantial part of this work has been published in *Mankind Quarterly*. The subject is important because education and intelligence are considered the key drivers of cultural change and economic growth, not only in developing countries but also in mature postindustrial societies. Other areas of special interest are the demographic changes that are taking place in countries today and that are shaping the world of the future.

Historically, *Mankind Quarterly* has earned a reputation for publishing articles in controversial areas, including behavioral race differences and the importance of mental ability for individual outcomes and group differences. During the "Bell Curve wars" of the 1990s, it became a target of attack when opponents realized that some of the work cited by Herrnstein and Murray had first been published in *Mankind Quarterly*. However, much of this science has stood the test of time. For example, the importance of genes for individual differences in intelligence is no longer controversial, and genetic effects on individual and group differences that were merely inferred in earlier research are now studied at the molecular level. There is nothing wrong with being at the embattled forefront of new scientific developments.

Most of the research that *Mankind Quarterly* publishes today is "normal" science, but the editors still welcome controversy and new ideas. They see it as part of the journal's mission to provide a forum for the presentation and discussion of theories and empiric research that challenge entrenched beliefs. Of course, the often contradictory views that are represented in *Mankind Quarterly* are those of the individual authors, not those of the journal's publishers or editors.

Notes for Authors

As a peer-reviewed academic journal of anthropology, *Mankind Quarterly* publishes articles on all aspects of the science of man, ranging from cultural and physical anthropology, and psychology and behavioral genetics, to demography, mythology, and the history of religion.

However, the editors are especially interested in articles relating to cultural and biological evolution, and to the interaction between biology and culture. Such topics include

(1) the historical origins of present-day cultural and biological diversity using approaches from history, archaeology, linguistics, mythology, and population genetics;

(2) the study of cultural and biological trends in contemporary societies including cross-cultural studies of personality, intelligence, and culturally transmitted beliefs and values, as well as the study of demographic trends and trends in physical characters and gene frequencies over time; and

(3) the implications of current trends for future human evolution.

Included in these areas of special interest are articles dealing with the evolution of personality, its expression in varying cultural, ecological, and economic conditions, and its implications for future cultural and biological evolution. Interdisciplinary approaches that integrate findings from historically separate disciplines and subdisciplines are especially encouraged.

Mankind Quarterly publishes research reports, theoretical articles, data-driven reviews, book reviews, and short communications on new discoveries or critical comments on published papers, either in *Mankind Quarterly* or elsewhere. Because *Mankind Quarterly* is read by individuals from diverse backgrounds, the authors of highly specialized or technical articles are asked to present the background and significance of their work clearly and concisely. Book reviews should also deal with publications that will be of interest to a non-specialist audience.

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Cover picture: A woman's gaze through a colorful hijab reflects the rich Islamic traditions of Indonesia. This image resonates with the articles Rusli & Nusi (2025) on page 400 and Mansi et al. (2025) on page 415, exploring religious thought and social harmony among Nahdlatul Ulama and Muhammadiyah Muslims in Gorontalo, Indonesia. Photo credit: bess.hamiti@gmail.com from Pixabay.

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Editorials

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πάντα ρὲι — Everything Flows

Editorial*

Things are the way they are because they got that way. This is a folksy summary of an important insight: that in order to understand the present, we must know how it developed over time. If we want to truly appreciate human diversity, we need to know how it developed over time: how past people lived, how their mentalities and cultures kept changing, how their physical and genetic constitution changed, and how earlier populations were absorbed or exterminated by foreign invaders. Ethnogenesis, balanced by the merging or extinction of nations, has been a continuous process that we can still observe in our time.

For the historical period we have, by definition, written records as our main source of information. For prehistory, we depend on archaeology — and on linguistics. Even when we have no written records from the past, we can use the comparative method to detect similarities between existing languages. Such similarities can have two possible origins: They can be the result of shared descent from an ancestral language — and physical descent from the speakers of that ancestral language — or they can be the result of borrowing where words and sometimes grammatical elements move from one language to another. In the first case we speak of a language family, in the second of a *Sprachenbund* (German, literally "language federation").

The study of the Indo-European language family began in the late 18th century with the work of the British lawyer and philologist William Jones. After becoming a judge at the High Court in Calcutta, Jones began learning Sanskrit, the sacred language of the Vedas, spoken most likely by invading Aryan tribes in the late 2nd millennium BC. He noticed something entirely unexpected: similarities between Sanskrit, Latin, and classical Greek. He also noted: "there is a similar reason, though not quite as forcible, for supposing that both the Gothic and the Celtic, though blended with a very different idiom, had the same origin with the Sanskrit; and the old Persian might be added to the same family. . . " (cited from Renfrew, 1990, p. 9). Jones concluded correctly that there must have been an ancient people that split up in prehistoric times, carrying versions of its language to places as distant as Europe and India.

But where did these first Indo-Europeans live? Although some 19th-century scholars had already proposed a Steppe pastoralist origin of the proto-Indo-Europeans, the more common view until the mid-20th century was a Northern European origin, with North-to-South migrations similar to those of the 5th and 6th centuries AD, when roving Germanic tribes invaded the carcass of the former Roman Empire. Eventually, the Northern European theory was forcefully challenged by Lithuanian archaeologist Marija Gimbutas (1956). In her kurgan theory, she proposed that the first Indo-Europeans were the people of an Early Bronze Age pastoralist culture in the Steppe north of the Black Sea and the Caspian Sea that was characterized by its distinctive burial mounds (kurgans).

The kurgan theory, in turn, was challenged by Colin Renfrew (1990), who postulated that Anatolian farmers, whose agricultural lifestyle gave them a demographic advantage over native European hunter-gatherers, carried the Indo-European languages into Europe. This theory was supported by early genetic evidence of a South-East to North-West gradient throughout most of Europe (Cavalli-Sforza et al., 1994).

The controversy was resolved only in the 21st century, when the sequencing of ancient genomes from archaeological sites demonstrated the large-scale though incomplete replacement of Neolithic Northern European populations by invaders from the Pontic-Caspian Steppe at the beginning of the 3rd millennium BC (Haak et al., 2015). This finding supported Gimbutas' theory and agreed with archaeological evidence about the spread of the Corded Ware culture in Central Europe and somewhat later the Bell Beaker culture in Western Europe.

This stage of research, where ancient DNA is used to track ancient migrations and population replacements, is now being followed up by a different kind of studies that seek to determine not only the

*Gerhard Meisenberg

genetic affiliations of bones unearthed from archaeological sites, but also their genetic traits. One example of this new research program is an article by Davide Piffer in this issue of *Mankind Quarterly*. It examines polygenic scores for a number of traits in 414 published and publicly accessible genomes from archaeological sites in Eastern Europe and adjacent regions, plus modern European genomes from the 1000Genomes project for comparison. The main question that this article seeks to answer is: Why were the Yamnaya (Gimbutas' kurgan people) so successful? Did they possess genetic traits that helped them to multiply and to displace other, competing populations, spreading their language and their genes over vast territories?

Virtually all important human traits show highly polygenic inheritance, which means they are each influenced by polymorphisms (genetic variations) in hundreds or thousands of different genes. Therefore, the author did not study individual polymorphisms. He rather calculated polygenic scores based on published genome-wide association studies for traits such as height, skin colour, educational attainment, and some psychological and psychiatric traits. The amount of information he obtained is staggering. He first used admixture analysis, demonstrating that the Yamnaya were not genetically unique. They rather were a blend of several earlier groups, with names such as Steppe Pastoralist and Eastern Hunter-Gatherer. This emphasizes the role of genetic admixture in the formation of ethno-linguistic groups.

Another take-home message is that human evolution is an ongoing process. Comparing ancient and modern populations, the results show for example that genetic predispositions to educational attainment and autism increased, confirming earlier observations (Piffer, 2025; Piffer & Kirkegaard, 2024), while genetic susceptibility to some other psychiatric traits is lower today than it was in prehistoric times.

Results of this kind also speak to another old controversy: the importance of group selection for human evolution. Did polygenic predispositions to traits such as educational attainment, height or skin colour change over time because natural selection was acting on individuals manifesting these traits? Or did they change because populations with certain genetic predispositions replaced other populations? Did, for example, populations with polygenic predisposition to higher intelligence exterminate and replace populations with lower intelligence polygenic scores? This would be group selection.

The study of ancient DNA has so far been applied to polygenic evolution taking place on time scales of some millennia. Presumably, larger sample sizes would be needed to study evolutionary trends in younger populations on time scales of centuries rather than millennia, for example in Christian Europe or the Muslim Middle East from the Middle Age to the Industrial Revolution. The study of selection in present-day populations, by contrast, is low-hanging fruit. All we need to do is to relate polygenic scores of post-reproductive living individuals to their lifetime reproductive output. This allows us to predict the genetic predispositions of future generations (e.g., Hugh-Jones & Abdellaoui, 2022).

The new applications of molecular genetics to human history and prehistory all converge on the same conclusion: Everything flows, as has already been stated by Heraclitus of Ephesus two and a half millennia ago. The earlier scholarly doctrine that human cultures keep changing but human genetics and with it "human nature" is frozen in time needs to be discarded. For example, until the late 20th century many scholars believed that the presently living human races are nearly immutable. They were thought to have evolved from various regional populations of *Homo erectus* over the last 500,000 years, a time scale too long to be interesting for students of history and late prehistory.

This earlier "multiregional" theory was snuffed out only toward the end of the 20th century when studies of mitochondrial DNA found a recent origin of "mitochondrial Eve", and a similarly recent date was soon found also for the Y chromosome. At that point it became undeniable that modern humans had a recent African origin and the present human races evolved only after the African exodus of anatomically modern humans about 60,000 years ago. Nevertheless, as late as 2005, a commentator in *Science* magazine asked: "Are humans still evolving?" (Balter, 2005). Today this question is even more absurd than it was 20 years ago, at least to those familiar with the science. How could anybody ever believe that through some kind of magic, humans had stopped evolving in early prehistoric times?

Perhaps the reason for the tenacious belief in human genetic immutability, without any good evidence and contrary to all we know about how evolution and genetics work, is the desire to feel safe in a thoroughly predictable, stable, unchanging world. In the absence of reality checks, humans are inclined to believe whatever makes them feel good, evidence be damned, as demonstrated by the popularity of traditional

religions and of the post-religious ideologies of educated people in the postmodern West. There could be a more specific reason why many knowledgeable people recoil from the inquiry into ongoing human evolution. Some seriously ill patients are reluctant to go to the doctor for fear of what the doctor may tell them. It might be an illness with a "guarded" prognosis — a medical euphemism meaning the patient is going to die. When Hugh-Jones and Abdellaoui (2022) studied ongoing polygenic evolution in the British population, their main finding was strong selection against genetic variants associated with higher educational attainment — implying a guarded prognosis for British society and the British nation.

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Doctrinal Compromise: Flexibility of Conceptual Landscape among Nahdliyin and Muhammadiyah Members in Gorontalo, Indonesia

Muhammad Rusli* Arfan Nusi†

Abstract

Muhammadiyah and Nahdlatul Ulama (NU), Indonesia's two largest Islamic organizations, exhibit a flexible conceptual landscape in Gorontalo. This study examines doctrinal compromise between members of Muhammadiyah and NU within religious and intellectual social spaces, addressing three key issues: (a) the forms of doctrinal compromise in religious thought, (b) the factors influencing members to adopt elements of the opposing group's perspectives, and (c) the implications of this compromise for the religious thought of both groups. Using a qualitative phenomenological approach, the study collected primary and secondary data through interviews with Muhammadiyah and NU informants, complemented by document analysis. The data were analysed through classification and thematic coding. The findings reveal three significant results. First, doctrinal flexibility is evident in religious practices, with Muhammadiyah members adopting NU rituals and vice versa without facing stigma. Second, mutual respect and social harmony encourage individuals from both groups to integrate aspects of opposing ideologies, particularly in contexts where one group forms a minority. Third, this compromise has blurred traditionally polarized theological and ideological boundaries, fostering harmony, adaptability, and a sense of brotherhood. The study concludes that the doctrinal compromise between Muhammadiyah and NU members reflects a pragmatic approach to coexistence, prioritizing unity over dogmatic differences. This approach minimizes confrontations and suggests that theological truth transcends numerical majority or popular consensus. Sustaining this harmony requires nurturing mutual understanding and reinforcing the inclusive spirit of Islam within both organizations.

Keywords: Muhammadiyah, Nahdlatul Ulama, Doctrinal compromise, Religious thought, Social harmony, Religious tolerance

1 Introduction

The Muhammadiyah group is often referred to as modernist Islam, characterized by a rational-progressive mindset, strong educational traditions, and urban-based communities. In contrast, Nahdlatul Ulama (NU) is traditionally considered a conservative Islamic organization rooted in *pesantren* culture, with members typically residing in rural areas and maintaining religious traditions (Noer, 1973). However, such typologies have become increasingly flexible in Gorontalo, where the boundaries between Muhammadiyah and NU identities are no longer rigid. This flexibility is especially evident in the practice of doctrinal compromise — a condition in which members of both organizations mutually adopt aspects of one another's religious practices.

In Gorontalo, Muhammadiyah members are often found participating in traditional NU religious activities, such as *mongaruwa* or *tahlilan* (ritual prayers for the deceased). Conversely, NU members have embraced certain Muhammadiyah practices, such as performing eight *rak'ahs* in *tarawih* and three *rak'ahs* in *witr* prayers, especially during Ramadan. These practices reflect not only individual piety but also a socio-religious dynamic that prioritizes harmony over strict organizational boundaries. According to Merton's theory (1938), this phenomenon reflects a balanced and adaptive social structure that promotes integration and cohesion in religious life.

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However, the sense of belonging between the two organizations remains distinct. Muhammadiyah fosters a sense of belonging through structured institutions, modern educational networks, and formal organizational hierarchies. NU, on the other hand, builds its sense of community primarily through *pesantren* (Islamic boarding school), local *kiai* (religious leader) authority, and strong family-based religious traditions. Despite these differences, the reality in Gorontalo shows increasing overlap and interaction, suggesting a shift from sectarian rigidity to mutual accommodation.

This phenomenon has not been widely addressed in previous studies. Existing literature on NU and Muhammadiyah mainly focuses on two themes: (1) their traditionalist versus modernist orientations (As'ad, 2019; Biyanto, 2017; Burhani, 2018; Nashir et al., 2019; Niam, 2017; Shabir & Susilo, 2018), and (2) their political tensions and contestations (Harirah, 2021; Hidayat, 2022; Putrie et al., 2020; Ulfiyah, 2021; Wardana & Hidayat, 2019). While these studies are valuable, they overlook the fluid and evolving nature of identity within and between these two major Islamic organizations. More recent studies (Al-Ansi et al., 2023; Arifianto, 2021; Arsadani et al., 2024; Hapsari & Iqbal, 2023; Qodir et al., 2023) have begun to explore social, ideological, and legal dimensions of Muhammadiyah and NU, revealing that the two are capable of convergence, especially in responding to contemporary global and national issues such as Islamic moderation and counter-extremism narratives.

The doctrinal compromise in Gorontalo shows that the differences between NU and Muhammadiyah are more *furuiyah* (instrumental) rather than *ushuliyah* (fundamental). This is evident in how members from both groups mutually accept each other's ritual practices, modes of thought, and theological outlooks without renouncing their original affiliations. The ongoing and sustained encounters in both formal and informal spaces — such as inter-family marriages, community religious events, and local educational institutions — have fostered a shared culture of mutual recognition and religious coexistence.

This study focuses on three key aspects. First, it explores how doctrinal compromise between NU and Muhammadiyah members is manifested in everyday religious practice and theological orientation in Gorontalo. Second, it identifies the sociocultural and historical factors that have contributed to the convergence of traditionalist and modernist thought. Third, it analyses the tangible impacts of this religious hybridization on the broader Islamic discourse in Gorontalo.

In emphasizing the phenomenon of "*ber-Muhammadiyah sekaligus ber-NU*" (being Muhammadiyah while simultaneously being NU), this study argues that religious identity in Gorontalo is not static, but adaptive and integrative. This research contributes to the scholarly understanding of Muslim identity in Indonesia by highlighting a lesser-known reality: the peaceful and organic fusion of traditionalist and modernist elements within grassroots religious life. Rather than being driven by doctrinal conflict or ideological polarization, the NU-Muhammadiyah relationship in Gorontalo is marked by cooperation, accommodation, and shared humanitarian values, particularly respect for religious plurality and community solidarity.

2 Literature Review

2.1 Doctrinal Compromise and Religious Flexibility

Doctrinal compromise refers to the flexibility or pragmatism that believers may adopt when navigating multiple religious norms or ideologies. In the Indonesian Islamic context, this compromise emerges especially when individuals find themselves in socio-religious environments that challenge their organization's doctrinal lines. Muhammadiyah is historically characterized by its puritanical and modernist stance, rooted in its rejection of religious innovations (*bid'ah*), syncretism (*takhayyul*), and local customs deemed un-Islamic (Burhani, 2013; Nakamura, 2012). Conversely, Nahdlatul Ulama (NU) maintains a more accommodative theology that values tradition (*turāth*), spiritual heritage, and *fiqh* rooted in classical Sunni jurisprudence (Bizawie, 2016; van Bruinessen, 1996).

Despite these differences, doctrinal compromise often occurs in practice. As observed by Woodward (2010), many Indonesian Muslims, regardless of formal affiliation, participate in hybrid religious practices as a form of cultural belonging. This flexibility is particularly visible in regions like Gorontalo, where Muhammadiyah members engage in NU rituals such as *tahlilan*, *qunut*, or *maulidan*, not out of theological agreement but due to community pressures or social harmony. Mardison (2013) frames this as a form of

"comfort-seeking" behaviour in which individuals prioritize communal acceptance over ideological rigidity.

This study's findings contribute to this discourse by showing that doctrinal compromise is often unconscious or tolerated, reflecting a survival mechanism rather than a theological shift. It affirms that in practice, religion is negotiated through daily social interactions rather than dictated strictly by institutional dogma.

2.2 Religious Landscapes of NU and Muhammadiyah

Historically, NU and Muhammadiyah have embodied two different expressions of Indonesian Islam. Muhammadiyah's foundation in the early 20th century was influenced by global reformist figures such as Muhammad Abduh and Rashid Rida, emphasizing reason, scripturalism, and educational modernization (Alfian, 1989; Burhani, 2013). It positioned itself against traditionalism, which it associated with uncritical ritualism and mystical practices. In contrast, NU, established in 1926, sought to defend the *ulama* tradition, rooted in *pesantren* education, *taqlid* to the four Sunni schools of law, and the continuation of *amaliyah diniyah* (van Bruinessen, 1994).

However, as scholars have noted, theoretical divisions often do not reflect grassroots realities. Hefner (2011) and Feener (2007) argue that local religiosity in Indonesia is often syncretic and pragmatic, with overlapping religious engagements being more common than strict adherence to organizational norms. This is consistent with the typology presented in this study—three categories of Muhammadiyah members in Gorontalo who variously accommodate NU practices based on social settings and interactions.

This phenomenon also aligns with the idea of "multiple religious belongings" (Cornille, 2010), where individual religious identities are shaped by plural practices and affiliations. Rather than seeing NU and Muhammadiyah as binary opposites, this framework allows for fluid identity construction, especially in regions where social relationships transcend ideological labels.

2.3 Reflection, Interpretation, and Comparison

Reflection on these findings suggests that Muhammadiyah's identity is no longer strictly defined by theological purity but is instead shaped by local sociocultural dynamics. Doctrinal compromise is not necessarily a loss of identity, but a form of adaptive *da'wah*, as members aim to survive in socially dominant NU environments while maintaining their progressive mission. Interpretively, this supports the idea that religious practice is deeply social, as Mardison (2013) notes, and shaped by a need for belonging and recognition. In this sense, belief is not always a rational commitment to ideology, but a negotiation with lived realities. This challenges conventional understandings of Muhammadiyah as a monolithic actor and shows the emergence of hybrid identities.

Comparatively, earlier works such as Mujani and Liddle (2004) emphasized ideological polarization between NU and Muhammadiyah, especially in the political domain. However, the current study aligns more closely with newer literature that emphasizes social Islam, hybridity, and coexistence (Hasan, 2009; Hefner, 2011; Woodward, 2010). This shift reflects broader patterns in Indonesian Islam where institutional affiliation is less important than relational dynamics and social adaptation.

2.4 Implications of the Findings

The implications of this research are both theoretical and practical. Theoretically, it adds to a growing body of literature that views Islamic organizations not merely as theological entities but as social systems influenced by local wisdom and relational negotiations. Practically, it suggests that inter-group religious harmony can be sustained through social flexibility, open communication, and the prioritization of shared values over dogmatic distinctions.

Furthermore, the study reveals a limitation in traditional binary frameworks that analyse Muhammadiyah and NU as rigidly opposed. This perspective overlooks the internal diversity and adaptability of both organizations in everyday contexts. Future research should therefore pay closer attention to localized expressions of religiosity and the nuanced ways in which religious identity is practiced rather than merely professed.

3 Methodology

This research adopts a qualitative phenomenological approach to understand how identity flexibility unfolds among members of Nahdlatul Ulama (NU) and Muhammadiyah in Gorontalo. Phenomenology is chosen because it allows the researcher to capture the lived experiences and subjective meanings behind religious interactions and doctrinal compromises. According to Creswell (2013), phenomenology seeks to understand the essence of human experience concerning a particular phenomenon, which in this case is the negotiation of religious identities between Muhammadiyah and NU members. The approach is particularly relevant for exploring values, perceptions, and meanings that cannot be quantified but are deeply rooted in social and religious practices.

The study was conducted in Gorontalo, one of Indonesia's 19 traditional cultural regions. This area is notable for its integration of local *adat* (customary law) and Islamic practices, which provides a fertile ground for observing how doctrinal boundaries between religious organizations are reinterpreted in everyday life. Muhammadiyah in Gorontalo is often perceived as a modernist-puritanical group, yet it shows accommodation to local traditions. Conversely, NU maintains traditional religious practices but has begun to engage more progressively with global and national issues.

Data collection relied on both primary and secondary sources. Primary data were gathered through field observations and in-depth interviews, focusing on the forms, driving factors, and practical implications of identity flexibility in religious life. Secondary data included documentation, journal articles, field notes, and photographs related to the religious landscape in Gorontalo.

The research does not use sampling, as qualitative studies emphasize informant selection rather than representative samples. Informants were selected using purposive sampling, a technique where participants are chosen based on their relevance to the research problem (Patton, 2002). The criteria for selection included: (1) being actively involved in either Muhammadiyah or NU organizations; (2) having experience in participating in cross-group religious practices; and (3) possessing influence within their respective communities, such as religious leaders (*ulama*, *ustaz*, or *kiai*), youth figures, or community elders. These individuals were considered capable of providing nuanced insights into the identity negotiation process. In addition to purposively selected informants, casual interviews were also conducted with incidental individuals to enrich the contextual understanding of the research.

Data were collected through semi-structured interviews, enabling the researcher to follow a set of core questions while allowing room for open-ended exploration. This format facilitated flexible dialogue and allowed informants to express personal views and experiences in their own terms. The interviews were supported by field notes and non-verbal observations.

For data analysis, the study followed the model proposed by Miles et al. (2014), which involves three interrelated processes: (1) data reduction, in which raw field data are selected, coded, and organized based on relevant themes; (2) data display, where information is presented in thematic matrices, summaries, and narrative forms; and (3) conclusion drawing and verification, wherein patterns and meanings are interpreted and validated against the research objectives. This was followed by an interpretative analysis, which involved three steps: (1) restatement of data collected from the field, (2) description to identify repeated patterns, trends, and divergences in the narratives, and (3) interpretation to uncover the deeper meaning of identity flexibility within the doctrinal landscape of NU and Muhammadiyah.

By using this approach, the study reveals how the lived religious experience in Gorontalo allows for intersecting identities, challenging the rigid dichotomy of modernist versus traditionalist Islam. The methodology facilitates the capture of complex social realities in which formal doctrinal differences are bridged through everyday religious and social interactions.

4 Results and Discussion

4.1 Forms of Doctrinal Compromise in the Conceptual Landscape of Nahdliyin and Muhammadiyah Members

In practice, many *Nahdliyin* do not strictly adhere to the official rulings of *Bahtsul Masa'il*, just as Muhammadiyah followers often do not rigidly implement the guidance of the *Majelis Tarjih dan Tajdid*.

Religious life in both groups is often characterized by flexible identities shaped by local culture and social context. Among Muhammadiyah members, for example, it is not uncommon to encounter practices associated with Nahdlatul Ulama (NU), such as *tahlilan* (communal prayers for the deceased) being integrated into religious routines. This form of doctrinal compromise is less about ideological alignment and more about community adaptation and shared spiritual values.

Informant 1, a former chairman of a Muhammadiyah student association (*Ikatan Mahasiswa Muhammadiyah* or IMM) Gorontalo branch and a participant of the *Darul Arqam Madya* (DAM) cadre training, shared in an interview (October 10, 2022):

> *"I participate in and conduct tahlilan because I trust the imam leading the tahlil prayers, believing that the prayers recited and affirmed by the congregation will surely be accepted by Allah, SWT."*

A similar perspective was shared by Informant 2, a Muhammadiyah member (Interview, October 11, 2022):

> *"One day, our extended family deliberated on holding a tahlilan when our grandmother passed away. As a result of the agreement, tahlilan was held due to a belief that the prayers recited during tahlilan would save our grandmother in the grave."*

This belief in the salvific power of communal prayer, even if associated with NU tradition, reflects a more inclusive understanding of ritual significance.

Another example of doctrinal fluidity can be observed in *Tarawih* prayers. Although Muhammadiyah's *Majelis Tarjih dan Tajdid* advocates for 11 *rak'ahs* (8 *rak'ahs* of *Tarawih* and 3 *rak'ahs* of *Witr*) based on *Hadith*, many Muhammadiyah members perform 23 *rak'ahs* when praying in NU-affiliated mosques, especially in their hometowns. This is not solely due to doctrinal differences, but also due to practicality and communal considerations, such as shorter duration for the 11-*rak'ah* format or the cultural norms of a given locality. Informant 3, a Muhammadiyah cadre, stated (Interview, October 12, 2022):

> *"For me, performing Tarawih prayers with 23 rak'ahs has become a regular practice, even though I am a Muhammadiyah cadre up to the level of Darul Arqam Madya. The mosque in my hometown, located near my house, follows the 23-rak'ah format. I've even led prayers with 23 rak'ahs there."*

Muhammadiyah members are also found to recite the *qunut* prayer during *Subuh*, a practice typically associated with NU. Informant 4, a Muhammadiyah administrator, shared (Interview, October 13, 2022):

> *"If I am appointed as the imam and the congregation behind me are mostly NU members, I recite the qunut prayer to accommodate them."*

Similarly, Informant 5, a Muhammadiyah cadre, described his experience (Interview, October 13, 2022):

> *"Graduating from a Muhammadiyah pesantren, the congregation asked me to be a permanent imam. As a result, I now lead prayers using practices like reciting qunut."*

These cases reflect five common patterns of doctrinal compromise among Muhammadiyah followers:

1. Participation in *tahlilan* is seen as a moral duty to pray for the deceased.
2. There is a sincere belief that *tahlilan* has salvific value in the afterlife.
3. Practices such as *tahlilan*, 23 *rak'ahs* of *Tarawih*, and *qunut* are perceived as normative by the broader Muslim community.
4. Not all Muhammadiyah members regard *tahlilan* as *bid'ah* (illegitimate innovation).

5. Flexibility in *Tarawih* and *qunut* practices is grounded in the belief that Allah accepts all sincere forms of worship.

Similar flexibility is also observed among NU members. This includes practices such as performing 11 *rak'ahs* for *Tarawih* prayers or omitting the *dua adzan* (double call to prayer) and the *mohudu tungkudu* (symbolic staff handover) before Friday sermons — rituals typically emphasized in NU tradition. Informant 6, a member of NU in a rural district, remarked (Interview, October 14, 2022):

> *"In my area, most mosques — despite being part of NU traditions — perform 11 rak'ahs of Tarawih and do not practice mohudu tungkudu."*

Informant 7, a village head and NU member, added (Interview, October 14, 2022):

> *"All Tarawih prayers in Bone Pesisir are similar to Muhammadiyah's 11-rak'ah practice. That's been the norm here for as long as I can remember."*

Informant 8, a regional NU official, confirmed this tendency (Interview, October 15, 2022):

> *"Bone Pesisir is indeed unique. While it deeply values NU tradition, it does not observe Tarawih with 23 rak'ahs."*

These patterns of divergence are not acts of ideological rebellion, but rather reflect long-standing community habits. Citing Saifullah (2018), these shifts are often pragmatic and unconscious, rather than the result of formal theological rejection. Moreover, there is no attempt by Muhammadiyah elites in Bone Pesisir to control or influence NU religious institutions. The widespread practice of 11-*rak'ah Tarawih* simply reflects the embedded norms of the community.

Pranowo (2009) contextualizes this dynamic by noting that "Islam is a process of becoming, not merely existing." Religious practices are fluid and adaptive to social and cultural contexts. Thus, deviation from 23-*rak'ah Tarawih* or other rituals does not negate one's NU identity. It rather reinforces the pluralistic and contextual nature of religious expression in Indonesia.

Informant 6 supports this by explaining that the preference for 11 *rak'ahs* is based on community habit rather than doctrine. Even though NU leaders like Informant 8 have encouraged returning to 23 *rak'ahs*, the community's attachment to long-standing practices remains resilient — not due to theological opposition, but tradition.

4.2 Factors Driving Muhammadiyah Members to Think Traditionally and NU Members to Think Modernly

There are four factors that drive some Muhammadiyah members to think traditionally and NU members to think modernly, including:

4.2.1 Social Ethical Considerations

Social ethical considerations are demonstrated by Informant 9, a Muhammadiyah member, who explained:

> *"In Muhammadiyah, there is no practice of tahlilan during funerals. However, since the majority of the community carries out tahlilan and we are invited to these events, we cannot help but respect the invitation as a form of tolerance, maintaining harmony, and upholding social ethics. This is because we do not want to sacrifice brotherhood, family ties, and neighbourly relations just to uphold our own beliefs." (Interview, 22 August 2023)*

A similar sentiment was conveyed by Informant 10, who also serves as a Muhammadiyah administrator in Bonebolango:

> *"I am aware that in Muhammadiyah, there is no tradition of tahlilan, but I have been participating in the tahlilan tradition for a long time. As the Head of Sogitia Village, I have no choice but to attend the tahlilan, because the majority of my residents practice it. The tahlilan tradition is*

also initiated with the approval of the Village Head as a government representative." (Interview, 25 August 2023)

These testimonies underscore the concept of doctrinal compromise as a form of social ethics in religiously plural societies. The actions of the informants reflect what Geertz (1973) termed as *abangan-santri* compromise — where the ritual life of Islam adapts to societal norms rather than strictly theological imperatives. The concept of *ta'ayush* (coexistence), as elaborated by Arkoun (2002), further affirms that religion in lived practice often prioritizes social peace and human relationships over doctrinal purity.

This pattern aligns with what Stark and Bainbridge (1985) call "religious economy", where religious actors make practical decisions based on social rewards and costs, thus forming a socially embedded religiosity. In this context, the *tahlilan* ritual transforms from a theological prescription into a symbolic social practice — a vehicle for community cohesion (Woodward, 2010).

Participation, therefore, is not an endorsement of theological belief but an act of ethical pragmatism, signaling conformity to communal values. This echoes what Berger (2011) referred to as the "social construction of reality" in religious life.

4.2.2 Social Adaptation Considerations

Certain situations and local conditions have prompted many Muhammadiyah members to navigate the socio-religious realities shaped by the predominantly NU community. Informant 11, a Muhammadiyah cadre from Gorontalo, shared:

"Several times I have led the tarawih prayer with 20 rak'ahs. I do this to prioritize the well-being of the majority by adapting, rather than forcing my own beliefs and doctrines from the training I received." (Interview, 10 September 2023)

Despite holding significant positions, such as Chair of the Muhammadiyah Student Association (IMM) branch in Gorontalo and Head of the Economic Division in Muhammadiyah Youth Gorontalo, Informant 11 demonstrates pragmatic adaptation. Raised in Jakarta and trained within the formal Muhammadiyah system, his relocation to a predominantly NU area required emotional intelligence and strategic social engagement. His experience echoes Geertz's (1973) concept of "religious syncretism", where symbolic adjustments serve the goal of communal peace rather than religious conversion.

The differentiation between a "member" and a "cadre" is important here. A member may sympathize with Muhammadiyah ideals, while a cadre has internalized the ideology through formal training (e.g., *Darul Arqam*) and carries organizational responsibilities (Burhani, 2013). Yet even among cadres, the realities of social embeddedness and communal expectations often necessitate situational religiosity (Wahid, 2001).

Another relevant perspective comes from Informant 12, a prominent IMM cadre and mosque *ta'mir* in Bongomeme, Gorontalo Regency:

"I chose to become a cadre of IMM and practice Muhammadiyah teachings while in the city. My family had no objection when I became a Muhammadiyah cadre, but they advised me not to impose Muhammadiyah teachings in the village, especially regarding the tarawih prayer with 11 rak'ahs at the mosque, as it might cause a controversy with the congregation who are accustomed to 20 rak'ahs. Even though the entire congregation knows I am a Muhammadiyah cadre, they still appointed me as the head of the mosque management." (Interview, 14 September 2023)

This informant's narrative exemplifies what Azra (2004) calls "*Islam Nusantara*-style pluralism", where religious leadership in rural Indonesia often requires prioritizing communal legitimacy over ideological exclusivism. His adaptive stance reaffirms the findings of Hefner (2011), who noted that Islamic leaders in plural societies often serve dual roles: upholding religious identity, and mediating community cohesion.

The dual alignment, between Muhammadiyah identity and NU practice, illustrates contextual Islam in action, as theorized by Madjid (2008), where *ijtihad* (reasoning) accommodates not only scriptural interpretation but also socio-cultural realities.

4.2.3 Respecting Tradition

Members of Muhammadiyah cannot fully detach themselves from the roots of tradition and the culture of the Gorontalo community. Informant 13, a member of the Muhammadiyah leadership, conveyed:

> *"As a Muhammadiyah member, I understand that Muhammadiyah is accommodative towards traditions. I have demonstrated this by attending tahlilan events, which I have always participated in when organized by my friends, relatives, and family from NU. It's not that I am just accepting the tahlilan tradition now, but rather it has been a familiar part of my life for a long time, especially since many of my family members are from NU." (Interview, 18 September 2023)*

Informant 13 feels that as a Muhammadiyah member, he has the duty to accept the tradition of *tahlilan*, as it is a long-standing practice passed down from generation to generation by ancestors, which cannot simply be ignored. *Tahlilan* has become an integral part of the religious activities of the Muslim community in Gorontalo, particularly for families in mourning after a death. This view aligns with studies emphasizing the role of local traditions in shaping collective religious expression (Huda, 2014; van Bruinessen, 2009).

In contrast, Informant 14, the Chairman of the *Tarjih* Council of Muhammadiyah Gorontalo City, stated:

> *"What I want to emphasize is that the issue is not the tradition, but rather the belief that certain traditions have become regarded as Islamic law that must be followed. The traditions in Gorontalo have positive aspects because our ancestors practiced them based on their experiences. For example, the tradition of hileyiya, which means moheyi or transferring food from our house to the house of mourning. It is not that they prepare the food for us, but when a neighbour or relative passes away, I take the initiative to carry out hileyiya. After gathering the food, we take it to the house of mourning, where we eat together to comfort the grieving family." (Interview, 21 September 2023)*

Informant 14 appears to disagree with the view that the tradition of *tahlilan* should be considered an obligatory religious practice. His presence at the mourning house is not for the purpose of performing *tahlilan*, but rather for practicing *hileyiya* (the act of moving or distributing food) as a form of social sensitivity to the bereaved family. Informant 14 carries out the *hileyiya* tradition in his own style, without diminishing the substance of the tradition. This includes inviting community members to bring food items such as rice, fish, meat, cooking oil, vegetables, spices, and other necessities to the mourning house. Together, they cook the meals to provide comfort and support to the grieving family. Once the meals are ready, the *tahlilan* ceremony begins, with all the community members gathering to pray together. However, Informant 14 does not participate in the *tahlilan*, as for him, the important thing is that the goal of comforting the bereaved family has been achieved.

This form of selective engagement illustrates a syncretic adaptation of religious and cultural identities, commonly seen in Indonesia's pluralistic Islamic practice (Hefner, 2011; Woodward, 2010). The practice of *hileyiya* by Muhammadiyah members without joining the *tahlilan* represents a nuanced respect for cultural heritage while adhering to theological boundaries.

In fact, the *hileyiya* tradition is part of the same sequence as the *tahlilan* ceremony, but Informant 14 chooses not to continue with the *tahlilan* because he considers that this tradition is not an obligatory religious practice. He participates in the *hileyiya* tradition because he views it as a gathering aimed at expressing empathy, a source of comfort and solace for the grieving family. For Informant 14 and other members of Muhammadiyah, the practice of *hileyiya* holds the value of *gotong royong* (mutual cooperation), with the goal of sharing in times of sorrow. This tradition of *hileyiya* symbolizes togetherness and brotherhood in the community (Geertz, 1960; Madjid, 2008).

In broad terms, the arguments presented by Informant 13 and Informant 14 can be understood in three main points. First, members of Muhammadiyah perform *tahlilan* based on moral responsibility as Gorontalo residents to take part in preserving and nurturing cultural traditions. Second, members of Muhammadiyah view the *tahlilan* tradition as an expression of social sensitivity towards others who are

grieving. This attitude aims to foster solidarity and reduce individualistic behaviours among Muslims from both Muhammadiyah and NU. Third, while not participating in the *tahlilan* ritual, they contribute to the grieving family through local traditions that focus on social support.

4.2.4 Conformity Practices

Informant 15, who was born and raised in a family with NU traditions, has always practiced Muhammadiyah rituals in religious worship. A similar attitude is also shown by Informant 16, a resident of North Gorontalo, who acknowledges participating in NU religious traditions but prefers to perform the *tarawih* prayer with 11 *rak'ahs*. According to him, the 23 *rak'ahs tarawih* prayer feels too long, and he finds it exhausting to follow. This situation reflects a broader trend among Muslims in Gorontalo, where the younger generation and some elderly individuals prefer a more concise form of *tarawih* prayer. The role of the imam is crucial in this practice. The preference for an imam who recites in a calm and swift rhythm influences participation, as expressed by Informant 15:

> *"We, the young people, will check the schedule to see who is assigned to be the imam at the mosque. If the imam we look up to is the one leading, then many young people and even the elders will definitely come to perform the tarawih prayer at the mosque, and we will complete all twenty rak'ahs." (Interview, 20 September 2023)*

This example illustrates the role of leadership charisma and time efficiency in contemporary religious participation (Feener, 2013; Hasan, 2009). Religious observance becomes not only a matter of ritual adherence, but is also shaped by convenience and aesthetic preference. In light of this, Informant 17, a lecturer at IAIN Gorontalo, stated:

> *"The number of Muhammadiyah followers increases during Ramadan because the majority of the Muslim community here are only willing to perform eleven rak'ah of tarawih. In fact, in some mosques in Gorontalo, once the tarawih prayer reaches the eighth rak'ah, about 80 % of the congregation leaves the rows, leaving only the elderly to continue with the twenty-three rak'ahs." (Interview, 23 September 2023)*

Although Informant 17's claim is not entirely accurate, as NU members who perform *tarawih* with 11 *rak'ahs* do not automatically become members of Muhammadiyah, the phenomenon can be explained within the framework of conformity theory (Asch, 2016). It illustrates how individuals can adjust their behaviours and religious expressions to align with group norms or preferences, especially when the environment is accommodating.

Such practices represent a form of adaptive religiosity, where individuals navigate multiple religious norms to suit their needs or contexts (Howell, 2013). For example, individuals might perform 11 *rak'ahs* during *tarawih* to suit physical capacity or follow an admired imam, without shifting institutional loyalties.

A key question remains regarding the practices of both groups during important Islamic holidays such as *Idulfitri*, *Iduladha*, and the start of Ramadan. During these events, Muhammadiyah and NU followers sometimes observe different days for the celebration due to differing methods of moon sighting. This division becomes particularly visible during communal prayers and feasts. Despite these differences, many members of both organizations still practice rituals from both traditions, especially in the context of annual gatherings and rituals, which may create opportunities for conformity. For instance, many Muslims will participate in the *Idulfitri* prayers with the group that aligns with their personal schedule or preference, even if it differs from their formal affiliation. This indicates a pragmatic religiosity that balances doctrine and social harmony (Beatty, 1999; Bubandt & van Beek, 2012).

In summary, the practices observed by Informants 15, 16, and 17 suggest that the adherence to specific rituals within the Muhammadiyah and NU communities is fluid. While religious identity remains important, the opportunity for personal choice and adaptation to communal practices shows the convergence of both groups in everyday worship and during significant religious events.

4.3 Concrete Implications of Doctrinal Compromise in the Conceptual Landscape of Muhammadiyah and NU Members

Members of Muhammadiyah often identify themselves with the organization through specific markers — having a Muhammadiyah membership card, actively participating in the organization's activities, studying in Muhammadiyah-affiliated educational institutions, or being born into a Muhammadiyah household (Azra, 2004; Nakamura, 2012). According to Informant 18 (interviewed on 5 September 2023), a former regional leader of Muhammadiyah in Gorontalo, there is no significant relational distance between Muhammadiyah and NU members. Regular interactions occur in shared public spaces such as workplaces, mosques, and neighbourhood activities, creating a harmonious and familial relationship between these two major Islamic organizations.

Although these interactions are generally informal, they nonetheless foster a structure of cohesion and mutual understanding. Dialogues between organizational elites can function as a unifying force, gradually breaking down entrenched barriers—whether in ritual practices or doctrinal discourse. This shows that the flexibility of religious identities has contributed to the establishment of community-based values and mutual reinforcement (Feener & Sevea, 2009).

At the grassroots level, the interaction between NU and Muhammadiyah adherents in rural Gorontalo manifests through associative and accommodative cultural mechanisms. The associative model is reflected in practices such as *bilohe* (mutual understanding), *depita* (sharing food), and *ambuwa* (communal gathering). Meanwhile, the accommodative model is seen in practices such as *buhuta wawu walama* (unity in togetherness), where embracing differences becomes a strategy to avoid discord (Geertz, 1960; Madjid, 2008). This was emphasized by Informant 19 (interviewed on 12 September 2023), a local Muhammadiyah community figure, who recalled a moment when NU relatives held *tahlilan* in his home after his father's passing. He acknowledged that regardless of the format, any prayer directed sincerely to God is valid, and he himself occasionally participates in preparations for such rituals when NU neighbours pass away.

This view is reinforced by Informant 20 (interviewed on 14 September 2023), a female member of *Aisyiyah* Muhammadiyah, who affirmed that her relationship with NU neighbours is cooperative and harmonious. In her words, distinctions between Muhammadiyah and NU have become irrelevant in daily life, especially when collaborating on community service activities like cleaning the mosque or maintaining public facilities (Burhani, 2014).

On the NU side, these sentiments are confirmed by Informant 21 (interviewed on 20 September 2023), who noted that NU and Muhammadiyah communities prioritize collective interests over organizational agendas. He recalled how NU members helped organize a Muhammadiyah Ramadan event — from stage preparation and food services to daily attendance throughout the week.

These examples indicate that social encounters are not only inevitable but essential to nurturing inter-group dialogue and cultural integration. These grassroots interactions prioritize humanistic values over sectarian boundaries. As emphasized by Informant 22 (interviewed on 26 September 2023), a cadre of NU under the *Ansor* Youth Movement, the people of Gorontalo had already practiced religious moderation and cultural tolerance through indigenous traditions long before formal campaigns on these concepts emerged. This has led to a durable solidarity between the two groups, especially in rural communities (Hasan, 2009; van Bruinessen, 2013).

The data also illustrates the flexibility of Muhammadiyah members in adapting to NU religious traditions. There are three observed typologies of adaptation among Muhammadiyah members:

1. **Accommodative Group**: This group embraces NU religious traditions such as *tahlilan*, *maulid*, and *Isra' Mi'raj* because they believe these practices carry moral and spiritual value aligned with Islamic principles. This group views Muhammadiyah not just as a puritan movement but also as a cultural *da'wah* institution that is responsive to local traditions. Often represented by educated youth, this group has shifted focus from issues like *bid'ah* to more pressing concerns related to community welfare and social engagement (Hefner, 2011).

2. **Selective Social Adaptation Group**: Represented by figures like Informant 23 (interviewed on 29 September 2023), this group adopts cultural traditions such as *hileyiya* (food distribution) without

participating in associated religious rituals like communal prayers or *dhikr*.

3. **Non-Ritual Social Adaptation Group**: This group embraces social customs not tied to worship, including practices like *huyulu* (community labor) and *ti'ayo* (mutual assistance), thus affirming solidarity without theological compromise.

These three typologies converge into what local communities refer to as *MUNU* (Muhammadiyah-NU), describing individuals who navigate and integrate the religious cultures of both organizations. However, this categorization could be further expanded by considering other emerging hybrid identities, such as *MUSA* (Muhammadiyah-Salafi), which leans toward scripturalist purification, and *MUMA* (Muhammadiyah-Marhaen), reflecting a fusion between Islamic reformism and leftist socio-political thought (Latief, 2012; Wildan, 2018).

These hybrid identities reflect the evolving character of Muhammadiyah in Gorontalo, especially among younger generations shaped by higher education, pluralistic experiences, and social engagement. As such, Muhammadiyah's adaptive engagement with NU traditions illustrates a context-sensitive model of religious life that transcends organizational boundaries while reinforcing local wisdom and unity.

This identity flexibility can be categorized into three distinct groups, as outlined in Table 1. The first group comprises those who are accommodative toward the religious traditions of Nahdlatul Ulama. These individuals tend to view Muhammadiyah not only as a reformist religious movement but also as a cultural movement. They participate in traditions such as *tahlilan*, *maulid*, and *Isra' Mi'raj*, and are typically represented by younger, highly educated intellectuals. The second group adapts primarily within social spaces without engaging in religious rituals. Although they participate in traditions like *hileyiya* (food distribution), their involvement does not extend to practices of prayer or *dhikr*. The third group focuses on non-ritualistic community engagement such as *huyulu* (community work) and *ti'ayo* (mutual assistance), and often interacts with both Muhammadiyah and NU traditions, reflecting a more inclusive orientation. These three typologies suggest an emergence of what is locally known as *MUNU* (Muhammadiyah-NU), a sociological blend of organizational identities among Gorontalo Muslims (see Table 1.

Table 1: Implications of identity flexibility.

No	First Group	Second Group	Third Group
1	The group that is accommodative toward the religious traditions of Nahdlatul Ulama	The group that adapts only to social spaces	The group that interacts with Nahdlatul Ulama members but does not engage in religious rituals
2	The group that positions Muhammadiyah as a cultural movement	The group that does not participate in religious rituals	The group that thinks inclusively
3	This group is represented by highly educated young intellectuals	The group that frequently interacts with Nahdlatul Ulama members	The group that interacts with both traditions

There is a dominant factor explaining why conflicts have not been triggered despite the open opportunities and potential for such conflicts, as seen in other regions. This factor lies in the adaptive nature of Gorontalo's Muslim community, which has been immersed in flexible religious practices shaped by their immediate social environment. In many cases, individuals unknowingly shift from the ideological purity of their original organization due to prolonged exposure and participation in hybrid traditions. Others, though aware of these shifts, intentionally follow the prevailing norms to maintain social acceptance and cohesion within the community.

This behaviour aligns with Mardison's (2013) view that social interactions often drive individuals to seek zones of comfort and security, which in turn becomes a strategy for group survival. Consequently, living in a predominantly NU neighbourhood, a Muhammadiyah member is likely to participate in NU traditions,

and vice versa. It is not theological rigidity but communal harmony that dictates religious expressions in these hybrid settings (Hasan, 2009).

5 Conclusion

This study has shown that the flexibility of the conceptual and practical landscape among Muhammadiyah and Nahdlatul Ulama (NU) communities in Gorontalo reflects a unique and context-sensitive model of Islamic life. The most important finding is the emergence of hybrid identities, particularly among younger Muhammadiyah members, who navigate and adapt to NU religious practices, such as *tahlilan*, *tarawih*, *qunut*, and the double *adhan*, without abandoning their ideological commitment to Islamic modernism and puritanism. Unlike NU, where religious identity is often embedded in daily rituals and traditional religious expressions, Muhammadiyah identity tends to be more ideological and structured, making adaptation more conscious and strategic rather than organic.

This article contributes to the discourse on Islamic pluralism by offering a sociological lens into how Muhammadiyah engages in a form of *da'wah kultural* — a strategy of social adaptation that prioritizes communal harmony over theological rigidity. It shows how geographic proximity, social interaction, and shared values among community members foster a lived Islam that is inclusive, fluid, and humanistic. These dynamics challenge the long-held assumptions that Islamic movements must remain in opposition to preserve their ideological boundaries. Instead, Gorontalo presents a model of inter-organizational complementarity rooted in mutual respect, not doctrinal compromise.

However, this study has several limitations. First, it focuses primarily on Muhammadiyah actors and their strategies of adaptation, without deeply exploring the internal perspectives of NU members regarding Muhammadiyah's presence in traditional spaces. Second, the study is limited to one geographic and cultural context, Gorontalo, which may differ significantly from other regions in Indonesia where conflict between Islamic organizations is more pronounced. Third, the study relies heavily on qualitative observation and interviews, which, while rich in nuance, would benefit from being complemented by a broader quantitative approach to generalize the findings.

Ultimately, while the historical dichotomy between Muhammadiyah and NU has often been shaped by rigid religious practices, symbols, and institutional identities, the reality in Gorontalo reveals a more dynamic and humanistic religious life. Belief cannot be reduced to numbers or organizational affiliation; it is rooted in personal conviction and community values. Therefore, an attitude of mutual respect, social engagement, and theological humility must continue to be nurtured within both NU and Muhammadiyah communities, as this is essential for preserving not only the dignity of Islam but also the fabric of Indonesian pluralism.

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Transcending Proportional Boundaries: A Study on the Shifting Thoughts of Nahdlatul Ulama and Muhammadiyah Muslims in Gorontalo, Indonesia

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Abstract

The dichotomy between the traditionalist Nahdlatul Ulama and the modernist Muhammadiyah has blurred and undergone a paradigmatic shift among local Muslims in Gorontalo, Indonesia. This study aims to examine the model of thought transformation among Nahdlatul Ulama and Muhammadiyah Muslims that transcends proportional boundaries, to identify the driving factors behind the progressive tendencies of Nahdlatul Ulama and the cultural accommodation of Muhammadiyah, and to explore the implications of these ideological shifts. Using a qualitative approach, the research draws on both primary and secondary data. Data collection was conducted through in-depth interviews with informants from both organizations and a review of relevant literature. The data were systematically analysed to identify key patterns in the evolving thought of these two groups. The findings reveal three main points. First, the traditional-modernist dichotomy between Nahdlatul Ulama and Muhammadiyah has undergone a significant transformation. Nahdlatul Ulama, long regarded as traditionalist, is increasingly adopting modern perspectives, while Muhammadiyah has begun to accommodate elements of local culture. Second, the progressive turn of Nahdlatul Ulama is driven mainly by the expansion of education, the influence of digital media, and discourses surrounding radicalism. Meanwhile, Muhammadiyah's cultural adaptation is encouraged by social interaction, the strength of tradition, and the need for flexibility in facing contemporary challenges. Third, despite this intellectual shift, the role of women in both organizations remains a contested issue. Although both Nahdlatul Ulama and Muhammadiyah have opened spaces for female participation, structural and ideological barriers continue to limit their leadership roles, reflecting broader patterns of gender marginalization within religious institutions.

Keywords: Nahdlatul Ulama, Muhammadiyah, Intellectual shift, Socio-religious transformation

1 Introduction

The religious typology that distinguishes *Nahdlatul Ulama* (NU) as a traditionalist group and *Muhammadiyah* as a modernist group has long been part of academic discourse in Islamic studies in Indonesia. *Nahdlatul Ulama* is often associated with traditionalism and a strong rural support base, whereas *Muhammadiyah* is viewed as a modern Islamic organization with followers primarily from urban areas (Aminuddin, 2018; Noer, 1994). However, this study reveals that such typologies are not universally applicable, especially in the context of Gorontalo. This phenomenon is observable in the religious practices of the Gorontalo community. *Muhammadiyah* followers in this region of Sulawesi often participate in *mongaruwa* (prayers for the deceased), *molubingo* (female circumcision), and *beati* (bai'at), which are historically more aligned with *Nahdlatul Ulama* traditions (Lahaji & Nusi, 2023). Conversely, *Nahdlatul Ulama* followers in Gorontalo are also known to engage in religious practices typically associated with *Muhammadiyah*, such as performing *tarawih* prayers in eleven cycles and other Puritan-style worship practices (Lahaji & Nusi, 2023).

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Similar phenomena are found in other regions with complex social and cultural interactions. For example, in Yogyakarta, the closeness between *Nahdlatul Ulama* and *Muhammadiyah* is evident among academics and the *pesantren* (Islamic boarding school) communities, resulting in a synthesis of Islamic thought. In South Sulawesi, local Islamic influences have also led *Muhammadiyah* to accommodate certain traditional elements in its religious practices.

Thus far, studies on "*Nahdlatul Ulama* and *Muhammadiyah*" have generally focused on two areas. First, research has explored *Nahdlatul Ulama* as a traditionalist and *Muhammadiyah* as a modernist movement (As'ad, 2019; Biyanto, 2017; Burhani, 2018; Fauzi & Ayub, 2019; Feener, 2007; Imron, 2025; Niam, 2017; Rofiah, 2016; Shabir & Susilo, 2018; Van Bruinessen, 1994). As Bachtiar (2020) notes, *Muhammadiyah* is known for its modernist ideas in addressing contemporary challenges, especially in facing the rise of Islamism and various social issues (Menchik, 2016; Ricklefs, 2014). Meanwhile, Fealy (2003) points out that *Nahdlatul Ulama*'s traditionalist identity is embodied in the central role of *kiai* (Islamic scholars) in religious and even political dynamics (Woodward, 2001).

Second, studies have also focused on political struggles and conflicts involving *Nahdlatul Ulama* and *Muhammadiyah* (Al-Ansi & Kartono, 2023; Harirah, 2021; Qodir et al., 2023; Ulfah, 2014; Wardana & Hidayat, 2019). These two dominant trends suggest that scholarly analysis of *Nahdlatul Ulama* and *Muhammadiyah* has been limited to themes of modernism, traditionalism, politics and conflict, while overlooking many other important aspects of their discourse.

The purpose of this paper is to address gaps in existing studies that have paid limited attention to the paradigm shifts occurring within the thought of *Nahdlatul Ulama* and *Muhammadiyah*. Specifically, this paper argues that these two organizations can no longer be strictly categorized as traditionalist or modernist. Instead, they exist within a shared spectrum—traditionalist-modernist and modernist-traditionalist. In line with this, the paper seeks to answer three key questions: (1) What is the model of thought transformation among *Nahdlatul Ulama* and *Muhammadiyah* Muslims that transcends proportional boundaries? (2) What factors contribute to *Nahdlatul Ulama*'s progressive stance toward modernity and *Muhammadiyah*'s accommodation of local culture? (3) What are the implications of these ideological shifts?

This paper explores how the traditional thought of *Nahdlatul Ulama* and the modernist approach of *Muhammadiyah* interact in shaping the understanding of Islam and culture in Gorontalo. An interdisciplinary approach is employed to further investigate the intersection of religion, culture and social dynamics, including the roles of women and marginalized groups in these transformations. Both *Nahdlatul Ulama* and *Muhammadiyah* acknowledge that Islam and culture are inseparable, particularly in the development of Gorontalo society. Islam flourishes through noble cultural values, while Gorontalo's culture thrives through its acculturation with Islamic teachings. Within this process, women and marginalized groups play active roles in both preserving traditions and fostering social innovations that strengthen harmony between religion and culture. Consequently, the interaction between these two organizations not only reinforces Islamic values in society but also opens space for historically marginalized groups to participate in social change.

2 Literature Review

2.1 Transcending the Boundaries of Proportion

Transcending the boundaries of proportion is defined as a conceptual framework that refers to an intellectual journey that goes beyond existing limits (Iqbal, 2013). This concept aligns with the idea of transdisciplinarity, which emphasizes the importance of cross-boundary intellectual movements as a strategy for addressing the complexity of knowledge (Nicolescu, 2014). Muhammad Iqbal (2013) explains that the term refers to a process in which an individual's thinking not only develops independently but also adopts the thoughts of other groups as part of a broader thinking methodology. This perspective is consistent with research suggesting that cross-disciplinary thinking can enrich analytical perspectives in the social sciences and humanities (Repko & Szostak, 2020). On the other hand, Affiah (2017) defines transcending the boundaries of proportion as an effort toward intellectual renewal, emphasizing the need for new approaches to understand reality. This is in line with the idea of conceptual innovation in philosophy, which underlines the importance

of moving beyond old boundaries to create a more contextual understanding (Frodeman & Klein & Pacheco, 2017).

2.2 Shifting Paradigms

Shifting paradigms can be understood as the emergence of new knowledge aimed at fostering openness of thought through interdisciplinary approaches. According to Kurniawan (2008), this concept arises from dynamic social interactions and the various social problems that evolve in their surroundings. Shifts in thinking often occur as an adaptive response by individuals to social changes and environmental challenges, enabling them to survive and play a more proportionate role in society (Voulvoulis et al., 2022). An interdisciplinary approach to understanding paradigm shifts allows for a more comprehensive analysis by incorporating various disciplinary perspectives. As described by Aryal (2023), such an approach can connect social, cultural, and technological aspects in responding to complex societal issues. Moreover, paradigm shifts serve as an intellectual refreshment effort, challenging rigid, normative, and textual patterns of thought, thus opening space for more critical and innovative thinking (Eloranta et al., 2024).

2.3 Nahdlatul Ulama

Nahdlatul Ulama (NU) is often understood as a response to Islamic reform movements. However, its immediate establishment was not solely rooted in resistance to the reformist propaganda of the time. Instead, *Nahdlatul Ulama*'s founding in 1926 was more influenced by international dynamics, such as the abolition of the caliphate by Mustafa Kemal Atatürk, the expansion of Wahhabi influence in Mecca, and the search for a new model of pan-Islamism (Feener, 2007; van Bruinessen, 1994). Beyond global factors, *Nahdlatul Ulama*'s founding also had strong national dimensions. Choirul Anam (2010) highlights that *Nahdlatul Ulama* emerged as part of the independence spirit, expressed through religious and educational activities to foster nationalism among Indonesian Muslims (Barton & Yilmaz & Morieson, 2021; Hosen, 2016).

Nahdlatul Ulama developed the teachings of *Ahl al-Sunnah wa al-Jama'ah* that adapt to the local social and cultural context. The model of Islam developed by *Nahdlatul Ulama* is not only recognized as "middle-path Islam", but also as a form of Islam deeply embedded in the identity of the Nusantara (Indonesian archipelago) society (Ulfah, 2014; van Bruinessen, 1994). From the perspective of the anthropology of religion, this flexibility illustrates how *Nahdlatul Ulama*'s version of Islam is not merely a theological doctrine but also a socio-political strategy to maintain harmony in multicultural societies (Sakai & Fauzia, 2016). Furthermore, *Nahdlatul Ulama* has transformed from a religious organization into a significant social and political force in Indonesia (Burhani, 2018). *Nahdlatul Ulama*'s role extends beyond strengthening traditional clerical networks; it also engages in national political dynamics, particularly through its involvement in political parties and social movements (Menchik, 2016; Mietzner, 2020).

2.4 Muhammadiyah

Muhammadiyah is understood as a religious organization oriented toward purification, namely a return to the pure essence of Islamic teachings while liberating the community from elements deemed as superstition, innovation (*bid'ah*), and heresy (Shihab, 1998). This movement emerged within a dual-patterned religious context — between syncretic Islam, which evolved in local cultures, and traditional Islam practiced in Islamic boarding schools (Tobroni & Arifin, 1994). In this context, *Muhammadiyah* acts as an agent of change, attempting to eliminate cultural elements considered incompatible with the principles of pure Islam. Purification in *Muhammadiyah* is not only a matter of religious reform but also part of a broader social rationalization that aligns with the societal transition from agrarian to industrial, or from traditional to modern (Fealy, 2003). As such, *Muhammadiyah* embodies not only a spiritual dimension but also an ideology that supports modernization through industrial theology and a rational ethos (Ropi, 2017). In line with this analysis, several studies show that the movement also aims to remove cultural elements perceived to hinder progress, replacing them with more scriptural and rational religious values (Burhani, 2006; Haq & Muhtadi & Kahmad & AS, 2022).

Muhammadiyah's efforts in its social transformation processes are evident through its systematic strategies in instilling a more puritanical Islamic doctrine, whether through education, preaching, or other social institutions (Azra, 2021; Sari & Saleh, 2020). *Muhammadiyah* pursues purification not only in

theological aspects but also within social and cultural domains by directing Muslims toward a more reason-based understanding grounded in authoritative religious texts (Al-Hamdi & Efendi & Kurniawan & Latief, 2019). Thus, *Muhammadiyah* plays the role of an agent of change that actively promotes societal transformation through the rationalization and modernization of Islamic values (Hamayotsu, 2011).

3 Method

This research employs a qualitative approach with a descriptive method, based on both primary and secondary data (Creswell & Creswell, 2017). Primary data were obtained through fieldwork, including direct observation and mapping of research aspects (Flick, 2018). The data collected include the forms of intellectual shift in *Nahdlatul Ulama* and *Muhammadiyah* that transcend conventional boundaries (van Bruinessen, 1994), the factors driving *Nahdlatul Ulama* toward progressive thought and *Muhammadiyah* toward an accommodative stance (Azra, 2021), as well as the implications of these shifts in thought for both groups (Ricklefs, 2014).

In data collection, the study involved two main groups: (a) *Nahdlatul Ulama* intellectuals, and (b) *Muhammadiyah* scholars. These groups were selected to examine how shifts in thought occur among Gorontalo Muslims in their interpretive processes and to determine whether intellectual capacity influences their perspectives and attitudes (Hefner, 2019). Additionally, the study engaged prominent figures with the competence to evaluate the accuracy and validity of the findings (Moleong, 2017).

The research was conducted over a two-month period and included several phases: desk review, field observations, and in-depth interviews (Neuman, 2014). Prior to fieldwork, various secondary sources were collected, including online news, to map the thoughts of both Muslim groups (van Bruinessen, 1994). Observations were conducted on religious studies held in online media as well as open discussions involving *Nahdlatul Ulama* and *Muhammadiyah* Muslims (Woodward, 2001).

Data analysis was carried out in two forms. First, the analysis followed the stages proposed by Miles and Huberman (1994), which remain relevant in qualitative research (Saldaña, 2021). These stages include data reduction from observations and interviews, data display in the form of summaries and synopses based on field themes, and data verification for conclusion drawing. Second, analysis was performed using interpretive techniques, including restatement of data obtained from observations and interviews, followed by description to identify patterns or trends in the data, and concluded with interpretation to uncover the meaning behind the collected data (Yin, 2018).

To enhance the credibility of the findings, this study employed data validation through triangulation (Denzin, 2017). Triangulation was conducted by comparing data from various sources, including interview results, observations, and literature reviews. Additionally, credibility testing was strengthened through expert discussions and rechecking interview findings with relevant informants to ensure consistency and accuracy of the obtained data (Guba & Lincoln, 1994).

4 Results

4.1 Models of Thought Transformation among Nahdlatul Ulama and Muhammadiyah Muslims Transcending Proportional Boundaries

Social transformations in Gorontalo illustrate that religious structures are dynamic, continually evolving alongside developments in social, political, and educational spheres. The increasing interactions between *Nahdlatul Ulama* and *Muhammadiyah* youth, both academically and within social movements, have fostered flexibility in interpreting and articulating Islamic values within the cultural context of Gorontalo.

For instance, Donal Tungkagi, a young *Nahdlatul Ulama* figure, was born and raised within *Nahdlatul Ulama* traditions, where religious practices inherited from previous scholars are integral to daily life. From an early age, he participated in religious rituals passed down through generations, regarded as forms of *ijtihad* by scholars in disseminating Islam in the archipelago. However, his exposure to higher education and broader social interactions has shaped his perspectives differently. While maintaining respect for his religious roots,

he has developed a more inclusive and progressive outlook, aligning with the post-traditionalist approach observed among *Nahdlatul Ulama* members in Gorontalo (Table 1).

Similarly, Dikson Yasin, a young *Nahdlatul Ulama* intellectual, was raised in a community that highly values local Islamic traditions. His early thinking was influenced by the strong cultural environment of Tilihuwa village, Gorontalo Regency, which instilled Islamic values based on long-standing traditions. Accustomed to religious practices handed down by local scholars, these became part of his religious identity. However, his academic journey, culminating in a doctoral degree at the State Islamic University of Walisongo Semarang, led to changes in his worldview. Engagement with diverse Islamic thoughts, intellectual discussions, and encounters with various religious traditions have contributed to this transformation.

In contrast, *Muhammadiyah*'s thought model appears modernist-accommodative, reflected in the thinking of *Muhammadiyah* intellectuals in Gorontalo who emphasize openness over purist zeal. Their approach to studying Islam incorporates not only religious texts but also socio-cultural, historical, and anthropological aspects. Their studies on Islam and culture, jurisprudence of diversity, and Islam in the Indonesian context are regularly discussed in various *Muhammadiyah* forums.

In an interview conducted on February 4, 2022, Ilyas explained that openness to culture should not compromise Islamic principles. He observed that *Muhammadiyah* no longer focuses as intensely on combating issues such as heresy (*bid'ah*), superstition (*khurafat*), and religious innovation (*takhayyul*), which were central to its early reformist agenda. According to him, the paradigm of the *Muhammadiyah* movement has evolved from a primary emphasis on the purification of Islamic teachings toward a broader focus on social welfare and humanitarian concerns.

This perspective aligns with that of Munkizul Umam Kau, Chairman of the *Tarjih* Council of *Muhammadiyah* in Gorontalo, who emphasized that as long as a tradition does not contradict the core principles of Islamic law, its existence is acceptable. He believes that criticism is warranted when a cultural tradition is elevated to the status of an absolute religious obligation, thereby conflating local practices with universal Islamic tenets. Integrating tradition with Islamic teachings in religious organizations like *Muhammadiyah* does not always proceed without challenges. Such transformations can lead to internal tensions, particularly between members who lean toward more moderate interpretations and those who hold more conservative views.

Statements from Ilyas and Munkizul are echoed by Salahudin Pakaya, Secretary of the *Muhammadiyah* Regional Leadership in Gorontalo. He emphasized that as long as Gorontalo culture does not deviate from Islamic teachings and monotheistic values, it is acceptable. He asserted that *Muhammadiyah* has always oriented itself towards progressive Islam based on knowledge since its inception.

Despite Salahudin's moderate stance towards tradition, this transformation still poses potential internal challenges within the organization. Integrating tradition and modernity can also carry risks, such as the potential loss of organizational identity. As a movement known for its spirit of renewal (*tajdid*), *Muhammadiyah* faces the dilemma of maintaining the purity of Islamic teachings while adapting to the socio-cultural dynamics of society. If not managed properly, accommodating tradition can lead to ambiguity in the organization's ideological direction.

4.2 Driving Factors behind Progressive Nahdlatul Ulama and Accommodative Muhammadiyah

4.2.1 Driving Factors Behind Progressive Nahdlatul Ulama in Relation to Modernization

There are three main factors that drive *Nahdlatul Ulama* (NU) Muslims in Gorontalo to adopt a traditional-progressive mindset:

1. **Educational factor**
   According to data from the Central Statistics Agency (BPS) of Gorontalo in 2022, the higher education participation rate in the province increased by 7.5 % over the past five years (Figure 1 BPS Provinsi Gorontalo, 2022). This reflects an improvement in human resources (HR) within *Nahdlatul Ulama*. According to *Nahdlatul Ulama* Gorontalo's internal report, the number of university students affiliated

Table 1: Thought transformation of NU and Muhammadiyah.

Aspect	NU	Muhammadiyah
Pattern of change	NU youth accessing higher education, especially outside Gorontalo, experience more inclusive and progressive thinking patterns while still adhering to Islamic traditions.	Muhammadiyah, initially known as a modernist movement based on Islamic rationalism, increasingly accommodates local culture in its social-religious practices.
Impact of social and academic interaction	Increased interaction between NU and Muhammadiyah youth in academic and social spheres leads to flexibility in understanding Islamic values within the cultural context of Gorontalo.	Muhammadiyah's thinking increasingly considers socio-cultural, historical, and anthropological aspects in studying Islam.
Thought model	Traditionalist-Progressive: 1. Islam develops within a historical context and adapts to local culture. 2. Islam not only stands on cultural practices but also gives meaning to the culture itself.	Modernist-Accommodative: 1. Based not only on religious texts but also considers social, historical, and cultural aspects. 2. Muhammadiyah's paradigm has shifted from purification to social and humanitarian issues.
Attitude towards tradition	Continues to respect tradition but is open to new perspectives in understanding Islam and culture.	Increasingly accepts local traditions as long as they do not contradict Islamic values, focusing on education and social progress.
Internal challenges	Implementing flexibility without losing NU's traditional identity.	Differences in views between moderate and conservative groups in accepting local traditions. Risk of ideological ambiguity if accommodation of tradition is not well managed.

with PMII (the student organization linked to *Nahdlatul Ulama*) rose from 1,200 members in 2010 to more than 3,500 members in 2022 (Laporan Internal NU Gorontalo, 2022).

This indicates that intellectual enlightenment is growing and becoming more adaptive to change. Several academic figures from the *Nahdlatul Ulama* community have contributed to building the organization's intellectual base. Among them are professor Usman Kaharu, as well as senior scholars such as Ani Hasan, Amir Khalid, and Novianty Djafri, who are actively involved in Islamic thought research and development. Additionally, a younger generation of academics has emerged, including Samsi Pomalingo, Dikson Yasin, Donal Tungkagi, and Eka Putra B. Santoso.

2. **Digital technology factor**
   Advancements in information technology have provided opportunities for younger *Nahdlatul Ulama* cadres to actively participate in disseminating moderate Islamic teachings. According to internal data from *NUtizen TV*, a digital *da'wah* platform managed by *Nahdlatul Ulama* Gorontalo, the average viewership per broadcast reaches 20,000 views, with a 15 % increase in subscribers every six months (*NUtizen TV*, 2023). This shows that digital-based *da'wah* has successfully captured public attention and created a tangible impact in shaping moderate religious opinions. With two broadcasts per week, the content covers various topics on moderate Islam, tolerance, and responses to social-religious challenges in the digital era.

3. **Radical Islam factor**
   Gerakan Pemuda (GP) Ansor, one of *Nahdlatul Ulama*'s autonomous bodies in Gorontalo, plays an

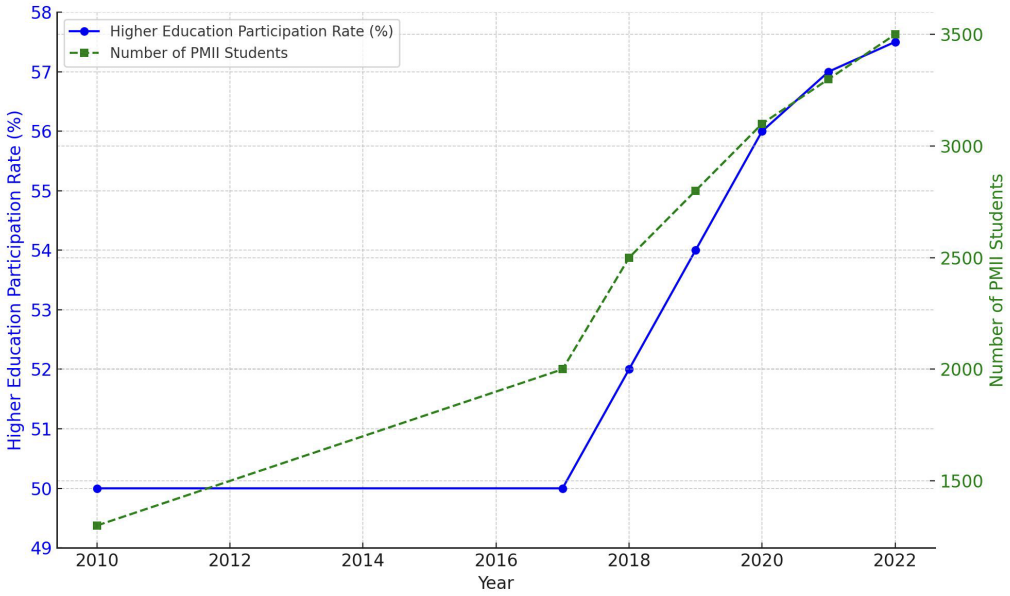

Figure 1: Increase in PMII students.

active role in safeguarding diversity and tolerance. According to GP Ansor Gorontalo's 2023 report, the organization has conducted more than 50 interfaith dialogue events and 30 cadre training sessions annually to strengthen the understanding of Islam as a blessing for all creation (*rahmatan lil 'alamin*) (Laporan GP Ansor Gorontalo, 2023). Under the leadership of Muhtojim Boki, Fadliyanto Koem, Fadli Alamri, Risan Pakaya, and Dikson Yasin, GP Ansor remains consistent as a stronghold against intolerance and radicalism.

4.2.2 Factors Driving Muhammadiyah's Accommodative Approach to Culture

Muhammadiyah understands how to position itself within cultural diversity, as reflected in three main factors that have driven the shift in their mindset — from puritanism toward a more accommodative approach to culture (Table 2).

However, this transformation also presents potential weaknesses that need to be explored more deeply. One such concern is the possible emergence of internal conflict within *Muhammadiyah*, especially among more conservative members. The integration between tradition and modernity risks blurring the organization's identity. Without adequate analysis, this change could create tensions between groups striving to preserve the purity of religious teachings and those more accommodating toward local culture.

4.3 Implications of the Shift in Thought of Nahdlatul Ulama and Muhammadiyah

The shift in thought between *Nahdlatul Ulama* and *Muhammadiyah* has contributed to the dismantling of "cultural barriers". This breakdown of civilizational divisions began around 1991, when figures from both organizations — Kiai Adam Zakaria representing *Nahdlatul Ulama* and Yusuf Polapa representing *Muhammadiyah* — jointly delivered a religious lecture at Baiturrahim Mosque in Gorontalo City during a *halal bi halal* event. Since then, *Nahdlatul Ulama* and *Muhammadiyah* have concentrated their programs and movements on jointly addressing social, educational, cultural, and religious issues. There are four implications of the shift in thought of *Nahdlatul Ulama* and *Muhammadiyah* (Table 3).

4.4 Marginal Perspectives in the Study of Nahdlatul Ulama and Muhammadiyah

Figure 2 shows the estimated percentage of members from marginalized groups—women, indigenous communities, and persons with disabilities—within student organizations affiliated with *Nahdlatul Ulama* (NU) and *Muhammadiyah*. These data reflect the proportion of inclusion reported by regional student wings of both organizations in 2022, highlighting a significant gap in inclusivity efforts. For example,

Table 2: Factors driving Muhammadiyah's accommodative approach to culture.

Factor	Description	Supporting data
Cultural contact	The interaction between Muhammadiyah and Nahdlatul Ulama occurs not only in formal activities but also in informal settings. Through these interactions, Muhammadiyah Muslims recognize the importance of customs in religious life, which ultimately contributes to social harmony and the strengthening of humanistic values. Sociological studies can explain how these interactions create social changes within the organization.	A survey of 60 Muhammadiyah members in Gorontalo shows that 75 % of respondents acknowledge that involvement in custom-based activities enhances their social relationships with the local community.
Social adaptation	Villages serve as the base for culturally oriented Nahdlatul Ulama Muslims. When Muhammadiyah establishes educational institutions and expands its preaching efforts in rural areas, they must face norms and values different from those they previously upheld. Adaptation becomes necessary to build closer social relationships with the local community. From an anthropological perspective, this adaptation strategy can be analysed as a form of acculturation and identity negotiation.	Data shows that 60 % of Muhammadiyah members living in villages adopt certain Nahdlatul Ulama religious traditions in order to maintain social harmony.
Strength of customs	Gorontalo Muslims had a strong customary system before the arrival of Nahdlatul Ulama and Muhammadiyah. The shift in Muhammadiyah's thinking is evident across generations of leaders who have increasingly shown openness toward Gorontalo identity. From a political science perspective, this can be seen as Muhammadiyah's strategy to maintain its existence within a custom-based social structure.	According to statistical data from the local Muhammadiyah organization, around 85 % of Muhammadiyah members in Gorontalo agree that respecting customs does not contradict the principles of Progressive Islam.

Muhammadiyah shows higher representation of indigenous groups (35 %) and persons with disabilities (10 %) than *Nahdlatul Ulama* (25 % and 8 %, respectively), while women's representation remains modest in both.

This figure underlines the underrepresentation of marginal voices in scholarly studies and organizational narratives of both *Nahdlatul Ulama* and *Muhammadiyah*, suggesting the need for more inclusive and intersectional approaches in Islamic intellectual discourse.

This graph reveals the fact that the perspectives of marginalized groups — women, indigenous communities, and people with disabilities — are still side-lined in the discourse surrounding the transformation of thought in *Nahdlatul Ulama* and *Muhammadiyah*. Despite both organizations continuing to grow and becoming more accommodating to social changes, attention to these groups remains minimal. Ironically,

Table 3: Implications of the shift in thought of NU and Muhammadiyah.

Indicator	Description	Implication
Joint focus on socio-religious issues	Nahdlatul Ulama and Muhammadiyah now prioritize humanitarian services over emphasizing ideological differences. Both organizations actively engage in joint social action.	Resistance from more conservative members and the potential blurring of each organization's distinctive identity.
Educational exchange in rural and urban areas	Educational institutions of Muhammadiyah and Nahdlatul Ulama are now open to students and educators from both sides. Many NU members study at Muhammadiyah institutions and vice versa.	The loss of unique educational identity for each organization and a paradigm shift in teaching and learning systems.
Shared commitment to nationalism	Both organizations are actively involved in defending national sovereignty, rejecting the caliphate system, and educating the public on the importance of Pancasila as the state ideology.	Potential differences in responding to broader political issues and resistance from more conservative internal groups.
Awareness of local cultural traditions	Muhammadiyah and Nahdlatul Ulama both accept and participate in local social traditions such as ti'ayo, huyula, and bilohe.	More puritanical Muhammadiyah members may still perceive some traditions as conflicting with their principles, and there is a potential loss of the exclusive values that distinguish each organization.

both *Nahdlatul Ulama* and *Muhammadiyah* often position themselves as pioneers of inclusive movements within Islam. However, when viewed from the data, their attention to women, indigenous communities, and people with disabilities is still below 40 %. *Muhammadiyah* is slightly more open in accommodating marginal perspectives than *Nahdlatul Ulama*, but this gap is not significant enough to be of real importance. The transformation of thought in both organizations is still dominated by elite male groups. Meanwhile, women, indigenous communities, and people with disabilities play important roles in shaping the socio-religious reality in Indonesia. If this inclusivity continues to be ignored, the modernization of thought in *Nahdlatul Ulama* and *Muhammadiyah* will only be an elitist discourse rather than a movement that truly represents the diversity of the Muslim community in Indonesia.

5 Discussion

This paper shows a shift in the thinking of *Nahdlatul Ulama* and *Muhammadiyah*. The indicators are found in two forms: first, in ideas and thoughts; second, in the practice of religious activities. In terms of thinking, the younger generation of *Nahdlatul Ulama* in Gorontalo has done a significant leap. Their way of thinking has coloured the intellectual landscape of religious knowledge in Gorontalo. Their interest in religious, social, political, and cultural studies continues to grow and develop. They even bring new perspectives by making breakthroughs in thought through books, journal articles, and online articles. As a result, the mind-set of *Nahdlatul Ulama* today carries the modern label similar to *Muhammadiyah* (Aminuddin, 2018).

Some more conservative groups have shown resistance to these new ideas, fearing they may erode the identity of the organization. Internal conflicts may emerge as a consequence of these differing views. Furthermore, the process of integrating tradition and modernity also brings the risk of losing the organization's

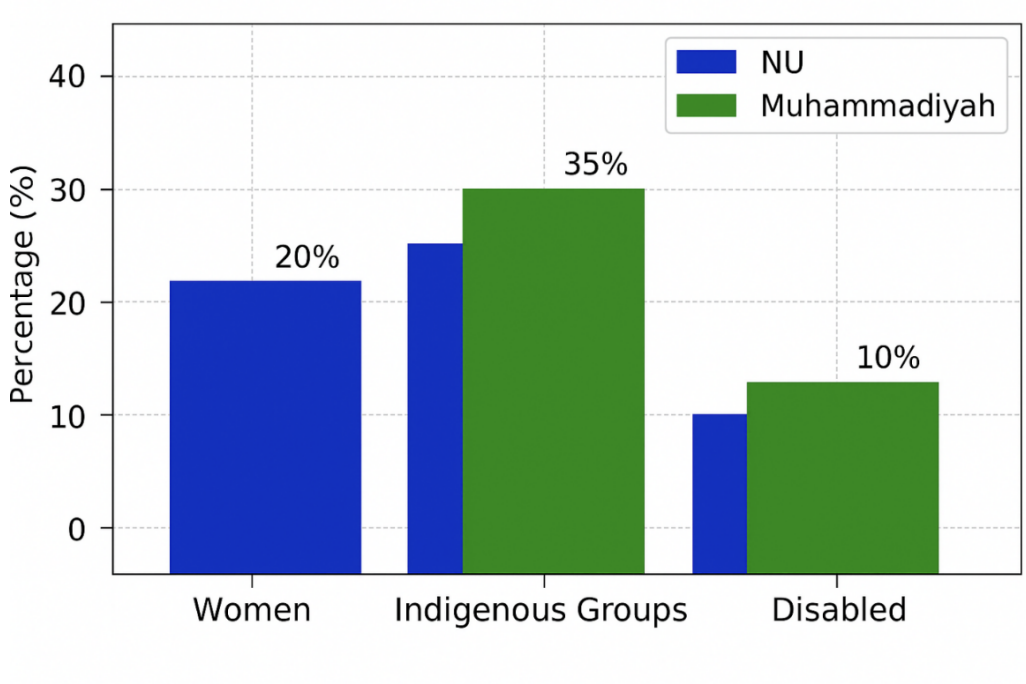

Figure 2: Estimated percentage of NU and Muhammadiyah student members from marginalized groups (women, indigenous communities, and persons with disabilities). Source: Internal survey conducted by PMII and IMM Regional Coordinating Boards, 2022 [unpublished data].

unique character. Therefore, it is important for *Nahdlatul Ulama* to maintain a balance between innovation and the preservation of the values that it has upheld for long (Biyanto, 2017).

Meanwhile, the younger generation of *Muhammadiyah* appears to be more accommodating of local culture. Although their ideas are inspired by modernist figures like Jamaluddin al-Afghani, Muhammad Abduh, and Rasyid Ridha — and even further back, their ideological roots are linked to the ideas of Ibn Taymiyyah — the *Muhammadiyah* Muslim group in Gorontalo shows a form of Islam that aligns with local culture (Burhani, 2006). However, it is worth analysing further whether this integration of tradition and modernity might create an identity dilemma for *Muhammadiyah*, particularly in maintaining the purifying principles of Islam that have always been its hallmark (Harirah, 2021).

The above interviews with informants from both Muslim groups illustrate the identity of the thoughts of *Nahdlatul Ulama* and *Muhammadiyah*. The post-traditionalist and neo-modernist phases are found in the argumentative scientific discussions commonly encountered in religious discourse and movements, not in deconstructing the religious spirit that has become the identity of each group. *Nahdlatul Ulama* remains focused on preserving tradition while responding to globalization, whereas *Muhammadiyah* stays consistent with modernism while responding to tradition. For instance, the arguments of Donal and Dikson from the *Nahdlatul Ulama* group tend to be firm in localizing the *Islam Nusantara* concept championed by Abdurrahman Wahid (Shihab, 1998). Similarly, *Muhammadiyah*'s response to tradition does not mean accepting the tradition as a whole. Munkizul Umam and Salahuddin Pakaya are firm in rejecting traditions they view as deviating from the principles of monotheism (Fealy, 2003). Meanwhile, Ilyas Daud is more flexible, only noting that religious traditions should not appear excessive. Therefore, the correct terms to describe these two groups would be "traditional-progressive *Nahdlatul Ulama*" and "modernist-accommodative *Muhammadiyah*" (Niam, 2017).

6 Conclusion

This study shows that the younger generation of both organizations no longer views their Islamic identity as something exclusive and rigid, but rather as a spectrum that is more fluid and mutually influential. This

hybridization process is evident in religious practices and perspectives on contemporary issues. For instance, some *Muhammadiyah* youth communities have begun adopting practices of *dhikr* and communal prayers, which have traditionally been more associated with *Nahdlatul Ulama*, while still adhering to the principle of monotheism (*tauhid*) that is characteristic of *Muhammadiyah*. On the other hand, the younger generation of *Nahdlatul Ulama* in Gorontalo has started to show a tendency towards rationalization in their religious understanding, following *Muhammadiyah*'s *tarjih* method, especially in responding to Islamic legal issues that intersect with modern life. This study also found that cross-organizational communities have formed organically, where *Nahdlatul Ulama* and *Muhammadiyah* youth collaborate in various social and religious activities without being overly bound by their respective organizational doctrines. This phenomenon has generated a new, more inclusive Islamic discourse, one that not only lies on the traditionalist-modernist spectrum, but also forms a more dynamic and contextual way of thinking in relation to the social conditions in Gorontalo.

However, in the dynamics of transformative thought, the perspectives of marginalized groups, such as women, indigenous communities, and people with disabilities, are still largely side-lined. The new Islamic discourse that has developed among the youth of *Nahdlatul Ulama* and *Muhammadiyah* is still primarily focused on changing the dominant mind set within the organizations, while the experiences and aspirations of these groups have not yet fully become part of the mainstream discussion. This indicates that although there is openness and hybridization in Islamic thought, the challenge of inclusivity still requires further attention. Additionally, this research reveals a transformation in how the younger cadres of both organizations understand the concept of Islam in the digital era. Social media has become not only a tool for *da'wah* but also an interactive space that encourages the reinterpretation of Islamic teachings beyond the classical boundaries of *Nahdlatul Ulama* and *Muhammadiyah*. The younger generation of *Nahdlatul Ulama*, who are more familiar with global thought, tend to reduce the exclusivity of their tradition, while *Muhammadiyah* youth are becoming increasingly open to cultural approaches they had previously overlooked.

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The Patient Health Questionnaire-4 (PHQ-4) as a Brief Screening Tool for Anxiety and Depression: A Study of Iranian Samples

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Abstract

The aims of the present study were (a) to develop a Farsi version of the Patient Health Questionnaire-4 (PHQ-4), (b) to explore correlations for anxiety and depression with psychological well-being, mental health, and happiness, and (c) to explore gender-related differences. A sample of 488 subjects representing the general population of Iran responded to the PHQ-4, the World Health Organization-Five Well-Being Index, the Self-Rating Scale of Mental Health, and the Self-Rating Scale of Happiness. Cronbach's α was .86 for the PHQ-4. Using a principal components analysis (PCA) with varimax rotation, one factor was extracted, labelled "Anxious/Depressed." Exploratory factor analysis indicated that the scale has both a one-factor and a two-factor structure. Confirmatory factor analysis showed the PHQ-4 has good fit indices for both structures. Cronbach's α was high for both. PHQ-4 scores correlated negatively with psychological well-being, mental health, and happiness scores, indicating good validity. The sex-related difference in the PHQ-4 was not statistically significant. The PHQ-4 showed good psychometric properties in the present general population sample from Iran. This study provides evidence for the usefulness of the Farsi version of the PHQ-4 for assessing the prevalence of anxiety and depression symptoms in Iranian community residents.

Keywords: Anxiety, Depression, Psychological well-being, Mental health, Happiness, Iran

1 Introduction

Mental health, as defined in 2022, is a state of mental well-being that allows individuals to cope with the stressors of life, recognize their abilities and competencies, learn effectively, work well, and contribute to society (Mental health, 2022). Mental health and mental disorders are generally determined by a combination of social, psychological, and biological factors that interact with each other (Fryers et al., 2005; Mental health, 2022; Sıncar et al., 2020). Mental health can be influenced by various individual and societal factors such as economic disadvantage, employment, working conditions, housing conditions, and (lack of) social support (Dohrenwend, 1990; Fryers et al., 2005).

Globally, a significant portion of the burden of global health is attributed to mental disorders. Among mental disorders, depression and anxiety are reported as the most frequent disabling mental health conditions (Dohrenwend, 1990). In 2019, depression and anxiety ranked among the top 25 causes of disability for all age groups (Institute for Health Metrics and Evaluation [IHME], 2024; Murray, 2020; Santomauro et al., 2021; WHO, 2023).

In the DSM-5, depressive disorders are defined as the presence of a sad, empty, or restless mood accompanied by somatic and cognitive changes that significantly affect an individual's functioning (Black & Grant, 2014, p. 155). Depression is often characterized by the presence of negative thoughts about oneself, the world, and the future, often accompanied by feelings of hopelessness, guilt, or worthlessness (Beck & Alford, 2009, p. 65). Depressive mood is influenced by biological, social, and emotional changes (Haehner

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et al., 2024). Depression is a common mental disorder. An estimated 3.8 % of the population experience it, including 5 % of adults (4 % in men and 6 % in women) and 5.7 % of adults aged 60 and older (Depressive Disorder (Depression), 2023).

Depression is a challenging condition to diagnose because it can manifest with a wide range of symptoms, including symptoms such as headaches, constipation, loss of appetite, back pain, or chronic fatigue. Rapid diagnosis and treatment of depression are crucial. Research has shown that many individuals who die by suicide had recently visited a primary care physician, but they were not diagnosed with depression and antidepressant treatment was not initiated for them (Beck & Beck, 1972).

The General Health Services Study of Psychological Problems (PPGHC), conducted by the World Health Organization (WHO) in various cultures to detect common psychological disorders in primary care settings, reports that almost half of depression and anxiety cases occur in the same individuals at the same time (Sartorius et al., 1996). Although it has been suggested that these two disorders can be separated (Wetzler & Katz, 1989), research has shown that a significant portion of individuals with Generalized Anxiety Disorder (GAD) also meet the criteria for depression, and vice versa (Sartorius et al., 1996). It is reported that up to 85 % of depression patients also experience significant anxiety symptoms, and up to 90 % of individuals with anxiety disorders develop depression (Gorman, 1996). The symptoms of depression and anxiety disorders seen in patients can meet the criteria for both mental disorders, making it challenging to differentiate between the two. However, it is essential to identify and treat both conditions because they are associated with significant morbidity and mortality. In this context, primary care health facilities play an important role in maintaining mental health, detecting patients with these disorders, and providing treatment (Tiller, 2013).

Anxiety is defined as a pervasive negative mood that affects emotional, cognitive, physical, behavioral, and relational states in various ways. In clinical literature, this term is applied to the presence of fear or anxiety that is disproportionate to the situation (Black & Grant, 2014, p. 123). GAD, the most commonly encountered mental disorder in the community, has a prevalence ranging from 2.8 % to 8.5 % in general medical practice and from 1.6 % to 5.0 % in the general population — although the diagnosed cases are merely the extreme end of a bell-shaped distribution, and any categorical distinction between "normal" and GAD is arbitrary. Until recently, due to its inability to be fully diagnosed and the scarcity of empirical studies in this field, GAD was considered relatively unimportant both by clinicians and the public (Judd et al., 1998; Spitzer et al., 2006).

Various tools have been developed to diagnose depression (e.g., Beck, 1961; EuroQol Group, 1990; Kroenke et al., 2001; Kroenke, Strine, et al., 2009; Radloff, 1977; Rush et al., 2003). In today's societies, there is a need for reliable diagnostic tools that can be used for rapid screening in primary care health facilities as common mental disorders like depression become increasingly prevalent (Kroenke et al., 2003). This is the purpose for which the PHQ-4 was developed (Löwe et al., 2010). Corson et al. (2004) reported that ultra-short tests consisting of two or three items identify approximately 80 % of depression cases in depression screenings.

The first two items of the PHQ-4 assess depression and the other two items assess anxiety, making it a useful tool for detecting both common mental disorders. The 2-item Patient Health Questionnaire for Depression (PHQ-2) is a shorter version of the 9-item PHQ-9. PHQ-2 focuses solely on depressive mood and loss of interest, thus representing the basic diagnostic criteria of the DSM-IV (Kroenke et al., 2003; Löwe et al., 2005). The results of a prospective criterion standard study conducted on a sample of 520 outpatients indicate that PHQ-2 has good criterion validity, convergent validity, and sensitivity to change (Löwe et al., 2005). In measurements using PHQ-2, it was found that a cutoff of 3 or higher is comparable to the PHQ-9 diagnostic algorithm for any depressive disorder and major depressive disorder (Kroenke et al., 2003).

The 2-item Generalized Anxiety Disorder Scale (GAD-2), which measures anxiety, is a shorter version of the 7-item Generalized Anxiety Disorder Scale (GAD-7) (Kroenke et al., 2007; Löwe et al., 2008; Spitzer et al., 2006). A validation study conducted with a sample of 965 primary care patients who were diagnosed through criterion standard interviews for the most common four anxiety disorders found that GAD-2 has good criterion validity (Löwe et al., 2010).

The findings obtained from a study with over 5,000 subjects, conducted to determine the validity and reliability of PHQ-4, show that this extremely short 4-item measurement can reliably and validly measure depression and anxiety in the general population (Löwe et al., 2010).

Kroenke, Spitzer, et al. (2009) have classified PHQ-4 scores operationally as normal (0–2), mild (3–5), moderate (6–8), and severe (9–12). During the standardization process of the PHQ-4's two components, PHQ-2 and GAD-2, a cutoff of 3 was found to be the most appropriate (Kroenke et al., 2003; Löwe et al., 2005). The PHQ-4 serves as a rapid, valid, and reliable screening tool rather than a diagnostic tool (Kroenke, Spitzer, et al., 2009; Mitchell & Coyne, 2007).

The aims of the present study were (a) to develop a Farsi version of the Patient Health Questionnaire-4 (PHQ-4), (b) to explore correlations for anxiety and depression with psychological well-being, mental health, and happiness, and (c) to explore gender-related differences.

2 Methods

2.1 Participants

Using a cross-sectional study, a sample of 488 subjects from the Iranian general population ($M_{\text{age}} = 29.5$, $SD = 11.5$; 73.4 % female) participated in the study. The participants were recruited via a self-selection method. They were provided with information regarding the nature and aim of the study, including the number and type of questions/content of the research. In the online questionnaire forms, the first question was "According to the above explanation, do you agree to participate in the study?" The scales completed by all the subjects who responded "yes" to this question were included in the study. This study protected participants' confidentiality.

2.2 Measures

2.2.1 The Patient Health Questionnaire-4 (PHQ-4)

The PHQ-4 consists of the first two items of Patient Health Questionnaire-9 (PHQ-9) and the first two items of Generalized Anxiety Disorder-7 (GAD-7). Each of the items is rated on a 4-point Likert scale: 0 (Not at all), 1 (Several days), 2 (More than half the days), and 3 (Nearly every day). Total scores are rated from 0 to 12. Scores are rated as normal (0–2), mild (3–5), moderate (6–8), and severe (9–12). Total scores ≥ 3 for the first 2 questions suggests anxiety, and ≥ 3 for the last 2 questions suggests depression (Kroenke et al., 2009). A higher score on the PHQ-4 indicates poorer mental health (Meng et al., 2024).

2.2.2 World Health Organization-Five Well-Being Index (WHO-5)

The five items of the WHO-5 ask about positive mood, vitality, and general interests. Each of the items is rated on a 6-point Likert scale. Previous studies have found acceptable psychometric properties of the WHO-5 in different versions and in various clinical and non-clinical samples (Dadfar et al., 2018). The Farsi version of the WHO-5 was available on the WHO website in 2017 (WHO, 2017).

2.2.3 Self–Rating Scale of Mental Health and Self–Rating Scale of Happiness

These scales consist of separate single-item questions: "What is your estimation of your mental health in general?" and "To what degree do you feel happy in general?" These questions are rated on a scale of 11 numbers from 0 to 10. The participants were requested (a) to respond according to their global estimation and general feeling (and not their present states), (b) to know that 0 is the minimum and that 10 is the maximum score, and (c) to circle a number which seems to them to describe their actual feeling accurately. High scores indicate a high level of mental health and happiness. The one-week test–retest reliabilities of the two self-rating scales ranged between .86 and .89, indicating high temporal stability and corroborating the trait-like nature of the scores (Abdel-Khalek, 2006; Abdel-Khalek & Lester, 2017; Dadfar et al., 2021, 2025).

2.3 Procedure

In the present study, the English version of the PHQ-4 was translated into the Farsi language by two native Iranian, Farsi-speaking bilingual individuals, and this version was back-translated into English by another person who was a native English speaker. Based on this, discrepancies were resolved and the final version of the Farsi PHQ-4 was developed. The PHQ-4, the WHO-5 and the self-rating scales were designed as a Google form and delivered to subjects living in various areas of Gonbad Kavos City, Golestan Province, Iran. The respondents were recruited by a self-selection method. Informed consent was electronically obtained from participants in accordance with the Declaration of Helsinki. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Data were collected between 30/07/2022 and 30/11/2022.

2.4 Data Analysis

The data were analyzed with descriptive statistics, Pearson correlation coefficients, and a principal components analysis (PCA) with varimax rotation using SPSS version 26. Eigenvalue greater than 1.0 and the scree plot test were used to determine the number of factors to be retained. Factor loadings $> .5$ were considered adequate. Confirmatory factor analysis (CFA) was applied with the AMOS program to evaluate whether the factor structure obtained by exploratory factor analysis (EFA) was fit.

3 Results

The mean total score for the Farsi version of the PHQ-4 was 3.98 ($SD = 3.22$). The skewness and kurtosis indicate that the distribution of the data is near-normal, with only mild positive skew (Table 1).

The Kaiser-Meyer-Olkin measure of sampling adequacy for the PHQ-4 was .803. Bartlett's test of sphericity produced a chi-square of 916.2 ($df = 6$, $p < .001$). The PHQ-4 is a unifactorial scale. One salient component with an eigenvalue of 2.84 was extracted and labeled "Anxious/Depressed", which explained 71 % of the total variance (Table 1 and Figure 1).

Table 1: Means (M), standard deviations (SD), skewness, kurtosis, and loadings of the items on the unrotated first principal component.

PHQ-4	Item 1	Item 2	Item 3	Item 4
Mean	1.29	.93	.86	.908
SD	.94	.95	.95	.99
Skewness	.459	.744	.840	.827
Kurtosis	-.646	-.419	-.300	-.414
Factor loading	.813	.858	.840	.858

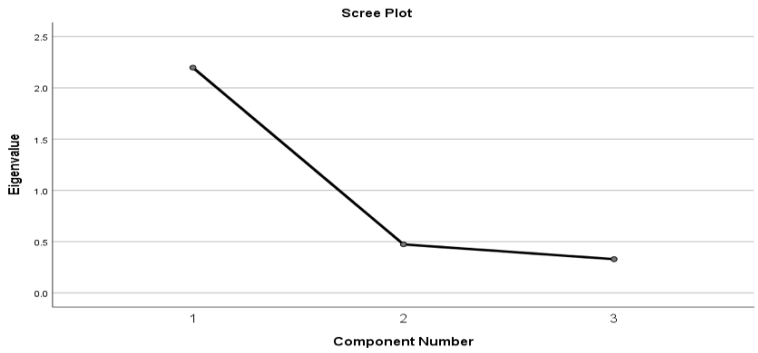

Figure 1: Scree plot of the Patient Health Questionnaire-4 (PHQ-4).

The single-factor solution presented in Figure 2 produced a good fit according to the fit indices. All estimated loadings were statistically significant ($p < .001$), the sign obtained was as expected, and the model was correctly identified (Table 2).

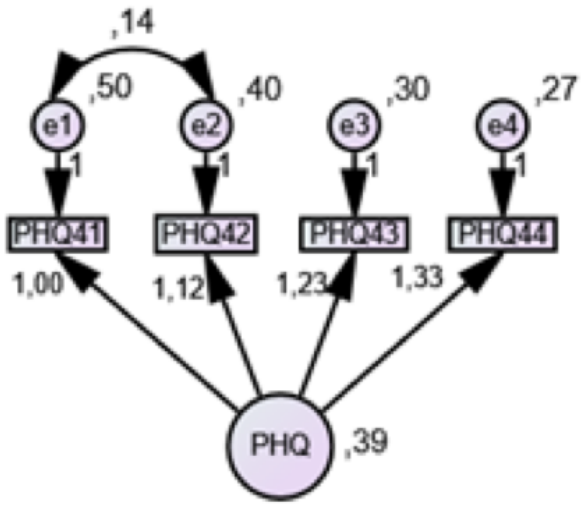

Figure 2: Measurement model with standardized loadings, PHQ-4 one-factor structure.

Table 2: Model fit values of single factor and two factor structures.

	One factor	Two factors	Recommended
χ^2/df ratio	1.23	1.23	< 5
GFI	0.99	0.99	> 0.95
AGFI	0.98	0.98	> 0.90
CFI	1.00	1.00	> 0.90
NFI	0.99	0.99	> 0.90
RMSEA	0.022	0.022	< 0.08
SRMR	0.0054	0.0054	< 0.05

The two-factor solution had equally good fit according to the fit indices. All estimated loadings were statistically significant ($p < .001$). The covariance between PHQ-2 and GAD-2 was calculated as .59 ($p < .001$). The correlation coefficient between PHQ-2 and GAD-2 was .87. Standardized regression weights ranged from .76 to .85 (Figure 3 and Table 3). Therefore, the internal consistency of the Farsi version of the PHQ-4 was high for both structures. The item-total correlations ranged from .503 to .689, all statistically significant at the .01 level. Cronbach's α was .86 (Table 4).

Table 5 shows that correlations of the PHQ-4 with WHO-5 and the two self-rating scales of mental health and happiness were large (-.71, -.53, and -.56, all statistically significant at the .01 level), indicating good validity.

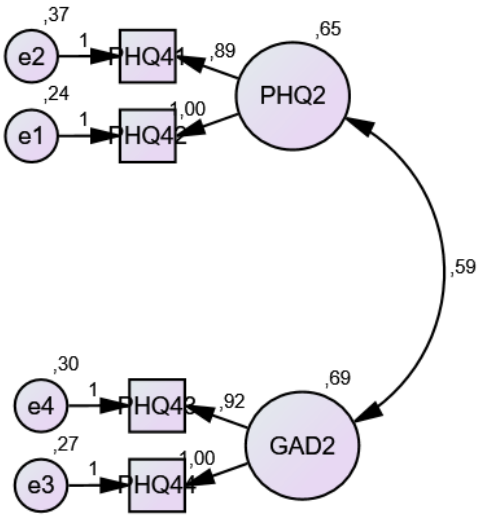

Figure 3: Measurement model with two-factors, standardized loadings.

Table 3: PHQ-4 single- and two-factor standardized regression weights.

One-factor model				Two-factor model			
Item		Latent	Estimate	Item		Latent	Estimate
PHQ41	←	PHQ4	.666	PHQ41	←	PHQ2	.765
PHQ42	←	PHQ4	.742	PHQ42	←	PHQ2	.853
PHQ43	←	PHQ4	.814	PHQ43	←	GAD2	.814
PHQ44	←	PHQ4	.846	PHQ44	←	GAD2	.846

Table 4: Inter-item correlations, item-total correlations, and Cronbach's α of the PHQ-4. All correlations are statistically significant at $p < .01$.

Over the **last 2 weeks**, how often have you been bothered by any of the following problems?	1	2	3	4
1. Feeling nervous, anxious, or on edge	1			
2. Being unable to stop or control worrying	.653	1		
3. Little interest or pleasure in doing things	.530	.611	1	
4. Feeling down, depressed, or hopeless	.573	.623	.689	1
PHQ-4 total score	.816	.855	.840	.859
Cronbach's α	.86			

Table 5: Means (M) and standard deviations (SD) of the other scales, and their correlations with the PHQ-4. All correlations are statistically significant at $p < .01$ (two-tailed).

Scales	M (SD)	r with PHQ-4 total score
World Health Organization-five Well-being Index (WHO-5)	14.98 (6.13)	-.719
Self-rating Scale of Mental Health	7.15 (2.34)	-.539
Self-rating Scale of Happiness	7.28 (2.27)	-.566

4 Discussion

The purpose of this study is to determine the validity and reliability of the Farsi version of PHQ-4, explore the relationships between anxiety and depression, psychological well-being, mental health, and happiness, and investigate gender differences in the general population of Iran. Exploratory factor analysis revealed a single-factor structure explaining 71 % of the variance. The factor loadings ranged from .813 to .858 and item-total correlations were similarly high, indicating high validity of the Farsi version of PHQ-4. These results show good internal consistency of this 4-item scale. Demirci and Ekşi (2018) standardized PHQ-4 in Turkish and found correlations between each item and the total score ranging from .54 to .74.

Using confirmatory factor analysis, researchers obtained good fit values for both single- and two-factor structures. Materu et al. (2020) reported a single-factor structure in an adaptation study with 2,426 participants in Tanzania. However, Kroenke et al. (2009) obtained a two-factor structure explaining 84 % of the variance in their standardization study in the United States. Löwe et al. (2010) confirmed both a one- and two-factor structure in a German population study. Kocalevent et al. (2014) standardized the Colombian version and confirmed a two-factor structure through confirmatory factor analysis. Stanhope (2016) found a two-factor structure in the confirmatory factor analysis of PHQ-4 in Australia. Ghaheri et al. (2020) confirmed the validity of the two-factor structure in an Iranian validation study. In a study conducted in Southeast Asia during the COVID-19 pandemic with 4,524 participants, a two-factor structure was found to be more consistent than a single-factor structure (Mendoza et al., 2022). Also, Havnen et al. (2023) reported a two-factor structure in Norwegian adults with attention deficit hyperactivity disorder (ADHD). Meng et al. (2024) obtained a two-factor structure in 512 Chinese healthcare students. The differences in the results among studies may arise from variations in statistical analyses and sample characteristics.

In this study, the internal consistency of the PHQ-4's Farsi version had high Cronbach's alpha (.88), indicating high reliability. Kroenke et al. (2009) reported an internal consistency coefficient of .85 for PHQ-4. Most other standardization studies also achieved Cronbach's alpha values greater than .80: Materu et al. (2020) .81; Löwe et al. (2010) .82; Kocalevent et al. (2014) .84; Demirci and Ekşi (2018) .83; Mendoza et al. (2022) .82; Stanhope (2016) .75, and Ghaheri et al. (2020) .76. A Cronbach's alpha value greater than .70 indicates that the scale is a reliable tool for measuring its construct (Adams & McGuire, 2023, p. 184).

Our results using confirmatory factor analysis indicate that the single- and two-factor structure of the scale both have good fit values. Previous studies support the validity of the single-factor structure. Standard regression factor loadings ranged from .66 to .84, all statistically significant ($p < 0.001$). The confirmatory factor analysis results support the validity of the single-factor structure. Additionally, when the two-factor structure of PHQ-2 and GAD-2 was considered in confirmatory factor analysis, similar fit values were obtained. The covariance between PHQ-2 and GAD-2 was calculated as .59, significant at $p < .001$, and the correlation coefficient between them was .87. Standard regression weights ranged from .76 to .85. The internal consistency of the Farsi PHQ-4 was high for both the single-factor and two-factor structures (see Table 2 and Table 3). With a correlation of .87 between PHQ-2 and GAD-2, the conclusion should be that there effectively are no two factors, that there is no separation between anxiety and depression.

Demirci and Ekşi (2018) reported CFI = 1.00, TLI = 1.00, SRMR = .008, RMSEA = .000 for both the single-factor and two-factor structures in their confirmatory factor analysis. Löwe et al. (2010) found good fit values in their confirmatory factor analysis, with CFI = 0.984, TLI = 0.988, RMSEA = 0.027, and a 90 % confidence interval for RMSEA of 0.023–0.032. Ghaheri et al. (2020) reported that the single-factor structure did not have robust fit values, but the two-factor structure did. Kocalevent et al. (2014) applied confirmatory factor analysis for both two-factor and single-factor structures, stating that the two-factor structure had fit indices, except RMSEA, that indicated good fit (CMIN/DF = 32.31; GFI = 0.989; NFI = 0.987; TLI = 0.923; CFI = 0.987, RMSEA = 0.145). The single-factor structure showed poorer fit (CMIN/DF = 114.45; GFI = 0.964; NFI = 0.953; TLI = 0.861, CFI = 0.954, RMSEA = 0.194). The findings of the present study are in line with these results.

Our study also investigated the relationship between the well-being index accepted by the WHO (WHO-5) and PHQ-4. The results indicated a strong and highly significant ($p < .001$) negative correlation between the two scales. The negative correlation suggests that as scores from the WHO-5 (measuring

well-being) increase, scores on the PHQ-4 (measuring anxiety and depression) decrease, confirming the validity of PHQ-4 as a measurement tool. Havnen et al. (2023) found a correlation of $r = -.75$ between PHQ-4 and WHO-5 in adults with ADHD. Ghaheri et al. (2020) reported correlations of -.51 between WHO-5 and PHQ-2, -.47 between WHO-5 and GAD-2, and -.55 between WHO-5 and PHQ-4. The relatively higher correlation in this study supports the findings in the literature.

In this study, a single-item "Self-rating Scale of Mental Health" and a single-item "Self-rating Scale of Happiness" were applied to determine the validity of PHQ-4. Both scales aim to assess an individual's positive mental state. Therefore, a negative relationship was expected between the scores on these scales and the PHQ-4 scores. The correlation analysis revealed a significant negative correlation between the PHQ-4 and both mental health ($r = -.53$) and happiness ($r = -.56$) at $p < .001$. These findings indicate that PHQ-4 is an effective and valid measure of depression and anxiety. Studies supporting this conclusion include Kroenke et al. (2009), who examined the correlation between the PHQ-4 and the Mental Health subscale of SF–20, reporting a strong correlation of .80. Kocalevent et al. (2014) found weak but significant correlations between PHQ-4 and the General Health Questionnaire-12 (GHQ-12), Hopelessness (BHS), Self-efficacy (GSES), and Life Satisfaction (QLS). Also, Demirci and Ekşi (2018) reported a statistically significant negative relationship between the PHQ-4 and Life Satisfaction ($r = -.38$, $p < .001$). All these results taken together show that much or most variation on these scales is caused by something we can call a "general factor of psychological well-being." General factors are common in psychology. We find them for intelligence, well-being, and psychopathology. Our results support the importance of general factors, at least in well-being and psychopathology. In other words, when we discuss the correlations with other tests measuring similar constructs and we find high correlations, this supports the contention that to a large extent all these tests measure the same construct, which is general psychological well-being. It can be argued that any one of these well-being tests, including the PHQ-4, can be used to measure this general factor but also that it is redundant with the others.

In our Iranian study, the mean PHQ-4 scale score was determined to be 3.95. This score falls within the cutoff range of 3–5 (mild), indicating that the mental health of Iranian society is relatively good. Similar results have been found in studies conducted in various countries. For instance, Demirci and Ekşi (2018) studied 450 healthy individuals from a Turkish sample and found that the average PHQ-4 score was 4.84. Similarly, Materu et al. (2020) reported a PHQ-4 score of 3.75 in their study on out-of-school adolescent girls and young women in Tanzania. However, in some societies, the total PHQ-4 score has been reported to fall within the 0–2 (normal) cutoff range. For example, Löwe et al. (2010) studied adults aged 14 and over in a German sample. They reported a PHQ-4 score of 1.76, while Kocalevent et al. (2014) reported a PHQ-4 score of 1.27 in a study conducted on the general population over 18 in Colombia. Studies conducted on younger groups outside the general population have also yielded noteworthy results. Khubchandani et al. (2016) found an average PHQ-4 score of 2.98 in a sample of university students in the United States. Other studies have measured PHQ-4 scores in patient groups. For example, Havnen et al. (2023) conducted a study on Norwegian-speaking individuals undergoing treatment for attention deficit hyperactivity disorder (ADHD) and found that the total PHQ-4 score among participants was 5.0. Kroenke et al. (2009) examined the averages for each item in a study conducted on a patient sample in the United States and found a general PHQ-4 score of 2.5. Considering the Iranian context's intense economic, social, and political factors, this Iranian score can be seen as quite significant. Comparing them, we see that Iranian "normal" people have more mental health problems than American patients.

The study found no statistically significant sex differences in PHQ-4 scores. In contrast, Ghaheri et al. (2020) reported statistically significant ($p < .001$) gender differences in PHQ-4 scores, with females ($M = 5.45$) scoring higher than males ($M = 3.67$). Kocalevent et al. (2014) also found that females ($M = 1.4$) had higher PHQ-4 averages than males ($M = 1.1$). The findings of this study do not align with these results. This is indeed a surprising finding, because it is well known that women are the more neurotic sex. At least our results are trending in the predicted direction.

The present study has some limitations. It is based on a convenience sample of Iran, and the findings were based only on Iranian community residents. Another limitation is the number of participants. This is a cross-sectional design. It needs to be highlighted that there is a possibility of translator bias or errors in this

study. A further limitation is the lack of other similar measures as indicators used to confirm theoretical consistency (construct validity, or at least criterion validity). Based on Table 4 we can conclude that there is only slight evidence for a correlational separation between anxiety and depression because the highest inter-item correlations are between items 1 and 2 and between items 3 and 4. But the other correlations, between anxiety items and depression items, are only slightly lower. Therefore, for practical purposes, the PHQ-4 cannot be used to distinguish between anxiety and depression. This is a limitation of this scale, or a limitation of our diagnostic categories. In reality PHQ-4 is a screening tool for general mental health. These limitations could be mentioned as possibilities for future works. A proposed next step would be to study the performance of different normal and abnormal groups on the PHQ-4. These are projects for future studies. One question that we could raise for future research is whether the correlations among the many alternative well-being measures are higher in poor countries than in rich countries, or higher in more educated than in less educated people in Iran. Perhaps the correlations among these alternative well-being scales are lower among those with higher education indicating that their emotional system is somehow more differentiated than that of less sophisticated individuals.

5 Conclusions

The PHQ-4 had good psychometric properties in the present sample from Iran. A principal components analysis (PCA) with a varimax rotation showed one factor labelled "Anxious/Depressed." Using exploratory factor analysis (EFA), the scale has both one-factor and a two-factor structure, consisting of a depression factor and an anxiety factor. Confirmatory factor analysis (CFA) showed the PHQ-4 has good fit values for both structures. This study provides evidence for the usefulness of the Farsi version for assessing the anxiety and depression symptoms in Iranian community residents.

The study demonstrates significant novelty by translating and validating an ultra-brief screening tool within this cultural context, providing a practical method to screen for depression and anxiety efficiently while reducing time and costs. The study findings suggest the use of the PHQ-4 in the national language of any country where it is used and where the national language is not English. Hence, we suggest that such trials be conducted in other non-English speaking countries.

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Exploring the potential of blockchain technology in enhancing transparency and accountability at local government level in South Africa

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Abstract

This qualitative study explores the potential of blockchain technology to enhance transparency and accountability in local government in South Africa. Despite efforts to promote good governance, local governments in South Africa continue to grapple with challenges of corruption, inefficiency, and lack of transparency. The decentralised, secure, and tamper-proof nature of blockchain technology offers a promising solution. This paper examines the current state of transparency and accountability in local government in South Africa and explores the potential applications of blockchain technology in this context. For data collection, the paper reviews existing literature and documents on blockchain technology and its applications in government and presents case studies of blockchain implementation in local government in South Africa. The findings suggest that blockchain technology has the potential to transform the way local governments operate, by increasing transparency, accountability, and trust in government. Furthermore, the study's findings revealed that local governments in South Africa have initiated various pilot projects leveraging blockchain technology, including the management of land registers, development of secure voting systems, monitoring, and management of essential services such as water and electricity supply, and implementation of robust identity management systems. However, the paper also highlights the challenges and limitations of implementing blockchain technology, including the need for significant investment in infrastructure and the lack of regulatory frameworks. The paper recommends developing a national blockchain strategy, establishing a blockchain regulatory framework, and investing in blockchain infrastructure.

Keywords: lockchain technology, Transparency, Accountability, Local government, Innovation, Corruption

1 Introduction

The importance of transparency and accountability in local government cannot be overstated. In South Africa, local government plays a critical role in delivering essential services such as water, sanitation, electricity, and roads to communities. However, the ability of local government to deliver these services effectively is often undermined by a lack of transparency and accountability (Mamokhere, 2022). Transparency is essential in local government as it allows citizens to access information about government activities, decisions, and spending. Accountability ensures that government officials are held responsible for their actions and that there are consequences for misconduct (Aranha, 2017). Lack of transparency and accountability creates an environment conducive to corruption, mismanagement, and abuse of power. In South Africa, local government faces numerous challenges that hinder its ability to deliver services effectively. One of the most significant challenges is corruption. The country has a high Corruption Perception Index (CPI) score, ranking 69 out of 180 countries globally, which indicates a moderate to high level of perceived corruption (Fourie & van der Waldt, 2021; Kgobe & Mamokhere, 2021). This ranking suggests that South Africa still has significant work to do in addressing corruption and promoting transparency and accountability in government.

As noted by Munzhedzi (2016), corruption in local government manifests in various forms, including bribery, embezzlement, and nepotism. The lack of accountability and transparency exacerbates corruption,

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making it difficult to detect and prevent. Without effective accountability mechanisms, corrupt officials can act with impunity, undermining the integrity of local government (Sibanda & Lues, 2021). The use of blockchain technology has been proposed as a potential solution to enhance transparency and accountability in government (AIShamsi et al., 2022; Bishr, 2019; Sibanda et al., 2024). Blockchain technology is a decentralised, digital ledger that records transactions and data across a network of computers (Dowelani et al., 2022; Hariguna et al., 2021). In simple terms, blockchain can be imagined as a big digital ledger that records transactions, like money transfers or data sharing, in a secure and transparent way. Instead of one person controlling the ledger, many people have a copy, making it hard to alter or manipulate. When a transaction happens, it is checked by a network of computers to ensure that it is legitimate, and then is added to the ledger, creating a permanent record (Hariguna et al., 2021). This technology ensures that all transactions are accurate, trustworthy, and publicly visible, making it a game-changer for industries that rely on transparency and accountability (Dowelani et al., 2022). As highlighted by Liu et al. (2019), its key features, including immutability, transparency, and security, make it an attractive solution for enhancing accountability and transparency in government.

The Raipur Municipal Corporation in India has leveraged blockchain technology to develop a transparent and tamper-proof system for issuing digital building permission certificates (Harigunani, 2024). This system has not only improved transparency but also generated significant revenue for the municipality. Additionally, the municipality has implemented a blockchain-based public grievance-management system, enabling citizens to file and track complaints, thereby promoting accountability and reducing corruption (Harigunani, 2024). Another example is the city of Dubai, which has implemented a blockchain-based system for tracking and verifying the authenticity of goods, reducing the risk of counterfeiting and improving transparency in supply chain management (Khan et al., 2022).

Kenya has emerged as a pioneer in harnessing blockchain technology to drive transparency, accountability, and efficiency in governance and public service delivery. As noted by Ondiek and Onyango (2024), the Kenyan healthcare sector has seen significant gains, with blockchain-based systems tracking pharmaceuticals, verifying authenticity, and ensuring regulatory compliance. This has led to a marked reduction in fraud, improved distribution of medical supplies, and enhanced patient care (Ondiek & Onyango, 2024). The country's land registry has also undergone a transformative overhaul with the introduction of "LandCoin", a blockchain-based platform that secures land titles, creates an immutable ledger, and minimises disputes and fraudulent activities (Wilkins & Mwanza, 2018). Kenya's national digital identity strategy, Huduma Namba, leverages blockchain to create a secure, transparent, and tamper-proof ledger for identity data storage and verification (Tonu et al., 2019). This innovative approach mitigates identity theft and unauthorised access, safeguarding citizens' personal data.

According to Ghazali (2018), in the education sector, Kenya has collaborated with the Africa Union and the University of Nairobi to develop a blockchain-based system for issuing and verifying academic degrees. This groundbreaking solution tackles the perennial problems of fraud and forgery associated with traditional paper-based certification (Ghazali, 2018). Through its adoption of blockchain technology, Kenya has taken a significant stride toward creating a more transparent, accountable, and efficient governance framework, with far-reaching benefits for its citizens. The Kenyan government's successful implementation of blockchain technology to enhance transparency and accountability in governance offers valuable lessons for South African municipalities seeking to improve their own accountability and service delivery. Through the adoption of similar blockchain-based solutions, South African municipalities can increase transparency, reduce corruption, and promote citizen engagement, ultimately leading to more effective and responsive governance.

The adoption of blockchain technology in Kenya faces several hurdles, including limited ICT infrastructure, insufficient workforce skills, and inadequate leadership buy-in (Imani, 2017). Furthermore, the entrenched culture of corruption in government financial processes, which blockchain technology aims to eradicate, presents a significant obstacle. To fully harness the potential of blockchain-enabled services, Kenya must address critical factors such as developing robust technical expertise, establishing supportive regulatory frameworks, and fostering a mindset shift towards decentralised governance (Imani, 2017).

In South Africa, the City of Johannesburg has explored the use of blockchain technology for land

registration, aiming to improve transparency and reduce corruption in the land administration process (Sibanda & Lues, 2021). While these examples are promising, further research is needed to explore the applications and effectiveness of blockchain technology in enhancing transparency and accountability in local government in South Africa. The research question guiding this study is: Can blockchain technology enhance transparency and accountability in local government in South Africa? This study aims to explore the current state of transparency and accountability in local government in South Africa, examine the potential applications of blockchain technology, investigate the challenges and limitations of implementing blockchain technology, and provide recommendations for policymakers and practitioners.

2 State of transparency and accountability in local government in South Africa

The state of transparency and accountability in local government in South Africa is a pressing concern that has garnered significant attention in recent years. Despite the country's democratic transition in 1994, which ushered in a new era of governance, local government in South Africa continues to grapple with issues of transparency and accountability (Mabizela & Matsiliza, 2020; Sithole, 2021). The Constitution of South Africa (1996), which is hailed as one of the most progressive in the world, enshrines the principles of transparency and accountability in its provisions. However, the reality on the ground paints a different picture. Local government in South Africa is characterised by lack of transparency, which has led to widespread corruption, maladministration, and poor service delivery (Mabizela & Matsiliza, 2020; Ramodula & Govender, 2020; Sithole, 2021). The auditor-general's reports over the years have consistently highlighted the poor state of financial management, lack of accountability, and inadequate oversight in local government (Kaziboni & Radulovic, 2023; Ramodula & Govender, 2020). For example, the 2021/22 auditor-general's report revealed that only 38 out of 257 municipalities in South Africa received a clean audit, while most municipalities had material findings against them (Auditor-General of South Africa, 2022). This lack of transparency and accountability has eroded public trust in local government, leading to widespread protests and demands for better service delivery (Ramodula & Govender, 2020).

In South Africa, municipal officials are controlled through a combination of top-down and bottom-up mechanisms. Top-down control is exercised through oversight and audits by provincial governments, as well as national government interventions when necessary (Sithole, 2021). The provincial government can take over municipal functions if a municipality fails to fulfil its obligations, as stated in the Constitution (Ramodula & Govender, 2020). Additionally, municipalities are subject to legislative and regulatory frameworks such as the Municipal Systems Act, 2000, which guides local public administration and human resource management. Bottom-up control is achieved through citizen participation and engagement. This includes mechanisms like ward committees, which provide a platform for citizens to participate in decision-making processes (Tshiki, 2024). Municipalities are also required to make their administration transparent and accountable to the public, allowing citizens to hold officials accountable for their actions (Koto & Kanjere, 2021).

According to Mazibuko and Fourie (2017), the provincial governments, which are supposed to exercise oversight over municipalities, often lack the capacity and resources to do so effectively. Furthermore, the national government's oversight role is often limited to providing funding and policy guidance, rather than actively monitoring and evaluating the performance of municipalities (Mazibuko & Fourie, 2017). According to Koto and Kanjere, (2021), this lack of effective oversight has created an environment in which corruption and maladministration can thrive. For example, the VBS Mutual Bank scandal, which involved the looting of millions of rands from the bank by municipal officials and politicians, highlighted the lack of effective oversight and accountability in local government (Mupangavanhu, 2021). The scandal led to widespread outrage and calls for greater transparency and accountability in local government.

Another significant challenge facing local government in South Africa is the lack of transparency in procurement processes. Procurement is a critical area of local government, as it involves the allocation of significant resources to service providers and contractors. However, the procurement process in local government is often shrouded in secrecy, leading to widespread corruption and irregularities (Mazibuko & Fourie, 2017). As noted by Koto and Kanjere (2021), the lack of transparency in procurement has

been exacerbated by the lack of effective regulation and oversight. For instance, the Municipal Supply Chain Regulations, which are supposed to govern procurement processes in local government, are often flouted with impunity (Koto & Kanjere, 2021). Tshiki (2024) argues that this lack of transparency and accountability in procurement processes has led to corrupt activities, with many municipalities awarding contracts to companies and individuals with close ties to politicians and officials. The consequences of this corruption are dire, as it leads to poor service delivery, inflated prices, and a lack of value for money. For example, the City of Johannesburg's procurement processes were recently found to be irregular, with many contracts awarded to companies with close ties to politicians and officials (City of Johannesburg Council, 2023).

The lack of transparency and accountability in local government in South Africa has been exacerbated by the lack of effective citizen participation and engagement. As claimed by Mazibuko and Fourie (2017), citizen participation and engagement are critical components of democratic governance as they provide citizens with a voice and a stake in the decision-making process. However, in South Africa, citizen participation and engagement in local government are often limited to tokenistic consultations and public hearings (Bester, 2020; Matloga et al., 2024). Many citizens feel disconnected from the decision-making process, which has led to widespread disillusionment and disengagement. Furthermore, the lack of effective citizen participation and engagement has created an environment in which corruption and maladministration can thrive. Lack of citizen oversight and engagement has allowed many municipalities to get away with irregularities and corruption, without being held accountable (Koto & Kanjere, 2021; Mazibuko & Fourie, 2017).

According to Harigunani (2024), one of the primary intentions of blockchain systems is to promote decentralisation and transparency, thereby reducing the need for top-down oversight. By leveraging blockchain technology, South African municipalities can indeed become more transparent and accountable to citizens. This is achieved through the creation of an immutable, tamper-proof ledger that records all transactions and activities, making it possible for citizens to track and verify the actions of municipal officials (Sibanda et al., 2024). Furthermore, blockchain-based systems can simplify complex procedures by providing a clear and accessible audit trail, enabling citizens to better understand and engage with municipal decision-making processes (Sibanda, Basheka & van Romburgh, 2024).

3 Understanding blockchain technology

At its core, blockchain technology is based on a simple yet powerful concept: a chain of blocks, each containing a set of transactions or data which are linked together through cryptographic hashes (Olalekan, 2024). As noted by Lansky (2021), this creates a permanent and unalterable record of all transactions or data that have taken place on the network. The basic principles of blockchain technology are rooted in cryptography, game theory, and distributed systems (Garcia, 2021; Kshetri & Voas, 2018). According to Maza (2019), advanced cryptographic algorithms and protocols ensure that transactions or data are secure and tamper-proof and that nodes on the network behave honestly and work together to validate transactions. Distributed systems means that the network operates in a decentralised manner, without the need for a central authority (Maza, 2019).

One of the key characteristics of blockchain technology is its ability to operate on diverse types of networks. There are three main types of blockchain networks: public, private, and consortium (Garcia, 2021). Shava and Mhlanga (2023) state that public blockchain networks, such as Bitcoin and Ethereum, are open to anyone to participate in the network. Private blockchain networks, on the other hand, are restricted to a specific group of users and are often used within organisations (Garcia, 2021). Consortium blockchain networks are a hybrid of public and private networks, where a group of organisations come together to form a network (Dai & Vasarhelyi, 2017; Sarker et al., 2021). Each type of network has its own advantages and disadvantages, and the choice of network depends on the specific use and requirements. For instance, public blockchain networks offer an elevated level of decentralisation and security but may be slower and more expensive to use (Dai & Vasarhelyi, 2017). Private blockchain networks, on the other hand, offer faster transaction times and lower costs but may be less secure and more centralised (Beck et al., 2017).

Blockchain technology has several features that make it an attractive solution for enhancing transparency and accountability. Unlike traditional centralised systems, blockchain technology operates on a decentralised network of nodes, each of which has a copy of the blockchain (Sarker et al., 2021). According to Tak (2023), this ensures that there is no single point of failure and that the network can continue to operate even when one or more nodes go offline. Another key feature of blockchain technology is its immutability. Once a transaction or data is recorded on the blockchain, it cannot be altered or deleted (Atzori, 2017; Jimoh et al., 2018). According to Lansky (2021), this ensures that the blockchain provides a permanent and tamper-proof record of all transactions or data. Blockchain technology provides a high level of transparency, as all transactions or data are recorded on a public ledger that can be accessed by anyone (Garcia, 2021).

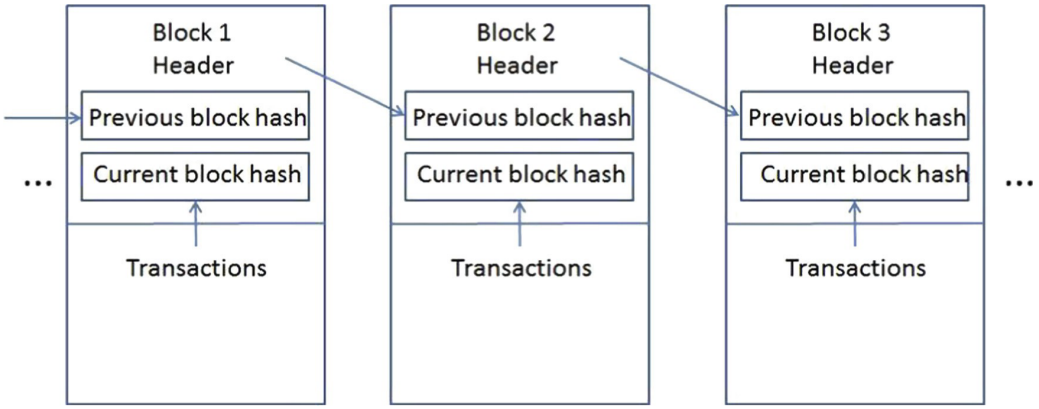

Figure 1: Simple blockchain. Source: Kshetri, 2021.

Figure 1 illustrates a straightforward sequence of interconnected blocks, where each block contains a unique digital fingerprint, or hash, of the preceding block. Specifically, block 2 incorporates the hash of block 1, while block 3 contains the hash of block 2, and so on. This creates an unbroken chain of blocks, with each subsequent block inextricably linked to its predecessor. The combination of this interlinked structure and a consensus algorithm ensure the blockchain's integrity, rendering it impervious to tampering and alteration.

While the benefits of blockchain technology in promoting transparency and accountability in government are evident, it is crucial to consider the potential challenges and limitations of its implementation. Azmi and Nugroho (2023) emphasise that one significant hurdle is the need for widespread technological infrastructure and expertise, particularly in developing countries or regions with limited resources. Moreover, the integration of blockchain technology into existing government systems may require significant institutional and regulatory reforms, which can be complex and time-consuming (Alketbi et al., 2020). Blockchain technology also raises questions about data privacy and security, particularly in cases where sensitive information is involved (Azmi & Nugroho, 2023). Therefore, it is essential to adopt a nuanced and content-specific approach to implementing blockchain technology in government, one that considers the unique challenges and opportunities of each country or region. This may involve investing in capacity-building and training programmes, developing new regulatory frameworks, and establishing robust data protection protocols (Lansky, 2021).

4 Research methodology

This systematic review aimed to explore the potential of blockchain technology in enhancing transparency and accountability at local government level in South Africa. A comprehensive search strategy was employed to identify relevant studies published in English between 2015 and 2024. The search terms used included "blockchain technology," "transparency," "accountability", "local government", and "South Africa". A systematic search of major databases, including Scopus, Web of Science, Google Scholar, and ScienceDirect, was conducted. These search engines were selected based on their relevance to the research

topic, comprehensive coverage of academic literature, and peer reviewed publication indexing, while Google was used to search for grey literature, conference proceedings, reports and other non-peer-reviewed sources. A total of 50 peer-reviewed articles and book chapters were selected for inclusion in the study, based on their relevance to the research topic and their publication date (Aspers & Corte, 2019).

The selected literature was analysed using thematic analysis, which involved identifying and coding key themes and concepts related to blockchain technology adoption in local government in developed and developing countries including South Africa. The thematic analysis was conducted in two stages. First, the literature was coded using an inductive approach, where codes were generated based on the data (Gerring, 2017). Second, the codes were grouped into themes, which were then analysed to identify patterns and relationships. The analysis revealed several key themes, including the potential of blockchain technology to enhance transparency and accountability in local government, and the challenges and limitations of implementing blockchain technology in local government. In addition to the peer-reviewed articles and book chapters, 20 documents were selected for inclusion in the study, including government reports, policies, and guidelines related to blockchain technology adoption in local government.

The quality of the included studies was assessed using the Critical Appraisal Skills Programme (CASP) qualitative checklist (Long et al., 2020). The CASP checklist is a widely used tool for assessing the quality of qualitative studies. The checklist evaluates the quality of studies based on criteria such as the clarity of the research question, the appropriateness of the study design, and the rigour of the data collection and analysis methods. Studies that scored high on the CASP checklist were considered to be of high quality, while those that scored low were considered to be of low quality. The data extracted from the included studies were synthesised using a narrative approach. The narrative synthesis involved summarising the findings of the included studies, identifying patterns and themes, and drawing conclusions about the impact of blockchain technology on transparency and accountability.

5 Results and Discussion

This section examines the findings and implications of leveraging blockchain technology in local government in South Africa, highlighting its potential to drive efficiency, transparency, and innovation.

5.1 Supply chain management

One of the potential applications of blockchain technology in local government in South Africa is supply chain management. According to Sibanda et al. (2024), blockchain technology can be used to track the movement of goods and services through the supply chain, ensuring transparency and accountability. For example, blockchain technology can be used to track the origin of goods, ensuring that they are genuine and not counterfeit (Casallas et al., 2020; Chigudu, 2020). This can be particularly useful for local government procurement, where ensuring the authenticity of goods and services is crucial. The media has on several occasions reported that the South African Police Service (SAPS) has seized and confiscated large quantities of counterfeit goods, valued at millions of rand, in various raids and operations conducted across different provinces and cities in the country. According to Kamble et al. (2019) the potential benefits of using blockchain technology in supply chain management include increased transparency, reduced risk of corruption, and improved efficiency. As observed by Tshiki (2024), South Africa's Corruption Perceptions Index (CPI) score has remained stagnant in recent years with scores in the 40s, indicating persistent struggles in tackling corruption and promoting accountability. In the 2022 CPI report, the country received a score of 43 out of 100, placing it 72nd out of 180 countries globally. This highlights the need for significant improvement in South Africa's anti-corruption efforts.

5.2 Land registration

Another potential application of blockchain technology in local government in South Africa is land registration. Blockchain-based solutions can provide a secure, decentralised and transparent framework for recording land ownership, mitigating the risks of disputes, corruption, and land title fraud (Liang et al., 2021). Blockchain technology can be used to create a digital ledger of land ownership, which can be accessed by all relevant

stakeholders. Aburumman et al. (2020) propose that this can help to ensure that land ownership is accurately recorded and that any changes to ownership are properly documented. Blockchain technology also improves efficiency in land registration because it can automate many of the processes involved in land registration, such as title searches and document verification, reducing the time and cost associated with these tasks (Min, 2019). Thus, the benefits include enhanced security, increased accessibility, reduced costs, improved data integrity, enhanced transparency in property valuation, and a simplified property transfer process (Maden et al., 2020; Trevor & Thomas, 2019).

According to Sibanda et al. (2024), potential challenges to consider when using blockchain technology include scalability limitations where blockchain technology may not be able to handle a large volume of transactions, which could lead to delays and inefficiencies in land registration procedures. Other challenges include the requirement for significant computational power and energy, which could lead to performance issues and increased costs (Min, 2019). Furthermore, Yermack (2017) identifies challenges of interoperability and integration where different blockchain platforms and systems may not be compatible with each other, integration with existing systems, cybersecurity risks, and regulatory uncertainty as well as the possibility of legal challenges that may arise, particularly when there are disputes about the ownership or transfer of land.

5.3 Voting systems

Blockchain technology has the potential to improve voting systems in local government in South Africa. Blockchain technology can be used to create a secure and transparent record of votes, reducing the risk of electoral fraud and corruption (Yadav et al., 2023). For example, blockchain technology can be used to create a digital ledger of votes, which can be accessed by all relevant stakeholders (Berenjestanaki et al., 2023). This can help to ensure that votes are accurately recorded and that any disputes or irregularities are thoroughly investigated. The potential benefits of using blockchain technology in voting systems include enhanced security, transparency, improved accuracy, increased efficiency, and cost effectiveness (Shahzad & Crowcroft, 2019). It is important for municipalities to consider voter education, as blockchain technology voting systems require voters to have a certain level of technical understanding, which can potentially create a barrier to participation (Pawlak et al., 2018).

The findings on the potential of blockchain technology in voting systems have significant implications for local government accountability in South Africa. Through leveraging blockchain technology, municipalities in South Africa can ensure the integrity, transparency, and accountability of their electoral processes (Shahzad & Crowcroft, 2019). This is particularly relevant for local government elections, where the use of blockchain-based voting systems can help to prevent electoral fraud and corruption. For example, municipalities such as the City of Johannesburg, City of Cape Town, or eThekwini Municipality could pilot blockchain-based voting systems in their upcoming elections, thereby enhancing the transparency and accountability of the electoral process. This can foster a culture of transparency, accountability, and citizen engagement in local governance. Potential benefits make it a worthwhile consideration for municipalities in South Africa seeking to enhance accountability, transparency, and citizen trust.

5.4 Public procurement

Public procurement is another area where blockchain technology has the potential to improve transparency and accountability in local government in South Africa. By leveraging blockchain technology, network participants can verify transactions, thereby enhancing transparency and accountability in specific government procurement processes and minimising the potential for corruption, while maintaining a permanent record of all transactions and activities (Kademeteme & Bvuma, 2023). This effectively eradicates opportunities for corrupt practices such as bribery and favouritism, ensuring that contracts are awarded solely on merit and adherence to regulatory requirements.

In the public sector in South Africa, procurement transactions are vulnerable to various corrupt practices including nepotism, embezzlement, bribery, patronage systems, extortion, and fraud (Mazibuko & Fourie, 2017). Corrupt activities may involve kickback schemes, false or inflated invoices, overpayment for goods or services, and payments for undelivered goods or services (Mazibuko & Fourie, 2017). Other forms of corruption in procurement include fronting in Black Economic Empowerment (BEE) companies, ghost suppliers, shell companies, and the solicitation of facilitation fees by state officials (Mazibuko & Fourie, 2017).

Koto and Kanjere (2021) argue that procurement corruption often thrives in environments characterised by principal-agent conflicts, lack of transparency, inadequate systems, incompetent or unqualified officials, and unmanaged conflicts of interest. Other vulnerable situations include urgent or emergency procurement, attempts to justify rule-bending, multi-jurisdictional transactions, weak accountability mechanisms, and inadequate internal controls (Koto & Kanjere, 2021; Mazibuko & Fourie, 2017). While blockchain technology may not prevent all corrupt practices, it can increase transparency and accountability by providing a tamper-proof record of transactions. Furthermore, the use of smart contracts can automate payment processes and ensure that payments are only made upon delivery of goods or services. The use of blockchain-based identity verification systems can help to prevent fronting and other forms of identity-related corruption.

According to van Eck and Agbeko (2024), by 2021 it had become evident that existing measures to address corruption in public procurement in the public sector in South Africa were ineffective. The State Capture Commission's report exposed widespread abuse of procurement processes, which led to significant funds being misappropriated from the state. In fact, over 30 % of the report focussed on procurement abuses, highlighting the urgent need for reform (van Eck & Agbeko, 2024). In response, the Public Procurement Bill was introduced to Parliament in June 2023, aiming to address the Commission's recommendations and overhaul the procurement system (van Eck & Agbeko, 2024).

South Africa's procurement landscape is characterised by a complex array of interconnected laws, with the Preferential Procurement Policy Framework Act 2000 serving as the primary framework (Anthony, 2018; Ngcamphalala, 2016). Additionally, provisions from the Public Finance Management Act 1999, Local Government: Municipal Finance Management Act 2003, Broad-based Black Economic Empowerment Act 2003, and Prevention and Combating of Corrupt Activities Act 2004 also apply (Anthony, 2018; Ngcamphalala, 2016). The new Public Procurement Bill does not simplify this landscape, leaving businesses and government departments to navigate these requirements, which remain open to interpretation and uncertainty. Ideally, new regulations should provide an opportunity to leverage innovative technologies and adopt modern best practices in contract negotiation.

Blockchain technology can be used to create a digital ledger of procurement transactions that can be accessed by all relevant stakeholders, to ensure that procurement transactions are accurately recorded and that any disputes or irregularities are thoroughly investigated (Mojaki et al., 2024). The potential benefits of using blockchain technology in public procurement include increased transparency and accountability which encompass real-time tracking, transparent bidding, as well as accountable contract management, supplier management, reduced risk of corruption and fraud, improved efficiency and cost saving, enhanced security and integrity, better decision-making and analytics, and increased citizen engagement and participation (Mojaki et al., 2024).

While blockchain technology offers numerous benefits in combating corruption, legislators and the National Treasury must carefully consider their unique socio-political and economic context, prioritise requirements, and weigh the trade-offs of various blockchain solutions (Fourie & Malan, 2020). It is essential to acknowledge that blockchain technology has limitations, particularly in addressing corruption risks associated with human interactions, such as bribery and collusion (Fourie & Malan, 2020). However, this limitation does not necessarily preclude the use of blockchain technology in combating corruption but rather highlights the need for a multi-faceted approach that combines technological solutions with institutional reforms and social norms change. Recognising the limitations of blockchain technology can assist policymakers to design more comprehensive anti-corruption strategies that leverage the strengths of technology while addressing its weaknesses. Additionally, scalability poses a potential challenge, given the vast scope of procurement activities across national, provincial, and local government spheres, including state-owned enterprises, public entities, and other organisations that are funded or controlled by the government, which are also subject to procurement regulations and oversight.

The application of blockchain technology in public procurement can have a transformative impact on local government in South Africa. Given the significant procurement needs of local governments, which are responsible for delivering essential services to communities, enhancing transparency and accountability in these processes is crucial. Through the harnessing of blockchain technology, local governments can mitigate the risks of corruption, ensure that procurement processes are fair, transparent, and competitive,

and ultimately improve service delivery outcomes for citizens (Fourie & Malan, 2020). South African municipalities can emulate the National Treasury which has successfully launched an e-procurement project, aimed at promoting fair, equitable, transparent, competitive, and cost-effective procurement through a user-friendly, single-entry, technology-driven platform (National Treasury, 2024).

5.5 Financial management

The financial state of local governments in South Africa is a concern, with many struggling to maintain stability due to inadequate revenue collection, escalating debt, and mismanagement of funds. This instability hinders their ability to adopt modern digital technologies, which are essential for efficient governance including management of their financial plight. The implementation of these technologies is often hindered by insufficient technical expertise, resistance to change, and the excessive costs associated with implementation and maintenance (Enaifoghe et al., 2023). While one of the primary benefits of digitalisation, including blockchain, is cost reduction, there might be a need for a thorough cost-benefit analysis to determine the feasibility of implementing blockchain solutions in local governments, compared to alternative solutions. This analysis should consider not only the initial implementation costs but also the long-term savings and benefits that blockchain technology can provide. Although blockchain technology is itself subject to these challenges, it also offers a promising solution for many of them. According to Zindi (2024), blockchain technology can enhance accountability, reduce corruption, and streamline financial transactions within municipalities.

The auditor-general's reports have exposed widespread financial mismanagement at the local government level, with numerous municipalities plagued by inadequate financial controls, unauthorised expenditures and outright theft of public funds, resulting in significant financial losses and compromised service delivery (Auditor-General of South Africa, 2020). This has led to a concerning number of municipalities teetering on the brink of collapse, unable to provide essential services to communities. According to the standing committee on the auditor general, the root causes of this problem lie in skill shortages, inadequate accountability, and weak leadership (Kaziboni & Radulovic, 2023). As noted by Bvuma (2023), blockchain technology presents a groundbreaking solution to combat corruption across all levels of government in South Africa, encompassing national, provincial, and local spheres. Blockchain technology can be seen as an alternative to re-centralisation, allowing municipalities to maintain autonomy while ensuring transparency and accountability.

Benefits of adopting blockchain technology in financial management at the local government level include improved financial transparency and accountability. This encompasses real-time tracking of financial transactions, immutable records of financial transactions, reducing the risk of tampering or alteration, as well as transparent budgeting which enables citizens to track how funds are allocated and spent (Khatoon, 2020). Blockchain technology also enhances financial security and integrity enabling secure, encrypted transactions, reducing the risk of fraud and cyber-attacks, reduction of corruption and ensuring that funds are used for their intended purpose, as well as improved audit trails (Grigalashvili, 2022).

The other benefit is increased efficiency and cost savings resulting from automated processes, reduced administrative costs, and improved cash flow management (Kashaija, 2022). The use of blockchain technology enhances data-driven decision-making, improved forecasting, and enhanced citizen engagement and participation in financial decision-making processes, enabling local governments to better respond to community needs and priorities (Kashaija, 2022). Regulatory and compliance challenges, organisational and cultural challenges as well as security and risk challenges should be noted when adopting blockchain technology.

Through the utilisation of blockchain technology, South African local governments can establish a transparent, immutable, and secure ledger for financial transactions, thereby promoting accountability, rebuilding trust, and addressing the root causes of financial mismanagement. Furthermore, blockchain technology can enhance the efficiency and transparency of municipal financial management, facilitating real-time tracking of financial transactions, transparent budgeting, and secure, encrypted transactions (Grigalashvili, 2022). Blockchain technology has the potential to drive transformative change and improvement in municipal governance, ultimately contributing to the realisation of the National Development Plan's vision for effective, efficient, and accountable local government (National Planning Commission, 2012).

6 Case studies: Blockchain technology in local government in South Africa

The implementation of blockchain technology in South African municipalities is still in its early stages, with only a few municipalities having launched pilot projects. Despite this, the potential benefits of blockchain technology for improving governance and service delivery are significant. The City of Johannesburg's blockchain-based land registry system is a prime example of a municipality leveraging blockchain technology to improve governance. The system aims to modernise and secure property transactions, reducing the risk of fraudulent activities and improving the overall efficiency of the land registration process (Ozkan et al., 2021). Through the utilization of blockchain technology, the City of Johannesburg can create a transparent and tamper-proof record of property transactions, enabling real-time tracking and detection of anomalies or irregularities (Shava & Mhlanga, 2023). The system can also enhance security, efficiency, data accuracy and accessibility, providing a secure and cost-effective solution for land registration (Ozkan et al., 2021).

According to Shava and Mhlanga (2023), the City of Johannesburg's blockchain-based land registry system requires internet connectivity to function effectively. However, in areas with limited internet penetration, this can pose a significant challenge. To address this issue, municipalities can explore alternative solutions, such as mobile-based or offline blockchain systems (Priem, 2020). Municipalities can also invest in improving internet connectivity in underserved areas, such as through partnerships with local internet service providers. The City of Johannesburg's experience highlights the importance of considering the infrastructure requirements for blockchain-based systems and exploring alternative solutions to ensure inclusivity and accessibility. However, a critical evaluation of the system reveals that while it has shown promise, there are still significant challenges to be addressed, including the requirement for reliable internet connectivity and digital literacy among residents.

The City of Cape Town's blockchain-based voting system for local elections is another example of a municipality leveraging blockchain technology to improve governance. The system aims to enhance the security, transparency, and efficiency of the electoral process, enabling voters to cast their ballots securely and confidently (Mhlanga, 2022). As highlighted by Zindi (2024), the system can also enhance security, efficiency, data accuracy, and accessibility, providing a secure and cost-effective solution for voting systems. However, the system encountered technical difficulties during its pilot phase, resulting in delayed voting times and user frustration (Zindi, 2024). Despite these challenges, the City of Cape Town persevered, refining the system and increasing voter education. The revised system showed improved efficiency and transparency, with voters able to cast their ballots securely and confidently (Zindi, 2024). An evaluation of the City of Cape Town's blockchain-based voting system showed promise, but the system requires reliable internet connectivity. This can be a challenge in areas with limited internet penetration (Shava & Mhlanga, 2023). Furthermore, the system's reliance on digital literacy among voters can also pose a challenge. There is need for the exploration of alternative solutions, such as offline voting systems or voter education programs (Shava & Mhlanga, 2023). Additionally, the city can also invest in improving internet connectivity in underserved areas, such as through partnerships with local internet service providers (Liu & Ye, 2021). The City of Cape Town's experience highlights the importance of considering the unique challenges and context of each municipality when implementing blockchain technology.

The City of Tshwane has pioneered a blockchain-based identity management system, streamlining citizen identity verification and fortifying the security of government services (Liu & Ye, 2021). The platform issues citizens a unique tamper-proof digital identity certificate, secured through blockchain technology. This certificate grants access to a range of municipal services, enabling residents to securely apply for permits, pay utility bills, and more (Mhlanga, 2022). Blockchain's encryption methods ensure the authenticity and confidentiality of personal data, preventing unauthorised modifications (Jakoet-Salie, 2020). Challenges of the system include reliable internet connectivity to support the system, the need for digital literacy among residents, and how to use digital identity certificates (Zindi, 2024). To address this challenge, the City of Tshwane invested in digital skills training and education programs to improve digital literacy among residents as well as significant investment in infrastructure (Zindi, 2024). Regarding the issue of scalability, the City of Tshwane's blockchain-based identity management system was designed to be scalable and adaptable to

the needs of the municipality (Mhlanga, 2022). However, the system's scalability was limited by the need for reliable internet connectivity and digital literacy among residents.

Rural municipalities in South Africa are also exploring the potential of blockchain technology. They, however, face unique challenges when it comes to implementing blockchain technology. The rural municipality of Umuziwabantu in KwaZulu-Natal has partnered with a local non-profit organisation to develop a blockchain-based system for tracking and managing livestock ownership and sales (Umuziwabantu Municipality, 2022). While the project is still in its early stages, it demonstrates the potential for blockchain technology to benefit rural communities and promote economic development. However, the implementation of blockchain technology in rural municipalities can be challenging due to limited internet connectivity and digital literacy among residents. As noted by Ajibade and Mutula (2022), the rural municipality of Umuziwabantu in KwaZulu-Natal has limited internet connectivity and digital literacy among residents. To address these challenges, rural municipalities can explore alternative solutions, such as mobile-based or offline blockchain systems (Ajibade & Mutula, 2022). Additionally, municipalities can also invest in digital skills training and education programs to improve digital literacy among residents. The Umuziwabantu municipality's experience highlights the importance of considering the unique challenges and context of rural municipalities when implementing blockchain technology.

7 Challenges and Limitations

One of the significant challenges in implementing blockchain technology in local government in South Africa is the lack of adequate technical infrastructure (Nel & Masilela, 2020; Romanello, 2021). According to Sibanda et al. (2024), many municipalities in South Africa face challenges such as outdated computer systems, inadequate internet connectivity, and insufficient IT personnel. These technical limitations can hinder the successful implementation of blockchain technology, which requires a robust and reliable technical infrastructure to function effectively. Another challenge is the absence of clear regulatory frameworks governing the use of blockchain technology in local government (Bishr, 2019; Kowalczyk & Napiecek, 2023). The lack of regulatory clarity can create uncertainty and confusion among municipal officials, making it difficult to implement blockchain-based solutions. Furthermore, existing laws and regulations may not be compatible with blockchain technology, requiring significant revisions or new legislation to facilitate its adoption (Casallas et al., 2020). Data security and privacy regulations need to be revised to accommodate the decentralised and distributed nature of blockchain technology. The Protection of Personal Information Act 4 of 2013 in South Africa may need to be revised to address the unique challenges of blockchain-based data management. Regulations governing electronic transactions and digital signatures may need to be updated to recognise the validity of blockchain-based transactions. Laws and regulations related to intellectual property, cybersecurity, and anti-money laundering may also require revisions to ensure they are compatible with blockchain technology. A comprehensive review of existing laws and regulations is therefore necessary to create a favourable regulatory environment for the adoption of blockchain technology in local government in South Africa.

Public awareness and education are also significant challenges in implementing blockchain technology in local government (Dowelani et al., 2022). However, this challenge may be overstated, as the success of blockchain technology implementation does not necessarily require citizens to fully understand the underlying technology. Instead, a user-friendly interface that provides clear instructions on how to interact with the system can be sufficient (Hariguna et al., 2021).

Scalability and interoperability are additional challenges that need to be addressed (Kamble et al., 2019). Blockchain technology is still in its initial stages of development, and many platforms are not yet scalable to meet the needs of large municipalities (Maden et al., 2020). Furthermore, different blockchain platforms may not be interoperable, making it difficult to share data and collaborate across different systems (Aburumman et al., 2020; Zindi, 2024). Addressing these technical challenges is essential to ensuring the successful implementation of blockchain technology in local government. Other challenges and limitations include the excessive cost of implementation, the need for significant cultural and organisational change, and the potential risks associated with cybersecurity and data protection (Rana et al., 2022). The

energy consumption costs associated with mining and validating transactions on a blockchain network can be substantial and may even outweigh the benefits of implementing the technology (Rana et al., 2022). Therefore, a thorough cost-benefit analysis must be conducted to determine the feasibility of implementing blockchain technology in local government.

The potential of blockchain technology to enhance transparency and accountability in South African municipalities is vast. However, there is a need for further research to explore its applications and effectiveness in the South African context. South Africa has a few policy guidance frameworks that support blockchain technology and its implementation, beside the South African National Blockchain Alliance (SANBA). They include The International Fintech Working Group (IFWG), which aims to develop a common understanding among regulators and policymakers of Fintech developments, including blockchain technology and the Crypto Assets Regulatory Working Group (CARWG), which focuses on regulating crypto assets, which are often built on blockchain technology (Sibanda et al., 2024). South Africa has various regulatory frameworks that indirectly support blockchain technology such as the Financial Intelligence Centre Act of 2001, the Financial Institutions Act of 2001, and the Currency and Exchange Act. No 9 of 1933 which has been amended and updated several times.

8 Conclusion and Recommendations

This paper explored the potential of blockchain technology in enhancing transparency and accountability in local government in South Africa. The main findings of the study suggest that blockchain technology has the potential to transform the way local governments operate, by providing a secure, transparent, and tamper-proof record of transactions and data. The findings revealed that blockchain technology can be applied in various areas of local government, including supply chain management, financial management, land registration, voting systems, public procurement, identity management systems, and the monitoring and management of essential services such as water and electricity. The case studies presented in this paper demonstrate the feasibility and benefits of implementing blockchain in local government, including transparency, accountability, and trust in government. The findings suggest that blockchain technology can be a valuable tool for promoting good governance and reducing corruption in local government.

To improve the blockchain landscape and application in local government, several policy propositions can be considered. These include investing in infrastructure development, such as high-speed internet and data centres, and establishing blockchain innovation hubs or centres of excellence. A clear and comprehensive regulatory framework should be developed, addressing data privacy, security, and intellectual property rights, as well as establishing standards and guidelines for implementation. Capacity-building programs should be provided for government officials, citizens, and private sector stakeholders to develop necessary skills and knowledge. Pilot projects demonstrating blockchain technology's potential in local government should be identified and supported, with funding mechanisms established to support development and implementation. Public awareness campaigns should be developed to educate citizens about blockchain technology's benefits and risks, with mechanisms established for citizen engagement and participation. Collaboration and partnerships between local governments, private sector companies, universities, and research institutions should be fostered, with a national or regional blockchain network established to facilitate knowledge sharing and coordination.

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On the Causal Relationship between IQ and GDP: An Instrumental Analysis

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Abstract

Although a substantial positive correlation between IQ and GDP per capita has been established at the national level over the past two decades (e.g. Lynn & Vanhanen, 2012), the causal direction of the observed association has been a subject of continuous debate. Here, we make use of a non-recursive path analysis involving two different instrumental variables in order to shed more light on the issue. The results of three analyses with two different instrumental measures strongly suggest that IQ is the cause of GDP and not the other way around. This conclusion is consistent with Lynn & Vanhanen's (2002) original conjecture as well as with several other studies employing different methodologies.

Keywords: IQ, GDP, Causal analysis, Instrumental variables

1 Introduction

Ever since the publication of Lynn & Vanhanen's seminal *IQ and the Wealth of Nations* in 2002, the precise causal nature of the strong positive correlation between nations' average IQs and GDPs per capita has been the subject of an intense debate. For example, Lynn & Vanhanen (2002) use both theoretical arguments and regression analyses while arguing that IQ influences national wealth rather than the other way around; Rindermann (2008) uses longitudinal path analyses (with educational achievement as a proxy for general intelligence) as well as structural equations modeling (Rindermann & Thompson, 2011) for making a similar claim. In the same vein, Weede and Kämpf (2002) argue for effects of IQ on economic growth. But their standard regression analyses and temporally static estimates of countries' IQ scores still prevent the interpretation of the results within an unequivocal causal framework. On the other hand, researchers such as Wicherts et al. (2010) and Volken (2003) have argued that the direction of causal influence between IQ and GDP has not been reasonably established due to lack of appropriate control measures and different potential confoundings between IQ and a plethora of measures related to general societal well-being.

In that sense, we have two competing accounts: The first one posits that high general intelligence leads to increased economic well-being within societies (e.g. by increasing levels of innovation and technological developments as well as by facilitating successful management of various economic and socio-political challenges). The other account argues that increased IQ levels are themselves the result of increased well-being. More precisely, it is hypothesized that better educational opportunities (e.g. Campbell & Ramey, 1994), improved nutrition (e.g. Stein et al., 2005), less frequent exposure to toxins (e.g. Grandjean & Landrigan, 2006), reduced levels of stress and trauma (e.g. Saltzman et al., 2006), better control of infectious diseases (e.g. MacKenzie, 2010), and generally more stimulating cognitive environments lead to higher measured cognitive abilities. Finally, it may well be the case that both mechanisms play a role (both IQ facilitates economic development and more developed countries manage to provide living and educational conditions which directly stimulate cognitive development). This argument has received some support from a partially longitudinal path analysis (Meisenberg & Lynn, 2012). This work is an attempt to investigate the causal connections between IQ and GDP directly and to quantify their respective strengths.

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Here, we make use of an instrumental approach within the non-recursive path analysis framework (e.g. Kline, 2010) in order to address this issue from a methodological perspective which, to our knowledge, has not yet been applied to the above mentioned problem. The instrumental approach makes use of a variable (the so-called Instrument) which can be assumed to be directly related only to one of the measures involved in the ambiguous causal relationship which is to be disentangled. The Instrument in question allows the non-recursive path model to allocate its weights along the different paths so as to reproduce the observed correlations in a manner which sheds light upon the precise causal nature of the relationship in question. In a similar fashion, as long as an Instrument is uncorrelated to other important predictors of the dependent variable which are inadvertently omitted from the analysis, the path coefficient from the independent to the dependent variable remains an unbiased estimate of the population parameter (e.g. Andrews et al., 2019).

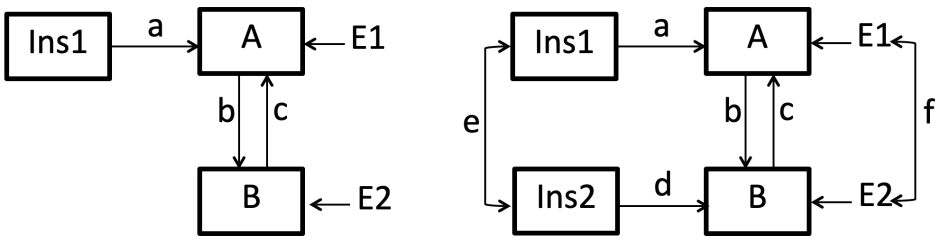

Figure 1: Non-recursive path models with an instrumental variable. For explanations, see text. Ins1, Ins2, Instruments, E1, E2, error terms..

Figure 1 and its caption provide a clear non-technical illustration of how the non-recursive path analysis investigates the causal structure between IQ and GDP. In the left panel, variables labeled A and B constitute the problematic pair of correlated measures, the causal relationship between which is to be disentangled; Ins1 denotes the Instrument which is supposed (on purely theoretical grounds) to be directly related only to one of the measures which we are interested in. In the figure this is variable A. Now, if Ins1 is really connected directly only to A, then its relationship with B depends on the empirically observed correlations. For example, if Ins1 does not correlate significantly with B, the path labeled b on the diagram is redundant, i.e. unnecessary in reproducing the observed correlations. This path can be thought of as representing the indirect effect of Ins1 on B through A. In other words, when there is no observed relationship between Ins1 and B, this path's estimate will tend towards zero and the relationship between A and B can be captured solely on the basis of path c. In this case, our model would indicate that B influences A but not vice versa.

Conversely, a significant observed correlation between Ins1 and B would indicate that the b path is important in reproducing this relationship. If the a and b paths reproduce all three observed relationships by themselves, the c path's estimate will tend towards zero and we will conclude that A influences B but not vice versa. Finally, if all three paths (a, b, c) are important for the model to reproduce the relationships observed between the three measures, then we will have an indication for a feedback loop. Within a feedback loop, in addition to the direct influence of one variable over another, we have both variables (A and B in Figure 1) influencing each other within a dynamic system whereby series of indirect effects accumulate over time. The crucial assumptions for the instrumental approach to give unbiased results are:

1. The Instrument is indeed related directly only to one of the measures in question and any other observed relationships are due only to indirect effects;

2. The system has settled to a stable state (attractor) before the measurement of the variables in question (i.e. the correlation between the measures no longer changes over time due to the system's internal dynamics).

Both assumptions are to be argued from a theoretical perspective because they cannot be demonstrated empirically within the non-recursive path model itself.

The right panel illustrates a similar non-recursive model where the same logic applies. Here, however, we have two different Instruments, each supposedly directly affecting only a single variable. This model has

more degrees of freedom which allows us to specify a correlated error structure. Errors are denoted by E1 and E2 in the diagrams; double arrows indicate unanalyzed correlations between variables (i.e. correlations included in the model which are not explained by a causal path) in contrast to single arrows which indicate path coefficients with explicitly specified causal directions. This allows us to test for variables which are omitted from the model but which affect the measures in question thereby increasing the observed association between them. Such a correlated error structure cannot be specified with only a single Instrument (left panel) due to identification problems which occur when the number of parameters specified for a model (indicated by lower-case letters in Figure 1) exceeds the number of observed associations. Both models displayed above are just-identified (degrees of freedom = 0), and the statistical significance of the individual path coefficients can be tested via the standard maximum likelihood methods described in the structural equations modeling literature.

2 Variables

Because we were interested in the causal relationship between IQ and GDP, we tried to procure measures which were instrumental in that context, i.e. we were looking for variables which were related directly either to *per capita* GDP or to general intelligence but not both. We selected two Instruments which, we believe, fulfill the requirements listed above, i.e. Instruments which can be plausibly presumed to be directly related to only one of the two target measures (IQ or GDP).

First, we selected countries' oil production (OIL) as an Instrument with respect to GDP. We can easily see how OIL is directly related to countries' access to economic resources; at the same time, it is highly implausible to assume any kind of direct relationship between the amounts of oil at the disposal of a particular nation and its aggregate IQ.

Second, we elected to make use of the average skin color within different countries as an Instrument with respect to IQ. Being a measure simultaneously related to both different groups' evolutionary histories[1] and various contemporary environmental factors, skin colour (SC) can reasonably be supposed to be related to IQ (e.g. Kanazawa, 2004, 2008; Lynn, 1991; Rushton, 2000; Templer, 2008; Templer & Arikawa, 2006). It makes little theoretical sense to expect that SC by itself exerts direct causal influence on economic development, hence our claim that SC can serve as a meaningful Instrument with respect to IQ in the context of its relationship to GDP. We provide a description of each of the measures used in the current study in the following paragraphs.

Our first analysis is simply a reanalysis of the data provided by Templer (2008) in the context of a non-recursive path model with SC as an Instrument which supposedly directly relates only to IQ. In that sense, we used Templer's data which the reader can easily find in the respective reference. Templer provides SC data for 129 countries. SC was obtained from Biasutti (1967) and was measured on a quasi-continuous scale ranging from 1 (very light) to 8 (very dark). Overall, the SC measure contains 20 distinct values and is hence treated as an interval scale in the analyses below which is consistent with Templer's (2008) original approach. In addition to SC, Templer used national average IQs and GDPs *per capita* obtained from Lynn & Vanhanen (2002, 2006).

Our second and third analyses involved OIL as an Instrument with respect to GDP. OIL was conceptualized by the number of barrels obtained per year by a given country divided by the country's population, a measure we can call "Oil *per capita*". The number of barrels produced yearly was taken from

[1] The two main theories referenced above regard high IQs as a specific evolutionary adaptation. Lynn (1991) puts forward the "Cold Winter Hypothesis", which regards higher cognitive capacities as an adaptation to the challenges (finding food and shelter, etc.) presented by colder climates (see also Rushton, 2000). Kanazawa (2004), on the other hand, argues that higher aggregate IQs arise as an adaptation to evolutionary novelty. His theory predicts that groups which had settled away from *homo sapiens*' evolutionary origin in Africa and had faced challenges adapting to their novel environments should demonstrate higher average cognitive capacities. Attempts at demonstrating the validity of these evolutionary accounts have included correlating national IQ averages with countries' average annual temperatures and with countries' geographic distance from humankind's evolutionary origin in Africa (e.g. Kanazawa, 2008).

the Worldometer database[2]; the same source was used for the estimates of each country's population. The most recent data concerning OIL was available for 2016.

Our national aggregate IQ measures used in analyses 2 and 3 were taken from Lynn & Vanhanen (2012) — more recent aggregate estimates incorporating newer studies than the ones employed by Templer (2008). The estimates for *per capita* GDP were also taken for 2016. This preserves the cross-sectional nature of the non-recursive path analysis as best as possible and reduces the risk of violating its second assumption listed in the introduction. These data were obtained from the World Bank's database[3]

We see that we have two different waves of GDP measurements: the one used by Templer (2008), and the 2016 measurement wave used in analyses 2 and 3. Similarly, we have two estimates of national IQs provided by different editions of Lynn & Vanhanen's aggregation efforts. This diversity of measurements, sources and samples (see the Appendix) should serve to increase the validity of our results should these prove to be consistent across the different analyses.

Finally, we should point out that all of the analyses provided below were based on the logarithms of the data pertaining to GDP and OIL production *per capita*. These transformations produced distributions with lower skewness which brought them closer to the Gaussian family. We should stress, however, that all results reported below remained virtually identical when we repeated the analyses on the raw untransformed measures of GDP and OIL which provides us with a helpful "robustness check".

The tables containing the data for our second and third analyses are available in the Appendix. All reported analyses were conducted via the open source lavaan module within the R environment (Rosseel, 2012).

3 Analyses and Results

Our first analysis uses Templer's (2008) data which includes IQ, (log-transformed) GDP, and SC as an Instrument. The correlations between the three measures were as follows: r(IQ, GDP) = .73, p < .001; r(IQ, SC) = -.91, p < .001; r(SC, GDP) = -.71, p < .001. Based on 129 countries, the results can be seen in Figure 2. The analysis suggests that IQ is the cause rather than the effect of economic development.

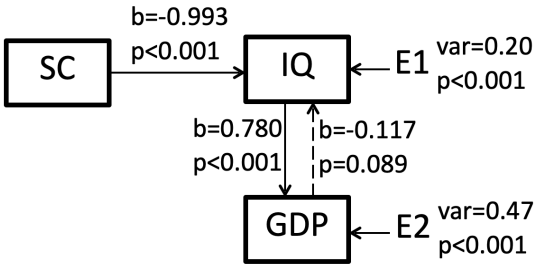

Figure 2: Standardized path coefficients, error variances, and significance levels. The statistically non-significant ($p > .05$) paths are shown as dashed arrows.

Our second analysis makes use of OIL as an Instrument with respect to GDP, i.e. we investigated the same relationship by making use of a different Instrument (OIL) acting upon our second target measure (GDP). We obtained data from 98 countries (see the Appendix) with complete data records for OIL and GDP (for 2016) and for IQ (2012). The results are shown in Figure 3 and are based on the following correlations: r(GDP, OIL) = .23, p = .022; r(GDP, IQ) = .74, p < .001; r(OIL, IQ) = -.03, p = .758.[4] We see that the exact same conclusions with respect to the direction of causal influence of IQ on GDP are implied by our second analysis as well.

The third analysis we conducted used both OIL and SC as Instruments within a model analogous to the one shown in Figure 1 (right). As briefly mentioned in the introduction, the approach involving two

[2] https://www.worldometers.info/oil/oil-reserves-by-country/

[3] https://data.worldbank.org/indicator/NY.GDP.PCAP.CD

[4] Note that the lack of correlation between IQ and OIL supports OIL's validity as an Instrument.

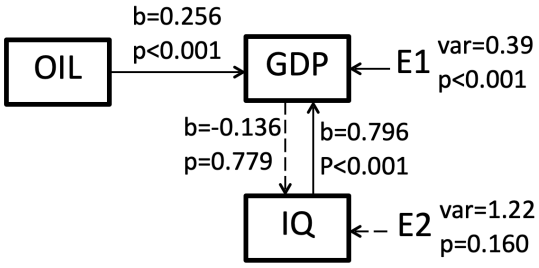

Figure 3: Standardized path coefficients, error variances and significance levels for the second analysis. The statistically non-significant ($p > .05$) paths are shown as dashed arrows.

Instruments provides additional information regarding the plausible values of the paths connecting our target variables (IQ and GDP in this case); it also allows for the estimation of the correlation between the errors (E1 and E2), which accounts for common causes for the target measures which may have been omitted from the analysis. This analysis used the same data as Analysis 2 in addition to SC taken from Templer's (2008) data. 76 countries with complete data records with respect to the four variables in question (see the Appendix) were entered into the non-recursive path model. The correlations between the four variables (IQ, GDP, OIL, and SC) are shown in Table 1; the results are reported in Figure 4.

Table 1: Correlations between GDP and OIL per capita, IQ and Skin Color (SC) for our third analysis. * $p < .05$, ** $p < .001$.

	GDP	OIL	IQ
OIL	0.230*		
IQ	0.739**	-0.073	
SC	-0.616**	0.094	-0.838**

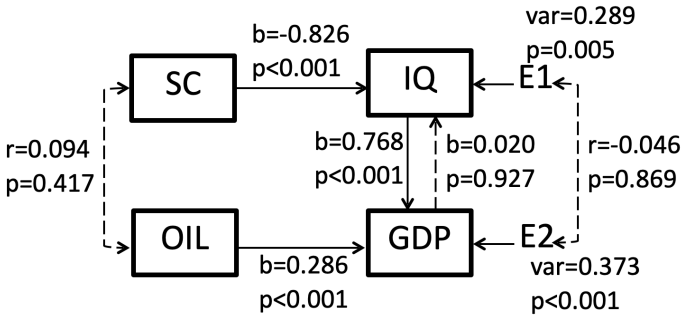

Figure 4: Standardized path coefficients, error variances, correlations (r) and significance levels for the third analysis. The statistically non-significant ($p > .05$) paths and correlations are shown as dashed arrows.

Again, we see the same pattern of results whereby IQ influences GDP but not vice versa. Interestingly, it appears that the correlation between the two error terms is negligible and far from significant which indicates that important predictors which influence both IQ and GDP were unlikely to have been omitted from the analyses. In that sense, the coefficients from the first two analyses seem unlikely to be subject to bias resulting from omitted common causes. Similarly, the lack of correlation between the error terms strongly suggests that the relationship between IQ and GDP is the result of a direct causal connection between the two target measures rather than resulting from the influence of variables not included in the model.

4 Discussion

The analyses presented above strongly suggest that IQ might be a stronger predictor of economic development than the reverse. The results from our analyses are strikingly consistent — all standardized path coefficients from IQ to GDP indicate a large effect (e.g. Cohen, 1992) and vary only between .768 and .796. These results are consistent with several other studies (e.g. Rindermann, 2008; Rindermann & Thompson, 2011) which employ different datasets and analytical techniques (for example, these studies make no use of instrumental variables) but arrive at the same general conclusions. This remarkable degree of consistency supports the validity of the reported findings.

Similarly, all three analyses indicate that the causal paths from GDP to IQ are entirely redundant. These paths seem unnecessary with respect to reproducing the observed correlations, their magnitudes are negligible, and they consistently fail to reach statistical significance.[5] This result may appear counterintuitive as it is well-known that the lack of educational opportunities and a cognitively stimulating environment as well as certain extreme conditions can hinder cognitive development as we discussed in the introduction. In the same vein, the observed results can be seen as being at odds with the Flynn effect (e.g. Flynn, 2012), which establishes a global increase in IQ during the 20th century. Today the rate of said increase is especially pronounced in developing countries. This was originally attributed to rapidly improving living conditions.

In order to reaffirm the relationship between IQ and environmental effects on living conditions within the proposed analytical framework, we conducted another non-recursive analysis. We used Templer's dataset and modeled the relationship between IQ (with SC as an Instrument) and infant mortality (IM) as a proxy for quality of life during crucial stages of cognitive development. We used the same model as the one depicted in Figure 2, but with infant mortality instead of GDP as the third variable depicted at the bottom. This time the results clearly indicated the presence of a significant feedback loop between IQ and IM. The standardized path from SC to IQ was equal to -0.787 ($p < .001$) and the path from IQ to IM was equal to -0.780 ($p < 0.001$), i.e. higher aggregate national IQs were associated with lower IM; importantly, the path from IM to IQ was also significant ($p = .001$) and in the predicted direction ($b = -0.173$). Still, the effect of IQ on IM was significantly stronger than the effect of IM on IQ. The difference between the two estimates was equal to -0.607 which was significantly different from zero ($p < .001$). These tentative results[6] are consistent with previous observations establishing environmental effects on IQ in the context of the Flynn effect; also, they show that nothing in our instrumental approach necessarily precludes IQ from emerging as an effect within a causal loop which should lend further credence to the results discussed above.

One plausible way to reconcile the results reported here with the Flynn effect and the environmental factors underlying it is to speculate that improvement in living conditions in developing countries (for which the Flynn effect is the most pronounced) is not overly correlated with their *per capita* GDPs. This may indeed be the case if a large portion of the improvement in living conditions in such regions is due to foreign aid and investment. Foreign aid/investment (direct material and financial aid and technological know-how as well as the general increase in availability of different medical, information and agricultural technologies) is not always directly included in the calculation of GDP, but it is probably partially responsible for developing nations' rapid increase in well-being. In that sense, foreign aid/investment presumably affects developing countries' living conditions to a much larger extent than their relative standing on the GDP continuum thereby diminishing the observed correlation between GDP and general well-being[7]. Although

[5] Indeed, as Figures 2 and 3 show, two of our analyses indicate that GDP has a small (insignificant) negative effect on IQ once the other path coefficients have explained the observed correlations away. This appears to be a case of "negative suppression" whereby high positive correlations between two measures reverse in sign when other important variables have been taken into account (e.g. Maassen & Bakker, 2001).

[6] This result should be regarded as preliminary because the Instrument used here (Skin Colour) may be connected to Infant Mortality through means other than IQ; actually, a direct biological link between the two may be suggested on the basis of the *r–K* selection theory (e.g. Templer, 2008; Rushton, 2004).

[7] Another reason for the higher rate of increase of IQ and living conditions in developing countries might have to do with the so-called advantage of backwardness effect whereby underdeveloped countries tend to show higher economic growth rates (e.g. Weede & Kämpf, 2002), for example by implementing new technologies developed by more advanced countries while sparing themselves the costs of research and development. Indeed, it has been shown that countries with high IQs and low initial prosperity exhibit the highest rates of economic growth (e.g. Meisenberg & Lynn, 2012). The extent to which this

this speculation can readily explain the unidirectional influence of IQ on GDP described above while still acknowledging that environmental effects play an important role in cognitive development, further studies would be needed in order to ascertain its veracity or lack thereof.

5 Conclusion

The presented findings can be taken to indicate that societies with higher aggregate cognitive capacities tend to manage to create intra-societal environments which more or less adequately provide the necessary and sufficient conditions for their citizens to experience unhindered cognitive development. Such environments seem not to be directly dependent on GDP, but rather ensure suitable living conditions coupled with intellectually challenging surroundings. This makes it likely that citizens reach their full cognitive potential and hence provide the human capital which is essential for sustained economic growth (see Hafer, 2017 and Meisenberg & Lynn, 2011, 2012 for similar arguments).

Naturally, no single study should be taken as conclusive, especially on a topic as complex as this. For example, it may be argued that our samples are less than adequate in terms of size and representativeness, that the chosen Instruments don't fulfil the prerequisites needed in order to obtain unbiased results, and so on. Similarly, despite the remarkable degrees of both intra- and inter-study consistency mentioned above, the possibility of biased results due to model misspecification and various confounding factors should be kept in mind. We do, however, hope that future critiques of the proposed conclusions present sound theoretical counterarguments coupled with rigorous empirical support.

Future studies employing a similar methodology can make use of various different instrumental measures. For example, aggregate indices of access to natural resources (i.e. indices reflecting not only oil but also precious metals and minerals), which embody broader economic relevance, may be employed as potentially more reliable Instruments with respect to economic development; similarly, geographic measures such as distance from humankind's evolutionary origin (Kanazawa, 2008) and average temperature (e.g. Lynn, 1991; Rushton, 2000) can be employed as Instruments with respect to IQ.

The data for aggregate IQ levels across different countries has never come in pre-specified time waves designed to facilitate testing of various hypotheses regarding the causal interplay between IQ and other measures such as GDP, living conditions, education, etc. Previous research has concentrated mainly on using variables which do come in such waves (e.g. the PISA assessments) as proxies for IQ (e.g. Rindermann, 2008; but see also Rindermann, 2007 for an argument claiming that IQ tests and international scholastic achievement reflect the same general cognitive construct). The main strength of the approach proposed here is that it attempts to investigate the causal structure between IQ and economic development by means of a cross-sectional design which requires no proxy variables and uses Instruments in order to compensate for the lack of a structured longitudinal dataset with respect to IQ. That being said, it would make sound theoretical sense to establish the proposed results further in the context of a temporally dynamic framework. For example, using data on economic growth (instead of static measures such as GDP) and temporal differentials in international scholastic achievement within models such as longitudinal path analysis and/or growth regression (Rindermann, 2008; Meisenberg & Lynn, 2012) would allow researchers to gain insights into the causal structure of the variables in question from a different perspective. If the results from different research strategies and analytical approaches converge, a more sound theoretical understanding of IQ in terms of its causal antecedents and consequents could be achieved.

Based on the discussed observations, we would venture to speculate that results of future studies will be similar to the ones reported here. This conjecture is not only consistent with a plethora of empirical observations but also makes sound theoretical sense within the paradigm regarding high general intelligence as a biological adaptation (e.g. Kanazawa, 2008; Lynn, 1991; Rushton, 2000), described as an abstract cognitive ability aimed at general problem solving. The problems which contemporary societies face include various technological, institutional, socio-political, economic, ecological and environmental challenges which, being evolutionarily and even historically novel, require precisely such an abstract cognitive competence in

phenomenon affects the correlations between IQ (including the Flynn effect), GDP, and general well-being remains to be investigated further.

order to be adequately addressed (e.g. Rindermann, 2008; Rindermann & Thompson, 2011; Meisenberg & Lynn, 2011, 2012; Weede & Kämpf, 2002). This makes different strands of intelligence research all the more relevant.

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Conflicts of Interest

None

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Appendix

Table A1: Data used for Analysis 2. Per capita GDP and Oil production per capita (OIL) are log-transformed.

Country	GDP	OIL	IQ	Country	GDP	OIL	IQ	Country	GDP	OIL	IQ
Albania	8.32	4.08	82	Ethiopia	6.56	-5.69	68.5	Pakistan	7.29	0.39	84
Algeria	8.29	5.59	84.2	France	10.52	0.19	98.1	Papua NG	7.75	2.86	83.4
Angola	7.50	5.44	71	Gabon	8.81	6.71	69	Peru	8.73	2.99	84.2
Argentina	9.46	3.95	92.8	Georgia	8.31	2.24	86.7	Philippines	8.02	0.17	86.1
Australia	10.82	3.81	99.2	Germany	10.65	0.46	98.8	Poland	9.42	1.21	96.1
Austria	10.72	1.62	99	Ghana	7.55	2.96	69.7	Qatar	10.98	9.14	90.1
Azerbaijan	8.26	6.51	84.9	Greece	9.79	-0.03	93.2	Romania	9.15	3.41	91
Bahrain	10.04	4.43	85.9	Guatemala	8.34	1.52	79	Russia	9.07	6.32	96.6
Bangladesh	7.41	-1.82	81	Hungary	9.48	1.04	98.1	Saudi Arabia	9.90	8.88	79.6
Barbados	9.76	2.11	80	India	7.45	1.20	82.2	Serbia	8.66	2.38	90.3
Belarus	8.53	3.04	95	Indonesia	8.18	2.59	85.8	Slovakia	9.71	0.44	98
Belize	8.72	2.79	76.8	Iran	8.61	7.48	85.6	South Africa	8.65	-1.39	71.6
Benin	6.96	-0.54	71	Iraq	8.37	8.05	87	Spain	10.19	1.15	96.6
Bolivia	8.01	2.84	87	Israel	10.54	0.42	94.6	Sudan	7.87	4.64	77.5
Brazil	9.07	4.31	85.6	Italy	10.34	2.29	96.1	Suriname	8.65	5.08	89
Brunei	10.19	7.80	89	Japan	10.58	-1.03	104.2	Syria	6.50	4.68	82
Bulgaria	8.93	0.81	93.3	Jordan	8.29	-2.43	86.7	Taiwan	10.05	-2.31	104.6
Cameroon	7.26	1.94	64	Kazakhstan	8.95	7.33	85	Tajikistan	6.69	0.17	80
Canada	10.65	8.39	100.4	Kuwait	10.20	10.07	85.6	Thailand	8.67	1.73	89.9
Chad	6.54	4.41	66	Kyrgyzstan	7.02	1.78	74.8	Trinidad & T.	9.69	6.16	86.4
Chile	9.53	2.03	89.8	Libya	8.98	8.86	85	Tunisia	8.24	3.53	85.4
China	9.00	2.87	105.8	Lithuania	9.62	1.48	94.3	Turkey	9.30	1.29	89.4
Colombia	8.69	3.79	83.1	Malaysia	9.16	4.65	91.7	Turkmenistan	8.73	4.52	80
Congo	7.65	5.57	73	Mauritania	7.36	1.41	74	Uganda	6.62	3.94	71.7
Croatia	9.44	2.87	97.8	Mexico	9.12	4.33	88	Ukraine	7.69	2.37	94.3
Cuba	8.99	2.40	85	Morocco	8.05	-4.01	82.4	UAE	10.62	9.24	87.1
Czechia	9.83	0.36	98.9	Myanmar	7.11	-0.09	85	United Kingdom	10.62	3.71	99.1
Côte d'Ivoire	7.60	1.24	71	Netherlands	10.74	2.08	100.4	United States	10.97	4.64	97.5
Denmark	10.91	4.53	97.2	New Zealand	10.60	2.51	98.9	Uzbekistan	7.90	2.83	80
DR Congo	6.12	0.57	68	Niger	6.21	1.71	70	Venezuela	8.21	9.25	83.5
Ecuador	8.71	6.12	88	Nigeria	7.67	5.11	71.2	Vietnam	7.92	3.80	94
Egypt	8.11	3.66	82.7	Norway	11.17	6.84	97.2	Yemen	6.98	4.47	80.5
Equ. Guinea	8.99	6.46	69	Oman	9.75	7.04	84.5				

Table A2: Data used for Analysis 3. Per capita GDP and Oil production per capita (OIL) are log-transformed.

Country	GDP	OIL	IQ	Skin color	Country	GDP	OIL	IQ	Skin color
Albania	8.32	4.08	82.0	1.7	Kuwait	10.20	10.07	85.6	4.0
Algeria	8.29	5.59	84.2	4.3	Kyrgyzstan	7.02	1.78	74.8	2.0
Angola	7.50	5.44	71.0	7.0	Libya	8.98	8.86	85.0	4.3
Austria	10.72	1.62	99.0	1.0	Lithuania	9.62	1.48	94.3	1.3
Azerbaijan	8.26	6.51	84.9	2.0	Malaysia	9.16	4.65	91.7	4.7
Bahrain	10.04	4.43	85.9	4.0	Mauritania	7.36	1.41	74.0	5.0
Bangladesh	7.41	-1.82	81.0	4.3	Morocco	8.05	-4.01	82.4	2.7
Belarus	8.53	3.04	95.0	1.3	Netherlands	10.74	2.08	100.4	1.0
Benin	6.96	-0.54	71.0	7.0	Niger	6.21	1.71	70.0	7.0
Brunei	10.19	7.80	89.0	4.0	Nigeria	7.67	5.11	71.2	7.0
Bulgaria	8.93	0.81	93.3	1.7	Norway	11.17	6.84	97.2	1.0
Cameroon	7.26	1.94	64.0	7.0	Oman	9.75	7.04	84.5	5.0
Chad	6.54	4.41	66.0	7.0	Pakistan	7.29	0.39	84.0	3.7
China	9.00	2.87	105.8	2.0	Philippines	8.02	0.17	86.1	4.0
Congo	7.65	5.57	73.0	6.7	Poland	9.42	1.21	96.1	1.0
Croatia	9.44	2.87	97.8	2.0	Qatar	10.98	9.14	90.1	4.0
Czechia	9.83	0.36	98.9	1.3	Romania	9.15	3.41	91.0	2.0
Côte d'Ivoire	7.60	1.24	71.0	6.3	Russia	9.07	6.32	96.6	2.0
Denmark	10.91	4.53	97.2	1.0	Saudi Arabia	9.90	8.88	79.6	4.0
DR Congo	6.12	0.57	68.0	7.0	Serbia	8.66	2.38	90.3	2.0
Egypt	8.11	3.66	82.7	4.0	Slovakia	9.71	0.44	98.0	1.3
Equ. Guinea	8.99	6.46	69.0	6.0	South Africa	8.65	-1.39	71.6	6.7
Ethiopia	6.56	-5.69	68.5	6.7	Spain	10.19	1.15	96.6	2.0
France	10.52	0.19	98.1	1.0	Sudan	7.87	4.64	77.5	6.7
Gabon	8.81	6.71	69.0	7.0	Syria	6.50	4.68	82.0	3.3
Georgia	8.31	2.24	86.7	2.0	Taiwan	10.05	-2.31	104.6	3.0
Germany	10.65	0.46	98.8	1.0	Tajikistan	6.69	0.17	80.0	2.7
Ghana	7.55	2.96	69.7	7.0	Thailand	8.67	1.73	89.9	3.7
Greece	9.79	-0.03	93.2	2.0	Tunisia	8.24	3.53	85.4	3.0
Hungary	9.48	1.04	98.1	1.0	Turkey	9.30	1.29	89.4	2.0
India	7.45	1.20	82.2	6.3	Turkmenistan	8.73	4.52	80.0	2.3
Indonesia	8.18	2.59	85.8	4.7	Uganda	6.62	3.94	71.7	7.7
Iran	8.61	7.48	85.6	3.0	Ukraine	7.69	2.37	94.3	1.7
Iraq	8.37	8.05	87.0	3.3	UAE	10.62	9.24	87.1	4.0
Italy	10.34	2.29	96.1	1.7	United Kingdom	10.62	3.71	99.1	1.0
Japan	10.58	-1.03	104.2	2.0	Uzbekistan	7.90	2.83	80.0	2.0
Jordan	8.29	-2.43	86.7	3.0	Vietnam	7.92	3.80	94.0	4.0
Kazakhstan	8.95	7.33	85.0	2.0	Yemen	6.98	4.47	80.5	6.0

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Unusual Burial of an Adult Individual from the Cathedral of the Armenian Apostolic Orthodox Church in Armenia (preliminary announcement)

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Abstract

The Mother See of Holy Etchmiadzin has been the administrative headquarters of the Armenian Church. During restoration work in June 2019, human remains from an ancient burial were discovered in the Cathedral within an archaeological context of 4th century AD. The gross anatomy of the bones was investigated through macroscopic and microscopic analyses. The reason for the extensive burning on much of the individual's body is unknown. The color of the burns ranged from black to white (calcined). We see white, furry or "bloom" growths, as crystals on the bone surface. Ground water can carry these salts into the pores of the bones during burial leaving them behind when the water evaporates.

Keywords: Armenia, White powder, Salt crystals, Fire exposure, Cathedral, Etchmiadzin, Taphonomy

1 Introduction

1.1 Early Medieval burial in the Holy Etchmiadzin Monastery

Etchmiadzin Cathedral is the mother church of the Armenian Apostolic Church, located in the city of Vagharshapat (Etchmiadzin). The original church was built in the early fourth century — between 301 and 303 according to tradition — by Armenia's patron saint Gregory the Illuminator, following the adoption of Christianity as a state religion by King Tiridates III. It was built over a pagan temple, symbolizing the conversion from paganism to Christianity. The core of the current building was built in 483/4 by Vahan Mamikonian. For much of its history, the complex around the cathedral, which includes the residence of the Catholicos (patriarch), was known as the Monastery of Etchmiadzin. It was formerly surrounded by 30 ft (9.1 m) high walls, made of brick or cob, and had eight circular towers (turrets). The walled monastery, a vast quadrangular enclosure, could be accessed through four gates. The cathedral stood — and continues to stand — at the center of a quadrangular courtyard 349 feet 6 inches (106.53 m) by 335 feet 2 inches (102.16 m).

As the center of Armenian Christianity, Vagharshapat has been an important location in Armenia not only religiously, but also politically and culturally. Along with several important early Medieval churches located nearby, the cathedral was listed as a World Heritage Site by UNESCO in 2000.

2019 on 26 May, an Early Medieval burial (4th century AD) site was discovered during excavations near the southern wall of the Holy Etchmiadzin Monastery (Figure 1). The burial was oriented in a north-westerly direction. A white residue presumed to be lime was detected during excavations. The sarcophagus was covered with rough tufa stones. The base of the sarcophagus was covered with earth. The bones demonstrate signs of burning and salt deposits.

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This article examines this unusual burial dating to the Early Medieval period, discovered the Holy Etchmiadzin Monastery. This also requires an assessment whether there were liturgical, practical or other motivations and justifications for burial in Holy Etchmiadzin Monastery. Each example of such a burial necessitates analysis to determine if the burial in this location was incidental, accidental, or intentional. The objectives of this article are as follows:

1. To assess the role and significance of post-depositional practices within the Medieval funerary context.

2. To identify and define different forms of post-depositional disturbance and to document any recognisable attributes of such practices.

3. To elucidate Medieval attitudes towards the dead, physical interaction with deceased individuals and human skeletal material.

4. To assess the significance of white substances in interpreting taphonomic burial processes and their funerary context.

1.2 Taphonomic factors

Taphonomy (from *taphos*, 'burial' and *nomos*, 'law') is integrated into many scientific disciplines, relating to the body itself (anthropology, forensic medicine, etc.), the body in interaction with the soil, otherwise known as the "decomposition island" (toxicology, genetics, forensic macro- and microbiology, etc.), in relation to the detection of the body (archaeology, botany, forensic geology, etc.). After death the human body is subject to the processes of autolysis and putrefaction. It is the combination of intrinsic and extrinsic factors which make every burial unique. Intrinsic factors depend on the nature of the body itself and the complexity of its structure such as age, sex and physical state at the time of death (Garland & Janaway, 1989; Henderson, 1987; Mant, 1987). Extrinsic factors can be divided into two main categories: the environment of the burial site, and human activities. The environmental factors which affect decomposition are water, soil, temperature, oxygen, and local fauna and flora (Gill King, 1996; Henderson, 1987; Janaway, 1996; Tibbett & Carter, 2008).

Salt is a generic term covering all the soluble salts in soil, mainly comprising Na, K, Ca, Mg, chlorides, sulphate, and sodium bicarbonates and carbonates. The salts deposited in and on an artefact (or bones) during burial can be divided into two groups: insoluble salts, and soluble salts. Soluble salts will dissolve in moisture in the air. This property is known as deliquescence. The salts can move through porous artifacts or bones as moisture is drawn out through evaporation. As the salts reach the surface of the artifact, they may crystallize as white, often furry growths on the surface. If the surface is less porous than the underlying structure they can crystallize just below the surface. These crystals exert immense pressure and may cause the surface layer to spall off. "Insoluble" salts are not truly insoluble but will take days or weeks to dissolve in water. They are not deliquescent and so will not cause further damage after excavation. Insoluble salts can, however, be quite disfiguring, and may require removal for identification or reconstruction of a bone or artifact.

Soluble salts can also be deposited into artifacts through past conservation treatments, including "acid cleaning". In this process, objects are dipped in a dilute acid solution to remove insoluble salt deposits from the surface of ceramics. The acid changes them into a water-soluble form. The soluble salts can then penetrate into the porous body of the artifact and later recrystallize on or under the surface as described above. Acid residues may also react with the artifact causing crystal growth.

Porous archaeological materials such as ceramics, stone, bone, and ivory often contain soluble salts. After excavation, these salts can crystallize at or just below the surface of the artifact causing damage. A variety of descriptive terms are used for this damage including spalling, flaking, powdering, and sugaring. The force of growing crystals can break apart the surface of bone, stone, ceramics and other porous materials so that detail is lost. In bad cases it can remove the entire surface of an artifact. In the worst cases, it can destroy an artifact.

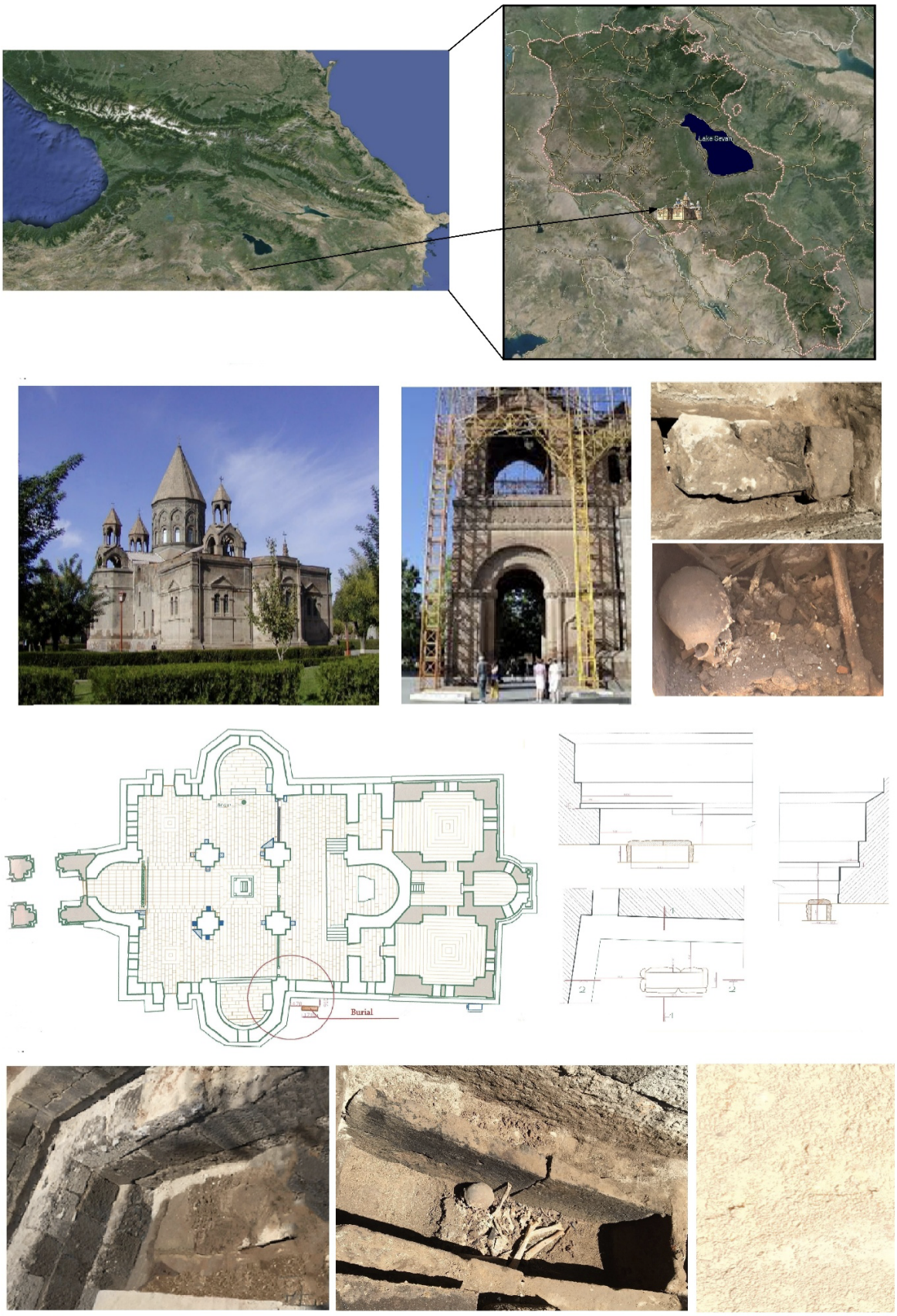

Figure 1: Cathedral of the Armenian Apostolic Orthodox Church.

1.3 Impact of combustion on bones

Fire is a very destructive force, capable of causing great damage. Burned human remains can be found in a variety of situations, from archaeological funerary urns to volcanic eruptions. Let us list the diversity of

possible origins for bone combustion: intentional discard of bone waste in hearths (Cain, 2005; Spennemann & Colley, 1989), alimentary cooking (Costamagno & Fano Martínez, 2005; Gifford-Gonzalez, 1989; Pearce & Luff, 1994; Wandsnider, 1997), ritual combustion (Tchesnokov, 1995; Vaté & Beyries, 2007), accidental combustion after burying (Bennett, 1999; Cain, 2005; David, 1990; Stiner et al., 1995), and natural fires (Bellomo, 1993; Bellomo & Harris, 1990). In spite of this range of contexts, the actual effects on the body and the bones (which we refer to as "heat-induced changes") are the same. In fact, the changes we see from fire are in many ways the same as normal diagenesis over time, just much faster. It is important to note that the skeleton does not 'turn to ash' when burned. Even in modern crematoria, which burn efficiently and at high temperatures, the skeleton will survive.

The human body is made up of soft and hard tissues, and fire has a dramatic effect on both. The heat causes significant changes to the bones. Bone goes through four stages of transformation when burned: 1. dehydration (removal of water from the bone due to moisture evaporating in response to the heat; this occurs at a temperature range of 100-500°C), 2. decomposition (the organic component of the bone (the collagen) is lost.), 3. inversion (changes to the inorganic, mineral part of the bone, the phosphates and carbonates; this occurs at a temperature range of 500-1100°C), 4. fusion (the crystals that form the bone mineral start to melt and coalesce together; this occurs at a temperature range of 700-1200°C). These four stages are not discrete phases — a given bone could be experiencing all four stages in different parts at the same time (Thompson et al., 2017). Some bones will burn more intensely than others, depending on factors such as body fat distribution, proximity to the heat source, etc. (Schmidt & Symes, 2015; Thompson, 2015).

The fire will cause the soft tissues to contract, which causes the skin to tear and the fat and muscles to shrink. The internal organs will also shrink. The muscles contract due to burning and this causes the joints to flex. As a result, burned bodies are often contorted into what is known as a pugilistic, or boxer pose (Thompson, 2015). Distinguishing between ante and post mortem alterations can be challenging even for the skilled paleopathologist and, as this case indicates, paleopathological diagnoses must be supported by detailed examinations.

1.4 White residues in burials

When white substances are found in burial contexts, it is often assumed that the white material is lime (CaO or $Ca(OH)_2$) or another derivative of limestone (Schotsmans et al., 2012). For centuries (ca. 11th millennium BP to present), white plaster (variously gypsum, lime or chalk) has been added to burials for many different reasons, although such finds have rarely been analysed (Schotsmans et al., 2015). For example, the earliest intentional use of gypsum in a funerary context, as confirmed by analysis, comes from *Körtik Tepe* in Turkey and dates to the Pre-Pottery Neolithic A (Erdal, 2015).

What are the intentions for the application of white powder? The interpretations of this custom are diverse and sometimes contradictory. Are some of the historical examples a Christian custom related to resurrection with the white colour as a sign of purity? Does it represent the transition from the world of the living to the world of the dead? Or was it applied for practical reasons? Several suggestions are made regarding the intentions. Lime could have been applied to burials to desiccate and preserve a body, with the intention to dissolve the body and accelerate decay, to facilitate a quick turnover for next interments, against body snatchers to make the remains useless for dissection, to absorb the putrefaction fluids, as a disinfectant, to protect the body, to conceal the body, to suppress the odour, to make the burial look neat etc. Who made these interpretations? Are they based on historical documents, on scientific evidence or on personal assumptions of the authors? As an illustration, Naphy & Spicer (2000, p. 88) state "that the decay of plague bodies might produce infected gasses. For this reason the extensive use of lime to 'dissolve' the bodies was a medical necessity." Similarly, Weiner (2010) mentions that "the addition of lime removes foul odours and kills pathogens" (Weiner, 2010, p. 194). Fiedler et al. (2009) state that the Roman custom of adding calcium hydroxide was used to dissolve the flesh from the bones and get rid of the odour, referring to a source of 1973 (Cüppers, 1973).

2 Material and Methods

In 2019, excavations led by Nyura Hakobyan (Institute of Archaeology and Ethnography, National Academy of Sciences, Republic of Armenia) uncovered an early Medieval tomb near the southern wall of Etchmiadzin Cathedral, in the ground in a typical stone sarcophagus facing north-west (Figure 1). The sarcophagus is made of stone and lined with polished tuff slabs. The sarcophagus is covered with unworked massive tuffs. The base of the sarcophagus is sprinkled with earth. The non-anatomical arrangement of human remains within the sarcophagus — characterized by disarticulated bones and disruption of the skeletal structure — suggests the likelihood of a secondary burial. The bones are compact within a spatially limited area, significantly smaller than the dimensions of a fully extended human body. This compact placement strongly indicates that the remains were exhumed and subsequently reinterred in a deliberate and non-primary context. Such a configuration serves as a critical diagnostic criterion in both archaeological and anthropological analyses, pointing to post-depositional human activity. Any skeletal material that is disinterred or disarticulated by means of this process is regarded as a secondary act. "Translation" is the term used to describe the disinterment and relocation of the whole skeleton or preserved remains of an individual, from their initial burial place to a secondary site of interment. The remains were redeposited in a new location within a church. Translations and elevations were reserved for those individuals who had exhibited signs of saintliness during their life or after death. "This was the ancient equivalent of canonization: only those honoured by a burial above ground in the church were considered worthy of liturgical cult" (Farmer, 2004, p. 21).

There is no written documentation indicating when or under what circumstances the remains were reburied. However, it is likely that the individual held particular importance within the church community. Burials within the church or on consecrated church grounds were not conducted arbitrarily; such spaces were traditionally reserved for individuals of notable religious standing, most commonly members of the clergy (Armenian Book of Canons, 1964)[1].

A white layer was found at the bottom of the grave (inside and outside). The bones also were covered with a white powder. The white plaster substance had been identified by archaeologist N. Akopyan as gypsum, lime

System: or a chalk-gypsum mix. Due to time and budgetary constraints, the white powder sample was not subjected to laboratory analysis. White powder was found in lumps 2-10 cm in diameter. The sarcophagus has been dated to the early 4th century on the basis of its construction, orientation, stratigraphic data and comparable parallels, i.e. before the foundation of Etchmiadzin Cathedral.

The study of burned human remains poses special challenges compared to the anthropological study of non-thermally altered bones as exposure to heat produces macroscopic color changes, warping, fragmentation, and shrinkage. Charge in bone color is caused by thermal degradation or pyrolysis of their organic components, producing a sequence of heat-related color changes (Walker et al., 2008). During a fire, temperatures do not remain constant but instead fluctuate and change throughout the fire's incipient growth, development, full involvement or flashover, decay, and/or extinction (DeHaan, 2006, 2008; DeHaan & Icove 2012; Icove & DeHaan, 2004; Pope, 2023). Depending on the type and duration of the fire, the maximum temperatures of the fire may only last for several minutes or longer but are not always constant, unlike the artificial fire environment of a furnace or crematorium. Oxygen levels also vary in and between fires from oxygen rich (wind-driven/ventilated) to oxygen poor (smoky smoldering). Bone color can therefore be influenced not only by the maximum temperatures which fluctuate, but also by the duration of the bone's exposure during the fire event and post-flashover conditions, varying cortical thicknesses, the availability of oxygen, the progressive stages of pyrolysis of the bone's organic matrix, byproducts of combustion and

[1] This compilation is one of the most important sources of Armenian ecclesiastical law and canonical tradition. It includes canons from the medieval and late medieval periods of the Armenian Apostolic Church, based on both Byzantine and Armenian traditions. Regarding the topic mentioned above — that random individuals could not be buried inside or within the grounds of a church — this principle is indeed reflected in various canons within the collection. According to several rulings in the *Kanonagirq*, burial inside a church was reserved exclusively for clergy, individuals who had exhibited signs of saintliness, or individuals of high status. The rest of the population was to be buried within the churchyard or cemetery, but not within the church structure itself.

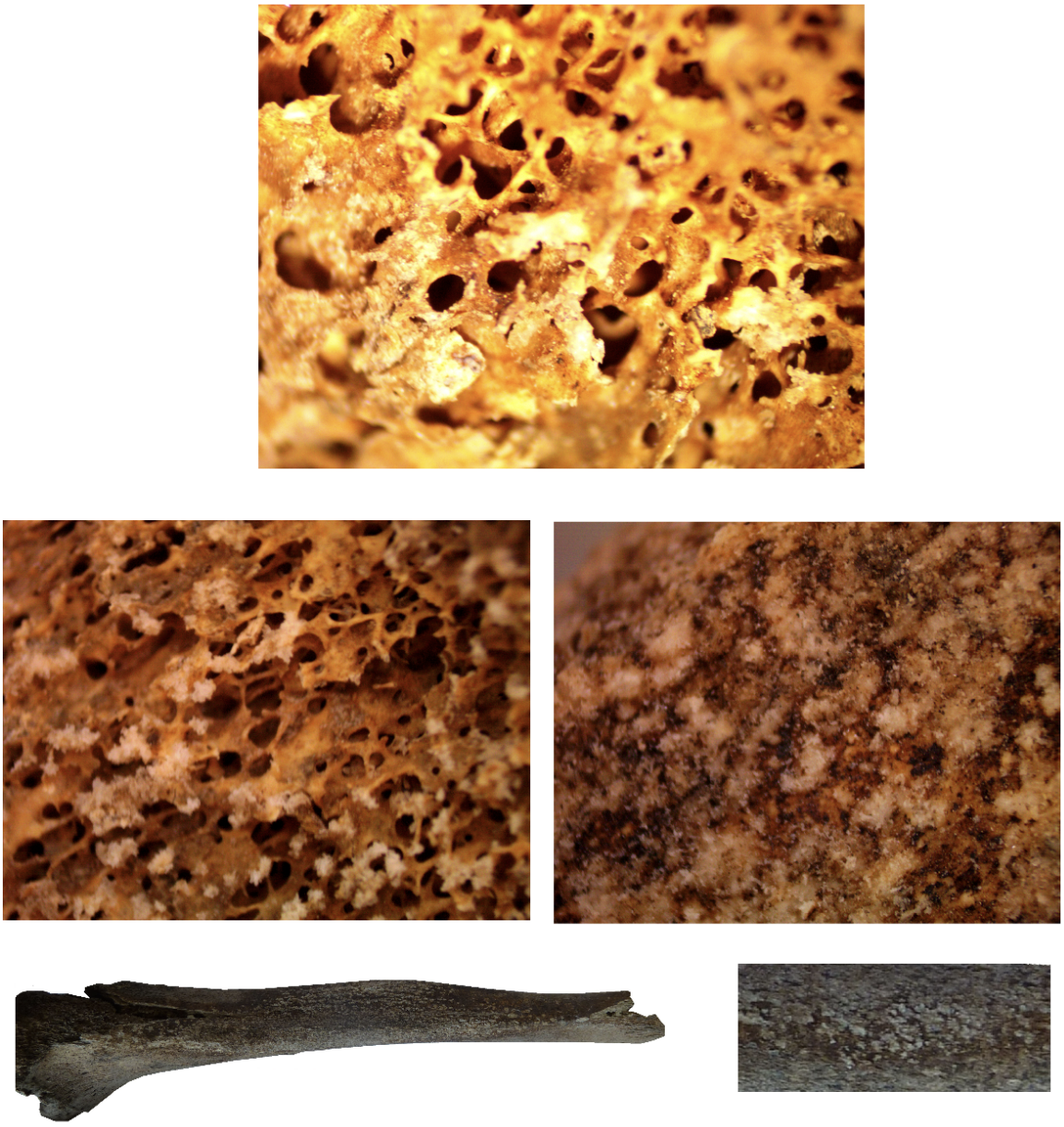

Figure 2: Crystalline structures observed on bones.

other contaminants, and post-fire exposure of the burned body to a smoky scene (Devlin & Herrmann, 2013; Symes et al., 2015). Fracturing, shrinkage, and warping accompany calcination (Schwark et al., 2011; Thompson, 2005). In temperatures under 700°C, there is little fragmentation except in the long bone epiphyses (Bohnert et al., 1998; Pope & Smith, 2004). Even though fire duration is important, greater bone fragmentation does not necessarily imply a longer duration of fire exposure. DeHaan (2012) experimented with a seven-hour fire and found that the head and upper limbs were left largely intact. Gonçalves et al. (2011) argued that warping would depend on bone collagen preservation, thus it would not be related to the presence of soft tissues.

Sex and age at death were estimated using standard anthropological methods. Sex was determined based on cranial and pelvic morphology (Buikstra & Ubelaker, 1994; Phenice, 1969). Age at death was determined based on the degree of obliteration of the cranial sutures (Buikstra & Ubelaker, 1994; Meindl & Lovejoy, 1985) and dental wear (AlQahtani et al., 2010; Cox & Mays, 2000). The stature was reconstructed on the basis of the long bones after K. Pearson & A. Lee (1903: Alekseev, 1966). To assess the development of the relief of the long bones, a three-point scale was used which included intermediate values of 1.5 and

2.5. The following indicators were calculated: 1. average scores for individual traits, 2. average score for the development of bone relief, 3. total average score (for the right and left bones) (Fedosova, 1986).

The temperature to which the bones had been exposed was estimated using a color scale developed experimentally by burning samples on experimental soil surfaces (Walker et al., 2008).

A scanning electron microscope was used for bone analysis at the Yerevan State University (N.A. Hovhanisyan). The scanning electron microscope has a higher resolution and a greater depth of focus than a conventional light microscope. In bioarchaeology, it is often used to understand the external morphology (texture) or surface topography of a specimen and to assess degradative change (Bell, 1990; Wilson et al., 2010).

3 Results

The state of preservation of the bones was mixed. Where the gypsum had remained relatively dry during burial, the bones of the skeleton were usually reasonably well preserved.

The discovered skeleton was incomplete (Figure 3). The skeletal preservation can probably be related to moisture ingress into the burial. Based on physical characteristics, the bones belong to a man aged 50-59 years. The skull is generally gracile, the brow ridges are moderately pronounced. The skull is oval in shape. It is characterized by a mesocranial type, with average transverse and longitudinal diameters (Figure 3-2, Appendix Table A1) (Alekseev & Debets, 1964). The skull has an average height, being hypsicranic according to the height-to-transverse ratio and orthocranic according to the height-to-longitudinal ratio. The diameter of the skull base is average, while the width is large. The occipital bone is of medium width, with a small occipital condyle and average circumference. The size of the parietal arc is large, and the chord diameter is within the average and large range. The mastoid process is moderately developed. The frontal bone is of medium width. The size of the frontal arc is average. The upper facial height and the length of the facial base are small.

First of all, we will point out the anomalies (non-metric traits variation of the skull) whose origin is not (or is weakly) related to diseases and physiological status of the individual, but is genetically determined. The following markers are included: *foramina infraorbitalia*, *processus temporalis ossis frontalis*, *foramina parietalia*, *os apicis lambda*, *os wormii suturae lambdoidea*, *torus occipitalis* (1.5), *foramina mastoidea*, *sutura palatina transversa* (Π-*shaped*), *canalis craniopharyngeus*, *processus paramastoideus* (Figure 3-3).

The upper right canine, first premolar, and molar were examined. The remaining teeth were lost. The odontometric measurements overall indicate that the crowns of the teeth are small. The mesiodistal dimensions of the first molar fall into the category of small to medium values (Zubov, 1968).

The strength indicator of the right humerus corresponds to the category of large values. An intercondylar foramen is observed on the right humerus. The right femur is classified as medium-long based on two length measurements, and the circumference of the mid-shaft is very large. A bony protuberance or plaque is noted on the neck of the femur at the site of *Poirier's facet*. Calculated based on the length of the femur and using the formula by K. Pearson & A. Lee, the individual's stature was 163.96 cm. Thus, the reconstructed height of the individual falls into the average category (Alekseev, 1966).

This individual was of robust build and physically trained. The radial tuberosities of the left radius are strongly developed, reflecting the corresponding development of the muscles that flex the shoulder and forearm. The right ulna shows good development of the distal lateral crest, to which the *pronator quadratus* muscle attaches. There is also good development of the lateral edge of the distal end of the radius, which is where this muscle also attaches.

Traces of significant functional loads on the ligaments of the pubic symphysis were found on the pelvic bones. Signs of enthesopathy have formed at the attachment sites of the superior and arcuate ligaments of the pubis. On the symphyseal surface of the pubic bone, there are pronounced areas of bone tissue lysis in the form of round holes with a diameter of 1–2 mm (Figure 3-11). Bone growths of irregular shape are also observed in the area of the upper edge of the acetabulum.

The greater sciatic tuberosity and the rough line of the femurs are very well developed, indicating significant loading on the muscles that flex, extend, adduct and abduct the thigh, as well as those that flex

Figure 3: Bones from the Cathedral of the Armenian Apostolic Orthodox Church: the preservation of the bones (1), nonmetric cranial signs (5), musculoskeletal stress (7-11), paleopathology (3, 4, 6, 12).

and extend the leg. The *linea aspera* on the femurs is also well developed (Figure 3-8), a structure formed under the influence of many years of horseback riding (Capasso et al., 1999). In addition, the individual exhibits inward-oriented, irregularly rounded osseous proliferations on fragments of the superior portion of the iliac wings. Enthesopathies of similar etiology are present within the pelvic cavity, at the superior margin of the sacroiliac joint surface. The pronounced development of muscular relief on the femurs, along with enthesopathies on the pelvic bones, indicates that the individual was likely a horse rider (Capasso et al., 1999; Khudaverdyan et al., 2016; *Pálfi*, 1992).

On the fragments of the tibiae, there is an enhancement of the *soleus* muscle line (Figure 3-9). The *m. soleus* is part of the *triceps surae*, primarily responsible for foot flexion and heel elevation. It does not significantly protrude above the level of the body but is quite long. The upper part of the individual's left

tibia shows a well-developed tuberosity (*tuberositas tibiae*) at the site of attachment of the *quadriceps femoris* muscle (*m. quadriceps femoris*).

On the articular surfaces of the calcaneus, signs of enthesopathy are observed. Multiple exostoses are noted on the calcaneal tuberosity (apophysis). The powerful *Achilles tendon* of the *triceps surae* muscle attaches to this tuberosity. The presence of exostoses indicates strong mechanical loads. The muscular reaction on the phalanges is average.

Intensive loads on the musculoskeletal system are evidenced by degenerative changes observed in the vertebrae of the individual examined. Degenerative-dystrophic changes were found, including cartilaginous nodes (*Schmorl's nodes*) and osteophytes in the thoracic and lumbar vertebrae, as well as deforming spondylosis. Central positioning of the intervertebral hernias is noted. Cartilaginous hernias form under significant compressive loads on the spine, primarily during periods of growth (Angel, 1966; Bridges, 1991). The pattern of spinal lesions, which are mostly localized in the thoracic and lumbar regions, along with the characteristics of muscle relief development, indicates the impact of mechanical stress, most likely associated with horseback riding (Tsirikos et al., 2001). The rider's posture causes the muscles in the back to contract to balance the spine and to prevent injury, which leads to large compressive forces being produced resulting in greater pressure placed on the intravertebral discs and facet joints (Nicol et al., 2014).

Porotic hyperostosis of the inner area of the orbit (*cribra orbitalia*) is expressed weakly (score 1). This characteristic forms in childhood and is most often associated with iron deficiency anemia, which develops in the chronic course of infectious and parasitic diseases (Stuart-Macadam, 1992). Weakly expressed signs of *cribra orbitalia* are not always manifestations of an adaptive response to anaemia, but can occur in the presence of localized inflammatory processes (Wapler et al., 2004).

Among dental pathologies, mineralized deposits of a light gray color are observed on the upper canine and premolar. Mineralized deposits can be observed on both the buccal (cheek) and lingual (tongue) sides. In addition to the content of trace elements in food and individual differences in tooth structure, the occurrence of this pathology is influenced by high-protein (meat) diets, which promote the mineralization of plaque by raising the pH of saliva (Forshaw, 2014). The individual had lost most of his teeth ante-mortem, and there was horizontal bone loss relative to the cementoenamel junction and vertical bone loss around an individual tooth (periodontal disease).

Salt crystals have been observed on bones (Figure 2). Salt crystals with a lumpy, uneven appearance are visible as a white growth on the surface of a lower limb bone. They are different from the white crystals on the surface bones. So, the white crystals on the surface bones are the consequence of a taphonomic event and are not due to a pathological condition.

The bones exhibit minor straight transverse cracking, deformation, and charring. The color observed in the burned bone ranges from bluish hue (which occurs when calcined bone gets wet) to black. At 500–800°C, organic components decompose and this results in color change, weight loss, reduction in mechanical strength, and changes in porosity. Since naturally occurring carbon is black in color, carbonized bone is also black (Symes et al., 2015). Black color results from the combustion of the organic components of collagen and carbon, while gray and white colors are the outcome of continued combustion that alters the crystalline structure (Devlin & Herrmann, 2013). The maximum combustion temperature reached up to 700 degrees. It is assumed that the individual may have perished in a fire or was deliberately subjected to burning. Our conjecture is that this was a holy martyr who was burned alive.

4 Discussion and Conclusions

The analysis of white residues from archaeological contexts demonstrates that such materials have been identified in many cultures across different time periods. The crystalline structures may be a form of calcium oxalate (CaC_2O_4). Calcium oxalates are common in nature. *Whewellite* and *weddellite*, the sedimentary mono- and dihydrates of calcium oxalate respectively, are minerals reported to be present in soils and sediments (Del Monte et al., 1987). Calcium oxalates occur widely in nature and can result from microbial activity. Watchman et al. (2005) report that oxalic acid is produced by bacteria and fungi in moist, shaded micro-environments. According to Del Monte et al. (1987), *weddellite* and *whewellite* are readily formed

in natural systems. According to the researchers, the secretion of oxalic acid from any microorganism interacts with the calcium carbonate present virtually everywhere, forming calcium oxalate monohydrate and dihydrate.

The remains from Etchmiadzin Cathedral were covered in white powder and were in a warm, humid environment. These conditions favour the formation of calcium oxalate. In Neolithic burials in the North area of *Çatal-höyük* (central Turkey), a white crystalline substance has frequently been observed on and in the bones. These deposits, generally referred to as 'salts' by the excavation team, have also been interpreted as possible adipocere (Knüsel et al., 2012). Instances of lime burials have been identified in the Jiroft culture in southeastern Iran dated to around the late 3rd millennium BC, where people of high status were buried under a hard layer of lime (Circle of Ancient Iranian Studies, 2007).

In the 5th century BC Herodotus describes a custom of the Ethiopians. "When the dead body has been dried, either in the Egyptian, or in some other manner, they cover the whole with gypsum, and adorn it with painting until it is as like the living man as possible. Then they place the body in a crystal pillar which has been hollowed out. . . . It neither gives out any unpleasant odour, nor is it in any respect unseemly" (Herodotus, 2009, p. 117). This quote by Herodotus is significant through times. It shows that in the 5th century BC people already believed that lime or gypsum had an effect on the smell.

The Romans used lime for many purposes. In the 1st century AD Pliny the Elder describes lime in detail in his "Chapters on Chemical Subjects". In chapter XVII, Pliny describes the corrosive properties of lime and the effect of lime on dead bodies and grave goods: "It is known that bodies of the dead which are buried in coffins of this material consume away within forty days, with the sole exception of the teeth. We know further that mirrors, body-scrapers, clothes and shoes, buried with the dead become petrified. . . . If fastened to the bodies, even of living men, it consumes the flesh." (Bailey, 1932, p. 117, 252)

In North Africa, plaster burials emerged between the 3rd and the 1st centuries BC and became recurrent features in Christian cemeteries of the 3rd and 4th centuries AD. There are examples of Christian cemeteries in Algeria and central Tunisia (*Tipasa*, *Timgad*) where stone coffins contained bodies, wrapped in a shroud, covered in plaster and enclosed in a wooden or lead inner coffin (Aufderheide, 2003; Sparey-Green, 1977).

In the early 4th century BC the rite became fashionable and plaster burials became a widespread practice in Italy, France, Germany and Britain (Sparey-Green, 1977). In Rome several lime burials were discovered in the catacombs of Saint *Pierre-et Marcellin* dated between the end of the 1st and the beginning of the 3rd century AD (Blanchard et al., 2007; Devièse et al., 2010). Other plaster burials were discovered in the Catacombs of *Priscilla*, founded in the 2nd century AD (Sparey-Green, 1977).

In France, at *Les Bolards*, 120 Roman chalk burials were discovered which appeared to be from young people (Planson, 1982, p. 170-173). Lime and plaster burials were revealed at cemeteries in the cities of Trier and Bonn in the Rhineland with most plaster bodies wrapped in a shroud, covered with plaster and buried in sarcophagus coffins (Reifarth, 2011a,b; Sparey-Green, 1977; Teegen & Reifarth, 2008). Remarkable is that the examination of the skeletal remains of St. *Maximin*'s plaster burials in Trier revealed an unusually high percentage of deceased racially not native to western Europe (Ramm, 1971; Sparey-Green, 1977).

In Britain, Late Roman and Early Christian plaster burials were recorded at more than 55 sites (Philpott, 1991, p. 90-96). Gypsum burials represent a high status rite in late Roman Britain, based on the association of gypsum burials with stone, lead or lead-lined wooden coffins, the richer grave goods within the coffins and, in some cases, the application of resins and balms to the gypsum-wrapped bodies (Philpott, 1991; Barber & Bowsher, 2000; Davies et al., 2002; Devièse et al., 2010; Reifarth, 2011b). At the eastern cemetery of Roman London, 81 (12.4 %) of the inhumation burials contained a white substance around the body. A representative sample of the white material from five burials in five plots was examined by the Ancient Monuments Laboratory with XRD and SEM and characterised as chalk. These burials had a slightly higher frequency of burial goods (Barber & Bowsher, 2000). Twelve plaster-packed lead or stone coffins were found in a cemetery in *Old Ford* on Colchester Road, east of the city (Sparey-Green, 1977). Another plaster burial was found in a Roman sarcophagus in *Westminster Abbey* (Stanley, 1870; Sparey-Green, 1977). Several Roman "white powder burials", were encountered during excavations at *Poundbury* and at

Alington Avenue to the West and the East of the city of *Dorchester* (Davies et al., 2002; Molleson et al., 1986). An overview of plaster burials in Roman Britain is summarised by Philpott (1991).

In Portugal, 19th-century burials covered with plaster were discovered in *Igreja das Freiras* (Church of the Nuns) in *Lagos* during archaeological excavations. The white material was not analysed and the intentions of deposition were not clear (Mendes et al., 2009). White substances of Medieval and post-Medieval burials were recovered in *Mechelen* (Belgium) during excavations of the former cemetery of the Cathedral of St. *Rombouts* (van de Vijver, 2012).

Herodotus (2009) describes the preservative properties of plaster in the 5th century BC, and a few centuries later, in the 1st century AD, Pliny the Elder describes its corrosive properties and how it consumes the body (Bailey, 1932). Several authors (Barber & Bowsher, 2000; Devièse et al., 2010; Philpott, 1991; Sparey-Green, 1977; Yorke, 1995) interpret the use of plaster in burials as an attempt to preserve the body and slow down decay. Because the physical resurrection of the body was expected and hoped for, it has been suggested that there may have been a connection with Christianity. This belief was recognised as Christian by the middle of the 2nd century AD (Schotsmans et al., 2012).

It is known (Hempel, 2006; Morris, 1976) that cholera victims were buried in lime. E. Chadwick (1842, pp. 28, 95, 128, 138, 164, 156) described regulations regarding the depth of graves and the addition of lime to prevent miasma from escaping. He also explained how coffins could be made "impervious to the escape of all morbific matter by coating the interior with a cement composed of lime, sand and oil which soon sets and becomes almost as hard and resisting as stone" and that "newly slaked lime can be employed to absorb carbonic acid".

In Armenia, early Medieval burials were found in sarcophagi covered with white powder (Jamkochyan, 1976). The plaster burial in Cathedral of the Armenian Apostolic Orthodox Church may be due to local sources of chalk and lime (unfortunately, the white material was not analysed). The skeletal material from the 'plaster' burial was in a degraded condition. We link bone degradation to gypsum in combination with seepage of ground water into the coffin. Ground water can carry the salts into the pores of the bones during burial leaving them behind when the water evaporates. The force of growing crystals can break apart the surface of bones. These crystals exert immense pressure and may cause the surface layer to spall off.

The use of white powder may have had symbolic value. It could have been of use to the dead person on the journey, or its white colour could have been a symbol of purity for the Christians (Philpott, 1991; Devièse et al., 2010). An alternative interpretation of the purpose of using lime or plaster in burials is to hasten the decay of the soft tissues. Jewish authorities permitted calcium to be sprinkled over the body in order to stimulate decomposition (Philpott, 1991). This suggests that lime may have been used in the disposal and disinfection of bodies due to either natural decay or disease (Devièse et al., 2010; Philpott, 1991). To date, it is not clear whether this was a religious rite, a visual element, or a practical custom related to disinfection. Similarly, lime burials are documented in the post-Medieval period and linked to pauper graves and plague burials. Lime is also observed in clandestine burials (Bass & Jefferson, 2003; D'Errico et al., 2011; Hochrein, 2002; Jackson, 2002; Jackson & Jackson, 2008; Jones, 1987; Laudermilk, 1932). A number of those sarcophagi were packed with white residues (Reifarth, 2011b).

The persecution of Christians can be historically traced from the first century of the Christian era. Christian missionaries and converts to Christianity have both been targeted for persecution, sometimes to the point of being martyred for their faith, ever since the emergence of Christianity. The Church schisms of the Middle Ages often provoked serious conflicts between Christian denominations, including the persecution of one another for their beliefs. Death by burning is mentioned multiple times, but unlike the Middle Ages, which primarily preferred traditional burning at the stake (as also seen in Antiquity with figures like Saint *Trofim* of *Nicomedia* and Saint *Anastasia* the Deliverer), the early Christian hagiographies provide a wider variety of descriptions of execution methods. Martyrs could be roasted alive on an iron grate (with coals), their bodies pressed against it with pitchforks (as with Saint *Lawrence*). They could be thrown into a cauldron of boiling pitch, sulfur, and wax (as with Saints *Januarius* and *Faustinus*), or into a cauldron of boiling oil (as with Saint *Vitus*), or subjected to molten lead (as with Saints *Crispin* and *Crispinian*), among other methods (Saramago, 1999).

In Armenia also, there have been persecutions of Christians. The traditional date for Armenia's

adoption of Christianity is considered to be 301 AD, during the first half of the reign of King Tiridates III the Great (287–330). A key role in the adoption of Christianity was played by Gregory the Illuminator, who became the first Catholicos of the Armenian Church (302-326). However, there were already Christian communities in Armenia before Christianity was adopted as the state religion, as evidenced by the mention in Eusebius's book of a letter from the Alexandrian bishop *Dionysius* (190–265) "regarding the repentance of the brethren in Armenia, where *Meruzan* was the bishop" (Eusebius HE, IX, 6.45.2).

The Patriarch of the Armenian Church in Constantinople, *Magakian* (*Ormanian*), points to persecutions during the reigns of the kings *Artashes* (early 2nd century), *Khosrov* (first half of the 3rd century), and Tiridates III (*Ormanyan*, 2006). There is also a tradition about the martyrdom of the Apostle *Thaddeus* during the reign of *Sanatruk* in the 1st century. Most of the martyrs who suffered in Armenia before 301 AD are recognized as universal Christian saints. As is known, during this time many who were unwaveringly devoted to the Christian faith were subjected to burning as the greatest punishment, including figures like *Athanagines*, *Theodorus* the General, and others (Avgerian, 1874, 1913; Gatrtchyan, 1852; Vardyan, 2005).

This burial in the Cathedral of the Armenian Apostolic Orthodox Church is the first burial with charred remains so far encountered in Armenia. Christianity emphasized abhorrence for cremation. Consequently, the remains could not have been exposed to fire (cremation) post-mortem. Only bodies of sinners and criminals were denied burial, deliberately cremated and scattered so that they would have no hope of resurrection (Sparey-Green, 1977). The remains in the Cathedral of the Armenian Apostolic Orthodox Church were interred with great honor.

The earliest evidence for the creation of relics from an individual is documented in 4th-century Passions, which are descriptions of a martyr's death. These describe how the remains of the martyred person were collected for reburial elsewhere in a shrine or tomb so that they may serve as a focal point for those wishing to celebrate their life and sacrifice, but also to serve as inspiration for Christians to commit to their beliefs in the face of adversity and persecution (Rollason, 1989, p. 5). This desire to create or sustain a reverence for a saintly individual appears to be the origin for the justification of moving physical or bodily remains from one location, to another more prominent position.

Bones intended to be translated and removed from the grave were believed to be of saintly people and therefore were regarded as holy artefacts. Consequently, coming into physical contact with the bones was a deeply meaningful and solemn act. Preparation of the soul in order to partake in the translations would have been essential. The first documented case of translation occurred in Italy between 351 and 354, with the translation of the bones of the martyr *Babylas* by the emperor *Gallus* (Rollason, 1989, p. 10). The veneration of a revered individual's grave has origins in Biblical passages where the graves of exceptionally holy people are recorded as being distinguished (Anonymous 1971: Book of Tobit 4, 18, Matthew 23, 29-31).

This is documented by Abbot *Wulfstan* of *Winchester*, in relation to the translation of the bones of St. *Swithun* in 971 (Keynes, 2007). *Wulfstan* describes in great detail the spiritual preparation required prior to the translation, not only for the individuals charged with the task of undertaking the physical movement of the saint's bones, but also for all members of the associated ecclesiastical community. The monks who were chosen to translate the remains of *Thomas Becket* at *Canterbury* in 1173 were selected due to their holy and untainted lives (Nilson, 1998, p. 14, 27). These monks then handed each bone removed from *Thomas*' grave to the archbishop, who himself placed them in a wooden box (Nilson, 1998, p. 29). The bones of King *Oswald* of *Northumbria* were translated from *Shropshire* to *Bardney* after his death in 642, where the bones were "placed in the church with fitting honours" (Colgrave & Mynors, 1969, p. 247). Bishop *Fursey*, who died in *Latiniacum*, France in 633, was also translated to a chapel within his church at *Péronne*, France "with all due honour" (Colgrave & Mynors, 1969, p. 277). St. *Alchmund* of *Hexham*, who died in 781, supposedly appeared in a vision to Bishop *Eadmond* between 1020 and 1041, requesting that his bones and those of Bishop *Acca* be translated "to a more honourable position within the Church" at *Hexham*, Northumberland (Battiscombe, 1959, p. 40). *Wilfrid* died in *Oundle* in 709 (Farmer, 2004, p. 180). When his body was translated to *Ripon* by a number of abbots, they chanted on the journey, and "The community came out with the holy relics to honour the cortège" (Farmer, 2004, p. 181). *Wilfrid* was subsequently "buried with all honour", or "with the honour befitting so great a bishop" (Farmer, 2004,

p. 181; Colgrave & Mynors, 1969, p. 517). When *Æthelthryth*'s body was translated in 660, the whole community of *Ely* was present. They are described as having stood around the grave as it was disinterred, chanting, "the brothers on one side and the sisters on the other" (Colgrave & Mynors, 1969, p. 395). This may be one form of "honours" or reverence which was bestowed on the deceased saints. Their resting place was dependent on their status as martyr, confessor or saint.

There is no actual evidence about how the remains ended up in the territory of the Cathedral of the Armenian Apostolic Orthodox Church. It is not impossible that the reburial of the remains in the tomb took place during the time of Gregory the Illuminator, under strict secrecy. Sacred relics have received special reverence in the regulations of the Armenian Church. Churches were later built on relic-bearing sites (Buzand, 1914).

The role of relics of saints in Medieval religion is essentially the only post-depositional practice that has been extensively investigated to date. The ideological importance of relics to Medieval lay and ecclesiastical society and their religious significance has been established (Cosgrave & Mynors, 1969; Crook, 2011; Neale & Webb, 1843; Nilson, 1998; Rollason, 1989).

Translations and elevations were the deliberate and intentional removal of a person's remains from their grave, in order to relocate those bones or preserved body to a church's interior, where they could be revered more appropriately in a sanctified location, as relics. This act represented the canonisation of the individual, which was the official recognition of that person being of saintly status. This act of disinterring a grave signifies the first incidence of structured post-depositional disturbance in relation to Christian practices. The act was an exclusive one; to be disinterred was a privilege reserved for only the most esteemed and worthy members of society. The miracles attributed to their skeletal material or preserved bodies were proof of a holy presence within the remains. The worship of these people, centuries after their death, combined with the continuous miraculous occurrences attributed to them, effectively made these people immortal.

This paper presents an analytical approach for the holistic investigation of white materials, salt crystals and fire exposure on human remains encountered in a burial context. Further genetic analyses will determine whose remains are located at the wall of the Cathedral of the Armenian Apostolic Orthodox Church.

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Appendix

Table A1: Individual measurements and indices of skull.

No by Martin and others		
1	Longitudinal diameter	181
8	Transversal diameter	140?
8:1	Skull indicator	77.35
17	Height diameter from base	135
17:1	Height-longitudinal indicator	74.59
17:8	Height-transversal indicator	96.43
20	Height diameter from po	124
20:1	Height-longitudinal indicator	68.51
20:8	Height-transversal indicator	88.58
5	Height of the skull base	102
9	The least width of the forehead	-
10	Maximum width of the forehead	118
11	Width of the skull base	129
12	Width of the nape	107.5
7	Length of the foramen magnum	39.7
16	Width of the foramen magnum	30.2
40	Length of the base of the face	95
40:5	Indicator of the relief of the face	93.14
45	Skull diameter	-
48	Upper height of the face	67
60	Length of the alveolar arc	55
61	Width of the alveolar arc	62.9
60:61	Alveolar arc indicator	87.45
62	Length of the palate	-
63	Width of the palate	37.5
63:62	Palatial indicator	-
55	Height of the nose	56
54	Width of the nose	-
54:55	Nasal indicator	-
51	Width of the orbit from mf	-
51a	Width of the orbit from d	-
52	Height of the orbit	36
71a	Smallest width of the lower jaw branch	34.5
69	Height of symphysis	29?
69 (1)	Height of the body	26.3
69 (2)	Thickness of the body	12.8

Table A2: Nonmetric cranial signs.

		Right	Left
1	Sutura frontalis	–	
2	Foramina supraorbitalia	–	–
3	Foramina frontalia	–	–
4	Spina trochlearis	–	–
5	Foramina infraorbitalia	+	X
6	Foramina zygomaticofacialia	–	X
7	Os zygomaticum bipartitum tripartitum	X	X
8	Spina processus frontalis ossis zugomatici	X	X
9	Stenocrotaphia	X	X
10	Processus frontalis squamae temporalis	X	X
11	Processus temporalis ossis frontalis	X	+
12	Os epiptericum	X	X
13	Os Wormii suturae squamosum	X	X
14	Os post squamosum	X	+
15	Os parietale bipartitum	–	–
16	Os Wormii suturae coronalis	–	–
17	Os bregmaticum	–	
18	Os Wormii suturae sagittalis	–	
19	Foramina parietalia	+	+
20	Os Incae completus	–	
21	Os triquetrum	–	
22	Os quadratum	–	
23	Os apices lambdae	+	
24	Os interparietales. sagittalis	–	
25	Processus interparietalis	–	
26	Os Wormii suturae lambdoidea	+	+
27	Sutura mendoza	–	–
28	Os asterion	–	–
29	Torus occipitalis (0-3)	2	
30	Os Wormiisut. occipitomastoideum	–	–
31	Foramina mastoidea on the seam	+	+
	offseam	+	+
32	Torus palatinus (0-3)	0	
33	Sutura palatine transversa (seam shape) U-shaped	+	
34	Sutura incisiva	–	
35	Foramen pterygospinosum	–	–
36	Canalis craniopharyngeus	+	
37	Foramina spinosum	–	–
38	Condylus occipitalis bipartitum	X	–
39	Processus paramastoideus	–	+
40	Manifestatio vertebrae occipitalis	–	–
41	Tuberculum praecondylare	X	
42	Canalis condyloideus	–	–

Table A3: Dental features of individual from Cathedral of the Armenian Apostolic Orthodox Church.

	Upper jaw **Vestibular-lingual diameter** **VLcor**
	Right
C	8.5?
P1	8.8?
M1	9.9
	Mesio-distal diameter **MDcor**
C	5.8
P1	6.7
M1	9
	Height of the crown **H cor**
M1	5.8
	Mesio-distal diameter of the cervix **MDcol**
M1	7.2
	Area of the cervix **MD × VL**
M1	57.42
	Index of the cervix **Icor (VL / MD) × 100**
M1	170.69
	Module of the cervix **mcor MD + VL /2**
M1	15.7

Table A4: Postcranial measurements of skeleton.

	Right	Left
Humerus		
4. Maximal midshaft breadth	66	X
5. Largest diameter Ø of the middle diaphysis	23	X
6. Smallest Ø of the middle diaphysis	20	X
7. Minimal midshaft breadth	65	X
7a. Midshaft circumference	67	X
7:1 Robusticity index	X	X
6:5 Cross-section index	86.96	X
Ulna		
11. Sagittal diameter	14	14.1
12. Transverse diameter	17	16
13. Upper transverse diameter	19	19.2
14. Upper sagittal diameter	25.5	26
3. Minimal shaft circumference	X	X
3:2 Robusticity index	X	X
11:12 Cross-section index	82.4	88.2
13:14 Platyleny index	74.6	73.3
Femur		
1. Maximal length	440	X
2. Natural length	429	X
6. Sagittal diameter of midshaft	33	31.3
7. Transverse midshaft diameter	31.2	31
9. Upper transverse shaft diameter	34	X
10. Upper sagittal shaft diameter	25.8	X
8. Midshaft circumference	101.2	100
8:2 Robusticity index	23.6	X
6:7 Pilastry index	105.77	100.91
10:9 Platymery index	75.9	X
Tibia		
8. Sagittal diameter at midshaft level	36.5	X
8a. Sagittal diameter at the nutrient foramen level	37	X
9. Transverse diameter at midshaft level	26.8	X
9a. Transverse diameter at the nutrient foramen level	27.8	X
10. Midshaft circumference	107	X
10b. Minimal shaft circumference	86	X
9:8 Cross-section index	73.5	X
10b:1 Robusticity index	X	X
9a:8a Cross-section index	73.2	X
10:1 Robusticity index	X	X

Table A5: The recording system for musculoskeletal stress.

	Right	Left	Average
Humerus			
Crista tuberculi minoris, crista tuberculi majoris	X	X	X
Tuberositas deltoidea	X	1.5	X
Tuberculum majus, tuberculum minus	X	X	X
Margi lateralis, medialis et anterior Epicondili lateralis et medialis	1.5	1.5	1.5
Total	1.5	1.5	1.5
Radius			
Tuberositas radii	3	2.5	2.75
Margo unterossea	2	X	X
Sulcus musculi flexoris halluces	X	X	X
Processus styloideus	X	X	X
Total	2.5	2.5	2.5
Ulna			
Margo interossea, margo posterior	2	2	2
Crista musculi supinatoris	1.5	1.5	1.5
Tuberositas ulnae	2	2	2
Total	1.84	1.84	1.84
Femur			
Trochanter major	2.5	X	X
Trochanter minor	2	X	X
Tuberositas glutea	2.5	3	2.75
Linea aspera	3	3	3
Epicondili	2	X	X
Total	2.4	3	2.7
Tibia			
Tuberositas tibiae	2.5	X	X
Margo anterior, margo interossea	2.5	2	2.25
Linea m. solei, m. soleus	2	2	2
Sulcus musculi flexoris halluces	X	2	X
Total	2.34	2	2.17
Fibula			
Tuberositas tibiae	2	2	2

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Post-Graduation Experiences of Sub-Saharan African Graduates in the U.S.: Challenges and Opportunities

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Abstract

African students who move to the United States as international students and live in the host country post-graduation present an important case study for policy makers and support networks to understand their lived experiences and their societal integration as working professionals. This article explores the experiences of Sub-Saharan African international students, specifically South Africans, Kenyans, and Nigerians, who pursued their studies in the US and upon completion of their studies decided to remain at their place of destination. Mixed-methods research was used to interview the participants and through coding, related themes were developed regarding their time as migrants post-graduation. The findings demonstrated that 82.1 % of respondents had a positive experience. They believed that deciding to remain in the US after completing studies presented them with economic and personal growth opportunities. It was apparent that 53.1 % gained employment in line with their academic qualifications. Despite professional gains, social challenges existed with 19.6 % of participants reporting feelings of loneliness. This paper thus suggests comprehensive support services, such as psychosocial facilities to assist these African graduates navigate the transition from international students to residents.

Keywords: International migration, Student mobility, Globalization of education, African graduates, Study abroad

1 Background of the Study

In a world of expanding global corporate collaborations and transnational social networks, opportunities for internationally educated professionals have dramatically increased in the last thirty years. This reflects both the incentives for these professionals to migrate and their increasing demand for their specialised skills in the host countries. Globalisation of education has resulted in increased mobility of students in the quest to exploit new educational opportunities. International students' mobility is an important channel through which high-skilled immigrants arrive (Suter & Jandl, 2006), and it is particularly attractive in view of the high integration potential of high-skilled graduates (Chiswick & Miller, 2011; Kahanec & Králiková, 2012).

In this perspective, the rise of international student mobility is driven by an increased demand for technical, specialized, post-secondary education that prompts students to go abroad in search of educational opportunities that are better than those available to them in their home country (Shield, 2013:2). Several studies have examined the reasons why students decide to study abroad and how they choose their destination country, using frameworks like the push-pull factor theory (Lisana, 2023; Mazzarol & Soutar, 2002). Pull factors such as education quality, and push factors such as limited job opportunities in both the host and home countries, influence the decision to study abroad. Yılmaz and Temizkan (2022) add that improved education, immigration opportunities, job prospects and cultural understanding are among the key reasons for studying abroad.

Different issues are responsible for the push and pull factors that induce people to move. Among push factors, Bernini et al. (2024) have noted impaired wellbeing occasioned by mismanagement of state resources. This has aggravated the poor condition of services, low wages or salary, misplacement of talent, human rights abuses, underemployment and poverty, which pushed most migrant postgraduate students out of their countries to secure employment abroad after completion of their studies (Benfifi, 2025; Reissová et

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al., 2024). Other push factors include political instability, lack of research facilities, inefficient institutions, disregard for local talent, discrimination in appointment and promotion, corruption, and limited access to quality education (Asiimwe & Musinguzi, 2024; Gomes, 2025). Economic or social factors that limit educational opportunity are particularly important push factors. In Africa, factors such as low level of economic development, political instability and religious or ethnic fractionalization, job opportunities in destination countries, selective immigration policies, wage gaps, geographical distance, former colonial links, and linguistic proximity between countries of origin and destination are the main factors driving highly skilled migration (Naval et al., 2024). These factors ultimately influence them to remain in their host country.

However, there is limited research on international students and their lived experiences post-graduation at their place of destination. Hence, the present research explores this topic and expands on the somewhat limited academic knowledge that currently exists on the actual experiences of foreign students, specifically South Africans, Kenyans and Nigerians in the US. It explores their lived experiences post-graduation broadly to add new insights through first-hand experiences of the sampled individuals, and to compare these with information gathered in the literature review. It is very crucial for policy makers and support networks to understand African graduates' experiences after they had decided to stay in the host country upon completion of their studies, as they present an important case study for policy makers and support networks to understand their lived experiences including societal integration and economic prospects.

Literature abounds on international student migration focused on well-known study destinations like USA, Canada, and UK. While international student migration is often viewed as a path for personal and professional growth, its broader implications remain a subject of debate. Some scholars see this type of migration as a post-colonial form of exploitation where rich countries disproportionately benefit from the skills and resources of economically disadvantaged countries by perpetuating global inequalities through brain drain. Conversely, other scholars characterise this kind of migration within the context of libertarianism or neoliberalism, emphasising that individuals are driven by personal choices and have the freedom to go wherever there are opportunities. These competing perspectives highlight the complexity of international migration, which has been characterised as a major propellant for global expansionism ranging from imperialism to neo-colonialism and neoliberalism (Pottie-Sherman, 2013; Thomas-Brown & Campos, 2016:115).

Massey (1988:383) indicates that some people leave their places of origin because their countries are poor, underdeveloped and consequently lacking in economic opportunity. They migrate to wealthy, developed nations to seek opportunities for employment at higher wages. Thus, growing social and economic inequalities between countries, and consequently unfulfilled life aspirations, trigger the migration intentions of millions, if not billions of people around the world (Czaika & Reinprecht, 2022). Kainth (2009) notes that some of the most important and frequently mentioned pull factors are better economic prospects, higher salary and income, better career expectations, better research facilities, a modern educational system, better opportunity from higher qualification, prestige of foreign training, intellectual freedom, better working conditions and better employment opportunities, relative political stability, presence of a rich scientific and cultural tradition, availability of experienced and supporting staff, technological gaps, and allocation of substantial funds for research.

Further, "employers in receiving countries take a different position; they have their own shortages of skilled people in specific fields and can drain a developing country of expertise by providing job opportunities" (Dodani & LaPorte, 2005). Conversely, better wages and employment conditions, better information, recruitment, and cheaper transportation are encouraging skilled migrants to seek jobs in developed economies (Lowell & Findlay, 2001). For example, "in a survey conducted by Ghana's Ministry of Health to establish trends and reasons for the loss of their doctors between 1969 and 1999, the most common reasons obtained include the search for better remuneration and conditions of service, better postgraduate training opportunities, and the desire to afford basic life amenities" (Dovlo & Nyonator, 1999). Ombogo (2023) corroborated the above assertions when he noted that brain drain occurs when skilled labour from developing countries (LDCs) migrate to developed countries (DCs) in search of better living standards, professional growth, political stability, and security.

In a study about the dynamics of student mobility, the international student's decision to stay after

graduation can be a complex and dynamic process that depends on many different factors. Migration involves a significant life change with challenges such as communication difficulties, limited resources, restricted access to health care, shattered families and social networks, and other associated changes in status and responsibilities (Ryan, 2011; Tol et al., 2013; Yeh et al., 2008). This point is reinforced by the qualitative study of "the lived experiences of migration" conducted by Demireva and Quassoli (2019), explaining that "mobility is a complex and dynamic process starting with the decisions that are made before and along the journey and proceeding with examination of the challenges to migrants' early adaptation, work and social integration, and the changes in their feelings of belonging and citizenship status." While push and pull factors such as recruitment strategies by employers in receiving countries, economic prospects, and career opportunities may attract Sub-Saharan African students, these factors do not fully capture the complexities of their experiences after graduation as they transition to residing in their host countries.

In exploring the lived experiences of migrants in their host countries, existing literature emphasises that they are faced with complex challenges and opportunities that shape the lived experiences of these individuals. For instance, a study by Rathakrishnan et al. (2021) reveals that many immigrants experience a sense of isolation and homesickness, heightened by the pressures of adapting to a new culture and workforce. Also, Rathakrishnan et al. explain that "homesickness has some significant negative influence on students' academic performance, living quality, and psychological well-being." Moreover, the research studies have shown that most of the time, migration raises the vulnerability to mental health complications due to feelings of insecurity and non-availability of their own community members. This can lead to distress and would turn into mental health consequences or other forms of health complications (Virupaksha et al., 2014:238). Similarly, International Organisation of Migration (2004) postulate that although migration does not necessarily threaten mental health, it may create a specific psychosocial vulnerability and, as a result, mental health can be affected when these pressures are combined with other risk factors. For instance, in the post-migration phase, highly skilled migrants may experience mental ill health, especially if they do not feel valued; feel overqualified for the jobs they are doing; and if they experience a discrepancy between aspirations and achievement (Ventriglio et al., 2021). Although challenges encountered by migrants can lead to mental distress, these challenges are not universal. Rather, they depend on factors such as social support networks, integration policies, and personal resilience.

In "Immigrating to North America: The Kenyan immigrant's experience", Kabuiku (2017) notes that African immigrants experience acculturation stress when trying to integrate successfully into the community in the host country. African immigrant professionals come with high expectations for both their professional and personal lives. This stems from the workplace demands, some of which they might not be accustomed to, as well as external pressures such as familial commitments, insufficient material possessions, and uncertain social status (Kabuiku, 2017). Many immigrants, for instance, come with high expectations, ranging from social mobility, career advancement, high income and improved living standards, to professional recognition and respect, as well as a better work-life balance, and so forth. However, these expectations are often met with challenges such as job market saturation, underemployment, and cultural differences in workplace dynamics. The ability to effectively integrate into a new work community is determined by the activities that are pursued and the immigrant support systems to make the African immigrant feel at home (Kabuiku, 2017).

Studies have shown social support to be an important moderator of stress relief and coping with poor health outcomes, while insufficient social support is associated with reduced quality of life (Centers for Disease Control and Prevention, 2005; Kong et.al., 2021). Wong and Leung (2008) and Mosher et al. (2009) explain that social support is an important factor influencing the health of migrant workers. Good social support often plays a positive role in promoting or protecting their physical and mental health, and can also significantly alleviate migration related stress. Otherwise, the process of adjusting to a new work environment or culture without robust support networks can be overwhelming and increase acculturative stress.

Nonetheless, a study conducted by Kirmayer et al. (2011) shows that although migration poses specific stresses, most immigrants cope well with the transitions of resettlement. Furthermore, van Horne et al. (2018) revealed that migrants in the United States consistently reported low levels of social satisfaction

and feelings of being welcome. This suggests that the issue goes beyond individual and support mechanisms. According to García-Ramírez et al. (2011), immigrants usually face conditions of asymmetrical intergroup relations and experience oppression because of the unjust socio-cultural conditions of host societies. For instance, "world wide data suggest that immigrants experience poorer working conditions and occupational health than native workers" (Damia-Martinez et.al., 2023:1; Sterud et al., 2018). These issues can negatively impact on individuals' well-being and contribute to stress.

Moreover, Mpofu and Hocking (2013) write that in Europe, immigrants experience occupational apartheid even when they do find jobs aligned with their education, experience inequalities in access to healthcare services (Lebano et al., 2020), and report lower life satisfaction than locals (Arpino & de Valk, 2018). Lee (2006) identified many examples of racial discrimination in the United States that relied on students' self-reported experiences. The author noted that most of the students from Asia, Africa, Latin America, and the Middle East experienced at least some discrimination, whereas none of the students from Europe, Canada, or Australia experienced any discrimination. However, it is important to note that the study did not objectively measure discriminatory practices. Lee (2006) labelled this discriminatory experience as neo-racism, or "new racism" based on factors such as cultural influence, economic power or global status. Further, "some studies such as the one conducted have identified that in certain developed countries executives are allegedly more racist when recruiting staff than their counterparts in some other countries" (ILO, 2001). For example, in one European study, 28 % of (non-EU) foreigners between the ages of 25 and 49 were unable to find work, the rates being as high as 35 % for Turks and Pakistanis and 60 % for recent immigrant groups such as the Somalis. (European Monitoring Centre on Racism and Xenophobia, 1999). In a similar vein, these statistics show the nature of discrimination but also highlight key regional differences. Thus, the data reinforce the structural dimension that certain immigrant groups experience significantly higher unemployment rates, a phenomenon that may be attributed to systemic biases rather than individual prejudice. This aligns with the concept of neo-racism, which posits that discrimination is associated with cultural and economic hierarchies rather than solely with racial categories.

Concerning wage discrimination, studies indicate that migrant workers often receive lower wages than native workers for the same kind of work, even when differences in education levels are taken into account (Hagen-Zanker, 2008). In support of the above views, Amo-Agyei (2020) mentions the "Report on the migrant pay gap: Understanding wage differences between migrants and nationals", which analyses wage data of 49 countries from the latest year available prior to the COVID-19 crisis. Amo-Agyei (2020) writes that "it shows evidence on how dire the situation actually is with regard to pay — so vital to the daily life of workers and their families". The report finds that in the years before the pandemic, wage inequalities between migrant workers and nationals were very high in many countries and widening in some. The International Labour Organization (ILO, 2020) reveals that "migrants earn nearly 13 % on average less than national workers in high-income countries". For example, "in some countries such as Cyprus, Italy, and Austria the pay gap in hourly wages is higher, at 42 % , 30 % and 25 % respectively." Another systematic review found that socio-economic difficulties such as low income, lack of social support, unemployment, and poor host language proficiency are associated with higher rates of depression (Akef et.al., 2024; Bogic et al., 2015). It should be noted that the studies primarily focused on low-skilled work where wage differences are evident. It is often challenging to analyse such inequalities among professionals due to lack of standard pay scales.

As immigrants navigate the challenges and opportunities after deciding to remain in their host country, they engage in a rational decision-making process based on a dynamic evaluation of the costs and benefits associated with their experiences. This assertion is supported by scholars in the social sciences asserting that "all action is fundamentally 'rational' in character and that people calculate the likely costs and benefits of any action before deciding what to do" (Scott, 2000). This approach is known as Rational Choice Theory. Rational Choice Theory (RCT) posits that these individuals go through a process in which they evaluate the potential costs and benefits related to each option. Rukema and Nkoko (2024:28) write that "the decision of immigrants to remain in the United States may be influenced by multiple determinants, including economic opportunities, career advancement, personal security, and opportunities that are not equally available in their countries of origin." For instance, when Sub-Saharan African immigrants move back to their countries,

this could lead to limited employment opportunities and low salary, whereas remaining in the United States would yield higher income and more employment opportunities (Rukema & Nkoko, 2024:28). Individuals move to another country with the expectation that it will improve their lives economically. Although non-financial reasons such as familial ties and lifestyle preferences play a significant role, RCT emphasises the monetary-related factors when analysing migration decisions. In the end, although immigrants face significant challenges in the host country, they remain in the US rather than returning to their home countries as they weigh their options and make decisions based on the long-term benefits and the relative advantages they perceive there.

2 Methodological Approach

This study used a sequential explanatory mixed methods design, consisting of quantitative and qualitative methods, in which the data was collected over a period of three months in two consecutive phases. This design, according to Cresswell and Plano Clark (2011), consists of first collecting quantitative data and then collecting qualitative data to help explain or elaborate on the quantitative results. A survey was administered first, followed by semi-structured interview. The rationale for this approach is that the quantitative data and results provide a general picture of the research problem. This is followed up by qualitative data collection to refine, extend, or explain the general picture (Subedi, 2016). Thus, in this study the researcher collected quantitative data and analysed it first which was the first phase. In the second phase, the qualitative data collection, participants were taken from the respondents in the quantitative part of the study.

2.1 Study Population

The target population consisted of individuals from Nigeria, Kenya and South Africa, including both female and male graduates holding master's or doctoral degrees from U.S. institutions. These individuals had chosen to remain in the United States following the completion of their studies. Included were Africans who had resided in the host country for a duration of one year or more post-graduation. The targeted sample size was 100 from each country, a total of 300 for collection of quantitative data. The sample size was constrained to this target number by limited time and financial resources to collect data from a geographically dispersed population. However, only 224 respondents participated: 59 from South Africa, 79 from Kenya, and 86 from Nigeria. Qualitative data collection included 21 respondents: 7 from South Africa, 7 from Kenya, and 7 from Nigeria. These were sent the online questionnaire.

The study employed a snowball procedure accompanied by purposive sampling. The researcher identified four individuals who met the criteria and were willing to participate. These individuals knew others who met the same criteria and assisted the researcher in locating them. These participants also referred the researcher to additional individuals, and so forth. Johnson (2014) supports this approach, stating that snowball sampling is a well-known, nonprobability method of survey sample selection that is commonly used to locate hidden populations. The method relies on referrals from initially sampled respondents to other persons believed to have the characteristic of interest. Because it was challenging to locate the sufficient participants, purposive sampling was used to find potential participants through internet recruitment. These participants were selected based on the established criteria.

For this research, the researcher collected two major kinds of primary data: a survey, and an interview questionnaire administered through virtual networking platforms namely Facebook, Twitter, and Instagram. These were the same platforms used to recruit research participants. Secondary data was collected from government publications, websites, books, journal articles, and internal records (Ajayi, 2017). In the quantitative online survey, a coded questionnaire was distributed to participants who had been identified as meeting the inclusion criteria. Additionally, the researcher collected qualitative data through an online questionnaire with a combination of open-ended and closed-ended questions. Data was collected over a period of three months in two consecutive phases: quantitative data collection followed by qualitative data collection. To reduce the risk of biases, a pilot study was conducted before real data, both quantitative and qualitative, was collected. This was done to ensure that the questions asked were easy for the participants to understand and free of obvious biases and errors.

2.2 Analysis

In the first phase, quantitative data analysis was performed utilizing the Statistical Package for the Social Sciences (SPSS) software, version 26.0. The analysis encompassed both descriptive and inferential statistical methodologies. Descriptive statistics involved calculating frequencies, percentages, and measures of central tendency, specifically the mean. For inferential statistics, a one-sample t-test was employed to assess the significance of Likert Scale responses relative to the neutral point (test value = 3). The results of the quantitative analysis were systematically presented in tabular format. In the second phase, the researcher analysed data using a qualitative method known as conceptual analysis. This is a form of content analysis in eight steps: (1) deciding on the level of process of analysis; (2) deciding how many concepts to code for; (3) deciding whether to code the existence of a concept; (4) deciding how to distinguish among concepts; (5) developing rules for the coding texts; (6) deciding what to do with the irrelevant information; (7) coding texts; and (8) analysing results. The researcher analysed the qualitative data manually because there were only 21 respondents. The questionnaires were printed out and the researcher followed all the above steps of conceptual content analysis. In a nutshell, narrative theme analyses were employed to find major themes and patterns in the questionnaire by looking for similarities and differences among them. The themes were derived from the study's objectives.

2.3 Ethical Consideration

Prior to the initiation of the research thesis, the researcher secured a certificate of ethical clearance from the University of Kwa-Zulu Natal (UKZN) Ethics Committee, following an evaluation of the study materials and procedures for compliance with the institution's code of conduct. An informed consent form was provided to participants, allowing them to elect participation in the online survey and questionnaire, which was conducted on a voluntary basis. This form furnished potential participants with essential information, including the study's purpose, the estimated duration required to complete the questionnaire, and the contact information of both the supervisors and the researcher.

The principles of respondent confidentiality and anonymity were upheld. Confidentiality entails the implementation of safeguards to protect participants' privacy and their data from unauthorized access, use, disclosure, modification, loss and theft, while anonymity guarantees that the researcher and associated personnel will not have access to identifying information of participants at any time (Ryerson University, 2015). Consequently, participants were assured that the collected data would remain confidential and were informed of their right to discontinue participation at any point, for any reason. They were also made aware that they could withdraw their information by contacting the researcher. In instances where participants were identifiable, all identifying information was excluded from the final report. The researcher ensured that the data obtained through the online survey and questionnaire contained no identifying information. To mitigate potential threats to data privacy, appropriate measures were taken to protect this data. Following the collection and analysis, the data was securely stored on Google Drive, with access restricted to the researcher and the supervisor via a password-protected system. Lastly, the researcher acknowledged all sources utilized in the research, employing the Turnitin program to assess the similarity index.

3 Results

This section presents a comprehensive analysis and key findings about the experiences of Sub-Saharan African graduates who continued to live in the US upon completion of their studies. Both the quantitative and the qualitative data reveal a range of positive outcomes, including professional and personal growth, while also highlighting challenges such as cultural adjustment, perceived discrimination, and loneliness.

3.1 Respondents' Age, Gender, Race, Marital Status, and Home Country

Table 1 shows the demographics and general characteristics of the 224 respondents. The largest group, 45.5 % (36 Nigerians, 39 Kenyans and 27 South Africans) were aged 30-35 years. 25.9 % of the respondents consisting of 23 Nigerians, 20 Kenyans and 15 South Africans were aged 36-41 years, 8.9 % including 8 Nigerians, 7 Kenyans and 5 South Africans were aged 42-47 years, 1.8 % (3 Nigerians, 1 Kenyan) were

Table 1: Respondents' age, gender, race, marital status, and home country.

	Respondent's characteristics	Frequency	Percentage
Age			
	18-23	1	0.4%
	24-29	39	17.4%
	30-35	102	45.5%
	36-41	58	25.9%
	42-47	20	8.9%
	Above 47	4	1.8%
Gender			
	Male	106	47.3%
	Female	112	50.0%
	Prefer not to say	6	2.7%
Race			
	Black	206	92.0%
	White	14	6.2%
	Coloured	3	1.3%
	Indian	1	0.4%
Marital status			
	Single	128	57.1%
	Married	81	36.2%
	Divorced	15	6.7%
	Separated	0	0%
	Cohabiting	0	0%
	Other	0	0%
Home country			
	Nigeria	86	38.4%
	Kenya	79	35.3%
	South Africa	59	26.3%

aged above 47 years, and one South African respondent (0.4 % was in the 18-23 years age bracket. Half of the respondents comprising of 38 Nigerians, 46 Kenyans and 28 South Africans were female; 47.3 % (46 Nigerians, 30 Kenyans and 30 South Africans) were male, and 2.7 % of the participants (2 Nigerians, 3 Kenyans and 1 South African) did not reveal their gender.

Most of the respondents, 92.0 %, were of the black race including 85 Nigerians, 78 Kenyans and 43 South Africans. 6.2 % (1 Nigerian and 13 South Africans) were white, 1.3 % (3 South Africans) were coloured, and 0.4 % (1 Kenyan) Indian. The table also shows that 57.1 % of the participants were single. These included 46 Nigerians, 46 Kenyans and 36 South Africans. 36.2 % (35 Nigerians, 26 Kenyans, 20 South Africans) were married and 6.7 % (5 Nigerians, 7 Kenyans, 3 South Africans) were divorced. In every case, the home country indicated in Table 1 was also their nationality as indicated on their passport.

3.2 Respondents' Educational Degrees

Table 2 shows the respondents' educational degrees. Most of the respondents, 63.4 % (67 Nigerians, 57 Kenyans and 18 South Africans) had earned a bachelor's degree only from their home country, 20.0 % (18 Nigerians, 22 Kenyans and 5 South Africans) had earned a bachelor's and master's degree, 13.4 % (30

Table 2: Respondent's qualifications earned in home country and abroad (U.S).

	Response	Frequency	Percentage
Qualifications earned from home country			
	Bachelors	142	63.4%
	Honors	0	0%
	Masters	0	0%
	Doctorate	0	0%
	Bachelors and Honors	30	13.4%
	Bachelors and Masters	45	20.0%
	Bachelors, Honors and Masters	7	3.1%
	Bachelors, Honors, Masters, and Doctorate	0	0%
	Bachelors, Masters, and Doctorate	0	0%
Qualifications earned from US/Abroad			
	Bachelors	0	0%
	Honors	0	0%
	Masters	143	63.8%
	Doctorate	35	15.6%
	Bachelors and Masters	4	1.8%
	Bachelors, Masters, and Doctorate	3	1.3%
	Masters and Doctorate	39	17.4%

South Africans, 0 Nigerians, and 0 Kenyans) had earned a bachelors and honours qualifications, while 3.1 % (6 South Africans, 1 Nigerian and 0 Kenyan) had earned a bachelor's, honours and master's degree from their home country. The findings also show that 63.8 % (47 Nigerians, 50 Kenyans and 46 South Africans) earned a master's degree only from USA/abroad, 17.4 % comprising of 23 Nigerians, 11 Kenyans and 5 South Africans earned a master's and doctorate from USA, 15.6 % (12 Nigerians, 15 Kenyans, and 8 South Africans) earned a doctorate only from USA/abroad, 1.8 % (2 Nigerians, 2 Kenyans) earned bachelor's and master's from USA/abroad, and 1.3 % (2 Nigerians, 1 Kenyan) earned bachelor's, master's and doctorate from USA/abroad.

Examining the quantitative data, the age distribution of the respondents follows the general pattern of migration. Studies conducted in the field of migration point to the fact that most of those who migrate in search of economic opportunities are young. It is worth mentioning that there are many reasons to believe that when young people are confronted with challenges of unemployment, poverty and insecurity in their home country, the only remaining option for them is migration.

Analysing graduate migration and gender dynamics, it was interesting to find out that the number of females who decided to remain in the US was higher than that of males. This may show a new trend and a change in the nature of migration. Traditionally males were believed to be the more migratory sex because they were considered as the breadwinners of the family and those left behind. Furthermore, the findings of this study point to the fact that Nigeria is a big contributor to non-returning graduates. This can be explained by a number of factors. Nigeria is the most populous country in Africa, with a young age structure. In addition, Nigeria has one of the highest numbers of people living in extreme poverty in the world and high youth unemployment (Yeboua et al., 2024:7). South Africa seems to have a low rate of non-returning graduates. While economic opportunities for young people are scant, one possible reason for their return could be other commitments such as family or cultural connections that make coming back more appealing. The figures in Table 2 clearly indicate that participants have benefited from studying

abroad, with improved job opportunities in their country of origin. However, while higher qualification such as a master's degree is key, it is also important to remember that unemployment among graduates with master's degrees and/or doctorate is also growing in African countries. This may deter graduates from returning to their home country.

3.3 Respondents by Area of Specialisation

Table 3: Respondents by area of specialisation.

Area	Frequency	Percentage
Science	41	18.3%
Technology and Engineering (SET)	49	21.9%
Business and Economics	33	14.7%
Health and Medical Sciences	36	16.1%
Social Sciences and Humanities	65	29.0%

The findings in Table 3 demonstrate that 29.0 % consisting of 27 Nigerians, 25 Kenyans and 13 South Africans of the participants have specialized in social sciences and humanities, 21.9 % (21 Nigerians, 16 Kenyans and 12 South Africans) in technology and engineering (SET), 18.3 % (16 Nigerians, 13 Kenyans and 12 South Africans) in science, 16.1 % (13 Nigerians, 10 Kenyans and 13 South Africans) in health and medical sciences and 14.7 % (9 Nigerians, 15 Kenyans and 9 South Africans) in business and economics.

Examining the area of specialization of the respondents, the majority have qualifications in a specialized area with prospects of securing better job opportunity abroad. For instance, qualifications in fields such as health, technology, business, and economics (but not social sciences and humanities) can secure job opportunities in a developed country like the US.

3.4 Respondents' Experiences After Deciding to Remain Abroad

Table 4: Respondent's experiences after deciding to remain abroad upon completion of studies.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I get jobs related to my academic qualifications	119 (53.1%)	7 (3.1%)	20 (8.9%)	13 (5.8%)	65 (29.0%)
I feel lonely in host country	44 (19.6%)	20 (8.9%)	53 (23.7%)	5 (2.2%)	102 (45.5%)
I get better opportunities compared to my home country	184 (82.1%)	20 (8.9%)	9 (4.0%)	3 (1.3%)	8 (3.6%)
Easy access of information in host country	183 (81.7%)	14 (6.2%)	9 (4.0%)	0 (0.0%)	18 (8.0%)
I have a lot of stress in host country compared to when I am in my country	65 (29.0%)	37 (16.5%)	72 (32.1%)	7 (3.1%)	43 (19.2%)
I feel happier in my host country	74 (33.0%)	41 (18.3%)	89 (39.7%)	4 (1.8%)	16 (7.1%)

According to the findings, 56.2 % (50 Nigerians, 37 Kenyans and 39 South Africans) of respondents agreed that they get jobs related to their academic qualifications, while 34.8 % (28 Nigerians, 34 Kenyans and 16 South Africans) disagreed. Additionally, 91.0 % of participants (75 Nigerians, 75 Kenyans and 54 South Africans) felt they had better opportunities compared to their home country, with only 4.9 % (8 Nigerians, 1 Kenyan and 2 South Africans) disagreeing. Regarding loneliness, 50.9 % (17 Nigerians, 20 Kenyans and 7 Nigerians) agreed that they feel lonely in the host country, while 47.7 % (31 Nigerians, 34

Kenyans and 37 South Africans) strongly disagreed. Further, the findings show that 32.1 % (35 Nigerians, 19 Kenyans and 18 South Africans) were neutral, 45.5 % (41 Nigerians, 46 Kenyans and 15 South Africans) agreed and 19.3 % (Nigerians, 13 Kenyans and 22 South Africans) disagreed that they have a much stress in the host country. Therefore, these results indicate that a significant number of respondents perceive the host country to be stressful while those who were neutral perhaps attribute stress to personal factors rather than being a characteristic of the host country. Also evident is that 51.3 % (43 Nigerians, 38 Kenyans and 34 South Africans) agreed and 8.9 % (8 Nigerians, 9 Kenyans and 3 South Africans) disagreed that they feel happier in their host country.

Examining participants' lived experience after deciding to stay in the US, it was evident that most of them had a good experience, and their expectations seemed to have been met. However, there were some who were not satisfied. The statements read:

> ***Respondent 17:*** *"I was offered a job after completing my studies and that was what I prayed for while studying for my degree. I didn't want to go home yet but also did not want to have any trouble with my visa. When they offered me a job, I was so grateful because it meant financial security and collaborating with many researchers in my field which is very important in academia" — Male, Nigeria*

> ***Respondent 6:*** *"It feels great to have a job that affords me the life I've always wanted. There are so many opportunities in the US if you go to the right places and seek them. Just like my home country, America has its own challenges, but I would rather be here for now and make more money while I still can than to be at home wondering if next month's expenses will be covered by my monthly salary." — Male South Africa*

> ***Respondent 7:*** *"Despite being financially stable, I love the fact that I have the freedom to be and live authentically without hiding who I am. I love socializing with like-minded people who create a safe space and embrace me" — Female, Kenya*

> ***Respondent 14:*** *"I miss home. Even though I have relatives to visit here, I miss my family, my mom, and siblings. I cry sometimes when I am alone because I know I can't board a plane and see them whenever I want. Life here can be lonely but most of us are here to improve our lives and that of our families". — Female, Kenya*

> ***Respondent 6:*** *"I have never lived in metropolis cities; I am a rural boy. After completing my studies, I got a job in a big city, and everything here is fast paced, and I am not used to this lifestyle. I prefer a quiet place and where I reside is a complete opposite, it's overwhelming me." — Male, South Africa*

> ***Respondent 12:*** *"Most of us know that America is diversified, multicultural and exceptional but being an African migrant living in America can be hard because they reduce you to the colour of your skin. It's a harsh reality but we are used to it. When you are Nigerian, it is even worse because everywhere we go in the world, they discriminate us based on our nationality, but we have to stay strong and continue to work hard because we are resilient" — Male, Nigeria*

> ***Respondent 13:*** *"I have been trying to get my husband to America for almost a year and 4 months, but the USCIS has been giving me the run around and COVID-19 slowed down the process. It was such a draining period for me because we have been far away from each other for a while but fortunately, he will be joining me soon." — Female, South Africa*

4 Discussion of the findings

Based on the quantitative data presented in Tables 1 to 4 and the qualitative results, a significant majority of respondents reported improved opportunities following their decision to remain in the United States.

The quantitative data includes statements such as, "I obtain jobs related to my academic qualifications", "I experience better opportunities compared to my home country", "I have easy access to information in the host country", "I encounter greater stress in the host country relative to my home country", and "I feel happier in my host country." These statements received substantial agreement or strong agreement from the respondents, indicating mainly positive experiences in the host country. Additionally, qualitative data analysis confirmed that respondents frequently emphasized better opportunities as their most notable experience, followed by higher salary than in their home countries,. One respondent also noted enhanced social life in the host country. Thus, it can be concluded that while it is possible that aspects like social life may be significant, professional opportunities and financial gains are prioritized.

In contrast, both quantitative and qualitative analyses revealed that respondents also faced negative experiences after opting to remain in the host country. Issues such as racism, loneliness, depression, challenges in cultural adaptation, and immigration-related concerns were reported by participants. The findings indicate a dichotomy in the experiences of migrants. Although many reported positive outcomes post-migration, including improved opportunities and salary, some respondents indicated that their employment did not align with their educational qualifications, leading to skill devaluation.

This observation corroborates prior observations by Siar (2013), who notes that even when the skills and education of highly skilled migrants are acknowledged, it is common for them to experience "deskilling" or to occupy positions significantly below their qualifications within the domestic labour market. Bauder (2003) asserts that "from a human rights perspective, deskilling constitutes a form of brain abuse." Moreover, deskilling not only incurs economic losses for migrants but also results in psychological and health issues, as migrants are not able to fully leverage their human capital (Siar, 2013). In terms of positive experiences, some participants noted a heightened sense of happiness compared to their circumstances in their home countries. This may be attributed to the possibility that some participants experienced unemployment prior to migration, leading to financial challenges and associated stress or unhappiness. In some cases, additional factors such as low wages and discrimination based on sexual orientation in the home country may have contributed to their struggles, thereby making life abroad seem more manageable.

On the negative side, respondents identified loneliness, stress, and difficulties in adapting to the host culture, with racism emerging as a particularly pronounced negative experience. This adds to much other research conducted in the United States, which examined the experiences of racism among Black Africans. It aligns with the findings of Boafo-Arthur (2014), who reviewed literature concerning the experiences of Black African immigrant students (BAIS) in U.S. higher education, identifying racial prejudice and discrimination as pivotal issues impacting their adjustment. The literature review indicates that Africans faced prejudice and discrimination based on their skin colour, culture, accent, and prevailing stereotypes related to their countries of origin, as reported by both local and other international students (including Black local students) (Zewolde, 2021: 14). However, Lee (2006) argues that this discriminatory experience be labelled as neo-racism, or "new racism" based on factors such as cultural influence, economic power or global status. Thus, this concept posits that discrimination is associated with cultural and economic hierarchies rather than solely with racial categories.

Furthermore, Berry (2017, cited in Albert, 2021) highlights that establishing new social ties in the host country is a fundamental task for immigrants during their socio-cultural and psychological adaptation process. Failure to forge connections within the host society can lead to social isolation and loneliness (Hurtado-de-Mendoza et al., 2014). Gitonga and Muthoni (2024) argues that loneliness can be exacerbated by factors such as rejection, discrimination, isolation, stereotyping, and micro-aggressions encountered within new communities.

5 Limitations and future work

The study used snowball sampling to recruit relevant participants. This could possibly introduce bias, as the study relies on referrals from individuals who may know each other, resulting in other members of the population not having an equal chance of being selected. While the study offers significant insights into post-graduation experiences of Sub-Saharan African graduates in the U.S., the use of snowball sampling

limits the generalizability of the results. In addition, the findings may not be applicable to all Sub-Saharan Africans specifically South Africans, Kenyans and Nigerians due to differences in backgrounds, visa statuses, resources, and support systems. Therefore, future research should utilize larger, more randomized samples. Although existing research on migration offers significant insights into the motivations driving Sub-Saharan graduates' decisions to migrate and pursue education abroad, as well as their lived experiences, there remains a substantial gap in the understanding of the challenges they face and the coping strategies they employ after opting to remain in the United States post-graduation.

6 Conclusions and recommendations

The experiences of Sub-Saharan African graduates who choose to remain in the U.S. post-graduation highlight a blend of opportunities and challenges. While many participants report major professional gains such as employment that aligns with what they have studied, and better financial opportunities, these achievements are often accompanied by personal and societal challenges. These challenges include loneliness, stress, difficulty adapting to the American culture, and encounters with racism. These results reveal the contrasting realities of their migration experience. They face systematic challenges in the host country but at the same time enjoy economic stability and personal gains that are unavailable in their home country.

Migrants mostly lack support and tend to struggle with their new social, economic and cultural surroundings. However, policies and government interventions of the host country sometimes overlook migrants' social integration. This paper advocates for comprehensive support services that address the different needs of immigrants transitioning from student to resident status in the U.S. These services may include psychosocial support that addresses stress caused by cultural adjustment, navigating the job market, and establishing social connections. Offering these services can help alleviate feelings of loneliness and stress related to adapting to a different culture. In addition, career counselling and community engagement programs may assist in creating a more inclusive environment that values the well-being of immigrants.

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Why Were the Yamnaya so Successful? An Evolutionary Polygenic Approach

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Abstract

Using ancient DNA from 414 Eurasian genomes and polygenic scores (PGS) derived from modern genome-wide association studies (GWAS), we investigate whether the *Yamnaya* and related Steppe populations exhibited genetic predispositions that may have contributed to their historical success. We calculated PGS for traits such as educational attainment (EA), height, cognitive function (IQ), skin pigmentation, and psychiatric conditions. To analyse temporal, geographic, and ancestry-specific effects, we employed Pearson's correlations, linear regression, and admixture modelling (ADMIXTURE). Our findings show that Steppe Pastoralist ancestry was linked to higher PGS for EA (β = 0.268), height (β = 0.234), and autism spectrum disorder (ASD) (β = 0.201), but lower PGS for depression and schizophrenia (β = -0.198 and -0.192, respectively). In contrast, Anatolian Farmer ancestry was associated with higher EA PGS (β = 0.391) but lower height PGS (β = -0.523). Temporal analyses revealed increases in EA (r = -0.215) and height (r = -0.194) PGS over time, consistent with previous evidence of directional selection in Europe over the past 12,000 years. Compared to ancient populations, modern Europeans from the 1000 Genomes project exhibit genetically lighter skin (lower skin colour PGS), higher EA and IQ PGS, but lower PGS for anxiety, schizophrenia, and depression.

Keywords: Ancient DNA; Polygenic scores; Yamnaya; GWAS

1 Introduction

The *Yamnaya* culture, originating in the Pontic-Caspian steppe around 3300 BCE, instigated one of the most profound demographic and cultural transformations in human prehistory (Anthony, 2007). Renowned for their rapid expansion across Eurasia, the *Yamnaya* disseminated not only their genes but also their (proto-)Indo-European language, which gave rise to the language family that now dominates from Europe to South Asia — a linguistic legacy underscoring their unparalleled demographic growth and likely military supremacy (Anthony, 2007; Haak et al., 2015; Kroonen et al., 2018). Their cultural innovations, including horseback riding and wheeled vehicles, facilitated their penetration into northern Europe by approximately 3000 BCE (5000 BP), followed by expansions into southern Europe and eastward across the Eurasian steppe to the Tarim Basin, Iranian Plateau, and ultimately India (Allentoft et al., 2015; Anthony, 2007). Contemporary populations bear witness to this enduring influence: modern Europeans derive up to 50 % of their genetic ancestry from *Yamnaya*-related groups, while South Asian populations retain 15–30 % (Haak et al., 2015; Lazaridis et al., 2016).

Despite extensive research on their migrations, the drivers of *Yamnaya* success remain contested. While scholars emphasize environmental factors, technological advancements, and pastoralist economies, the potential role of polygenic adaptation — selection acting on complex traits influenced by multiple genetic loci — remains underexamined. Did the *Yamnaya* possess genetic predispositions enhancing cognitive abilities, physical stature, or stress resilience that synergized with their cultural practices to fuel demographic dominance?

Recent advances in ancient DNA analysis and polygenic scoring (PGS) methodologies now enable direct investigation of this hypothesis. Contemporary studies have identified signatures of polygenic selection for traits including educational attainment, cognitive function, height, pigmentation, and psychiatric characteristics across European and East Asian populations (Piffer, 2025; Piffer & Kirkegaard, 2024).

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Notably, ancestry-specific polygenic score analyses in the UK Biobank revealed associations between ancient steppe ancestry and phenotypic traits such as height and mood regulation in modern British individuals (Irving-Pease et al., 2024). By aggregating effects of thousands of genetic variants, PGS offers unprecedented capacity to infer phenotypic tendencies in ancient groups.

In this study, we apply polygenic scores derived from genome-wide association studies (GWAS) in modern cohorts — including educational attainment, height, IQ, pigmentation, and psychiatric traits — to allele frequencies from 414 ancient Eurasian genomes spanning 6000–3000 years before present. These include key *Yamnaya*-associated populations from Russia, Ukraine, and Eastern Europe, supplemented by samples from the Middle East and Central Asia (Lazaridis et al., 2025; Nikitin et al., 2025). Integrating spatiotemporal mapping of sample locations (Natural Earth, 2024) and admixture modelling, we address four key questions:

Temporal dynamics: Did polygenic scores for adaptive traits shift significantly during the *Yamnaya* expansion, distinguishing them from preceding and contemporaneous populations?

Biogeographic influences: How did geographic parameters (latitude/longitude) and ancestral components (e.g., Steppe Pastoralist vs. Anatolian Farmer) shape these genetic predispositions?

Replication validity: Do ancestry-trait associations observed in modern British populations persist within ancient genomic datasets?

Evolutionary significance: Could polygenic adaptation have directly enhanced fitness or indirectly facilitated cultural transmission, thereby driving *Yamnaya* demographic success?

By interrogating these dimensions, we present the first comprehensive analysis of polygenic adaptation in a population that irrevocably shaped Eurasia's genetic and cultural landscapes.

2 Methods

2.1 Data sources

Polygenic scores (PGS) were calculated using the most recent and extensive GWAS for each trait. To filter variants, we applied clumping and thresholding (C+T) using PLINK 1.9 (Chang et al., 2015), setting a standard GWAS p-value threshold of $p < 5 \times 10^{-8}$ with a linkage disequilibrium (LD) of $r^2 < 0.1$. Allele frequencies were computed using PLINK 2.0 (Chang et al., 2020). The frequency files were loaded into R (version 4.4.1) (R Core Team, 2023) and merged with the GWAS summary files to compute the polygenic scores.

EA: We used PGS derived from two major European ancestry GWAS datasets: (1) The multi-trait analysis of European genome-wide association summary statistics, which includes years of education, cognitive performance, self-reported math ability, and highest math class taken, encompassing approximately 1.1 million individuals (Lee et al., 2018), referred to here as "EA3". (2) The largest European-based GWAS to date, involving about 3 million individuals (Okbay et al., 2022), referred to as "EA4". To enhance robustness and minimize error, we averaged EA3 and EA4, yielding a more stable indicator.

IQ: The most recent and largest GWAS of general cognitive function (Davies et al., 2018) identified 434 independent SNPs at $p < 5 \times 10^{-8}$.

Height: For height, we used the significant ($p < 5 \times 10^{-8}$) SNPs from the largest GWAS to date (Yengo et al., 2022), which comprised a multi-ancestry sample (after LD pruning with a threshold of $r^2 < 0.1$).

Schizophrenia (SCZ): A recent schizophrenia GWAS by Trubetskoy et al. (2022) identified 342 independent SNPs in a combined, multi-ancestry GWAS that were significant at a genome-wide level ($p < 5 \times 10^{-8}$) with a LD of $r^2 < 0.1$.

Autism spectrum disorder (ASD): The largest GWAS of ASD hampered (Grove et al., 2019), which identified 88 top loci, 69 of which had $p < 5 \times 10^{-8}$.

Depression: The most recent and extensive meta-analysis was used (Als et al., 2023). After executing C+T, 305 SNPs remained.

Anxiety: A recent GWAS of anxiety disorders based on a large (∼1.2 million) multi-ancestry sample identified 55 significant independent loci (Friligkou et al., 2024).

Skin colour-UKBB: We utilized the genome-wide association study (GWAS) on skin color from the pan-UKBB dataset (https://pan.ukbb.broadinstitute.org/GWAS; phenocode: 1717). After applying clumping and thresholding (C+T) for SNP selection, 1,323 SNPs remained.

Ancient genotype data, including allele frequencies and sample metadata (e.g., date, geographic coordinates, and population labels), were derived from published datasets from the European Nucleotide Archive (ENA) (2022) at the European Bioinformatics Institute (EBI) (https://www.ebi.ac.uk/ena) with the following accession numbers: PRJEB81468 and PRJEB81467. Merging the two datasets resulted in a sample of 414 ancient genomes. Modern population data from the 1000 Genomes Project (1KG) were included for comparative analysis.

2.2 Genome imputation

The ancient genomes were imputed using GLIMPSE2 (Rubinacci et al., 2023). This tool is at the forefront for imputing low coverage genomes, offering low error rates and consistent accuracy across both ancient and modern DNA samples (Sousa da Mota et al., 2023). 1000 Genomes Project phase3 was used as reference panel (http://ftp.1000genomes.ebi.ac.uk/vol1/ftp/release/20130502/). For this, raw sequence data in .bam format were processed to generate imputed genotypes. The imputation process aimed to infer missing genotypic information and provide a more comprehensive set of genetic variants for each individual. The output BCF files were then merged with BCFtools (Danecek et al., 2021).

2.3 Polygenic score calculation

Polygenic scores (PGS) for EA4 and EA3 were computed using GWAS-significant SNPs ($p < 5 \times 10^{-8}$). Allele frequencies from ancient and modern populations were matched to GWAS effect alleles. For each SNP, the genotype-phenotype effect (β) was multiplied by the allele frequency to calculate a genetic variant score (GVS). Mean GVS across SNPs was used as the individual-level PGS. A weighted average score combined EA4 and EA3 scores. Z-scores were generated to standardize PGS across populations.

2.4 Statistical analysis

Temporal trends in PGS were assessed using Pearson's correlation and loess regression. Population-level differences were evaluated via ANOVA and Tukey's Honest Significant Difference (HSD) test. These tests were limited to populations with sample size equal to or larger than 10. Linear regression modelled PGS as a function of date, latitude, longitude, and sequencing coverage. The R packages **dplyr**, **ggplot2**, **lawstat**, and **broom.mixed** were used for data manipulation, visualization, and statistical testing.

2.5 Admixture

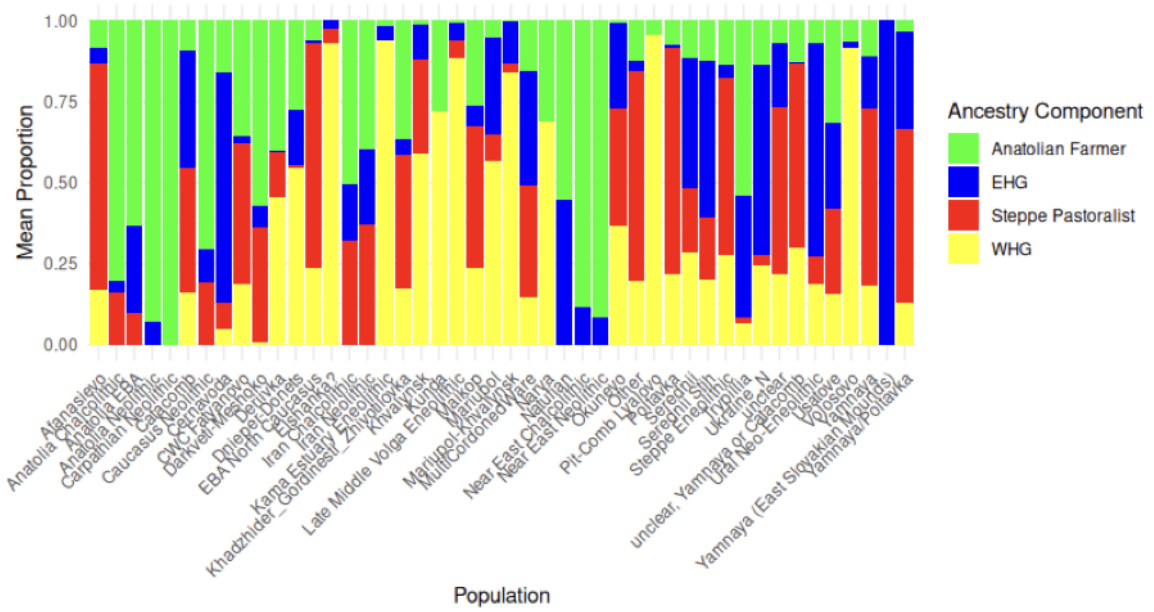
Admixture components for the samples were computed using ADMIXTURE software (Alexander et al., 2009), a powerful tool for estimating individual ancestries from multi-locus SNP genotype datasets. The ADMIXTURE analysis works by decomposing genotype data of each individual into fractions representing potential ancestral populations. Admixture data was merged with the PGS dataset in R by organizing individuals based on their sample identifiers.

3 Results

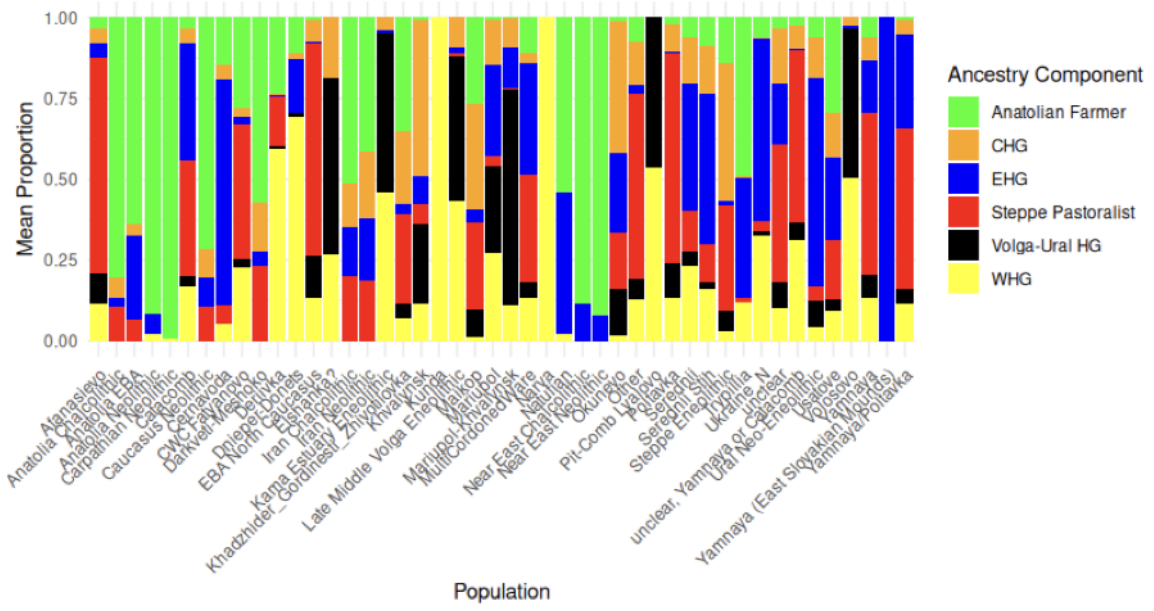
3.1 Admixture

The analysis explored various models, and the one with the lowest cross-validation (CV) error incorporated eight components. The four-component model exhibited the lowest CV error (0.524), suggesting that it most accurately captures the genetic structure of our dataset without overfitting. However, the Caucasus Hunter-Gatherer (CHG) component was absorbed by the Steppe Pastoralist component. Because the CHG component is prominent in the North Pontic Region (NPR), to have finer detail, we also used the six-component model, which included CHG besides an earlier Eastern Hunter-Gatherer (EHG) component which we called *Volga-Ural* hunter-gatherers.

Based on the distribution of these components among different cultural groups, we identified their most probable ancestral origins. The plots showing the distribution of the four and six components are shown in Figures 1a and 1b.



(a) Four ancestral clusters.



(b) Six ancestral clusters.

Figure 1: Admixture model with K = 4 and K = 6 ancestral clusters. EHG = Eastern Hunter-Gatherer, WHG = Western Hunter-Gatherer, CHG = Caucasus Hunter-Gatherer.

Figure 1. Admixture model with K = 4 and K = 6 ancestral clusters. EHG = Eastern Hunter-Gatherer, WHG = Western Hunter-Gatherer, CHG = Caucasus Hunter-Gatherer

3.2 Summary statistics

The dataset was summarized using key descriptive statistics to provide an overview of its temporal, coverage, and geographic characteristics. The chronological span of the data ranges from 3,275 to 12,700 years BP (before present), with an average of approximately 5,600. The average depth of coverage was 2.77, with

values ranging from 0.0028 to 20.26. Geographically, latitude spanned from 31.99° to 57.34°, with an average of 48.73°, indicating a predominantly mid-to-high latitude distribution. Similarly, the longitude values extended from 20.11° to 91.03°, with an average of 42.95°, approximately corresponding to the area between the *Volga* and the *Don* rivers. The locations of the samples are shown in Figure 2.

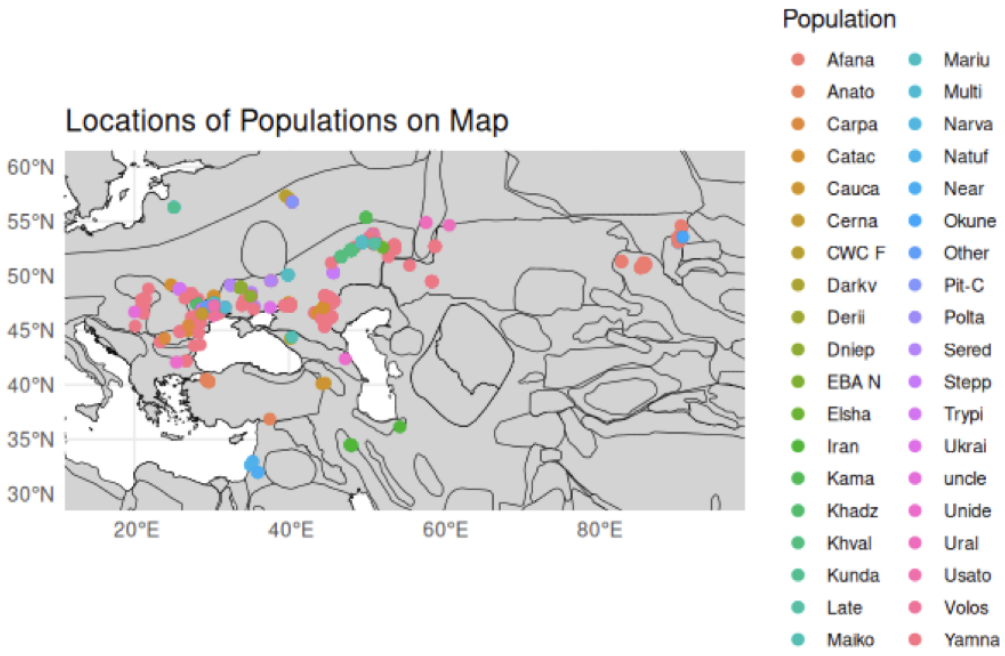


Figure 2: Location of samples. Afana = Afanasievo; Anato = Anatolia; Carpa = Carpathian; Catac = Catacomb; Cauca = Caucasus; Cerna = Cernavodă; CWC F = Corded Ware Culture Fatyanovo; Dark = Darkveti-Meshoko; Derii = Deriivka; Dniep = Dnieper-Donets; Eba N = Early Bronze Age North Caucasus; Elsha = Elshanka; Kama = Kama Estuary Eneolithic; Khadz = Khadzhider-Gordinesti-Zhivotilovka; Khval = Khvalynsk; Late = Late Middle Volga Eneolithic; Maiko = Maikop; Mariu = Mariupol; Multi = Multi Cordoned Ware; Natu = Natufian; Near = Near East; Okune = Okunevo; Pit-C = Pit-Comb Lyalovo; Polta = Poltavka; Sered = Serednii; Stepp = Steppe; Trypi = Trypillia; Ukrain = Ukraine; uncle = Unclear; Unide = Unidentified; Ural = Ural Neo-Eneolithic; Usato = Usatove; Volos = Volosovo; Yamna = Yamnaya.

3.3 Education analysis

3.3.1 Temporal trends in polygenic scores

A significant negative correlation was observed between educational attainment (EA) and age of the genome (r = -0.215, $p < .001$, N = 414), indicating lower EA scores in earlier populations (Figure 3). This trend persisted when restricting the analysis to populations <10,000 years BP (r = -0.230, $p < .001$, N = 412).

3.3.2 Population differences

ANOVA revealed significant variation in EA scores across populations ($F = 32.68$, $p < .001$). Tukey's HSD identified significantly lower scores in *Khvalynsk* (mean difference = -0.782, $p = 0.035$) and *Mariupol-Khvalynsk* (mean difference = -0.821, $p = .025$) compared to *Afanasievo*. Modern EUR populations in Thousand Genomes (1KG) showed higher scores than several ancient groups (e.g., EUR.1KG vs. *Khvalynsk*: mean difference = 1.085, $p < .001$). Modern EUR populations (1KG) had significantly higher EA scores than all ancient populations except *Afanasievo*, *Catacomb* and *Trypillia* (Figure 4). This suggests a gradual increase in EA-associated alleles over time, aligning with temporal trend results.

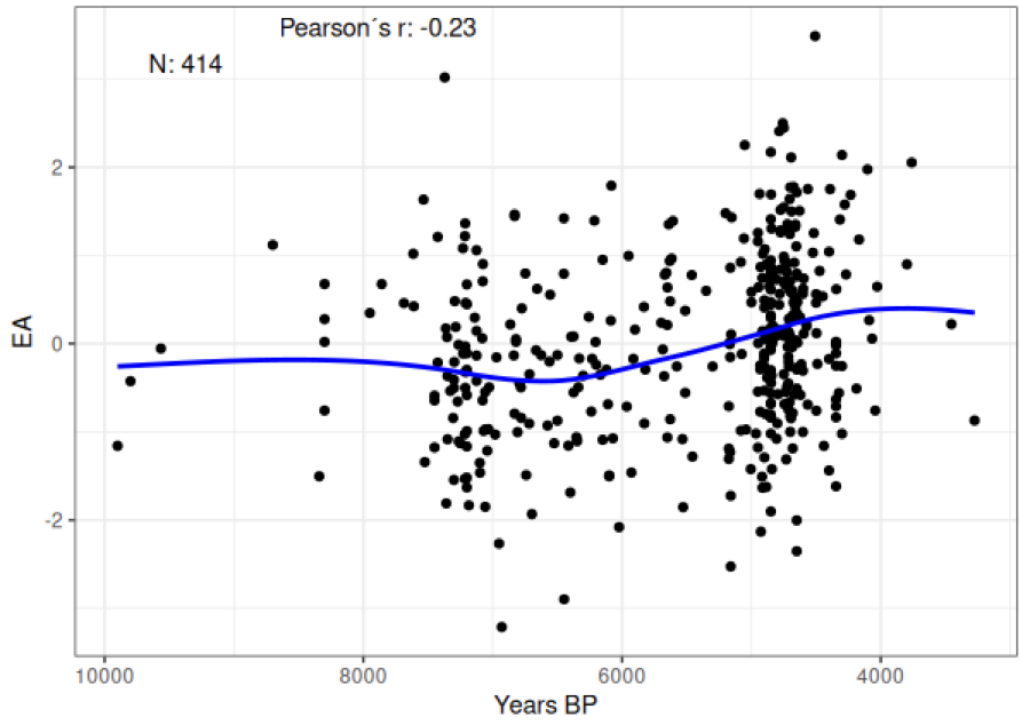


Figure 3: Time trend of educational attainment polygenic scores (EA), plotted against time before present (Years BP).

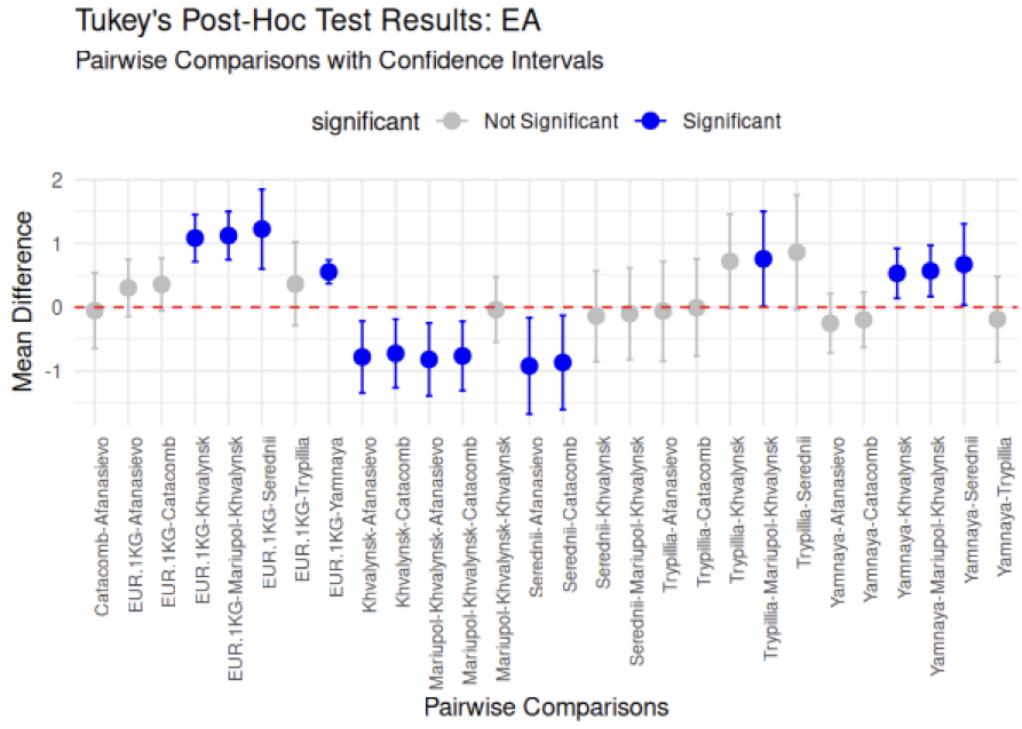


Figure 4: Tukey's post-hoc results: Educational attainment (EA).

3.3.3 Regression analysis

Linear regression analysis identified date (β = -0.237, $p < .001$) and latitude (β = -0.283, $p < .001$) as significant predictors of EA. Earlier populations from northern regions exhibited lower EA scores. In contrast, longitude and coverage were non-significant predictors ($p > .05$).

Subsequently, admixture components (N = 4) were incorporated into the regression model. As shown in Figure 5, time before present continued to exhibit a negative effect on EA (β = -0.161, p = .038). In contrast, Steppe Pastoralist ancestry (β = 0.268, p < .001) and Anatolian Farmer ancestry (β = 0.391, p < .001) had significant positive effects on EA.

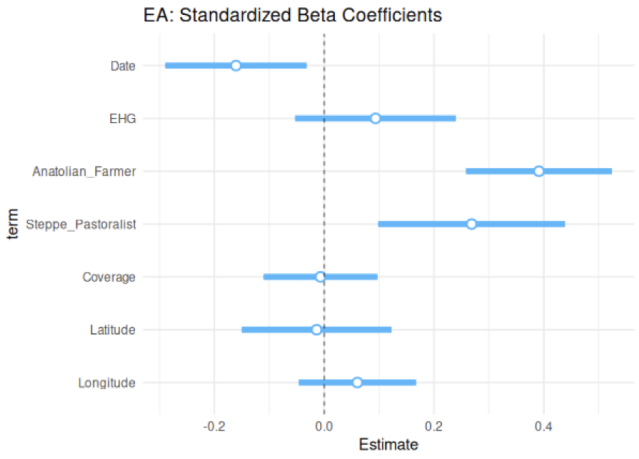


Figure 5: Effects of date, latitude, and admixture components on educational attainment (EA) polygenic scores.

3.4 IQ analysis

3.4.1 Temporal trends in polygenic scores

We observed a significant negative correlation between IQ PGS and time before present (r = -.109, p = .026, N = 414), indicating that earlier populations exhibit lower IQ PGS values. This relationship remained statistically significant when restricting the analysis to populations younger than 10,000 years before present (r = -.128, p < .001, N = 412) (Figure 6).

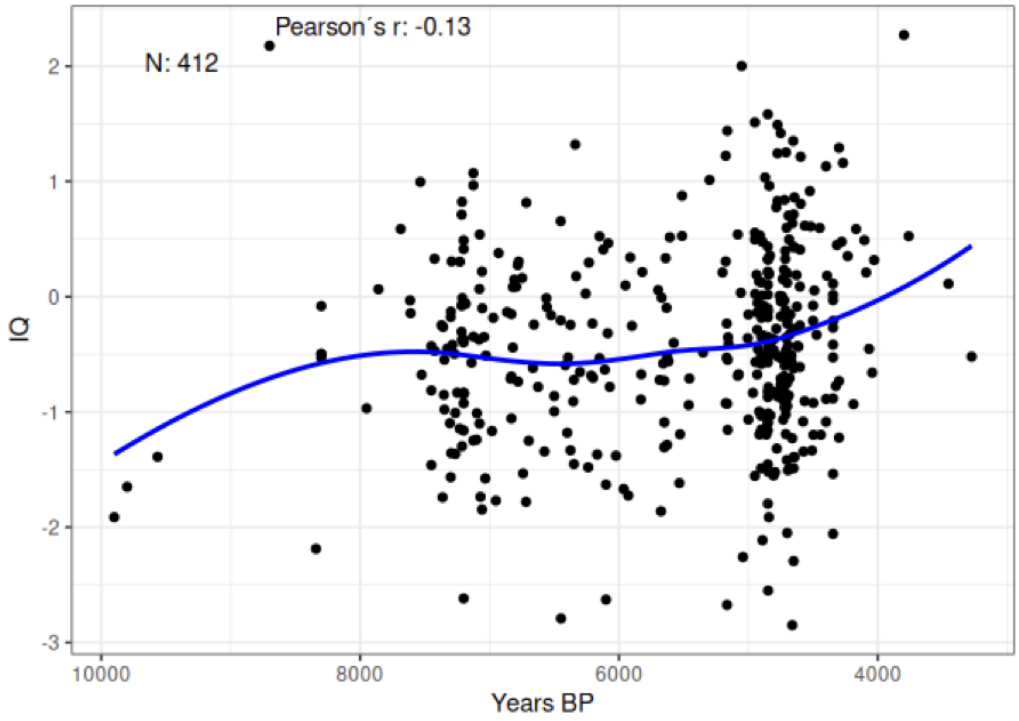


Figure 6: Correlation between years before present and IQ polygenic score.

3.4.2 Population differences

ANOVA revealed significant variation in IQ polygenic scores across populations ($F = 16.5$, $p < .001$). Tukey's HSD identified significantly lower scores in *Afanasievo*, *Khvalynsk*, *Mariupol-Khvalynsk*, *Serednii* and *Yamnaya* compared to EUR (mean differences = 0.680, $p = .020$; 0.814, $p < .001$; 0.827, $p < .001$; 0.900, $p < .001$; 0.712; $p < .001$) (Figure 7). These results suggest significant differences in IQ PGS between ancient and modern populations.

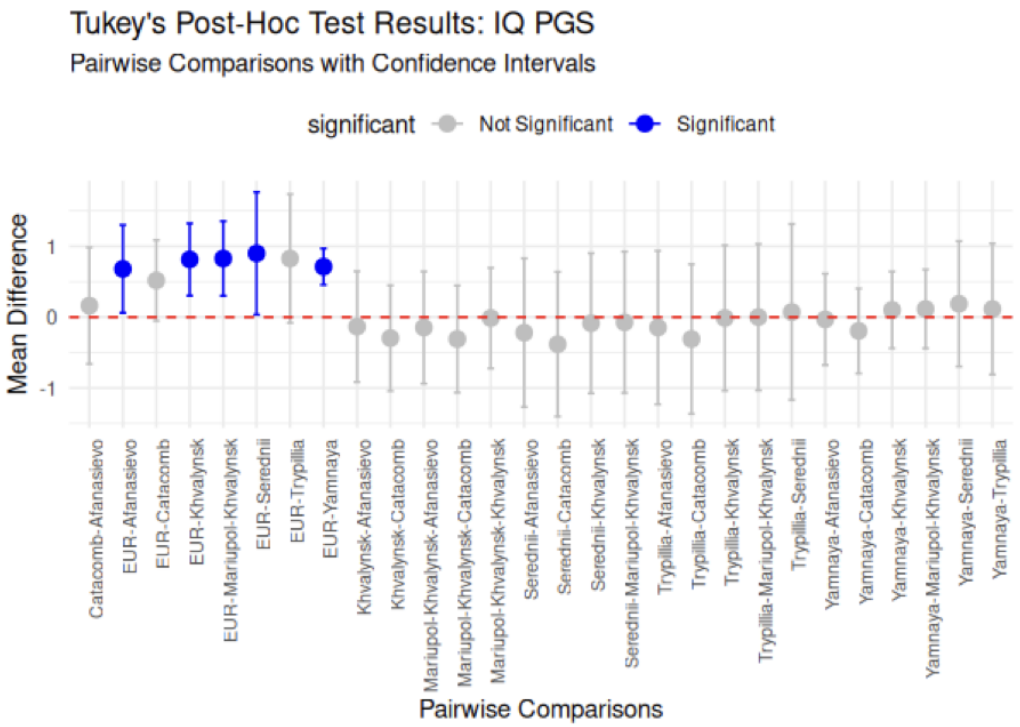


Figure 7: Tukey's post-hoc results: IQ polygenic score.

3.4.3 Regression analysis

Linear regression analysis identified date (β = -0.120, $p = .017$) and latitude (β = -0.172, $p = .002$) as significant predictors of IQ PGS, with earlier populations and those from higher latitudes exhibiting lower scores. In contrast, coverage was not a significant predictor ($p > .05$).

When admixture components were incorporated into the regression model, date no longer had a statistically significant negative effect on IQ PGS (β = -0.115, $p = .108$) although the sign of the effect was still negative indicating a trend for earlier populations to score lower, as shown in Figure 8. None of the ancestry components demonstrated significant effects on IQ PGS.

3.5 Height analysis

3.5.1 Temporal trends in polygenic scores

We observed a significant negative correlation between height polygenic scores (PGS) and years before present (r = -.194, $p < .001$, N = 412), indicating that earlier populations exhibit lower height PGS values. This relationship remained statistically significant when restricting the analysis to populations younger than 10,000 years before present (r = -.180, $p < .001$, N = 410) (Figure 9). Given the curvilinear nature of this temporal trend, we further subset the data to populations with $\geq$10 individuals and generated a color-coded scatterplot (Figure 9) to evaluate whether the pattern reflected differences in ethnic composition. Visual inspection revealed that the curvilinear trajectory was driven by the genetic ancestry of sampled groups: *Trypillia* individuals, who descend from Anatolian farming populations, displayed markedly lower Height PGS values than other groups. This disparity accounted for the observed downward slope in the temporal analysis, highlighting the influence of population structure on the correlation between Height PGS and age.

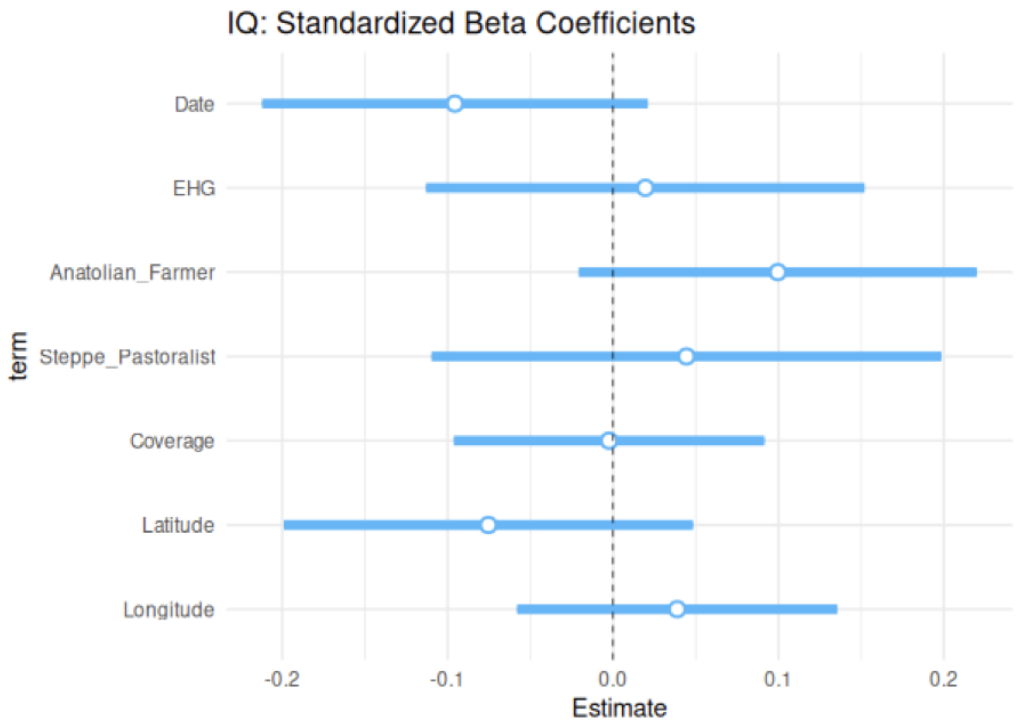


Figure 8: Effects of date, latitude, and admixture components on IQ PGS.

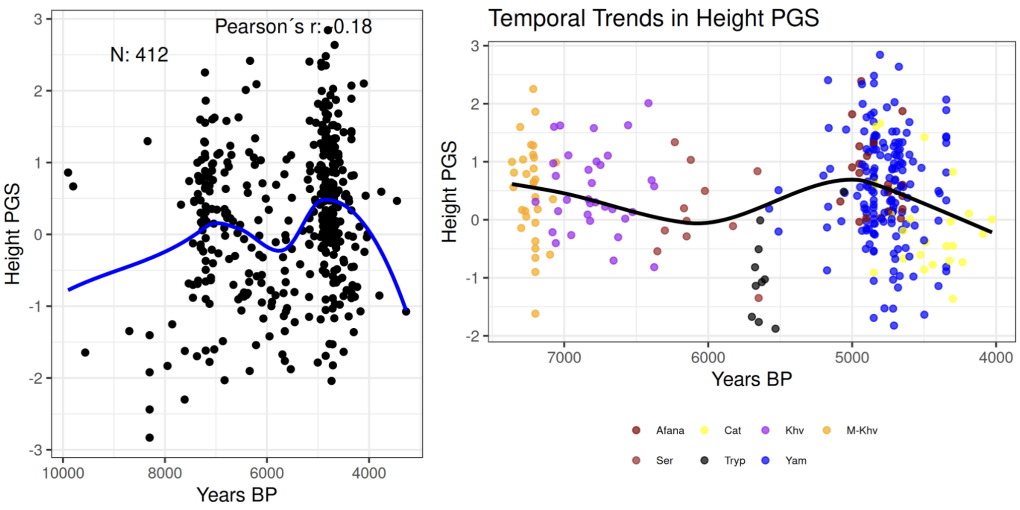


Figure 9: Correlation between years BP and height PGS. Afana = Afanasievo; Cat = Catacomb; Khv = Khvalynsk; M-Khv = Mariupol-Khvalynsk; Ser = Serednii; Tryp = Trypillian; Yam = Yamnaya.

3.5.2 Population differences

ANOVA revealed significant variation in height PGS across populations ($F = 17.23$, $p < .001$). Tukey's HSD identified significantly lower scores in *Trypillia* compared to *Afanasievo* (mean difference = -1.684, $p < .001$) and *Khvalynsk* (mean difference = -1.448, $p < .001$). Modern EUR populations showed significantly lower scores than *Afanasievo* (mean difference = -0.942, $p < .001$) and *Yamnaya* (mean difference = -0.729, $p < .001$). Additionally, *Trypillia* had significantly lower scores than *Yamnaya* (mean difference = 1.472, $p < .001$) (Figure 10). These results suggest significant differences in height PGS-associated alleles among ancient and modern populations.

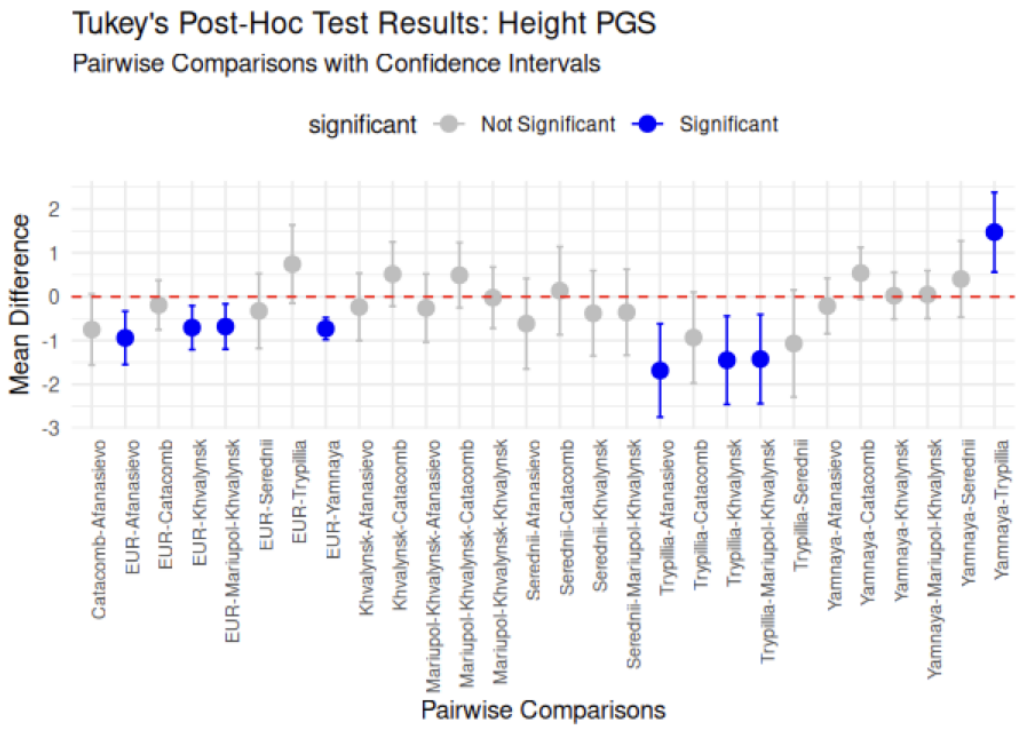


Figure 10: Tukey's post-hoc results: Height.

3.5.3 Regression analysis

Linear regression confirmed date (β = -0.186, $p < .001$), latitude (β = 0.186, $p < .001$) and longitude (β = 0.170, $p < .001$) as significant predictors of height PGS, with earlier, southern, and western populations exhibiting lower scores. Coverage was non-significant ($p > .05$).

Next, admixture components were added to the regression model. As illustrated in Figure 11, time before present no longer showed a significant negative effect on height PGS (β = 0.057, p = .294). However, Steppe Pastoralist ancestry had a significant positive effect on height PGS (β = 0.234, $p < .001$), while Anatolian Farmer and EHG ancestry exhibited significant negative effects (β = -0.523 and -0.358, respectively, $p < .001$). Coverage had a significant negative effect (β = -0.105, p = .017).

3.6 Schizophrenia

3.6.1 Temporal trends in polygenic scores

We observed a significant positive correlation between schizophrenia polygenic score (SCZ PGS) and years before present (r = .179, $p < .001$, N = 414), indicating that more ancient populations tended to exhibit higher SCZ PGS values. This relationship was almost identical when restricting the analysis to populations younger than 10,000 years before present (r = .183, $p < .001$, N = 412) (Figure 12).

3.6.2 Population differences

ANOVA indicated significant variation in SCZ polygenic scores (PGS) across populations (F = 8.975, $p < .001$). Post-hoc analysis using Tukey's HSD revealed that modern European (EUR) populations have significantly lower SCZ PGS than *Khvalynsk*, *Mariupol-Khvalynsk*, and *Yamnaya* (mean differences = -0.776, -1.111, and -0.274, with $p < .001$ and p = .034, respectively). Additionally, *Mariupol-Khvalynsk* exhibited higher SCZ PGS than both *Catacomb* and *Yamnaya* (mean differences = 0.943, p = .006 and 0.838, $p < .001$, respectively), as shown in Figure 13.

3.6.3 Regression analysis

Linear regression analysis revealed that years before present and latitude (β = 0.174 and 0.209, respectively, $p < .001$) were significant predictors of SCZ polygenic scores (PGS), with more ancient and more northern

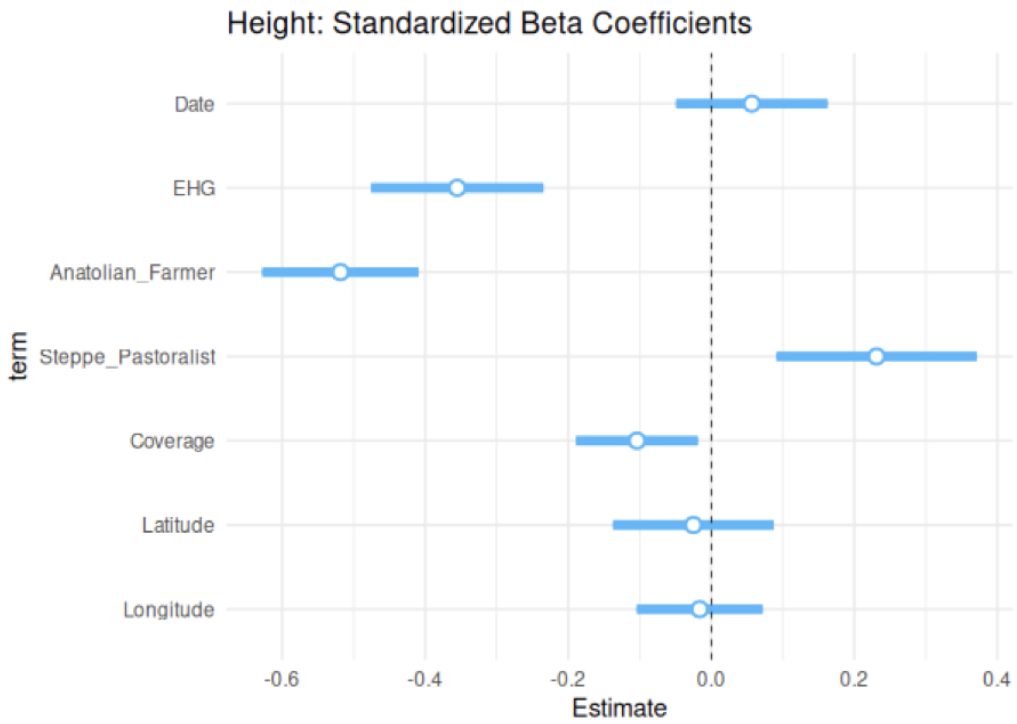


Figure 11: Effects of date, latitude, and admixture components on height PGS.

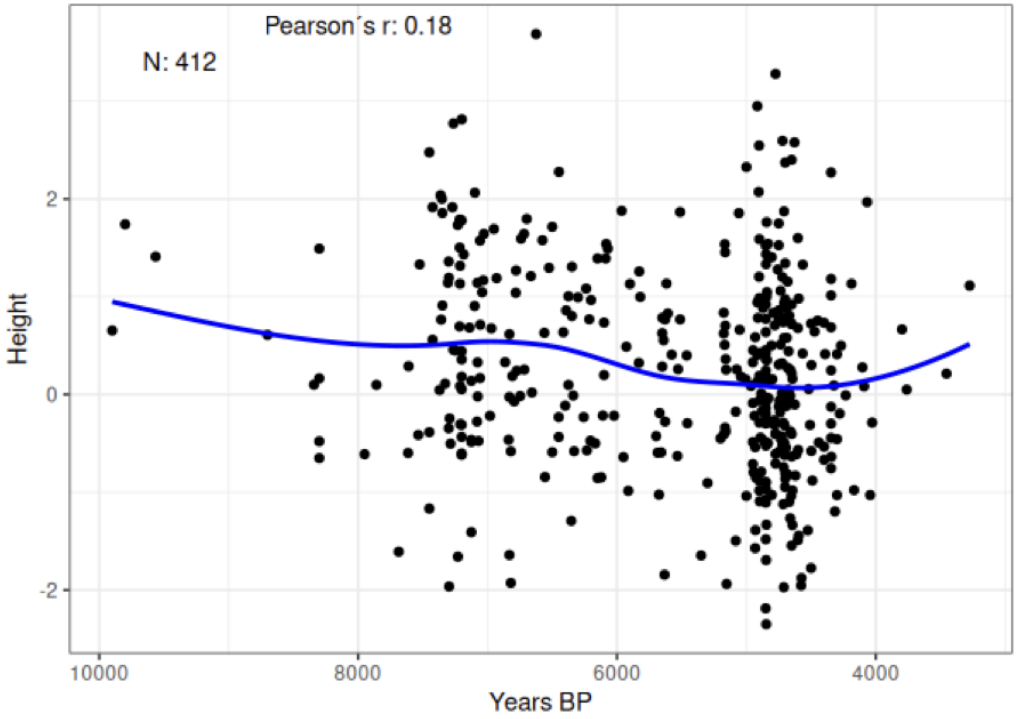


Figure 12: Correlation between years before present and schizophrenia polygenic score (SCZ PGS).

populations showing higher scores. Coverage also emerged as a significant predictor (β = 0.108, p = .027). However, when admixture components were included in the regression model, the previously observed positive effect of years before present on SCZ PGS became non-significant (β = 0.098, p = .143), as illustrated in Figure 14. Furthermore, EHG and Steppe Pastoralist ancestries were found to have negative associations with SCZ PGS (β = -0.365, $p < .001$ and β = -0.192, p = .031).

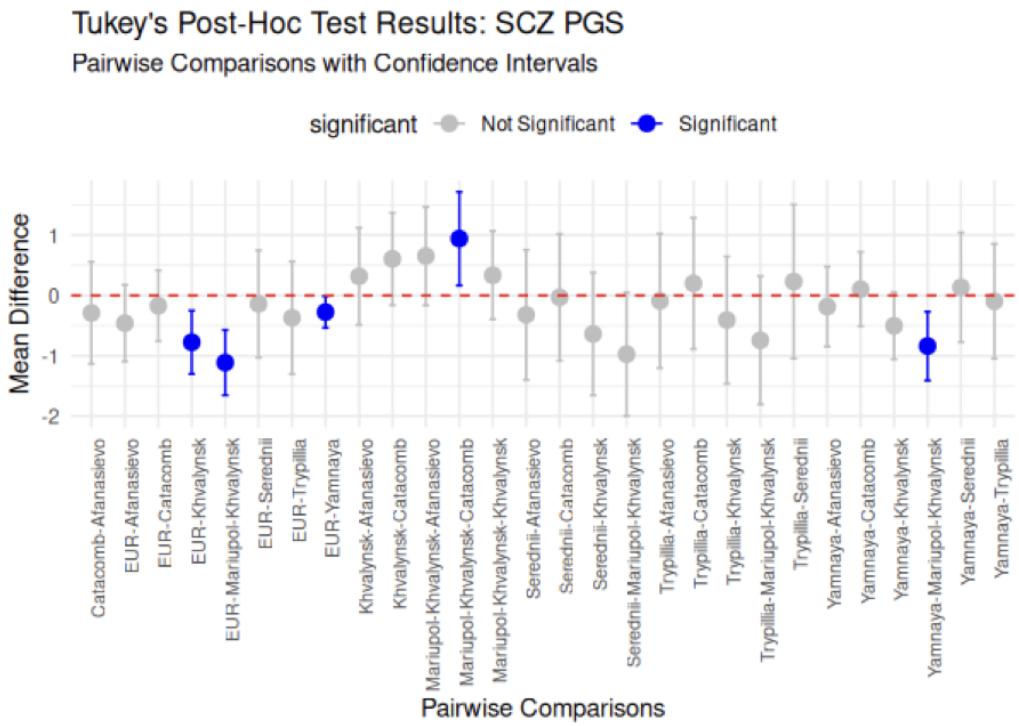


Figure 13: Tukey's post-hoc results: Schizophrenia polygenic score (SCZ PGS).

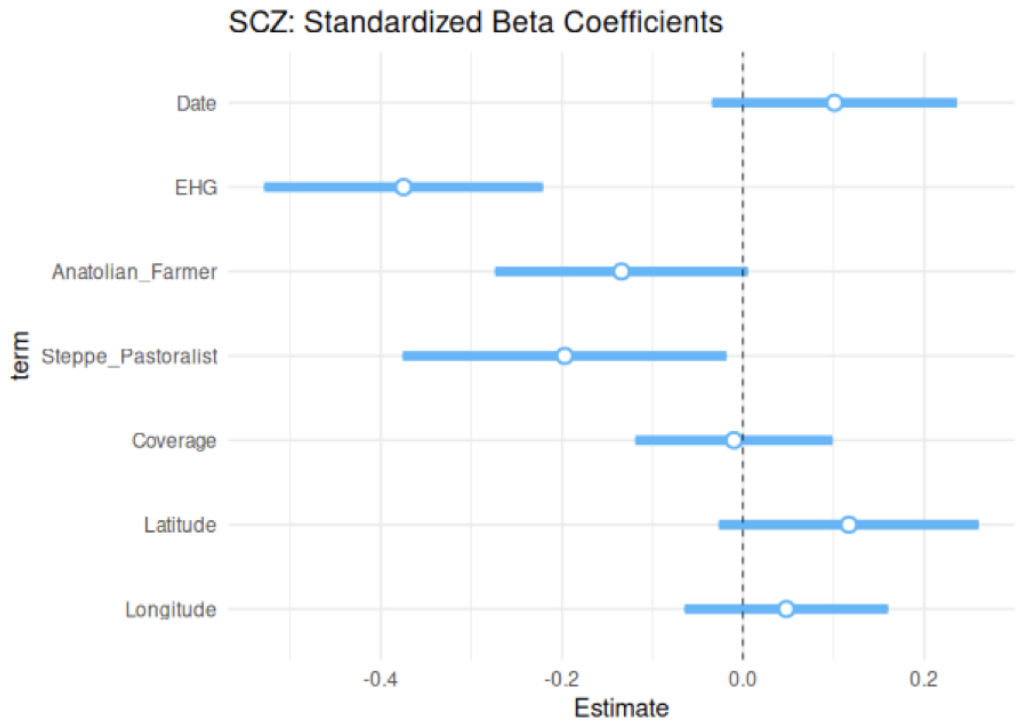


Figure 14: Effects of date (years before present), latitude, and admixture components on schizophrenia polygenic score (SCZ PGS).

3.7 Autism spectrum disorder (ASD)

3.7.1 Temporal trends in polygenic scores

We observed a negative correlation approaching significance between ASD PGS and years before present (r = -.093, p = .059, N = 414), indicating that earlier populations tended to exhibit lower ASD PGS values.

This relationship was weaker when the analysis was restricted to populations younger than 10,000 years before present (r = -.047, p = .336, N = 412) (Figure 15).

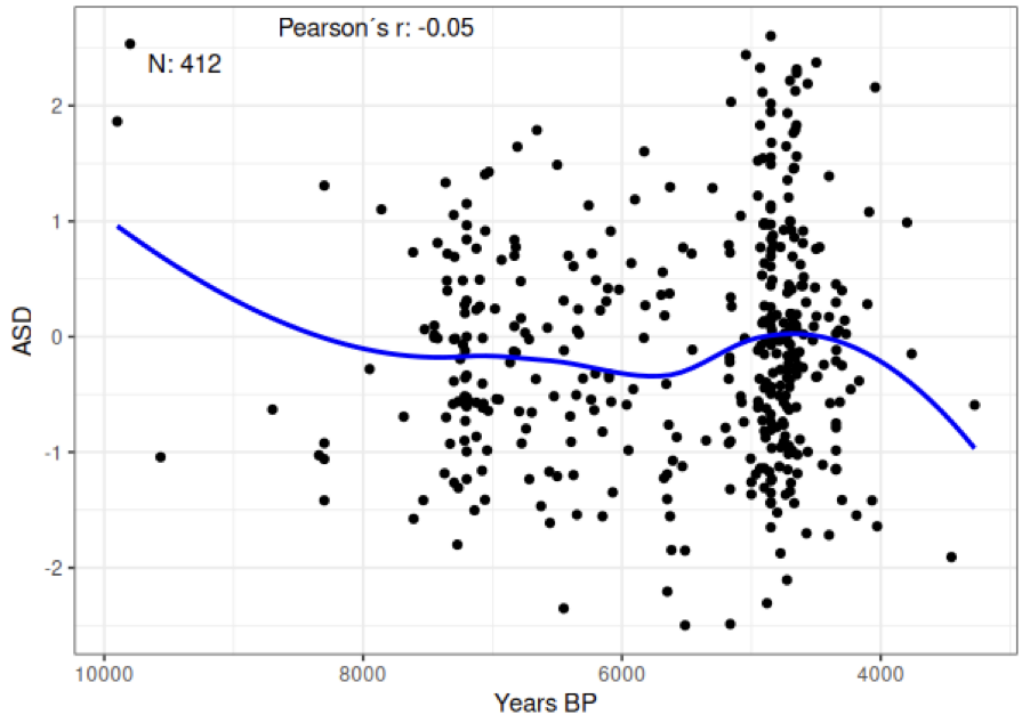


Figure 15: Correlation between years before present and autism spectrum disorder polygenic score (ASD PGS).

3.7.2 Population differences

ANOVA revealed non-significant variation in autism spectrum disorder polygenic scores (ASD PGS) across populations (F = 1.946, p = .060). Tukey's HSD identified significantly lower scores in *Trypillia* compared to EUR (mean differences = 1.028, p = .027) (Figure 16). These results suggest significant differences in ASD PGS between ancient and modern populations.

3.7.3 Regression analysis

Linear regression analysis revealed that time before present (β = -0.117, p = .019) was a significant predictor of ASD polygenic scores (PGS), with earlier populations showing lower scores. Coverage also emerged as a significant predictor (β = 0.145, p = .004). However, when admixture components were included in the regression model, the previously observed negative effect of time before present on ASD PGS became non-significant (β = 0.021, p = .759), as illustrated in Figure 17. Furthermore, EHG ancestry was found to have a negative association with ASD PGS (β = -0.176, p = .026), while Steppe Pastoralist ancestry showed a positive association (β = 0.201, p = .029).

3.8 Anxiety

3.8.1 Temporal trends in polygenic scores

There was no significant correlation between anxiety PGS and years before present in the full dataset and in the 10 Kya subsample (r = .028 and .014, p = .564 and .771, respectively) (Figure 18).

3.8.2 Population differences

ANOVA revealed significant variation in anxiety PGS across populations (F = 9.39, p < .001). Tukey's HSD identified significantly lower scores in EUR compared to *Afanasievo*, *Khvalynsk*, *Mariupol-Khvalynsk* and *Yamnaya* (mean differences = -0.872, -0.648, -0.717, -0.476, respectively, p < .001) (Figure 19). These results suggest significant differences in anxiety PGS between ancient and modern populations.

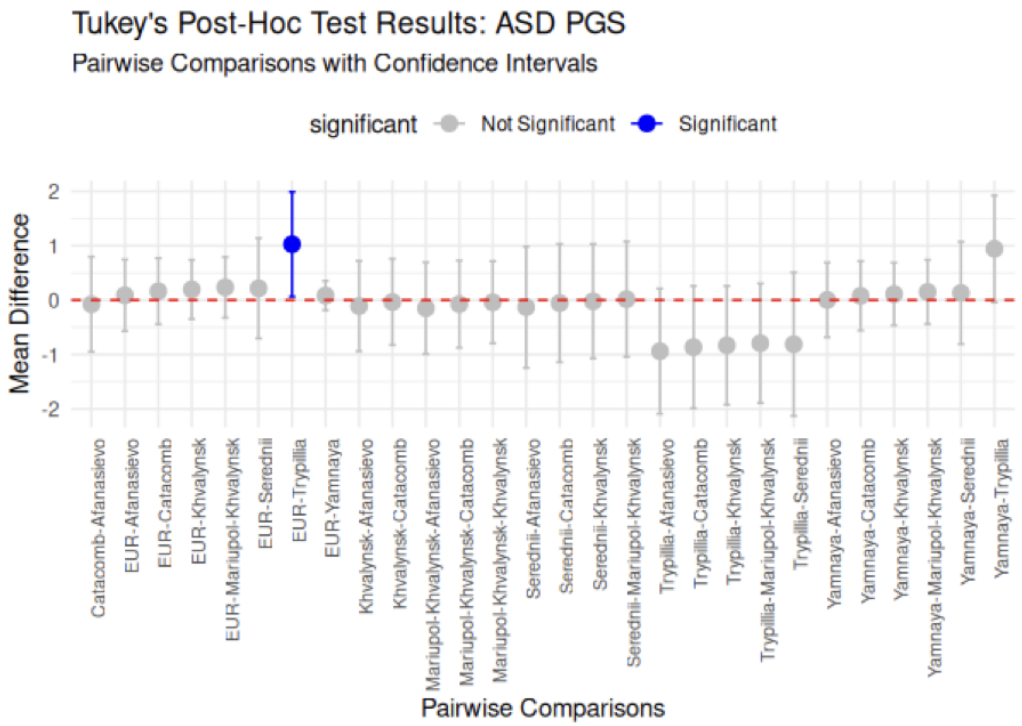


Figure 16: Tukey's post-hoc results: Autism spectrum disorder polygenic score (ASD PGS).

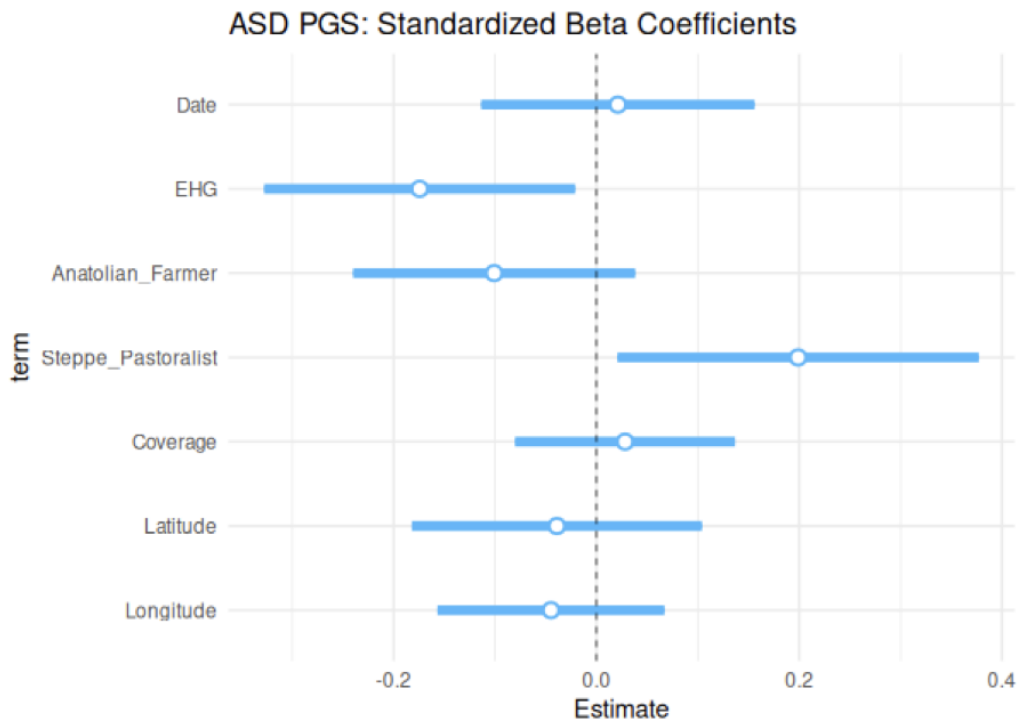


Figure 17: Effects of date (years before present), latitude, and admixture components on autism spectrum disorder polygenic score (ASD PGS).

3.8.3 Regression analysis

Linear regression analysis revealed that latitude ($\beta = 0.176$, $p = .002$) was a significant predictor of anxiety PGS. When admixture components were included in the regression model, EHG ancestry was found to have a positive association with anxiety PGS ($\beta = 0.176$, $p = .029$), while the other ancestry components did

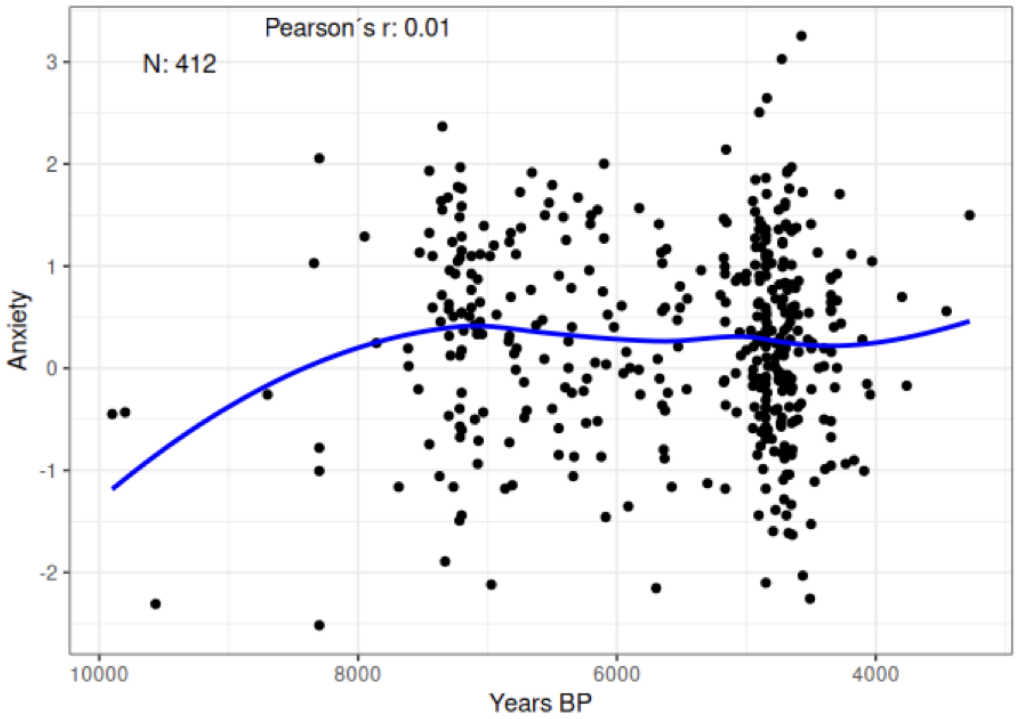


Figure 18: Correlation between years before present and anxiety polygenic score.

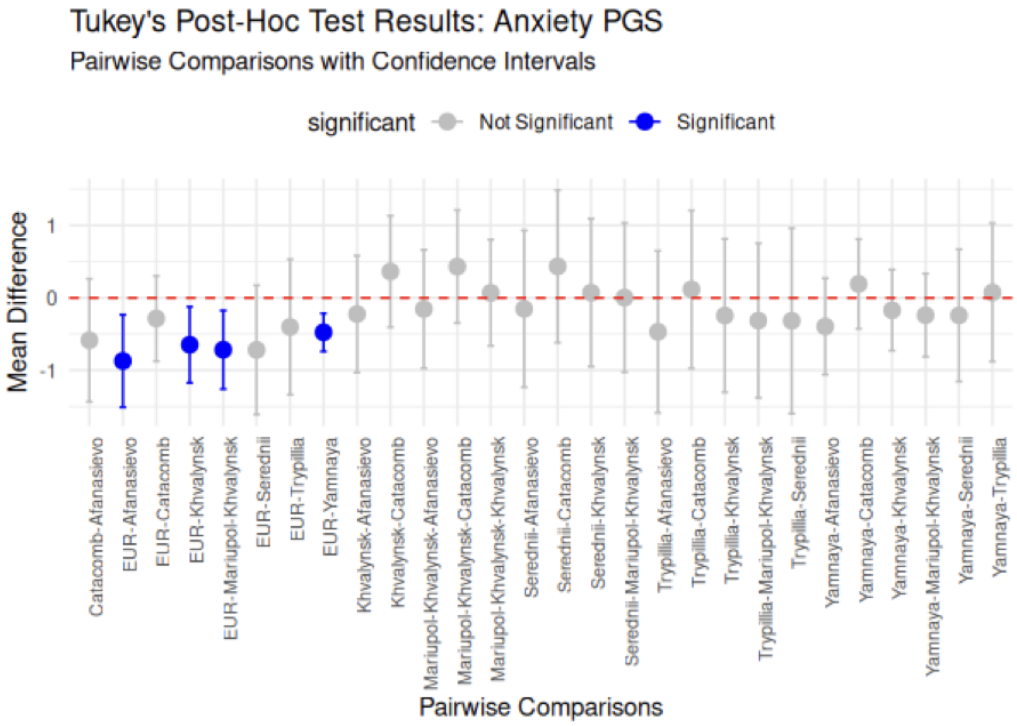


Figure 19: Tukey's post-hoc results: Anxiety polygenic score.

not have significant effects (Figure 20).

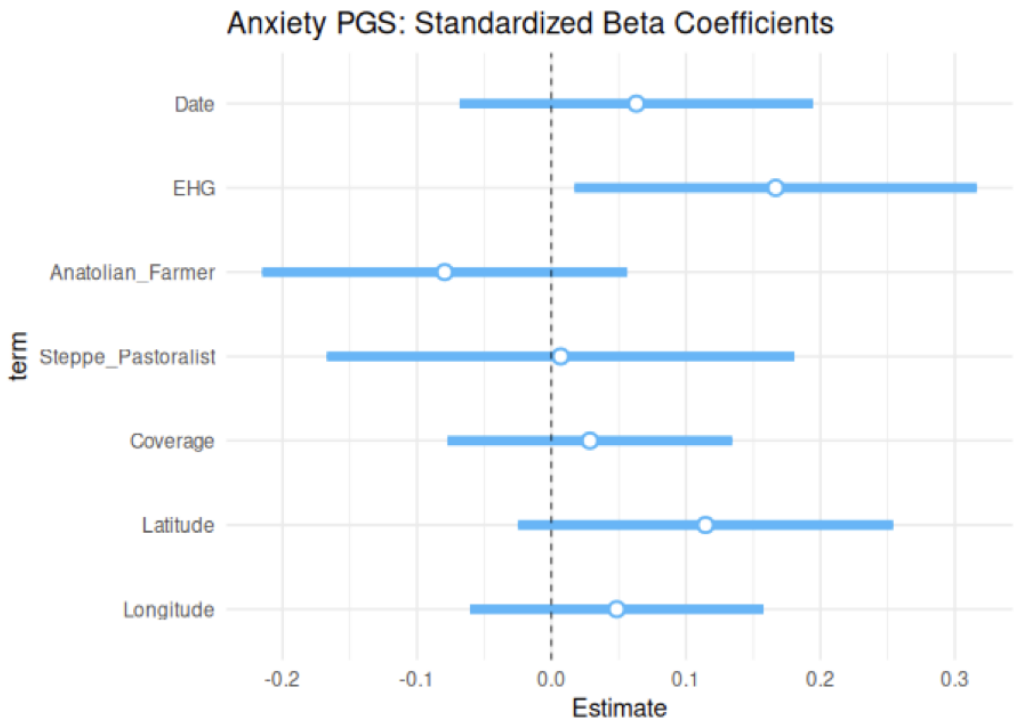


Figure 20: Effects of date (years before present), latitude, and admixture components on anxiety polygenic score.

3.9 Depression

3.9.1 Temporal trends in polygenic scores

There was no significant correlation between depression PGS and years before present in the full dataset and in the 10 Kya subsample (r = .053 and .042, p = .279 and .389, respectively) (Figure 21).

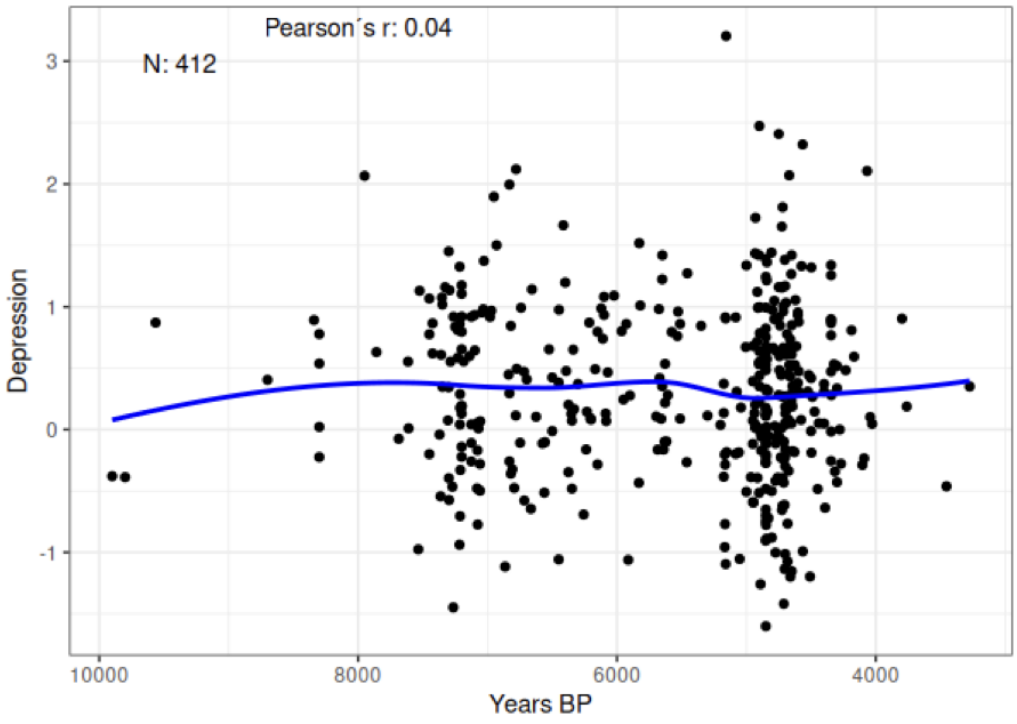


Figure 21: Correlation between years before present and depression PGS.

3.9.2 Population differences

ANOVA revealed significant variation in depression polygenic scores across populations ($F = 8.743$, $p < .001$). Tukey's HSD identified significantly lower scores in modern Europeans (EUR) compared to *Afanasievo*, *Khvalynsk* and *Yamnaya* (mean differences = -0.755, -0.566, -0.534, respectively, $p = .011$, $p = .033$, $p < .001$) (Figure 22). These results suggest significant differences in depression PGS between ancient and modern populations.

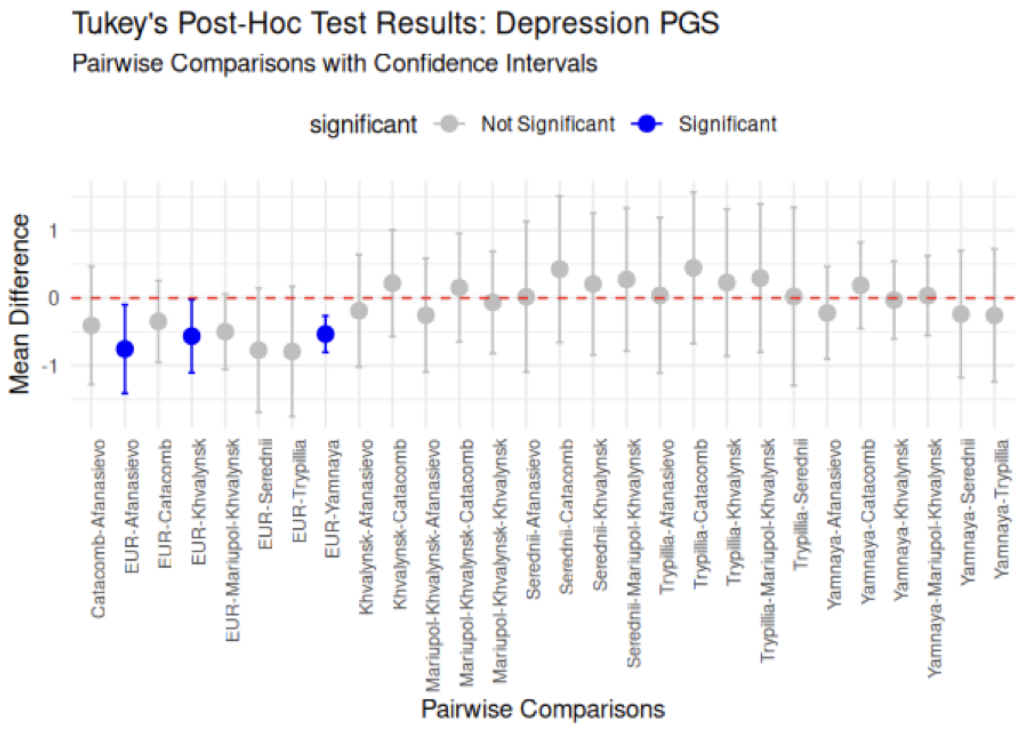


Figure 22: Tukey's post-hoc results: Depression polygenic score.

3.9.3 Regression analysis

Linear regression analysis did not find any significant predictors of depression PGS. When admixture components were included in the regression model, Steppe Pastoralist ancestry was found to have a negative effect on Depression PGS (β = -0.198, $p = .039$), while the other ancestry components did not have significant effects (Figure 23).

3.10 Skin colour analysis

3.10.1 Temporal trends in polygenic score

We found a significant positive correlation between skin colour PGS and years before present ($r = .108$, $p = .029$, N = 414), suggesting that more ancient populations tend to have darker skin. When the analysis was restricted to populations younger than 10,000 years before present, this relationship became slightly less significant ($r = .085$, $p = .08$, N = 412), as shown in Figure 24.

3.10.2 Population differences

ANOVA revealed significant variation in skin colour PGS across populations ($F = 49.69$, $p < .001$). Tukey's HSD identified significantly higher scores in all ancient populations except *Trypillia* compared to modern European (EUR) (Figure 25). These results suggest significant differences in skin colour PGS between ancient and modern populations, with a trend for skin colour getting lighter.

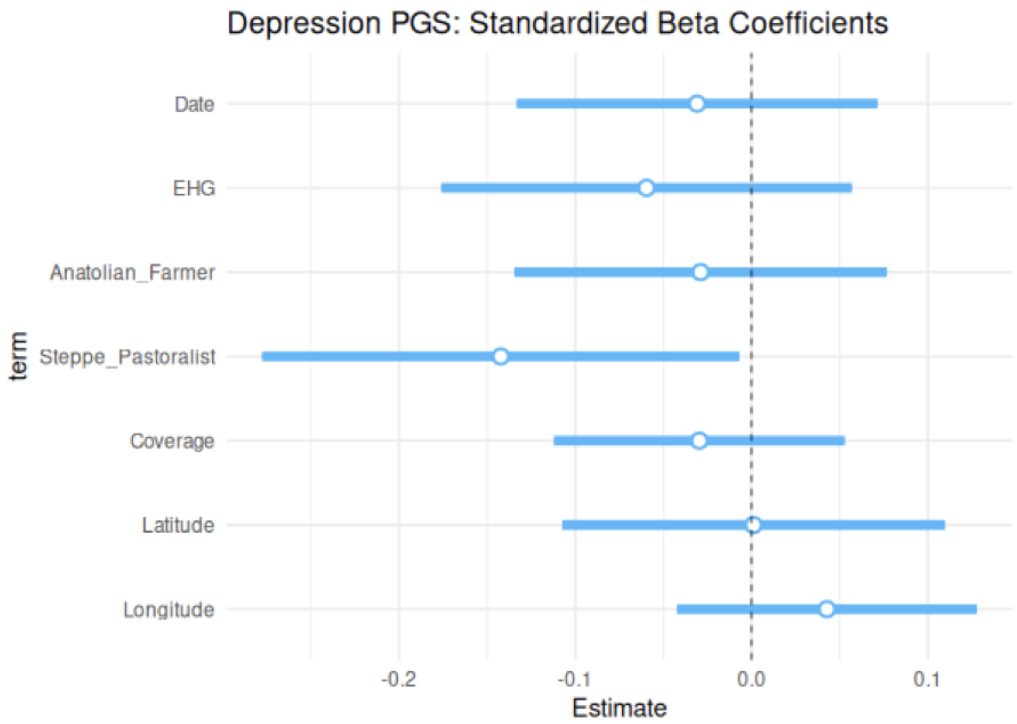


Figure 23: Effects of date, latitude, and admixture components on depression polygenic score.

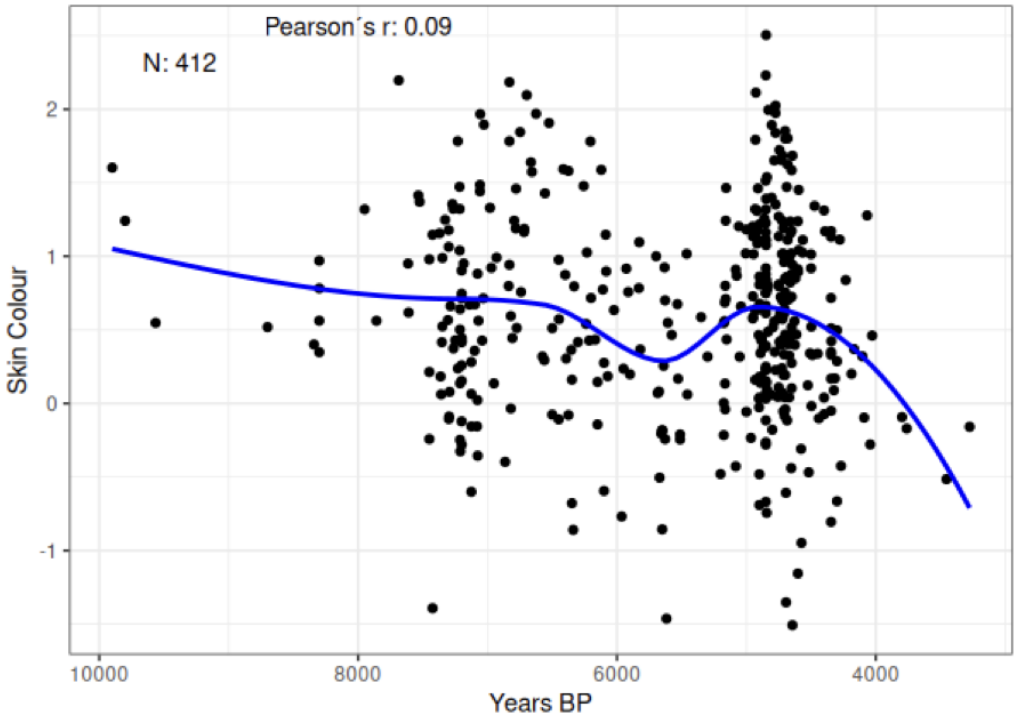


Figure 24: Correlation between years before present and skin colour polygenic score.

3.10.3 Regression analysis

Linear regression analysis revealed that latitude (β = -0.121, p = .025) and longitude (β = 0.129, p = .015) were significant predictors of skin colour PGS, with populations from northern and western regions exhibiting lower scores (predicting lighter skin). In contrast, years before present was not a significant predictor ($p > .05$), while coverage had a strong positive effect (β = 0.259, $p < .001$).

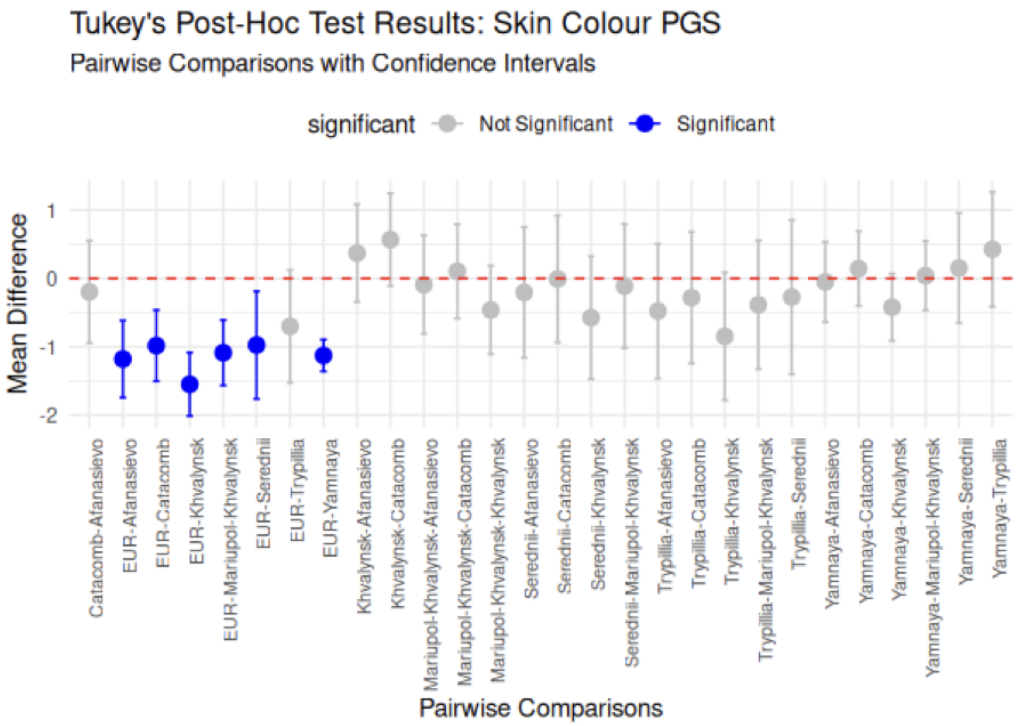


Figure 25: Tukey's post-hoc results: Skin colour polygenic score.

When admixture components were added to the regression model, years before present showed a significant positive effect on skin colour PGS ($\beta = 0.218$, $p = .001$), as illustrated in Figure 26. Additionally, EHG ancestry had a significant negative effect ($\beta = -.249$, $p = .001$), while Steppe Pastoralist ancestry exhibited a significant positive effect ($\beta = .229$, $p = .008$).

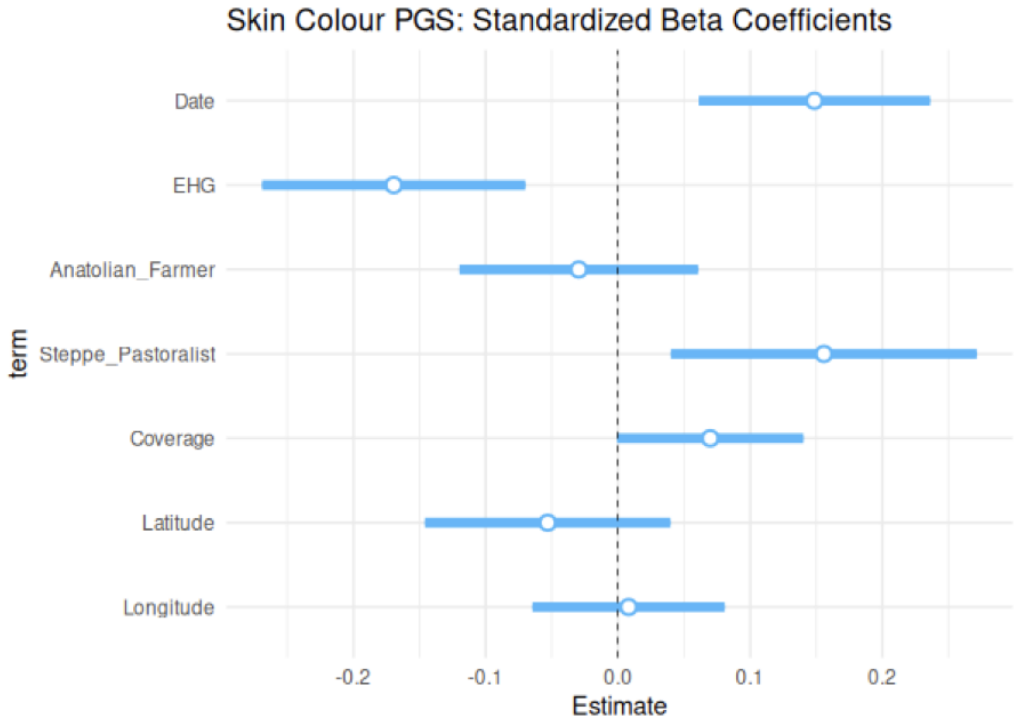


Figure 26: Effects of date (years before present), latitude, and admixture components on skin colour polygenic score.

4 Discussion

The integration of polygenic scores (PGS) and admixture modelling with ancient genomic data offers unprecedented insights into the evolutionary forces that may have shaped the *Yamnaya*'s demographic dominance. Our findings reveal distinct genetic signatures associated with key adaptive traits, providing a novel framework to evaluate hypotheses about their success. Below, we synthesize these results and explore their implications for understanding the interplay of genetic ancestry, environmental adaptation, and cultural expansion.

Steppe Pastoralist ancestry was strongly associated with elevated educational attainment polygenic scores (EA PGS) ($\beta = 0.27$), even after controlling for temporal and geographic confounders. This aligns with hypotheses that cognitive traits linked to problem-solving, social coordination, or technological innovation — enhanced by Steppe-related alleles — may have facilitated the *Yamnaya*'s ability to manage complex pastoralist economies, navigate vast territories, and transmit cultural practices. However, Anatolian Farmer ancestry also had a positive effect on EA PGS ($\beta = 0.39$), replicating results from earlier studies (Piffer & Kirkegaard, 2024). Notably, when Western Hunter-Gatherer (WHG) ancestry was used as the omitted control in regressions, the observed east-west gradient in EA PGS raises questions about whether complex societies (e.g., pastoralism or farming) emerged as a cause or consequence of selection for higher EA. Did elevated EA PGS enable the development of sophisticated economies, or did these cultural systems impose selective pressures favouring cognitive traits? The spatial and temporal overlap between rising EA PGS and the spread of Steppe ancestry suggests bidirectional gene-culture coevolution, though disentangling causality requires further integration of archaeological proxies for social complexity. Notably, despite deriving most of their ancestry from various hunter-gatherer groups including Caucasus-related, Eastern European, and Ukrainian Neolithic hunter-gatherers (Lazaridis et al., 2025), the *Yamnaya* exhibited EA PGS comparable to farmers and substantially higher than other hunter-gatherer groups such as the WHG (omitted reference group in the regression analyses), the *Khvalynsk*, or even the closely related, mixed foraging-pastoralist *Serednii Stih* culture (Figure 4). This finding suggests strong selective pressure favouring enhanced cognitive abilities among the *Yamnaya* population.

Steppe ancestry exhibited a positive correlation with autism spectrum disorder (ASD) polygenic scores (PGS), raising intriguing questions about the role of neurocognitive profiles in *Yamnaya* success. While this association could suggest selective pressures favouring ASD-related traits, a more nuanced interpretation aligns with recent genetic insights: Alleles associated with ASD often exhibit pleiotropic effects, overlapping with loci linked to enhanced cognitive abilities such as pattern recognition, systematic thinking, and attention to detail (Clarke et al., 2016; Crespi, 2016). This cognitive profile — characterized by attention to objects rather than social cues — may have been advantageous in contexts requiring technical innovation (e.g., metallurgy) or spatial navigation.

An alternative hypothesis posits that ASD-associated traits reflect an "extreme male brain" phenotype (Baron-Cohen, 2002), which could have been adaptive in a highly competitive, male-dominated pastoralist society where assertiveness and systematic thinking conferred survival advantages. Such pleiotropy underscores the limitations of interpreting PGS for psychiatric traits in isolation. Selection may have acted on cognitive advantages tied to ASD-associated loci while inadvertently increasing ASD predisposition — a dynamic mirrored in modern studies linking ASD-associated variants to STEM career achievement (Warrier et al., 2022).

We did not detect significant associations between anxiety PGS and either Steppe Pastoralist or Anatolian Farmer ancestry. However, modern Europeans exhibited significantly lower anxiety PGS than *Yamnaya*, *Afanasievo*, and *Khvalynsk* populations (Figure 19). This temporal decline may reflect relaxed selection on anxiety-related traits as environments became less hazardous over time. High anxiety levels, potentially adaptive in prehistoric contexts with frequent threats, may now represent an evolutionary mismatch in modern, safer settings. Similarly, the negative association between Steppe ancestry and depression PGS (Figure 23), coupled with lower depression PGS in modern Europeans, suggests persistent negative selection against this phenotype.

Steppe ancestry was associated with higher height PGS ($\beta = 0.234$), indicating potential advantages in mobility, resource competition, or warfare. Conversely, Anatolian Farmer ancestry showed a strong negative

association with height (β = -0.523). This pattern was corroborated by direct population comparisons, with *Yamnaya* individuals exhibiting significantly higher height polygenic scores than *Trypillia* groups.

This pattern may reflect metabolic trade-offs favouring smaller body size in early agricultural populations, where reduced stature improved efficiency in labour-intensive farming tasks. Nutritional stress during the Neolithic transition — evidenced by poorer health in early farmers compared to hunter-gatherers — could have further driven selection for smaller body size (Marciniak et al., 2022). Later improvements in agricultural efficiency may have relaxed these pressures, though modern Europeans still exhibit lower height PGS than ancient Steppe groups (Figure 10), likely due to higher Anatolian Farmer ancestry in southern European populations. These findings align with UK Biobank analyses, where Steppe ancestry — not selection — explains height variation across Europe (Irving-Pease et al., 2024).

The negative correlations of EA, height, and IQ PGS with years BP initially suggested positive directional selection. However, when admixture components were included, the temporal effect on IQ PGS became non-significant (β = -0.115, p = .108), implying that population replacement (e.g., expansion of *Yamnaya* or Anatolian farmers) rather than in situ selection drove much of the rising trend. Similarly, the EA PGS latitude effect (β = -0.283, $p < .001$) — with northern populations scoring lower — contradicts Cold Winters Theory (Lynn, 1991, 2006), which posits that colder climates select for higher cognitive ability.

The positive correlation between skin pigmentation PGS and years BP (r = .108) reflects selection for lighter skin in northern latitudes (β = -0.121 for latitude). However, our ancestry-specific results contrast with earlier studies: Eastern Hunter-Gatherer (EHG) ancestry predicted lighter skin (β = -0.249, p = .001), while Steppe Pastoralist ancestry correlated with darker pigmentation (β = .229, p = .008). This reversal suggests either (1) spatiotemporal heterogeneity in selection across Steppe populations, (2) methodological differences in ancestry decomposition, or (3) divergent variant inclusion in PGS calculations.

While our results highlight genetic predispositions, the *Yamnaya*'s success cannot be reduced to polygenic scores alone. Instead, we propose a synergistic model:

- **Cultural amplification:** Elevated EA PGS may have enhanced transmission of innovations (e.g., wheeled vehicles) that amplified Steppe mobility.
- **Demographic expansion via admixture:** The *Yamnaya*'s genetic legacy persists through adaptive introgression, disseminating Steppe-associated alleles across Eurasia.

A key limitation is that modern GWAS-derived PGS may misrepresent ancient genetic architectures. For instance, alleles linked to educational attainment today could have influenced unrelated traits (e.g., spatial memory) in prehistoric contexts.

Future studies should: (1) Integrate functional genomics to identify causal variants; (2) Expand sampling to Central Asia to disentangle local adaptation from ancestry effects; (3) Combine genetic data with archaeological proxies (e.g., tool diversity) to test gene-culture coevolution.

Our analysis provides compelling evidence that the *Yamnaya*'s genetic legacy — particularly elevated EA and height PGS — may have catalysed their expansion across Eurasia. These traits, amplified by cultural practices and ecological flexibility, likely facilitated dominance in a rapidly changing world. However, the transient nature of these advantages, eroded by admixture and shifting selection pressures, underscores the dynamic interplay of ancestry and environment in human evolution. By bridging ancient DNA and polygenic scoring, this study advances a nuanced understanding of how genetic predispositions can drive — and be reshaped by — demographic and cultural revolutions.

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Creating Future People: The Science and Ethics of Genetic Enhancement*

Review by: Aldric Hama Author of the Book: Jonathan Anomaly†

If you were able to give your future children better than average odds at a productive and healthy life by screening and selecting embryos or editing genes for desirable physical and mental traits, would you do it? According to a 2023 survey, 34 % of Americans surveyed were "mostly willing" to use gene editing of embryos created through in vitro fertilization (IVF) to raise the likelihood that their offspring enters a "top-100 ranked college" and 43 % were also "mostly willing" to utilize embryo screening for genetic variants for high educational attainment (Meyer et al., 2023). Interestingly, people with "high educational attainment", a bachelor's degree or above, who presumably know something about trait heritability and genetics, tended to express greater likelihood of both gene editing and embryo screening than average but only by a few percentage points. This finding suggests that the majority of those with high educational attainment are fairly blasé about the future of their children and the kind of society they will create.

Americans, however, are fairly pragmatic compared to others who are less than enthusiastic about using gene editing for "enhancement" purposes. For example, among the Japanese general public, around 40 % of those surveyed agreed that gene editing of embryos for genetic diseases is appropriate (Kobayashi et al., 2022). However, only about 8 % agreed that gene editing should be allowed for couples to "have a child that possesses a specific desired trait," which would include (not stated in the survey) high cognitive ability.

Some have pointed out that relaxed natural selection, a result of modern medicine, agriculture and the welfare state, has led to accelerated accumulation of genetic mutations (Blau, 2023). Particularly concerning is the accumulation of mutations that affect brain functioning. Given below-replacement birth rates of the educated and accumulating mutations, it is not at all clear if future generations of humans in advanced societies will be able to expand the bounds of modern civilization or even maintain it. Although only between 10 % and 30 % of people favor embryo selection and gene editing for the purpose of genetic enhancement, perhaps this is sufficient to preserve civilization. But what kind of society will emerge from a population in which some people have been genetically enhanced and the majority remain non-enhanced?

Jonathan Anomaly considers the impact of genetic interventions by a few on the rest of society. Anomaly engages readers to consider the potential downstream social effects he has identified of utilizing gene editing and embryo selection for a range of physical and mental enhancement. The main questions Anomaly asks and attempts to address include (from *Preface*):

"Will parents left alone to make choices for their own private reasons solve the problem [of whether or not to genetically enhance]?"
"Will new laws or norms be needed to coordinate our actions?"
"What are the moral advantages of relying on free choice in comparison with different kinds of restrictions [such as social pressure or government imposed]?"

These questions and others arise, for example, in his examination of aesthetic enhancement. Physical appearance counts for something in Western consumerist society, as Anomaly points out. Tall or aesthetically pleasing people tend to make up the sociopolitical elite. Perhaps it will be possible to attain physical and aesthetic perfection through gene editing. If the technology is available and affordable, and if the choice to utilize gene therapy for aesthetic enhancement rested with parents, what might happen?

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†Routledge, 2024

Anomaly suggests that with aesthetic enhancement, the threshold or ideal would likely shift over time. He suggests a "red queen phenomenon" would arise (p. 61), in that one needs to run continuously just to stay in place. On one hand, beauty suggests general health, low parasitic and mutational load, and low oxidative stress (p. 58). Editing genes for beauty could change associated genes, for example those affecting intelligence (Dunkel et al., 2018). Anomaly also suggests that once a threshold is reached, it could be "fruitless", with respect to changes in associated genes as well as aesthetics, to attempt to go further (p. 64).

What would society in the future look like with an overabundance of beautiful people? (Or high-IQ people?) What will happen to those who were not genetically enhanced? Perhaps those who do not meet a threshold will face discrimination, or a future society will do what it can to accommodate the unenhanced. For example, society currently makes facilities accessible for the disabled and for most occupations, other than those based on aesthetics, applicants are (one hopes) judged on perceived competence.

In the case of aesthetic enhancement, individuals today pursue enhancement, chemically or surgically, to the extent they can afford it or tolerate it. As there appears to be no social benefit to enhancement beyond a basic level, perhaps it may be good to limit access to this kind of genetic enhancement. To impose legal restrictions would most likely mean those who are not wealthy and connected will be the ones excluded from access. At the same time open access to enhancement technology, while also subsidizing the cost for those who cannot afford it, means coercive taxation, by taxing those who do not plan to or want to use it. With respect to subsidizing potential costs, the required sums will be substantial, similar perhaps to those for gene therapy treatments (Wong et al., 2023). There are also issues of clearly identifying each and every contributor to enhancement technology and compensating those who hold the patents.[1]

Anomaly scrutinizes genetic enhancement of intelligence to the same degree as aesthetic enhancement. As with physical enhancements, there are significant tradeoffs at the individual and social levels. Having the government regulate access may lead to increased cognitive inequality.

In aggregate, as Anomaly points out, high-IQ countries have more wealth, higher social cooperation and trust, and less corruption than low-IQ countries. For individuals, high IQ predicts better average educational, occupational and health outcomes, more so than do other mental traits (p. 4). High-IQ people also tend to "support polices that reinforce political institutions that increase prosperity" (p. 7). Thus, thoughtful parents (the 10 % to 30 %) have good reasons to boost their children's IQ.

However, Anomaly points out, high IQ is associated with depression and traits such as sophistry, rationalization and political ideology which are heritable (p. 9, 26). Although innovative technologies may spring from high-IQ individuals, unscrupulous high-IQ individuals may use these technologies for personal gain at the expense of others. He cites Julian Savulescu's argument that we need to apply moral enhancement before venturing into cognitive enhancement. Furthermore, perhaps those with high IQ will look upon those with low IQ as people with reduced moral status. Those with high IQ will have greater opportunities to engage in society and at a higher level than those with low IQ. Therefore, goes the thinking, high-IQ people have higher moral status.[2] Anomaly suggests several possible solutions to avoid a potentially deep division between the enhanced and unenhanced. None of them are mutually exclusive, but they are likely to unleash further issues that, at the moment, appear to be intractable.

Because we know little about the downstream effects of enhancing IQ, one solution would be to not utilize gene editing and embryo selection at all; to ban it. However, seeing that it is becoming difficult even to maintain civilization at current levels, given the sub-replacement fertility of high-IQ people and high fertility rate of those with low IQ combined with generational accumulation of deleterious mutations, doing nothing is hardly an option. Thus, we owe it to the future to seriously reflect now on the issues Anomaly

[1] One could expect a similar level of "lawfare" between competing genetic enhancement companies that was seen between drug companies that developed and marketed COVID-19 vaccines. https://petrieflom.law.harvard.edu/2024/07/12/modernas-u-k-vaccine-patent-pledge-cut-short-by-boilerplate/; https://www.fiercepharma.com/pharma/gsk-takes-mrna-patent-fight-moderna-suing-over-vaccines-covid-rsv.

[2] The high IQ (cognitive elite) while pitying the low IQ cognitive underclass but not knowing what to do with them, will create a "custodial state," what Charles Murray and Richard Herrnstein characterized as a "high-tech and more lavish version of the Indian reservation," to keep them from "underfoot" as the rest of America goes about its business (Herrnstein & Murray, 1994).

raises, before gene editing and embryo selection technologies either mature or get outlawed before becoming truly useful.

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Meyer, M. N., Tan, T., Benjamin, D. J., et al. (2023). Public views on polygenic screening of embryos. *Science*, *379*, 541–543. (While this survey is cited by Anomaly, people's attitudes towards gene editing and embryo selection are not as optimistic as Anomaly makes them out to be (p. 124).)

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