DISTRIBUTION OF FINGERPRINT PATTERNS BETWEEN THE BUKUSU AND KABRAS IN WESTERN KENYA

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other learning institution.

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We confirm that the work reported in this thesis was carried out by the candidate under our supervision

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DEDICATION

To my family members, father Chestimore Joshuah Lunani, mother Minayo Everlyn, and Sister Vallary Lunani Baraka, for their cooperation and support during the entire period of my study.

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I express thanks to the All-Powerful God for bestowing upon me the wisdom and fortitude necessary to complete this study project. To Him be given all praise and glory. I am appreciative of my supervisors, Dr. Godwil Munyekenye and Dr. Mark Kilongosi Webale, for providing me with all the help, direction, and counsel I need. Once more, I would want to express my gratitude to my supervisors for their unwavering efforts in making this research project successful and finished.

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ABSTRACT

Fingerprinting is one of the oldest and most reliable biometric tools taken as legitimate proof of identification of an individual. Gender, ethnicity, and familial relationship are used as tools of individual identity and their associations with fingerprint patterns have been demonstrated in previous studies but were inconsistent. The objective of this study was to describe the distribution of fingerprint patterns in a population in Western Kenya. The specific objectives were to determine the associations between fingerprint patterns and sub-patterns with fingers, gender, ethnic group, and sibling status in a population. In a cross-sectional observation study, a total of 240 study participants were recruited via a clustered sampling technique. Demographic information was collected using a questionnaire. Fingerprints were collected using fingerprint ink pad and classified according to Henry's classification system. The association of fingerprint patterns with fingers, gender, ethnic groups and relationship status was determined using the chi-square test. Statistical significance was set at $P \leq 0.05$. The frequency of arch, composite, loop, and whorl patterns was comparable across the five fingers as well as between gender and ethnic groups for both the right and left arms ($P > 0.05$). However, there was significant variation in the frequency of arch, composite, loop, and whorl fingerprint patterns for all the fingers between siblings and non-siblings ($P < 0.05$). The ulnar loop was found to be the most occurring fingerprint sub-pattern across the five fingers, between the gender and ethnic group as well as between sibling and non-siblings. Plain whorl, radial loop, plain arch, tented arch, central pocket whorl, double whorl, loop arch composite and whorl arch composite followed respectively. There is similarity in fingerprint patterns across the fingers as well as between gender and ethnic groups but not siblings and non-siblings between the Bukusu and the Kabras western Kenya. Therefore, fingerprint patterns may not be used to discriminate fingers, gender, and ethnic groups but can be used as a tool to distinguish between siblings and non-siblings in the population.

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LIST OF ABBREVIATIONS AND ACRONYMS.

DNA	Deoxyribonucleic acid.
LHI	Left Hand Index
LHM	Left Hand Middle
LHP	Left Hand Pinkie
LHR	Left Hand Ring
LHT	Left Hand Thumb
NACOSTI	National Commission for Science, Technology, and Innovation.
RHI	Right Hand Index
RHM	Right Hand Middle
RHP	Right Hand Pinkie
RHR	Right-Hand Ring
RHT	Right-Hand Thumb
SPSS	Statistical Package for the Social Sciences
WHO	World Health Organization

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OPERATIONAL DEFINITION OF TERMS

Arch	These fingerprints form an arch that rises in the centre and tapers off at both ends
Composite	A Composite pattern is a combination of two or more patterns either of the same or different types in one print.
Fingerprint	Fingerprints are unique biological patterns, or ridges, found on the fingertips of humans and other primates, which are used for verification and identification. Fingerprints are formed during fetal development and remain unchanged over an individual's lifetime.
Loop	These fingerprints have loops or whorls of ridges with one or more ridges that enter and exit in the same place.
Whorl	These are the most complex type of fingerprint and feature two or more ridges that form a circle, spiral, or ellipse.

CHAPTER ONE: INTRODUCTION

1.1. Background Information

The ridges and valleys on the skin of the fingertips generate unique and identifiable patterns called fingerprints, also known as friction ridge skin impressions (Houck M, 2016; Champod et al., 2017; Sharma et al., 2021). Raised ridges and recessed furrows on the skin's surface combine to generate these patterns, which are utilised for individual identification. These patterns are totally formed throughout intrauterine life and don't change till the person passes away (Ravindra et al., 2021). Since fingerprints are consistent and unique, they are considered the most dependable form of identification (Houck, 2016). The individual differences in ridge patterns, ridge counts, and minutiae points specific ridge features including ridge ends, bifurcations, and dots are what make fingerprints distinctive.

Henry's categorization approach divides fingerprint patterns into four primary categories see figure a: arch, loop, whorl, and others (Sharma et al., 2021).

Figure 1: Fingerprint patterns. From top left to bottom right: loop, double loop, central pocket loop, plain whorl, plain arch, and tented arch

The ridgeline that enters the finger from one side, rises slightly in the centre, and exits the other side without creating any loops or recurving patterns is what distinguishes the Arch patterns. Figure b below shows a global representation of the distribution of fingerprint patterns.

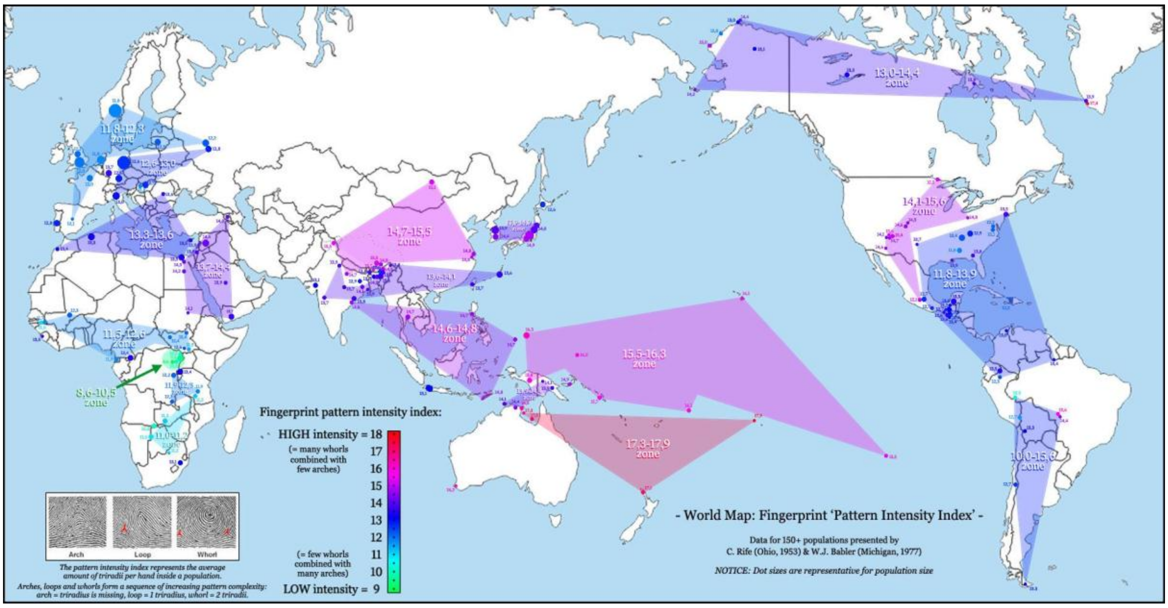


Figure 2: FINGERPRINTS WORLD MAP - Global Distribution of Whorls, Loops & Arches. http://fingerprints.handresearch.com/dermatoglyphics/fingerprints-world-map-whorls-loops-arches.htm

According to Heng et al. (2018), the arch patterns make up between 5% and 15% of all fingerprint patterns globally. Sub-patterns of the arch include tented arches and simple arches. Ridgelines that enter from one side of the finger, bend or create a loop, then depart on the same side are what define loop patterns. According to Shehu et al. (2018), loop patterns are the most prevalent fingerprint pattern, making up 60–65% of the global population. They are divided into two types: the ulnar loop, which has ridges flowing towards the little finger, and the Radial loop, which has ridges flowing towards the thumb. The whorl fingerprint patterns account for about 30–35% (Satheesha et al., 2018) and it has circular or spiral ridges that form concentric patterns. The whorl is sub-patterned into plain whorls, central pocket loops, double loops, and accidental whorls. A combination of two or more different fingerprint patterns is termed as composite. The composite patterns are the least occurring patterns in the total world population. The composite pattern account for less than 15% of the world population (Shrestha and Malla, 2019).

Previous findings have shown that there are variations between fingerprint patterns when comparing individual fingers, gender, ethnicity and family relationship-status. A study conducted in Bulgaria which involved 390 participants aged 19 to 30, with 277 females and 113 males, among whom 285 were right-handed (73.1%), 94 left-handed (24.1%), and 11 ambidextrous (2.8%), with varying distributions across gender, determined that the loop pattern was significantly higher across the right-hand fingers (Petrova et al., 2017), while another study in China demonstrated that the loop fingerprint pattern was the most dominant pattern across the left-hand fingers (Heng et al., 2018). In Northern Taiwan, men have a higher frequency of whorls and women typically exhibit more loops and arches (Shehu et al., 2018) which is similar to a study in Nigeria which found that whorls were higher in men while arches were more common in women. (Anyanwu, 2020). However, a higher frequency of radial loops, in males, and ulnar loops, in females, was reported in Nepal (Shrestha & Malla, 2019). A previous study in Nigeria reported that the frequencies of the ulnar loop, whorl, arch and radial loop were similar for the right-hand fingers, but occurrence of the ulnar loop was higher for the left-hand fingers between two ethnic groups (Abimbola et al., 2021). However, a study in Costa Rica concluded that rates of occurrence of Arch, whorl, and loop fingerprint patterns were similar across six ethnic groups (Segura-Wang & Barrantes 2009). Cumulative evidence from the previous studies showed that there is insufficient evidence to show correlations between the conclusions drawn and a specific fingerprint. Therefore, the present study determined the distribution of fingerprint patterns in a population in western Kenya Population.

1.2. Statement of the Problem.

Fingerprint pattern is influenced by environmental and genetics factor in the womb making the patterns unique to individuals. The frequency of occurrence of predominant fingerprint patterns varies geographically and even in individuals within the same region. Genetic variants, associated with ordinal fingerprint patterns, show strong correlations with finger length and hand proportions (Rishi et al., 2024). The genetic variants of both parents are mixed in all biological siblings, hence siblings are more likely than unrelated individuals to share the same fingerprint pattern category. Meanwhile, the signals for fingerprint patterns can be inherited as autosomal dominant genes which affect men and women equally. The Ethnic group is itself homogeneous with respect to dermatoglyphic genes, but also distinct from every other group. Therefore, it is important to determine the association between fingerprint patterns between hands, sibling-status, gender and ethnic group in a population in western Kenya.

1.3. Purpose of the Study

This study aimed at determining the distribution of Fingerprint patterns in western Kenya which will add more knowledge of fingerprints to the Forensic and investigation departments.

1.4. Research Objectives and Research Questions

1.4.1. General Objective

To determine the distribution of fingerprint patterns in a population in western Kenya.

1.4.2. Specific Objectives

1. To determine the distribution of fingerprint patterns across the five fingers of both hands in a population in western Kenya.
2. To compare fingerprint patterns between males and females in a population in western Kenya.

3. To compare fingerprint patterns between two ethnic groups in a population in western Kenya.
4. To compare fingerprint patterns between siblings and non-siblings in a population in western Kenya.

1.4.3. Research Questions

1. What is the distribution of fingerprint patterns in the fingers of both hands in western Kenya?
2. How do fingerprint patterns compare between males and females in a population in western Kenya?
3. How do fingerprint patterns compare between two ethnic groups in a population in western Kenya?
4. How do fingerprint patterns compare between siblings and non-siblings in a population in western Kenya?

1.5. Justification of the Study

The association of fingerprint patterns distribution is important to forensic departments and fingerprint experts in cases of identification of victims of mass disasters and identification of dead bodies found with no identification documents. Classifying fingerprint patterns in gender is important to investigation departments as it helps in the criminal investigation process including Identifying potential gender of suspects. The association of fingerprint patterns with ethnic groups could prove useful for forensic anthropologists when profiling the ancestry of human remains. This information is also important to modern law enforcement when trying to profile suspects.

1.6. Limitations of the Study

The relationship status of the study participant was not genetically determined but self-report. Also, the study might have a small sample size, which could limit the generalizability of the findings to the larger population. Technological innovations of the study participants such as plastic surgery were not excluded which may give a different finding.

1.7. Assumption of the Study

The assumption is based on the understanding that fingerprint patterns are primarily determined by genetic factors and are formed during fetal development (Kücken, 2007). Finger length is determined by various factors, including genetics, hormonal influences, and individual growth patterns (Li et al., 2022). These factors involve the formation of friction ridge skin during fetal development, which gives rise to unique patterns such as arches, loops, and whorls. It is therefore assumed that fingerprint patterns are related to the fingers. The variations in fingerprint patterns between genders are believed to be influenced by hormonal and genetic factors. Hormones, such as testosterone, have been suggested to play a role in the development of fingerprint patterns (Roselli, 2018). The genetic makeup of an individual, including their sex chromosomes, influences the overall characteristics of their fingerprints (Knief et al., 2017). It is well established that males typically have larger hands and fingers compared to females, and this physical difference can influence the overall size and scale of the fingerprint patterns (Sánchez-Andrés et al., 2018). This raises the assumption that gender influences distribution of fingerprint patterns. It is widely accepted that individuals within the same ethnic group, and sibling status share a high degree of genetic similarity (Mark et al., 2017). Therefore, it is reasonable to assume that (a person’s sibling relationships and ethnicity has an effect on the occurrence of particular fingerprint patterns) there is relationship between fingerprint patterns with siblings and ethnic groups.

CHAPTER TWO: LITERATURE REVIEW

2.1. Biology of Fingerprints

Development of fingerprint patterns starts during fetal development, typically around the tenth week of gestation (Hiersch, 2020). The genetics factors inherited from both parents and the environmental factors surrounding the fetus determine the fingerprint patterns (Sharma et al., 2018). The genetic information inherited from parents contains instructions that govern the formation of various features in the body, including the development of the skin. Specific genes such as the "HOXC13" gene play a role in determining the arrangement and distribution of epidermal ridges that form fingerprints (Burchill et al., 2023). The epidermal layer undergoes a unique pattern of growth, folding, and buckling, leading to the formation of characteristic ridge patterns (Glover et al., 2023). These ridge patterns create the unique loops, arches, and whorls that we see on our fingertips The epidermal layer contains sweat pores and the sweat glands responsible for producing sweat, which plays a role in the formation of latent fingerprints (Planalp et al., 2017). The dermal papillae, which are extensions of the dermis into the epidermis, are responsible for giving rise to the characteristic ridge patterns (Barbaro et al., 2017). Fingerprint patterns are heritable, meaning they are passed down from parents to their offspring (Debta et al., 2018).

Environmental factors, such as the mother's nutrition, exposure to substances, or external pressure on the mother's abdomen, may play a significant role in determining fingerprint patterns (Amatruda et al., 2019). During pregnancy, the environment in the womb can affect the development of the fetus, including the formation of fingerprints. Once the genetic blueprint is established during early development, the pattern remains unchanged throughout an individual's life, with the exception of minor changes that can occur due to injuries or skin diseases (Bateson, 2017).

The three main categories of fingerprints identified by Henry's categorization method are arch, loop, and whorl. There are two sub-patterns within the arch pattern: the plain arch and the tented arch. Whereas the loop pattern is separated into ulnar loop and radial loop sub-patterns, the whorl pattern is subdivided into plain whorl, double whorl, and centre pocket whorl sub-patterns (Mamaema, 2021). To further narrow down to specific individuals, the print types are further classified into small features referred to as minutiae. Examples of these features include bifurcations, terminations, lakes, independent ridges, points of the island, spurs, and crosses.

2.2. Fingerprinting techniques

Since 2017, significant improvements in automated fingerprint recognition systems have been made, allowing for faster and more accurate identification of suspects. In 2017, a new method was developed to automatically extract fingerprints from medical imaging using digital processing techniques (Ma et al., 2018). This process is more accurate than traditional methods and can be used to compare prints with existing databases. Additionally, a new algorithm was developed to improve the effectiveness of recording, analyzing, and evaluating latent fingerprint images (Gu et al., 2019). This algorithm reduces the error rate when matching prints and allows for more reliable and accurate search results. In 2018, researchers developed a new artificial intelligence system that uses deep learning techniques to identify fingerprints more accurately. This system was found to be as accurate than traditional techniques (Chen et al., 2019). Additionally, researchers developed an algorithm that can detect false matches in automated fingerprint recognition systems (Li et al., 2022). This is important because it ensures a higher level of accuracy and prevents the system from incorrectly equating criminals or suspects with the wrong fingerprint.

Furthermore, in 2019, a study was performed which found that the accuracy of automated fingerprint identification systems could be improved by using a combination of minutiae points and ridge characteristics. This combination improved the accuracy of the system by up to 20% (Yong, Zakaria, and Nik Hassan, 2020). Additionally, researchers have developed an improved method for extracting latent fingerprints from a variety of surfaces, including plastic, cloth, and metal. This method incorporates near-infrared light and a silicon-based imaging chip to better detect the fingerprint (Vadivel et al., 2021).

In the context of fingerprint patterns, morphometrics incorporates the analysis of shape and size of the patterns. The pattern of deterioration of latent fingerprints is influenced by several environmental conditions, including the type of substrate, and the degree to which it is exposed to natural light, sweat secretion, temperature, and humidity (Chen et al., 2021). In order to ascertain whether the unknown print discovered at the crime scene corresponds with the known prints that are on file, fingerprint analysis involves examining the quantity and quality of the information. In order to do the analysis, fingerprint examiners utilise a portable magnifying tool called a Loupe, which enables them to view a print's minute details, or minutiae. For the purpose of counting the friction ridges, a pointer known as a ridge counter is used.

There is a possibility of finding fingerprints at indoor and outdoor crime scenes (Hagan 2018). A variety of environmental hazards might harm the latter in several ways. In many instances, criminals would attempt to remove the evidence or hide it in several different methods to avoid being caught by law enforcement officials (Yong et al., 2020). In this context, forensic investigators sometimes have difficulties locating and developing latent fingermarks in surroundings of this kind.

Computerized systems search numerous local, state, and countrywide fingerprint databases for possible matches in cases involving the criminal justice system (Mutisya, 2017). The method utilized to execute the search determines the value provided by many of these systems, which indicates how close of a match there is. After that, fingerprint examiners go through the possible matches and decide what to do next. The current study utilized fingerprinting techniques in the determination of the distribution of fingerprint patterns in the Kenyan population.

2.3. Fingerprint Patterns Distribution

With the recent advancements in artificial intelligence technologies and the growing potential of hand biomechanics, fingerprint analysis can be used to determine an individual's origin (Liu et al., 2019). Fingerprint patterns are typically classified into loops, whorls, composite, and arches. Each pattern type has its unique characteristics, and the distribution of these patterns varies considerably across populations, reflecting a complex interplay of genetic, ethnic, and environmental factors. Recent works have explored the distribution of fingerprints and classify them globally, regionally, and nationally. In terms of the distribution of fingerprints worldwide, loop patterns seemed to be the most common, followed by whorl patterns and arches (van Mensvoort, 2009). Similar trends are seen in Africa, where loops predominate, followed by whorls then arches (van Mensvoort, 2009). The current study aimed to determine the distribution of the fingerprint pattern in western Kenya.

2.4. Fingerprint pattern distribution on the fingers of the left and right-hand

The distribution of fingerprint patterns across the fingers refers to the characteristic arrangement of different fingerprint patterns on individual fingers (Jain & Pankanti, 2000). The patterns vary differently across the different fingers of the hands. Genetic and external influences during fetal development play a role in shaping the distribution of fingerprint patterns (Sharma et al., 2018), and understanding these distribution patterns can be valuable in forensic investigations, biometrics, and other applications that rely on fingerprint analysis.

Previous studies have shown a substantial body of research on the distribution of fingerprint patterns in different populations. For example, studies on the Indian population showed a higher prevalence of loop patterns, while in Caucasian populations, whorls were found to be the most common (Bose et al., 2022; Karmakar et al., 2009). Contrasting results were found in African populations, where arch patterns were more prevalent, thus demonstrating the diverse distribution of fingerprint patterns across different ethnic groups (Okajima, 1975). This variation may be linked to factors such as ancestry, environmental influence, and genetic background. Loop pattern was recorded to be the most prevalent fingerprint pattern in the majority of other parts of the world while Oceanian people often have whorls as the most prevalent category. A similar trend was also observed in several (east) Asian countries (Mensvoort, 2019). Regionally, a study in the Arabic region showed that individuals from Middle Eastern region populations had a higher frequency of loops and a lower frequency of whorls (Bair & Talebian, 2019). Another study in Europe compared the fingerprint patterns of individuals from different regions of Europe and showed that people from northern Europe had a higher frequency of whorls on their fingertips, while people from southern Europe had a higher frequency of arches (Bock et al.,2017) suggesting that finger print patterns vary within geographic regions. In the south of Africa, the loop was reported to be the most common fingerprint pattern followed by the whorls and the arches respectively (Mensvoort, 2019).

A variation of dominance of a specific fingerprint pattern across different countries in the globe has also been demonstrated by previous studies. A study in Nepal reported that loop was the most dominant, followed by Whorl, arch, and composite (Shrestha & Malla, 2019). In a different study, the loop was frequently observed in the Malaysian population, followed by Whorl, composite, and then Arch (Heng et al., 2018). Another study in Nigeria concluded that there is a significant difference in fingerprint pattern distribution, with the frequency of the loop pattern being the highest in the population, followed by that of whorls and arches (Anyanwu, 2020). An Indian study on the distribution of fingerprints among medical students found loop patterns to be the most prevalent fingerprint patterns (Kanchan & Chattopadhyay, 2016). Different studies in India reported that whorl patterns were the second most prevalent after the ulnar loop, and then the arch patterns (Bansal et al., 2014; Nithin et al., 2019). In Pakistan, Whorl was reported as the most dominant pattern, followed by loop, arch, and composite (Subhanuddin et al., 2022). A study in Pakistan study found that loop was the most dominant, followed by Whorl, and arch in that order (Sajid et al., 2021). Similarly, a different study in Malaysia showed that loop patterns were the most dominant, followed by Whorl, arch, and composite (Heng et al., 2018). These studies suggest variations in dominance of fingerprint pattern types in different countries.

A variation in the frequency of fingerprint patterns across the fingers has also been demonstrated previously; a study conducted by Sara Holt in the United Kingdom found that ulnar loops were most common on the little finger while radial loops were predominant on the index finger (Holt, 1968). Whorl patterns were found more often on the thumb and ring finger, while arches were relatively rare but when present, usually appeared on the index and middle fingers (Holt, 1968). A different study in the United States of America found the frequency of the loops to be the most common pattern on all fingers, particularly on the little finger while Whorls, were more common on the thumb and ring finger, and arches, being the least common, often occur on the index finger (Jain et al., 1999). A different study in the USA found that females have a higher frequency of loops on the index finger while the whorl and arch patterns had a similar distribution to all the fingers (Acree, 1999). A different study in India showed the frequency of distribution of the arches, loops, and whorls fingerprint patterns on the five fingers, the loop was found to be more frequent followed by the whorl and arch respectively across the five fingers (Bansal et al., 2014).

A study conducted in Nigeria showed an association between the loop and little finger in both the Aniomas and the Urhobos communities, while arch and whorl patterns were not associated with the five digits in the two communities (Eboh, 2012). A different study in Nigeria found an association between the loop fingerprint pattern and the middle finger of females, whereas no association was found between arch, loop, and whorl patterns on the remaining fingers, of either gender. (Ojigho et al., 2020). A study in Nepal showed an association between the whorl pattern with a male's thumb and ring finger on the right hand, whereas there was no association between the arch, loop, composite and whorl patterns with the remaining fingers of males, or any of the fingers of females, (Hirachan et al., 2019). A Cross-section study in India showed an association between the loop patterns and both the right and left thumbs, whereas there was no association between the arch, loop, and whorl patterns with the other four fingers of the Central Indian population (Nagrale et al., 2021). These studies suggest that fingerprint patterns are not uniformly distributed across the fingers, however, there is no information about the distribution of finger print patterns across the five digits in the Kenyan population.

2.5. Fingerprint pattern distribution between genders

Historically, fingerprints have been employed in forensic investigations, criminal identification, and more recently, in biometric systems for authentication and security purposes (Bose & Kabir, 2017). While individuality is well-established, researchers have also explored whether there are any discernible differences in the distribution of fingerprint patterns between males and females. Fingerprint patterns are primarily determined by genetic factors and the developmental processes during fetal development, as mentioned earlier (Li et al., 2022). The concept of gender has been an essential factor in many aspects of human life, from the way society is organized to the choices that individuals make. Fingerprint patterns are one area where differences based on gender have been observed (Kahrizi et al., 2020). Hormonal factors have been proposed as potential explanations for gender differences in fingerprint patterns (Johnson et al., 2020). Hormones such as estrogen and testosterone play a crucial role in the development of secondary sexual characteristics and can contribute to gender-related variations in fingerprint patterns. (Johnson et al., 2020). Variations of these patterns based on gender have long been noted in Northern Taiwan in New Taipei City, with men tending to display more whorls, and women typically exhibiting more loops and arches (Shehu et al., 2018). Another study in the United States of America compared gender patterns and found that women generally tend to have more arch patterns than men, while men tend to have more whorl patterns (Egger & Starcic, 2019).

A variation of fingerprint pattern distribution between genders is shown in different studies. A study in Zimbabwe found Ulnar loops to be the most predominant digital pattern type in both sexes with the female having a higher occurrence, followed by whorls in males and arches in females (Igbigbi & Msamati, 2002). A different study in Nigeria reported that the ulnar loop predominated in Itsekiri females and Urhobo males (Jaiyeoba-Ojigho et al., 2019) while whorl, loop, and arch were significantly different between males and females of the Esan community in Nigeria (Anyanwu, 2020). On the contrary, a different study in Nigeria concluded that there was no significant association between gender and fingerprint pattern (Eboh, 2013). In an Indian study, females had a higher incidence of loops and whorls, whereas males showed a higher incidence of arches (Koneru et al., 2014). A different study in India found the predominant pattern among both Males and Females to be the Ulnar loop followed by Plain whorl and the arches respectively (Khadri et al., 2013). Males were associated with radial loops while females were associated with ulnar loops in Nepal (Shrestha & Malla, 2019). A study in the Nanded district of Maharashtra estate found that the principal pattern in both genders was the loop pattern and that the frequency was more for males than for a female (Binorkar & Kulkarni, 2017). Another study in Malaysia had the most prevalent type of fingerprint pattern among both males and females being the loop patterns (Binorkar & Kulkarni, 2017). A Chinese study concluded that Men and women have somewhat different ten-fingerprint pattern prevalence, with the loop patterns occurring the most between the two genders (Xie & Lin, 2020). Hence, from the reviewed studies, sexual dimorphism of the fingerprint patterns may be attributed to differences in heritability and developmental variation among the sexes (Oguh et al., 2019). However, there is no information on fingerprint patterns among males and females in a population in western Kenya.

2.6. Fingerprint pattern distribution across ethnicities

People often believe that skin color is the true marker of racial differences, but the reality is very complex, as fingerprints can be used to differentiate race and even ethnic communities (Cole, 2020). The four major fingerprint patterns are distributed in all ethnic groups worldwide, but the characteristics vary differently, and genetic factors are also known to play a crucial role in determining fingerprint pattern types (Liu et al., 2019).

Studies have explored the genetic basis of fingerprint patterns among different ethnic groups. For instance, a study in China conducted a genome-wide association study and identified genetic variants associated with specific fingerprint pattern types in a Chinese population (Liu et al., 2019). Understanding the genetic underpinnings of ethnic variation in fingerprint patterns can provide valuable insights into the complex interplay between genetics, ethnicity, and fingerprint patterns. In addition to genetic factors, environmental influences may contribute to ethnic variation in fingerprint patterns. Environmental factors such as diet, climate, and lifestyle can affect the development and appearance of friction ridge skin (Ballantyne et al., 2020). For instance, a study that examined the effects of prenatal and postnatal environmental factors on fingerprint patterns in a diverse population found evidence of environmental contributions to pattern variation (Ballantyne et al., 2020). The role of ethnicity in fingerprint pattern variation has been the subject of considerable research.

It has been previously demonstrated that ethnicity plays a major role in fingerprint pattern variation. A study that compared the fingerprint patterns of individuals belonging to different ethnicities found that Europeans had significantly more whorls on their fingertips compared to individuals from other ethnicities/ (regions?) (Mrugacz et al., 2019). Another study showed that individuals from Middle Eastern populations had a higher frequency of loops and a lower frequency of whorls compared to individuals from other regions (Kahrizi et al., 2020). A different study from the African-American population compared fingerprint patterns among three different ethnicities and found that individuals from African-American populations had significantly more loops and fewer whorls compared to individuals from Caucasian and Asian populations (Benshera et al., 2021). A Brazilian study compared the fingerprint patterns of different ethnic groups in Brazil and showed that individuals from Indigenous American populations had significantly more arches and a lower frequency of whorls compared to individuals from other populations (Carneiro et al., 2023). A descriptive study of southern Nigeria concluded that fingerprint patterns vary among the ethnicity groups of Urhobos and Ibos' residing in Warri, South Southern Nigeria, such that the ulnar loop is associated with the Ibo’s left finger (Abimbola et al., 2021). A different study in Nigeria concluded that the whorl and arch patterns were common in both Itsekiri males and females while the ulnar loop predominated in Itsekiri females and Urhobo males (Jaiyeoba-Ojigho et al., 2019). In Nigeria, a study showed that the Igbo ethnic group has a higher count of all the minutiae types in comparison to the Yoruba ethnic group (Akpan et al., 2019). A Malaysian study showed that Whorls and Loops were the most prevalent pattern across all ethnic groups tested, and in contrast to Indians, the distributional patterns of Malays and Chinese were comparable (Heng et al., 2018). The Esan West ethnic group of Nigeria presents a higher arch fingerprint type (56.44%) compared to the Esan North community (24.38%) and Esan Central (19.18%) (Anyanwu, 2020). In Ghana, Ewes have a prevalence of loops over whorls and arches, with the frequency of loops among Ewes, particularly in females, being much higher than the African average (Awuah, 2020). A Chinese-Javanese mixed-ethnicity family had a whorl variation pattern on the thumbs as a marker of Javanese ethnicity otherwise, the Chinese ethnicity is distinguished by a radial loop on the index finger and a tented arch pattern on both the index and the little finger (Nikmah & Fatchiyah, 2017). Overall, studies suggest there is variation in finger print patterns between ethnic groups residing in the same region or geographical area. However, there is no information on fingerprint patterns across ethnic groups in a population in western Kenya. Therefore, this study compared fingerprint patterns between two ethnic groups in a population in western Kenya.

2.7. Fingerprint Pattern distribution between Siblings and Non-Siblings

Family members, including siblings, may be important in the process of forensic investigation as they may help narrow down the investigation scope (Zhu et al., 2020). Understanding the fingerprint pattern distribution among siblings and non-siblings can provide insights into the relative contributions of genetics in shaping fingerprint patterns. Studies show a higher concordance of fingerprint patterns among monozygotic twins compared to dizygotic twins (Van Oorschot et al., 2019). This suggests a significant genetic influence on fingerprint pattern distribution among siblings. Also, studies show that sibling pairs have a higher similarity in fingerprint pattern distribution compared to unrelated pairs, suggesting a genetic component of similarity (Ulery et al., 2018). The heritability estimates further support the genetic influence on fingerprint pattern distribution (Zhu et al., 2020).

A study in Egypt determined that the arch, loop, and whorl fingerprint patterns in siblings were significantly more similar than in non-siblings (Hassain et al., 2020). Another study in Egypt found that the three major fingerprint patterns of the siblings were more similar than those of the non-siblings (Ahmed et al., 2019). A different study found that the arch, loop, and whorl fingerprint patterns of the siblings were more similar than those of the non-siblings (Tavakoli et al., 2017). A Malaysian study concluded that siblings demonstrated similarities in all patterns, i.e., the arch, composite, loop, and whorl, compared to non-siblings (Heng et al., 2018). Similar findings have been reported in Nigeria (Iroanya et al., 2020) and Malaysia (Gan et al., 2018). A different study reported that siblings were found to have similar fingerprint patterns, with a majority having the loop pattern followed by Whorl, then arch (Abd Alhalim, 2018). A study in Nigeria concluded that sibling detection by fingerprint similarity might have the potential as a novel forensic tool that can be used for intelligence operations (Hefetz et al., 2022). A different Study in Malaysia also confirms that siblings' arches, loops, and whorl fingerprint patterns are likely to be more similar as compared to non-siblings' fingerprint patterns (Gan et al., 2018). Taken together, there is no information on fingerprint patterns in siblings and non-siblings in a population in western Kenya, highlighting an importance in comparing these patterns in this region.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Study Site

The research project was carried out in western Kenya from two sub-counties of Webuye West and Malava. Choosing this location is mainly because it has two different communities from the same ethnic group (Abaluhya) bordering each other and separated by River Nzoia, which may result in a difference in weather patterns for the two communities and hence may lead to a difference in fingerprint patterns prevalence (Liu & Silverman, 2001). According to Statista infographics, Webuye is located in a region with a tropical climate, and the majority of the land in the area is dedicated to subsistence agriculture. The elevation is 1,523 meters, its latitude is 0.6166667 degrees, and its longitude is 34.7666667 degrees (4,997 ft. above sea level). The yearly average temperature is 24 degrees Celsius. Malava has a Tropical monsoon climate and is located at an elevation of 0 feet above sea level (Classification: Am). The annual temperature in the district is 23.31° C, which is 0.81% higher than the national average. Malava gets around 211.61 millimetres (8.33 inches) of rain every year and has 296.89 wet days (81.34% of the time).

3.2. Research Design and Target Population

This was a descriptive cross-sectional study targeting a population of Webuye west and Malava sub-counties. Information on sex, gender, and siblings was recorded on the questionnaire. The specific criterion for ascertaining collected prints is checking for the presence of the different pattern marks

3.2.1. Sampling Methods

The study employed a cluster sampling technique. This is a technique or a method of sampling that employs the probability method where the population is divided into clusters, and then some clusters are randomly selected as the sample. The process of sampling includes: defining the population, dividing the population into clusters, selecting a cluster of clusters, and data collection.

3.2.2. Dividing the Population into Clusters

The defined population was divided into clusters according to Communities. The two communities were further grouped into zones of different sub-ethnic groups, and a single sub-ethnic group will be selected from each cluster. The communities to be considered as a representation of the region were the Webuye West and Malava constituencies. The selected sample groups were then divided in accordance with gender.

3.2.3. Select Clusters.

A cluster was then selected randomly from all the sample clusters in the larger population, which was, in turn, a representation of the result. The study targets to work with at least two hundred and forty donors. A hundred and twenty represent the females and a hundred and twenty for the females.

3.3. Sample Size Determination

The sample size was calculated with a prevalence of 50% based on the formula.

$$n = Z^2 \times P \times {}^{q}/_{e^2}$$

n = sample size

z = level of confidence according to the standard normal distribution (for a level of confidence of 95%, z = 1.96, for a level of confidence of 99%, z = 2.575)

p = estimated proportion of the population that presents the characteristic (when unknown, we use p = 0.5)

q = tolerated margin of error (for example, we want to know the real proportion within 5%) (Fink, 2003)

$= (1.96)^2 \times 0.5 \times 0.5 / (0.7)^2$

$= 240$

Where,

- $Z= 2.4$ for a 95% confidence interval
- $p = 0.5$
- $q = 1-p$
- e= margin of error= 7%
- N = population of Webuye West (152,515) and Malava (5,131) constituencies according to the census 2019, Kenya National Bureau of Statistics

For finite populations,

$N_0 = n/1 +(n/N)$

$= 240/1+(240/157646)$

$= 240/ (1+0.00152)$

$= 240/1.00152$

$= 240$

Hence, this study recruited 240 individuals.

3.4. Eligibility Criteria

3.4.1. Inclusions.

Only Study participants who signed informed consent were included in the study.

3.4.2. Exclusion

Subjects with a major deformity (congenital/accidental) on the upper extremity (syndactyly, polydactyly) with leprosy or with gender identity disorder or with chronic skin disease, having worn fingerprints or extra or bandaged fingers were excluded from the study.

3.5. Data Collection

Prior to fingerprinting, the individual's hands were washed. For moist fingers, alcohol was used in wiping the hands. For a hand that was dry or flaky, a tiny amount of cotton was used to wipe away any excess. The donors were instructed to relax and gaze away from the fingerprint gadget. With the right hand, the investigator grasped the individual's right hand at the base of the thumb. Then the investigator capped his palm over the individual's fingers, tucking beneath those that are not now being printed. Using the left hand, the investigator guided the finger being imprinted by rolling from nail edge to nail edge, catching the tip of each finger down to the first joint. The side of the finger bulb was put on the card during the rolling imprint process. The finger was then rolled to the other side so that it pointed in the opposite way. A gentle, steady motion while rolling the finger was applied. The maximum pressure required to capture a clean fingerprint is equal to the weight of the finger. When rolling each finger, the side with the highest resistance was rolled first. Rolling occurred towards the body for the thumbs and away from the body for the fingers. When rolling the right index finger, for example, roll from left to right.

Following the individual fingerprints, the four-finger slap or simple print was recorded. Press the inkpad with all four fingers of the right hand while keeping the fingers together. The four fingers were then pushed at a 45-degree angle into the appropriate area at the bottom of the card to capture all four prints simultaneously. This procedure was repeated for the left hand. The two thumb slaps or simple prints were taken simultaneously by putting both thumbs in the boxes at the bottom of the card. It was ensured that all relevant demographic data was provided in the proper places and that the individual who was fingerprinted signed the card.

The collected fingerprints were read using a magnifying hand lens to determine the different types of patterns and sub patterns. The data representing each type of fingerprint from each finger was then recorded on Excel spreadsheets which then proceeded to data analysis.

3.6. Data Analysis

The data were imported into Excel, cleared, and then exported to SPSS 25.0. The prevalence of different fingerprint types was presented using descriptive analysis. The chi-square test was used to ascertain the distribution of fingerprint patterns between siblings, non-siblings, men and females, and ethnic groupings. $P \leq 0.05$ was the statistical significance level set for the analysis.

3.7. Ethical consideration

The research authorization was received by NACOSTI (Ref: 989668), and the ethical approval for the project came from the Masinde Muliro University Ethical Review Committee (Ref: (MMU/COR: 403012 Vol 6 (01))). Permission was also granted from the local government to carry out the study. The Helsinki Declaration was followed in the conduct of the study (Parsa-Parsi et al., 2014). By completing the surveys and submitting their fingerprints, research participants gave their written informed permission.

Insofar as it was practical, the data controller notified the data subject of their rights, the reason for the collection, the third parties to whom the personal data has been or will be transferred, the safeguards put in place, an explanation of the organizational and technical security measures put in place, whether the data collection is required by law or not, and any potential consequences before collecting the data.

Confidentiality was ensured throughout the study by not involving personal identifiers, including the participants' names. The Biometric data was protected from any use other than the intended research objectives. Codes were used as a record of the participants. All study forms and filled questionnaire records were archived in a secure cabinet at Kirinyaga University, with access only limited to research purposes. Non-significant raw data were destroyed accordingly. Children were placed under special protection and were entitled to special protection when processing their data. Parents of guardians signed the informed consent for the children (Deliversky and Deliverska, 2018). Every chapter of the act was considered with high confidentiality to protect the biometric data of the participants. Non-significant raw data was destroyed accordingly.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. Prevalence of fingerprint patterns in western Kenya

The distribution of fingerprint patterns and sub-patterns of the study participants is shown in figure 3 below. A total of 28 (11.9%) thumb, 26 (10.8%) index, 26 (10.8%) middle, 25 (10.4%) ring, and 25 (10.4%) pinkie fingers haboured arch patterns. The proportion of composite pattern was 11 (4.6%), 8 (3.3%), 3 (1.3%), 6 (2.5%), and 3 (1.3%) for the thumb, index, middle, ring, and pinkie fingers, respectively. There were 133 (55.4) thumb fingers,

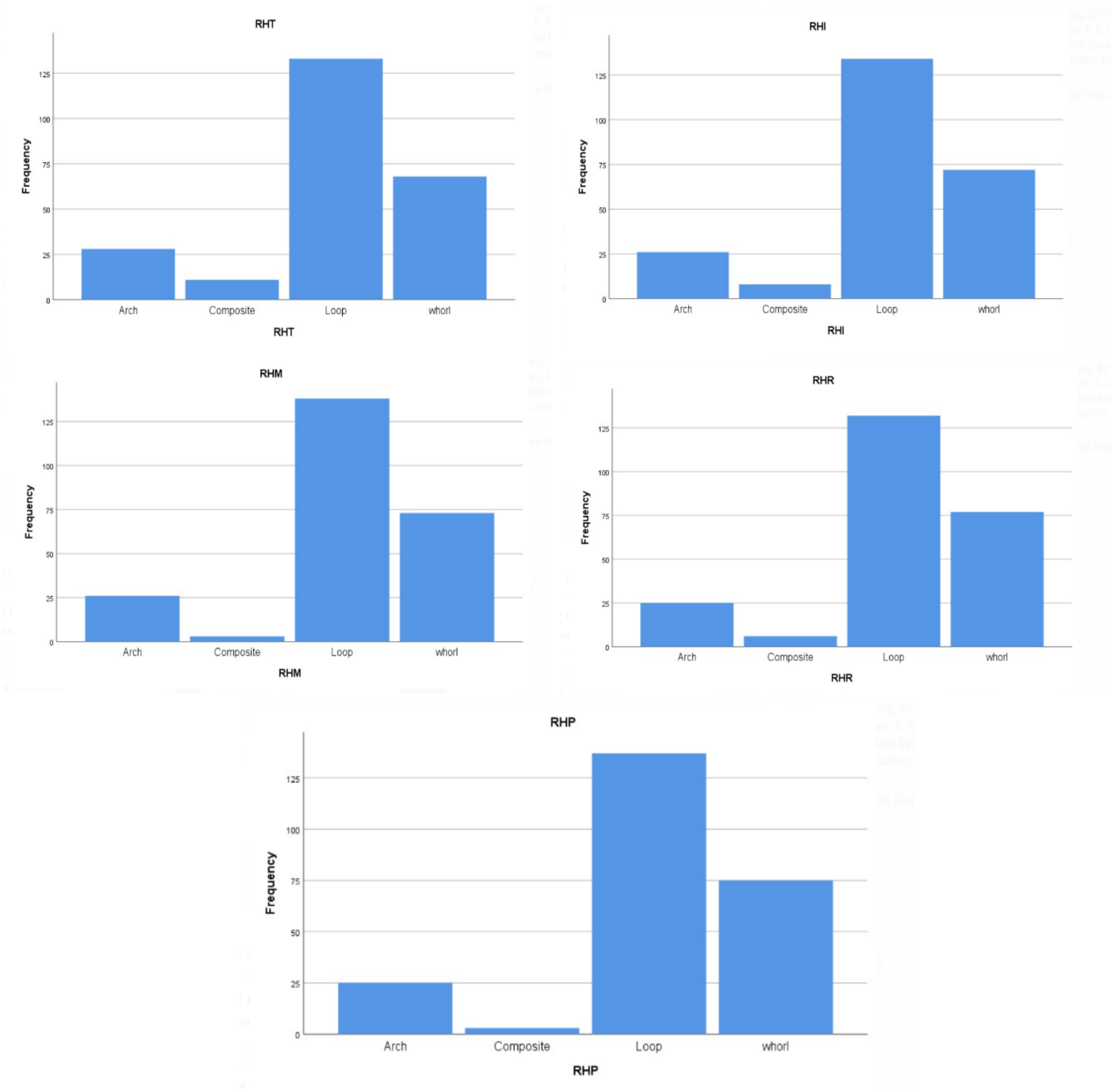


Figure 3: Distribution of fingerprint patterns in the Fingers of the Right hand: Representation of the arch, composite, loop, and whorl fingerprint patterns in the RHT, RHI, RHM, RHR, and RHP.

134 (55.8%) index, 138 (57.5%) middle, 132 (55.0%) ring, and 137 (57.1%) pinkie fingers identified to have loop pattern. Whorl pattern was observed in 68 (28.3%), 72 (30.0%), 73 (30.4%), 77 (32.1%), and 75 (31.3%) thumb, index, middle, ring, and pinkie fingers, respectively. Likewise, the distribution of fingerprint patterns was similar across the left-hand fingers (P = 0.937). The counts of the arch pattern were 28 (11.7%), 26 (10.8%), 25 (10.4%), 25 (10.4%), and 25 (10.4%) for the thumb, index, middle, ring, and pinkie fingers respectively. The composite pattern was observed in 8 (3.3%) thumb, 2 (0.8%) index, 5 (2.1%) middle, 6 (2.5%) ring, and 9 (3.8%) pinkie fingers. Loop pattern was identified in 133 (55.4%) thumb, 137 (57.1%) index, 135 (56.3%) middle, 135 (56.3%) ring, and 135 (56.3%) pinkie fingers while whorl pattern was detected in 71 (29.6%) thumb, 75 (31.3%) index, 75 (31.3%) middle, 74 (30.8%) index and 71 (29.6%) pinkie fingers.

The fingerprint patterns were further analyzed into sub patterns. Observations for the right-hand fingers revealed that the plain arch sub-patterns had a frequency of 17 (60.7%) for the thumb finger, 16 (61.5%) for the index finger, 20 (77.0%) for the middle finger, 21 (75.0%) for the ring finger, and 14 (56.6%) for the pinkie finger. The distribution of the tented sub-pattern on the right hand for the thumb, index, middle, ring, and pinkie was 11 (39.3), 10 (38.5%), 6 (23.0%), 4 (25.0%), and 11 (44.0%), respectively. There were 5 (45.5%), 4 (50.0%), 1 (33.3%), 5 (83.3%), and 1 (33.3%) Loop arch sub-patterns. The whorl arch sub-pattern count for the thumb was 6 (54.5%) for the thumb, 4 (50.0%) for the index, 2 (66.7%) for the middle, 1 (16.7%) ring, and 2 (66.7%) for the pinkie fingers. A total of 47 (35.3%), 42 (31.3%), 44 (31.9%), 42 (31.8%), and 46 (33.6%) were observed for the radial sub-pattern distribution from the thumb to the pinkie, respectively. The ulnar sub-patterns had a frequency of 86 (64.7%) for the thumb, 92 (68.7%) for the index, 94 (68.1%) for the middle, 90 (68.2%) for the ring, and 91 (66.4%) for the pinkie fingers. The count for the central pocket sub-pattern was 12 (17.6%), 2 (2.8%), 1 (1.4), 0 (0%), and 2 (2.7%) from the thumb to the pinkie finger respectively. There were 7 (10.3%), 6 (8.3%), 1 (1.4%), 6 (7.9%), and 4 (5.3%) for double whorl sub-pattern. The count for the plain whorl sub-pattern was 49 (72.1%) for the thumb, 64 (88.9%) for the index, 71 (97.2%) for the middle, 71 (92.2%) for the ring, and 69 (92.0%) for the pinkie.

Analysis of fingerprint sub-patterns for the left hand showed that the plain arch sub-pattern count was 25 (89%) for the thumb finger, 17 (65.4%) for the index finger, 18 (72.0%) for the middle finger, 19 (67.9%) for the ring finger, and 22 (88.0%) for the pinkie finger. A count of 3 (20.7%), 9 (34.6%), 7 (28.0%), 6 (21.4%), and 3 (12.0%) was observed for the tented sub-pattern for the thumb, index, middle, ring, and pinkie fingers, respectively. The occurrence of the loop arch sub-pattern was 4 (50.0%) for the thumb, 1 (50.0%) for the index, 4 (80.0%) for the middle, 3 (50.0%) for the ring, and 4 (44.4%) for the pinkie. The whorl arch sub-pattern was detected in 4 (50.0%) thumb, 1 (50%) index finger, 1 (20.0%) middle, 3 (50.0%) ring, and 5 (55.6%) pinkie fingers. The radial sub-pattern frequency from the thumb to the pinkie fingers was 47 (35.3%), 44 (32.1%), 42 (31.1%), 43 (31.9%), and 43 (31.9%), respectively. There were 86 (64.7%), 93 (67.9%), 93 (68.9%), 92 (68.1%), and 92 (68.1%) observations for the ulnar sub-pattern from the thumb to the pikie fingers respectively. The central pocket sub-pattern appearance was 12 (16.9%) for the thumb, 1 (1.3%) for the index, and 4 (5.6%) for the middle fingers. Five (7.0%), 2 (2.6%), 3 (4.0%), 2 (2.7%), and 2 (2.9%) from the thumb to the pinkie fingers, respectively, haboured double whorl sub-pattern. The plain whorl sub-pattern prevalence was 54 (76.1%) for the thumb, 72 (96.0%) for the index finger, 72 (96.0%), on the middle finger 72 (97.3%) on the ring finger, and 65 (91.5%) on the pinkie finger.

The graphs show the distribution of the four types of fingerprint patterns across the five fingers of the right hand. That is, the right-hand thumb (RHT), right hand index (RHI), right hand middle (RHM), right hand ring (RHR), and the right-hand pinkie (RHP) fingers.

Generally, the loop pattern appeared to have a higher occurrence across all the five fingers. The composite pattern had the least occurrence in terms of numbers across all the fingers.

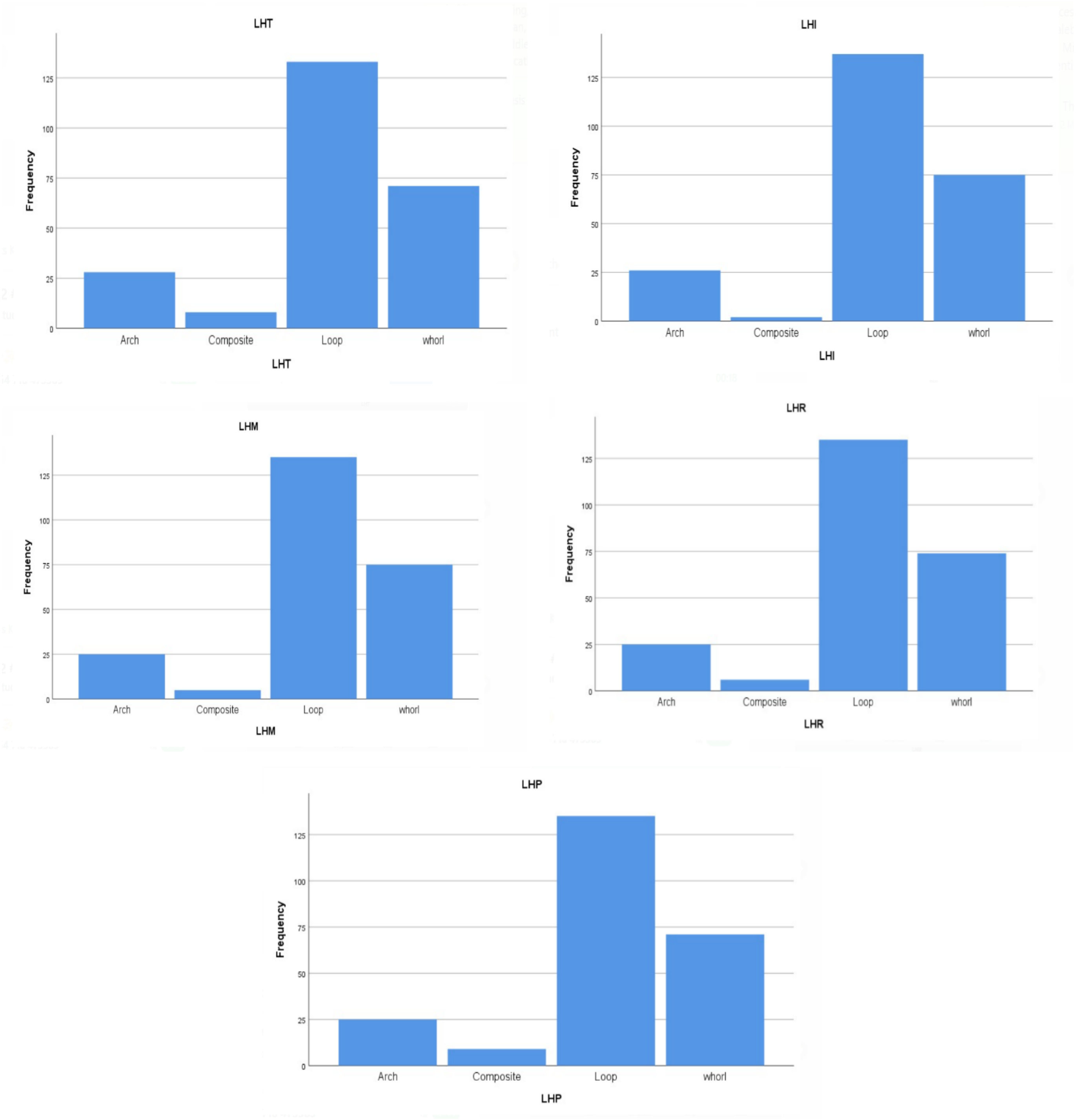


Figure 4: Distribution of fingerprint patterns in the Fingers of the Left hand: Representation of the arch, composite, loop, and whorl fingerprint patterns in the LHT, LHI, LHM, LHR, and LHP.

The graphs show the distribution of the four types of fingerprint patterns across the five fingers of the left hand. That is, the left-hand thumb (LHT), left hand index (LHI), left hand middle (LHM), left hand ring (LHR), and the left-hand pinkie (LHP) fingers. Similarly, to the right hand, the loop pattern appeared to have a higher occurrence across all the five fingers. The composite pattern also had the least occurrence in terms of numbers across all the fingers. The whorl patterns come second, followed by the arch pattern.

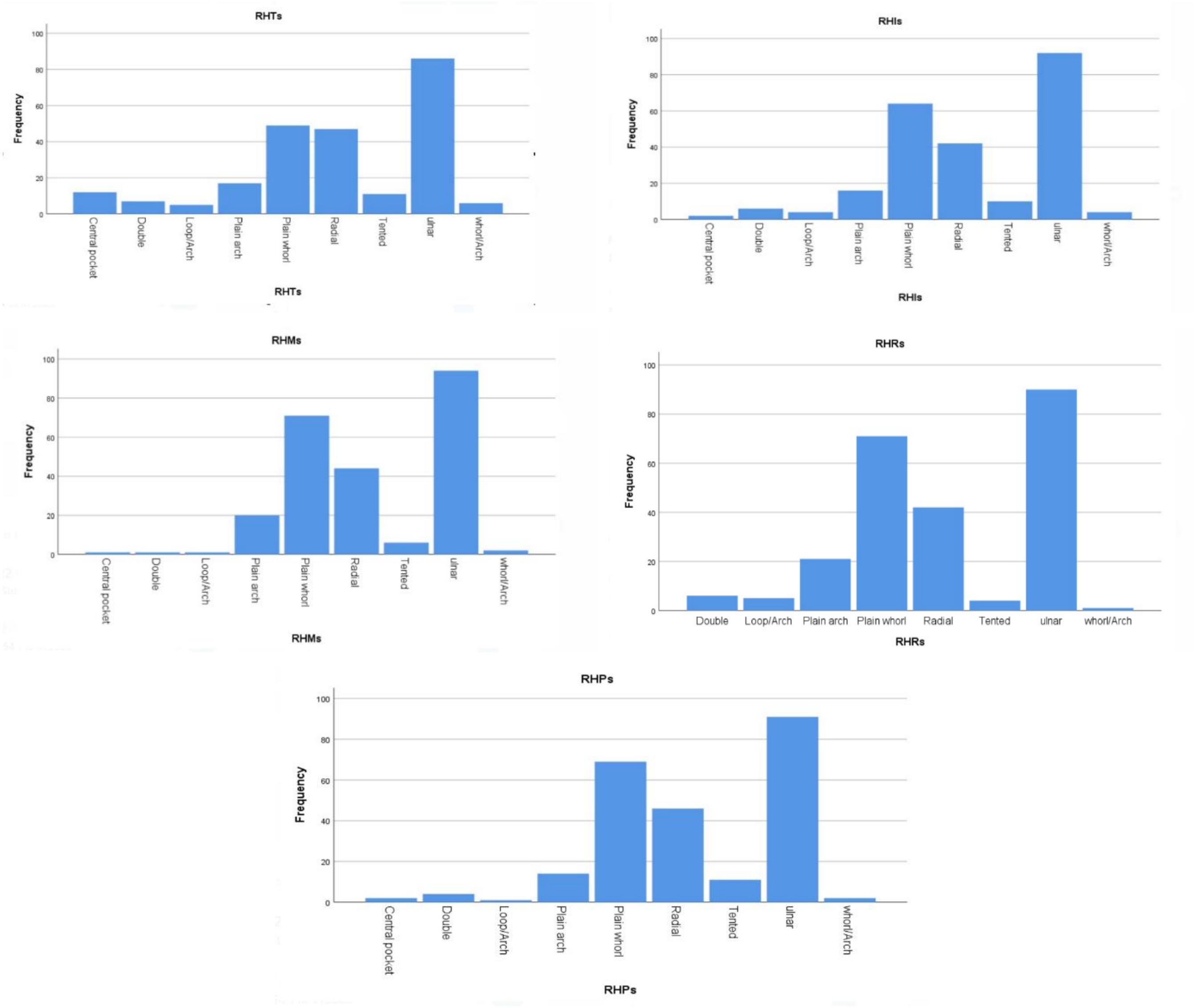


Figure 5: Distribution of fingerprint sub-patterns in the Right Hand Fingers. Representation of the fingerprint sub-patterns in the RHT, RHI, RHM, RHR, and RHP.

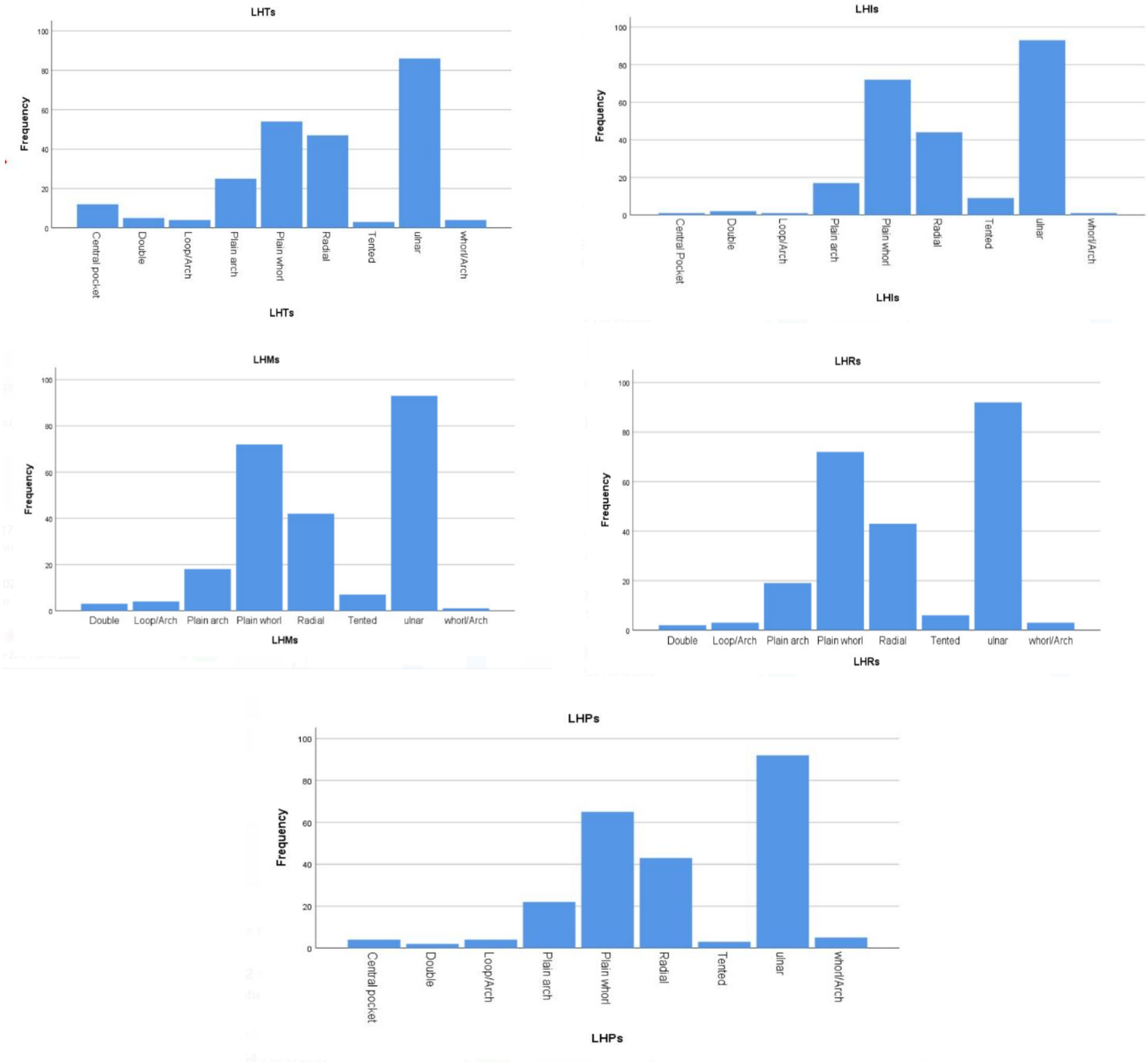


Figure 6: Distribution of fingerprint sub-patterns in the Left Hand Fingers. Representation of the fingerprint sub-patterns in the LHT, LHI, LHM, LHR, and LHP

The graphs in group 5 and 6 above shows the distribution of the nine types of fingerprint sub-patterns across the five fingers of the right and left hand. The ulnar sub-patterns appeared to be more common across the fingers. The sub-patterns belonging to the composite pattern appeared to be least occurring across the fingers.

Discussion

The frequencies of the four fingerprint patterns were similar across the right-hand digits (*P* = 0.736). Similarly, the distribution of the arch, composite, loop, and whorl fingerprint patterns was comparable across the left-hand digits (*P* = 0.937). However, the loop pattern had a slightly higher occurrence for both hands. This observation is partly in line with studies in Nigeria (Hirachan et al., 2019), and Thailand (Ojigho et al., 2020) that showed similarity in frequencies of Loop, whorl, and arch patterns across the five fingers. The ulnar loop sub-pattern was the most frequent across the five fingers of the left and right hands, as shown in (figure 5 and 6) and the remainder are Plain arch, Tented arch, Loop arch, Whorl arch, Radial, Ulnar, Central pocket whorl, Double whorls, and plain whorl, an observation that mirrors studies in India (Kapoor & Badiye, 2017). However, the findings of this study are contradicted by a study in Costa Rica that reported higher incidences of arches and whorls on the left hand (Segura-Wang & Barrantes, 2009). The similarities and differences observed between this and previous studies may be attributed to maternal environment, blood group, and finger lengths, which vary globally (Satheesha., et al 2018; Yini Liu et al, 2020; Silamlak Birhanu Abegaz, 2021) and have been associated with fingerprint patterns. For instance, a number of maternal environmental factors, including the density of the amniotic fluid surrounding the fetus, the size of the fetus, the friction in the womb, and the location in the womb amongst other fetal movement patterns determine the fingerprint pattern in the womb (Singh RK et al, 2018). In addition, people with whorl-shaped fingerprints on both of their little fingers tend to have longer little fingers than those who do not (Li et al. 2022). Most importantly, loop fingerprint patterns are frequently associated with blood group AB while arch and whorl are frequencies identified in blood group A individuals (Saranya Manikandan et al, 2019). Taken together, the common fingerprint pattern distribution in ten fingers varies in different countries.

4.2. Fingerprint patterns among males and females in a population in western Kenya.

The distribution of fingerprint patterns and sub-patterns across genders for the study participants is shown in figures 7 and 8 below. The Arch (12.5% vs. 10.8%), composite (5.0% vs. 4.2%), loop (50.0% vs. 60.8%), and whorl (32.5% vs. 24.2%) patterns for the right-hand thumb were comparable between males and females, respectively (P = 0.395). The prevalence of Arch (10.8% vs. 10.8%), composite (3.3 % vs. 3.3%), loop (53.3% vs 58.3 %), and whorl (32.5% vs 27.5%) patterns for the right-hand index were similar between male and female, respectively (p = 0.857). The arch (10% vs 11.7%), composite (2.5% vs 0%), loop (53.3% vs 62.7%), and whorl (34.2% vs 26.7 %) patterns for the right-hand middle were also comparable between male and female, respectively (p = 0.173). The prevalence of the arch (10.1% vs 10.8%), composite (3.3% vs 1.7%), loop (51.7% vs 58.3%), and whorl (35.0 vs 29.2%) patterns for the right-hand ring were also comparable between male and female (p = 0.609). Similarly, the arch (10.0% vs 10.8%), composite (0.8% vs 1.7%), loop (53.3% vs 60.8%), and the whorl (38.8% vs 26.7%) patterns for the right-hand pinkie were similar between male and female, respectively (p = 0.461).

The distribution of the arch (12.5% vs 10.8%), the composite, (3.3% vs 3.3%), the loop (50.8% vs 60.0%), and the whorl (33.3% vs 25.8%) patterns for the left-hand thumb were comparable between male and female, respectively (p = 0.533). The rates of the arch (10.0% vs 11.7%), composite (1.7% vs 0%), loop (54.2% vs 60.0%), and the whorl (34.2% vs 28.3%) patterns for the left-hand index finger were similar between male and female, respectively (p = 0.367). The prevalence of the arch (10.0% vs 10.8%), composite (0.8% vs 3.3%), Loop (54.2% vs 58.3%), and whorl (35.0% vs 27.5%) for the left-hand middle fingers were comparable between male and female, respectively (p = 0.376). Similarly, the distribution of the arch (10.0% vs 10.8%), composite (2.5 % vs 2.5 %), loop (52.5% vs 60.0%), and whorl (35.0% vs 26.7 %) patterns for the left-hand ring were comparable between male and female, respectively (p = 0.574). Finally, the arch (10.0% vs 10.8 %), composite (3.3% vs 4.2%), loop (53.3% vs 59.2%), and whorl (33.3% vs 25.8%) for the left-hand pinkie fingers were comparable between male and female, respectively (p = 0.647).

The prevalence for the sub-patterns were (4.2% vs. 5.8%) for central pocket, (5.0 % vs 0.8 %) for double, (2.5% vs 1.7 %) for loop arch sub pattern, (8.3 % vs 7.5%) for the plain arch, (23.3% vs 17.5%) for plain whorl, (18.3% vs 20.8 %) for radial, (4.2% vs 5.0%) for tented, (31.7% vs 40.0%) for ulnar, and (2.5% vs 2.5%) for whorl arch sub-patterns in males and females right-hand thumb, respectively. The right-hand index sub-pattern analysis showed a prevalence of central pocket (0.8% vs. 0.8%), double (2.5 % vs 2.5 %), loop arch sub-pattern (0.8% vs 2.5 %), plain arch (6.7 % vs 6.7%), plain whorl (29.2% vs 24.2%), radial (15.8% vs 19.2 %), tented (4.2% vs 4.2%), ulnar (37.5% vs 39.2%), and whorl arch (2.5% vs 0.8%) between male and female, respectively. The distribution for the middle finger sub-patterns was observed to be (0% vs. 0.8%) for the central pocket, (0 % vs 0.8 %) for double, (0.8% vs 0 %) for the loop arch, (7.5 % vs 9.2%) for the plain arch, (34.2% vs 25.0%) for plain whorl, (15.8% vs 20.8 %) for radial, (2.5% vs 2.5%) for tented, (37.5% vs 40.8%) for ulnar, and (1.7% vs 0%) for whorl arch sub-patterns in male and female, respectively. The right-hand ring showed the rates of (0% vs 0%) for central pocket, (3.3 % vs 1.7 %) double, (2.5% vs 1.7 %) loop arch, (8.3 % vs 9.2%) plain arch, (31.7% vs 27.5%) plain whorl, (15.8% vs 19.2 %) radial, (1.7% vs 1.7%) tented, (35.8% vs 49.2%) ulnar, and (0.8% vs 0%) whorl arch sub-patterns in male and female, respectively. The distribution for the right-hand pinkie was, (1.7% vs. 0%) for the central pocket, (1.7 % vs 1.7 %) for double, (0.8% vs 0 %) for the loop arch, (4.2 % vs 7.5%) for the plain arch, (32.5% vs 25.0%) for plain whorl, (17.5% vs 20.8 %) for radial, (5.8% vs 3.3%) for tented, (35.8% vs 40.0%) for ulnar, and (0% vs 1.7%) for whorl arch sub-patterns in males and females, respectively.

The prevalence for the central pocket (4.2% vs. 5.8%), double (3.3% vs 0.8 %), loop arch (1.7% vs 1.7 %), plain arch (10.8% vs 10.0%), plain whorl (25.8% vs 19.2%), radial (18.3% vs 20.8 %), tented (1.7% vs 1.7%), ulnar (32.5% vs 39.2%), and whorl arch (1.7% vs 1.7%) sub patterns were recorded in males and females thumb, respectively. The central pocket (0%vs. 0.8%), double (2.7%vs 0 %), loop arch sub pattern (0.8% vs 0 %), plain arch (5.8 % vs 8.3%), plain whorl (32.5% vs 27.5%), radial (15.8% vs 20.8 %), tented (4.2% vs 3.3%), ulnar (38.3% vs 39.2%), and whorl arch (0.8% vs 0%) sub patterns were observed in the male and female left-hand index, respectively. The rates on the left-hand middle were (0% vs 0%) for the central pocket, (2.5% vs 0%) for double, (0.8% vs 2.5%) for loop arch sub-pattern, (7.5 % vs 7.5%) for the plain arch, (32.5% vs 27.5%) for plain whorl, (15.8% vs 19.2%) for radial, (2.5% vs 3.3%) for tented, (38.3% vs 39.2%) for ulnar, and (0% vs 0.8%) for whorl arch sub-patterns in male and female, respectively. The prevalence for the left-hand ring was (0% vs 0%) for the central pocket, (0.8% vs 0.8%) for double, (1.7 % vs 0.8%) for the loop arch, (7.5 % vs 8.3%) for the plain arch, (34.2% vs 25.8%) for plain whorl, (15.8% vs 20.0%) for radial, (2.5% vs 2.5%) for tented, (36.7% vs 40.0%) for ulnar, and (0.8% vs 1.7%) for whorl arch sub-patterns in male and female, respectively. The rates of (2.5% vs 0.8%) for the central pocket, (1.7% vs 0%) for double, (1.7% vs 1.7%) for the loop arch, (8.3% vs 10.0%) for the plain arch, (29.2% vs 25.0%) for plain whorl, (16.7% vs 19.2%) for radial, (1.7% vs 0.8%) for tented, (36.7% vs 40.0 %) for ulnar, and (1.7% vs 2.5%) for whorl arch sub patterns were observed in male and female for the left-hand pinkie, respectively.

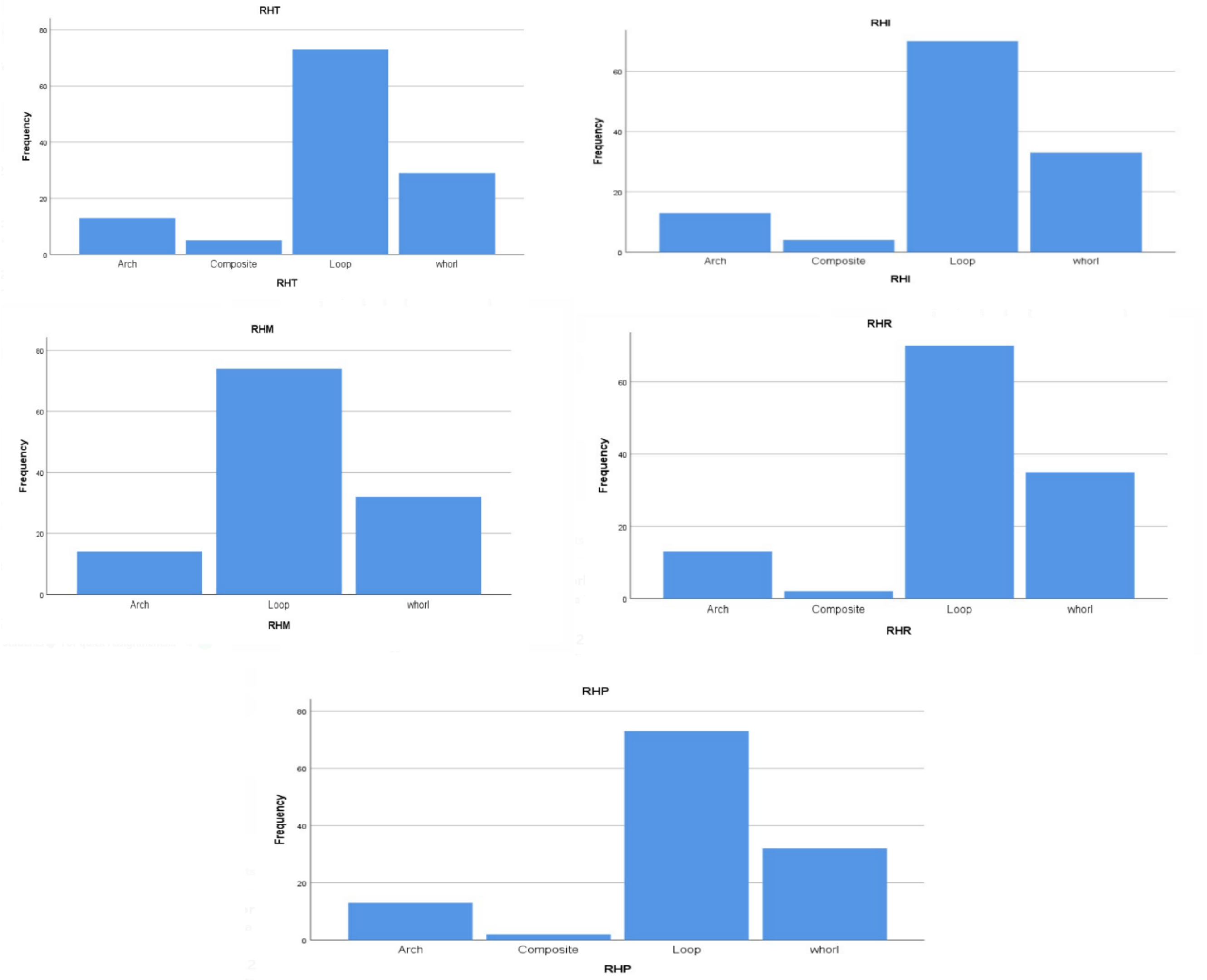


Figure 7: Distribution of the arch, composite, loop, and whorl fingerprint patterns in the right hand Fingers in Female. A representation of the distribution of fingerprint pattern on the RHT, RHI, RHM, RHR, and RHP of the female gender. P-value = 0.395

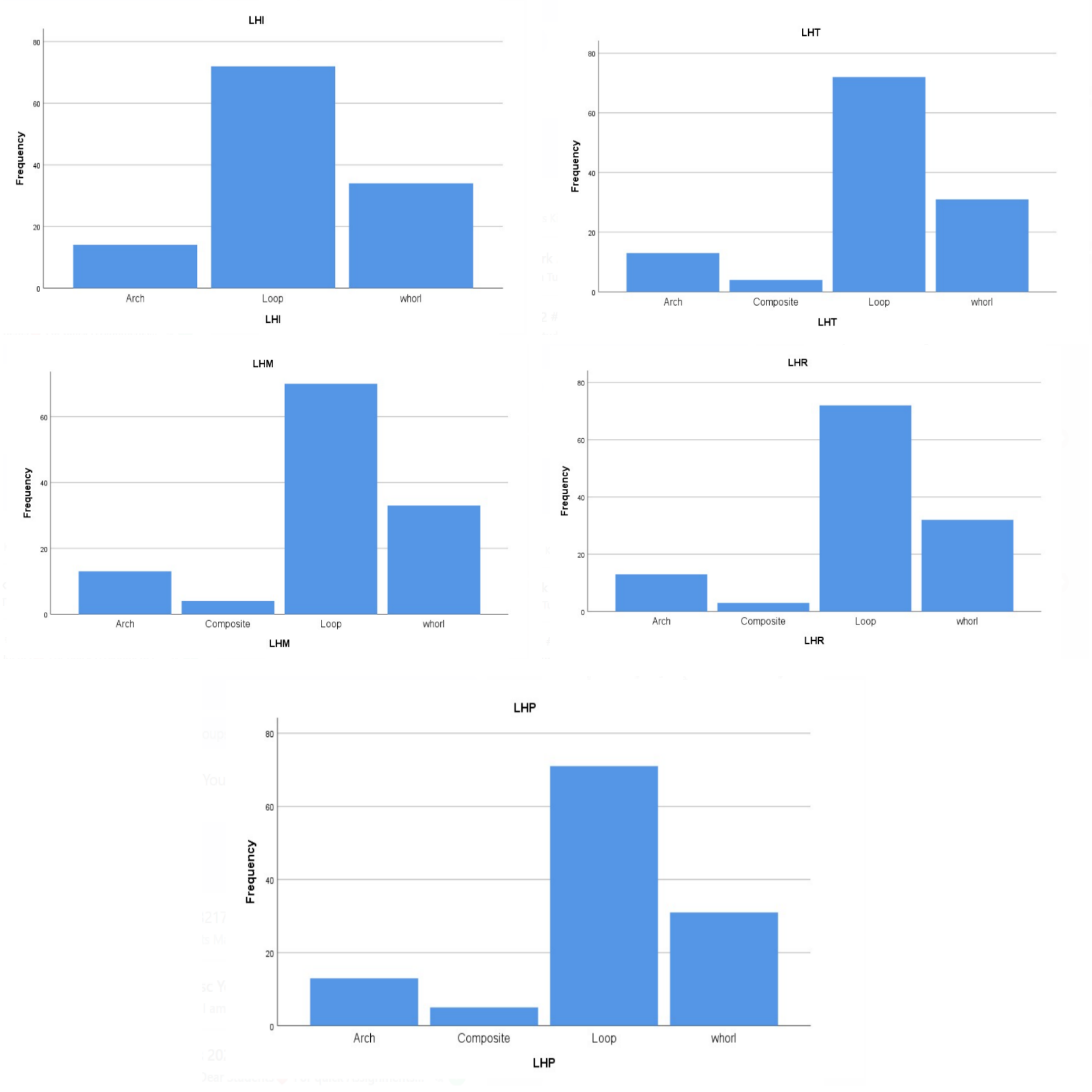


Figure 8: Distribution of the arch, composite, loop, and whorl fingerprint patterns in the Left Hand Fingers in Female. A representation of the distribution of fingerprint pattern on the LHT, LHI, LHM, LHR, and LHP of the female gender. P-value = 0.857

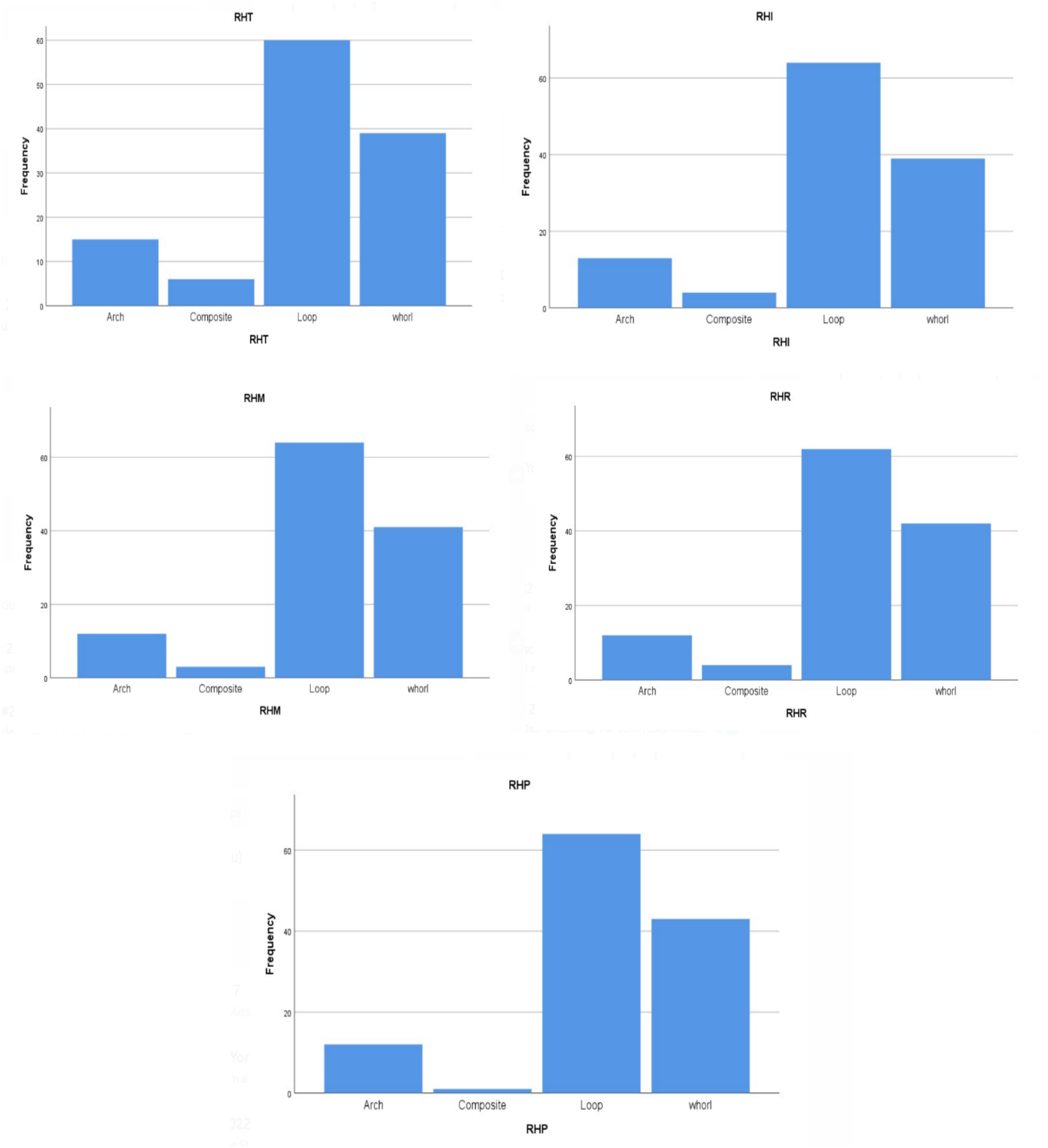


Figure 9: Distribution of the arch, composite, loop, and whorl fingerprint patterns in the Right Hand Fingers in Male. A representation of the distribution of fingerprint pattern on the RHT, RHI, RHM, RHR, and RHP of the male gender. P-value = 0.173

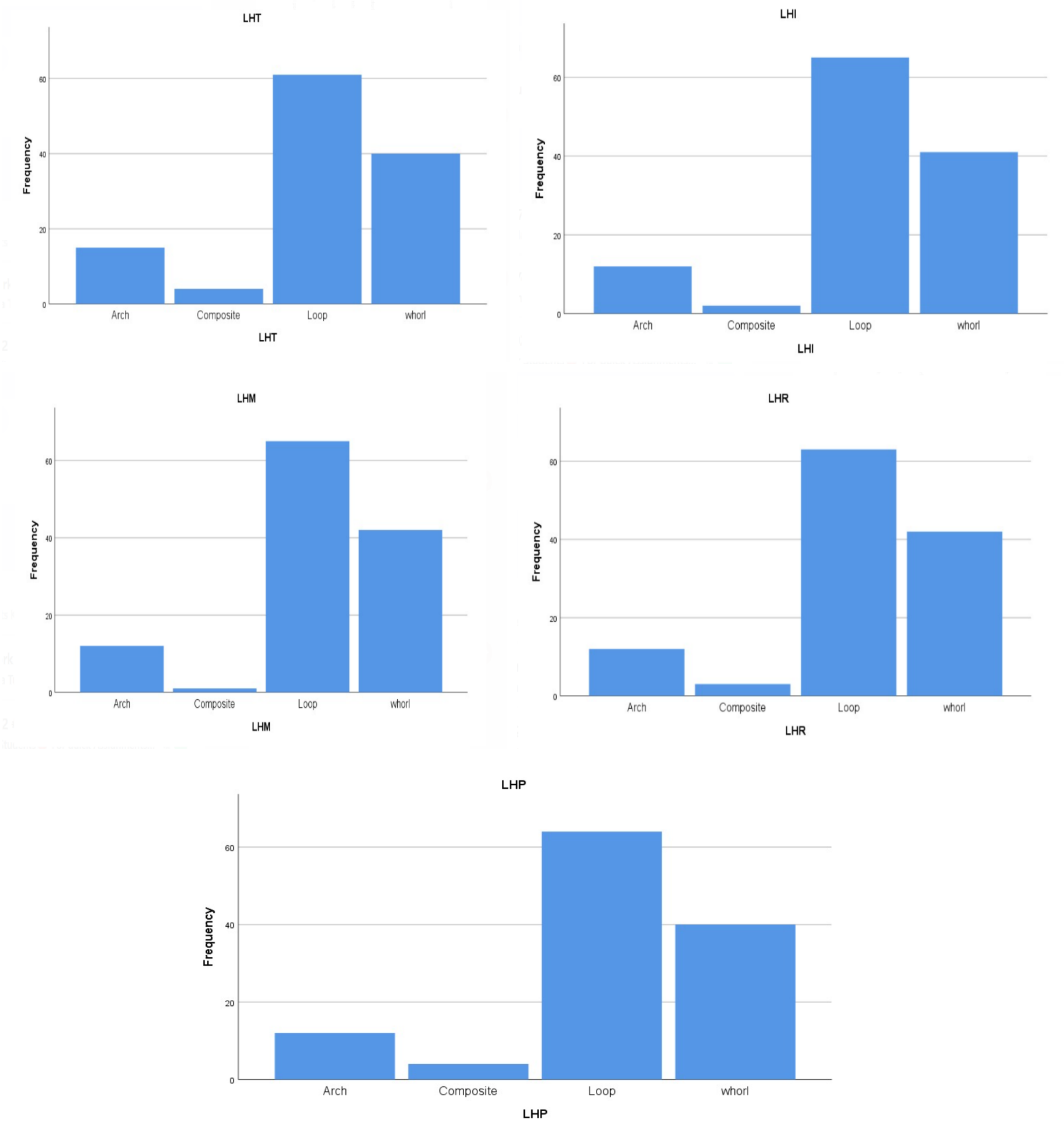


Figure 10: Distribution of the arch, composite, loop, and whorl fingerprint patterns in the Left Hand Fingers in Males. A representation of the distribution of fingerprint pattern on the LHT, LHI, LHM, LHR, and LHP of the male gender. P-value = 0.609.

The charts 7, 8, 9, and 10 above shows the distribution of fingerprint patterns in the right and Left Hand Fingers in both male and female. The loop pattern appeared to have a higher occurrence across all the five fingers in both gender. The composite pattern also had the least occurrence in terms of numbers across all the fingers in both genders.

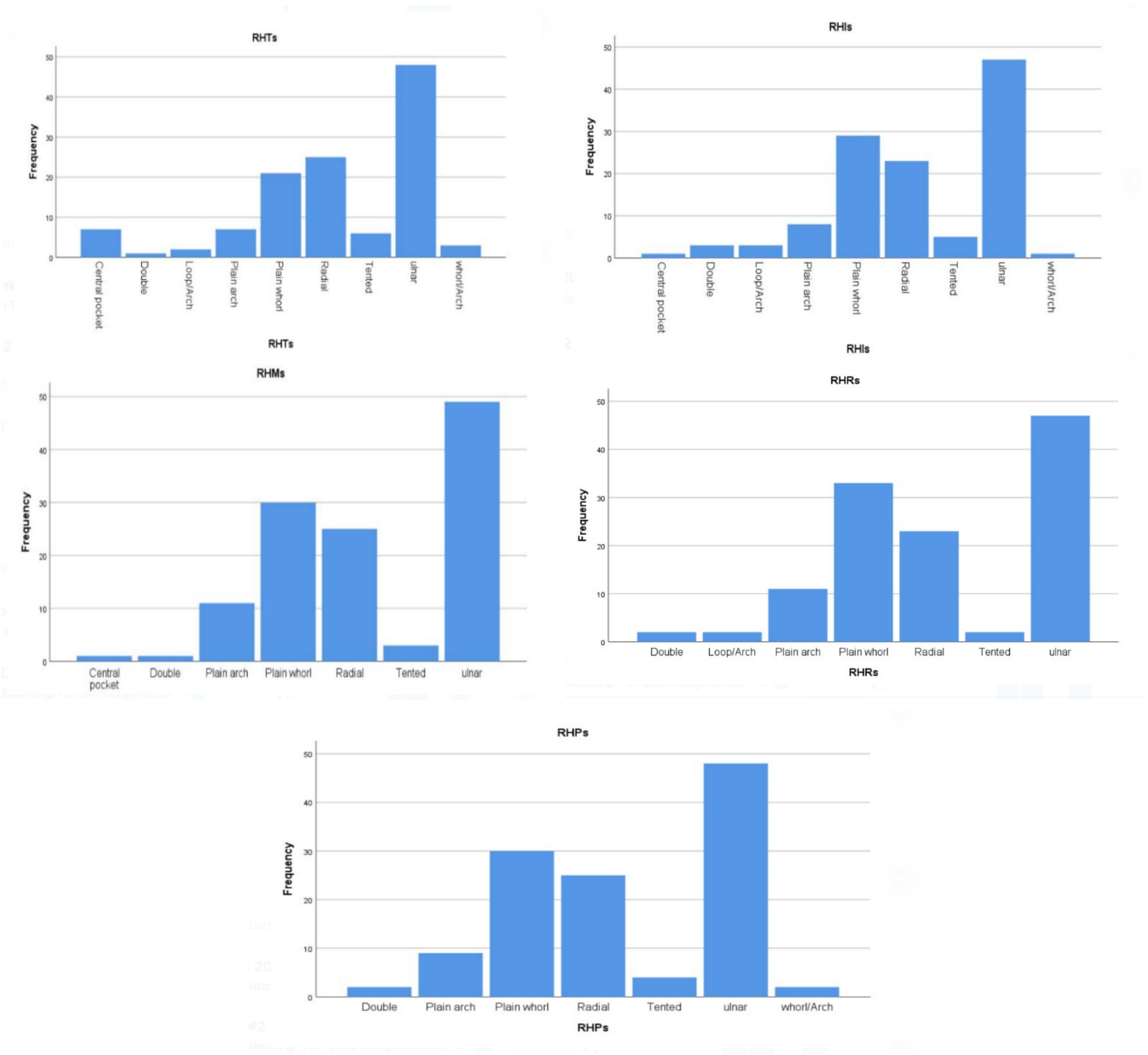


Figure 11: Distribution of fingerprint sub-patterns in the Right Hand Fingers in Females. A Representation of the distribution of nine fingerprint sub-patterns on the RHT, RHI, RHM, RHR, and RHP of the female gender. P-Value = 0.461.

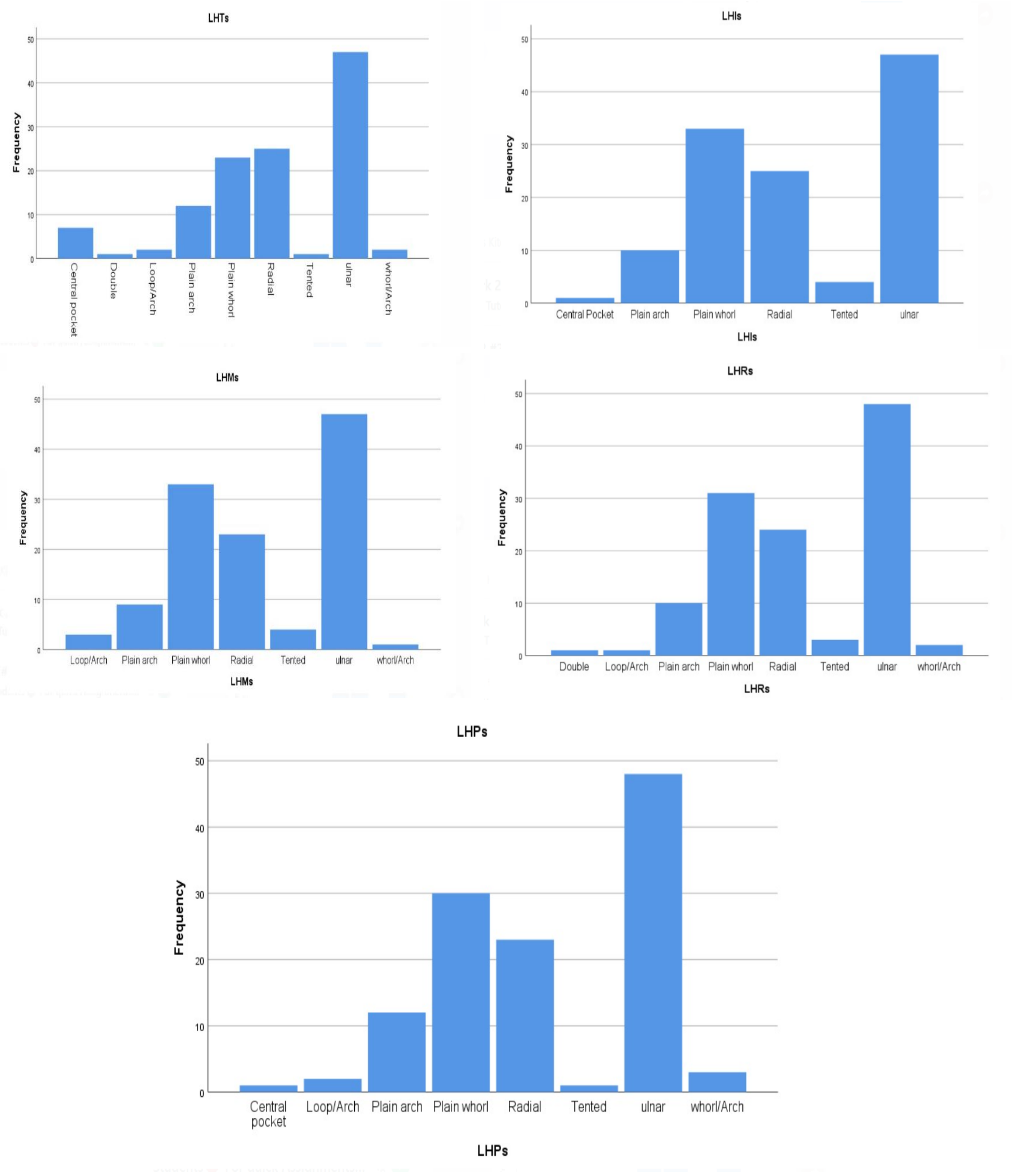


Figure 12: Distribution of fingerprint sub-patterns in the Left Hand Fingers in Females. A Representation of the distribution of nine fingerprint sub-patterns on the LHT, LHI, LHM, LHR, and LHP of the female gender. P-Value = 0.533

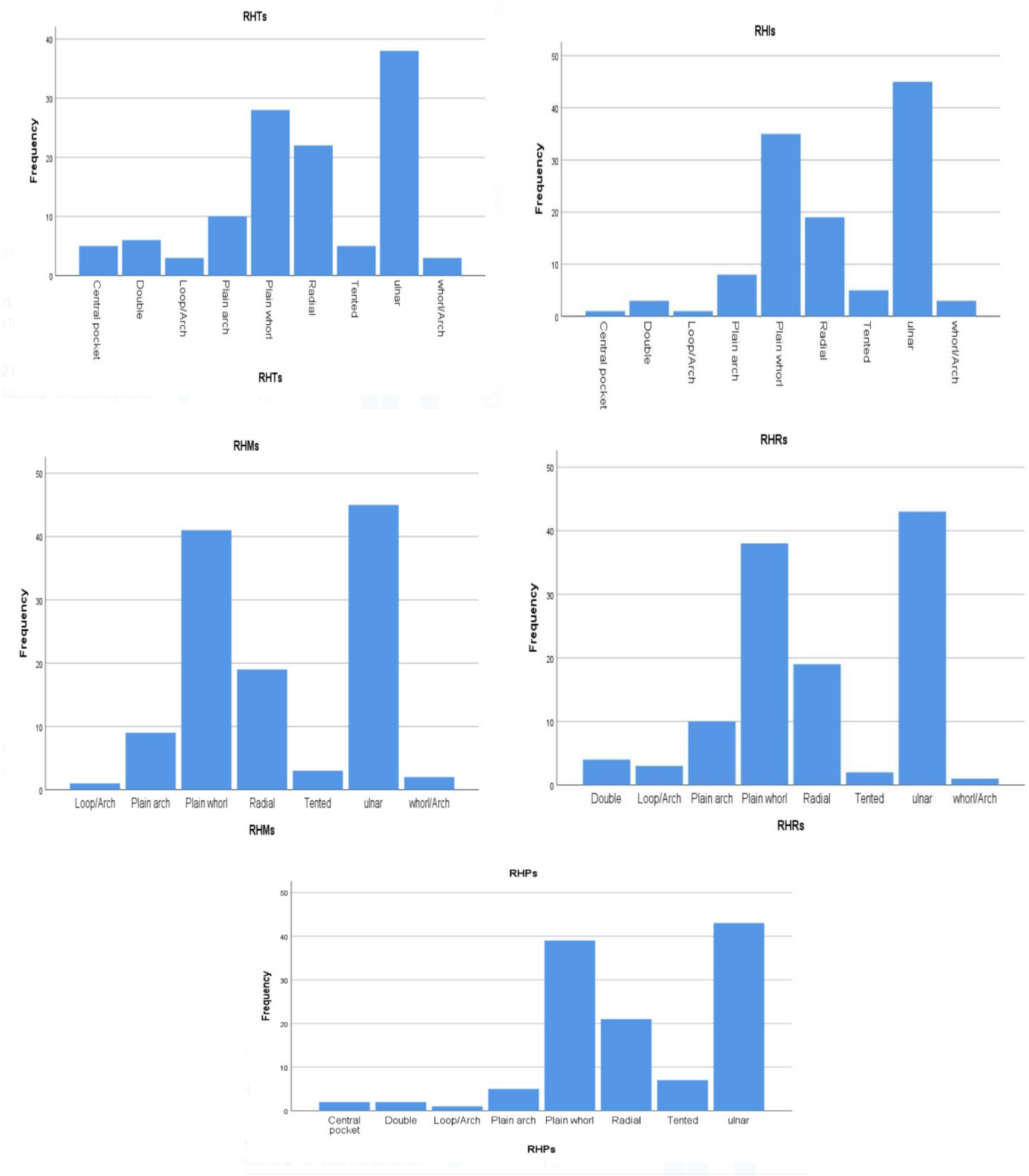


Figure 13: Distribution of fingerprint sub-patterns in the right hand Fingers in males. A Representation of the distribution of nine fingerprint sub-patterns on the RHT, RHI, RHM, RHR, and RHP of the male gender. (P-Value = 0.367).

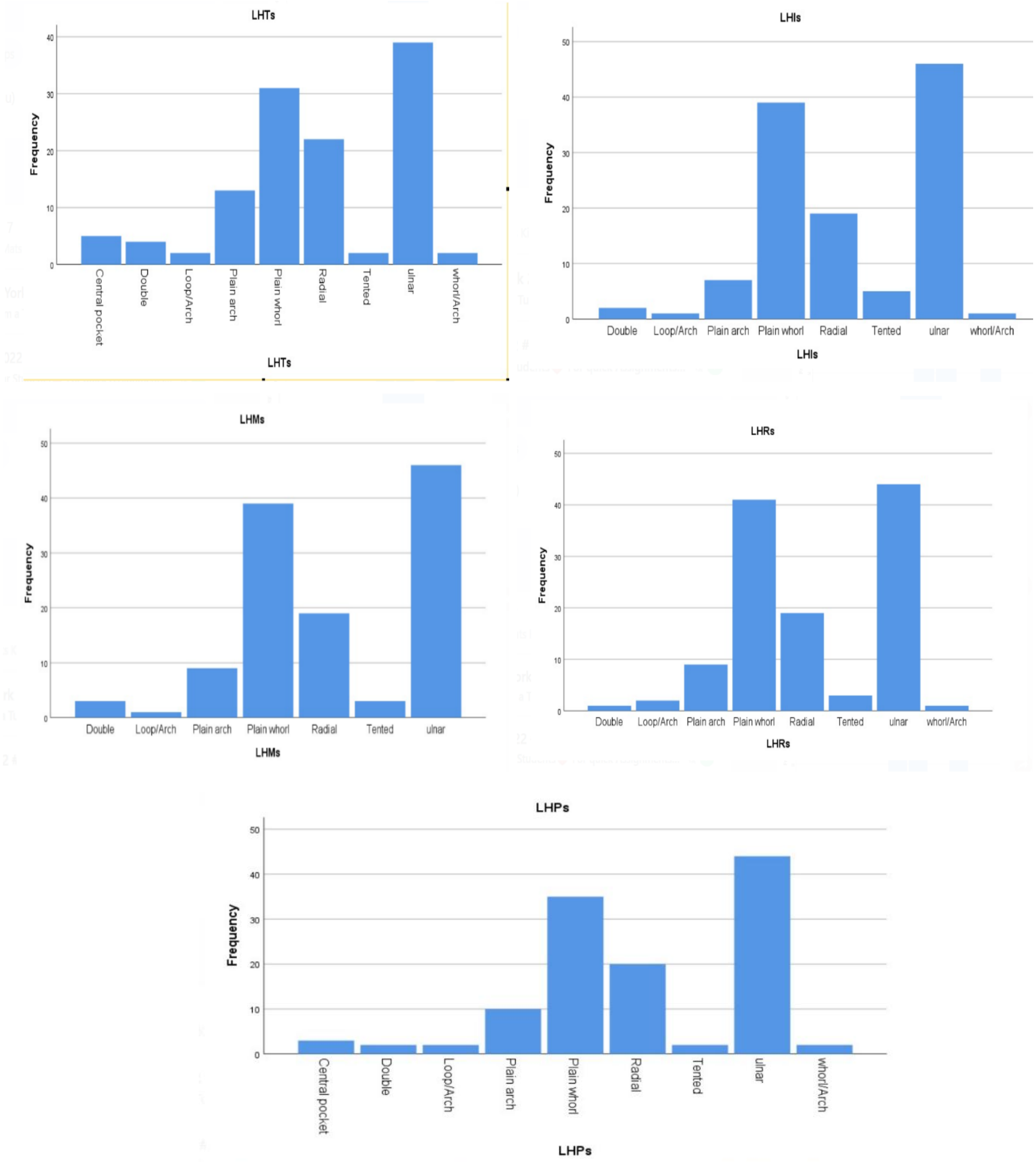


Figure 14: Distribution of fingerprint sub-patterns in the left hand Fingers in males. A Representation of the distribution of nine fingerprint sub-patterns on the LHT, LHI, LHM, LHR, and LHP of the male gender. (P-Value - 0.647)

The charts 11, 12, 13, and 14 above shows the distribution of the nine fingerprint sub-patterns in the right and Left Hand Fingers in both male and females. The ulnar loop sub-pattern appeared to have a higher frequency across all the fingers in both gender. The double loop and the composite based sub-patterns including the loop/arch and the whorl arch had the least occurrence in terms of numbers across all the fingers in both genders.

Discussion

The frequencies of fingerprint patterns were found to be similar between the two genders across all ten fingers as shown in figure 11 and 12. These findings on gender are consistent with a study (Heng et al., 2018) conducted in Malaysia that found a similar result for the distribution of male and female fingerprints among young adults and siblings in the community. Moreover, the results also show that the ulnar sub-patterns are the most prevalent in both males and females across the five fingers of the left and right hands the remainder being Plain arch, tented arch, Loop arch, Whorl arch, Radial, Ulnar, Central pocket whorl, Double whorls, and plain whorl, an observation that is consistent with a study in Indian (Badiye et al. 2014). On the contrary, the results of this study are opposed to the study in Nigeria that examined variations in finger dermatoglyphics among the Esan ethnic group of Edo State and found that the arch, loop, and whorl fingerprint patterns differ significantly between the male and female genders (Oguh et al., 2019). The similarities and differences seen in the previous studies and the current study may be due to autosomal dominance inheritance of genes associated with fingerprint patterns, which may vary globally depending on environmental and climatic factors, therefore affecting fingerprint patterns in either gender (Bhat et al. 2014). For instance, if an individual inherits a dominant allele for a gene associated with fingerprint patterns, they will express the trait regardless of their gender. This means that both males and females carrying the dominant allele will exhibit the same fingerprint pattern associated with that particular gene. Taken into consideration, fingerprint pattern distribution varies differently between males and females in different countries. Therefore, the fingerprint patterns of the individuals in western Kenya may not be used to differentiate between genders.

4.3. Distribution of fingerprint patterns among the various ethnic groups in a population in western Kenya

Distribution of fingerprint patterns and sub-patterns across ethnic groups for the study participants is shown in charts 15, 16, 17, and 18 below. The Arch (15.0% vs. 8.3%), composite (4.2% vs. 5.0%), loop (50.8% vs. 60.0%), and whorl (30.0% vs. 26.7%) patterns for the right-hand thumb were comparable between Bukusu and Kabras (P = 0.318). The arch (14.2% vs. 7.5%), composite (3.3% vs, 3.3%), loop (49.2% vs. 62.6%), and whorl (33.3% vs 26.7%) patterns for the right-hand index fingers were also comparable between the ethnic groups (p = 0. 154). The arch (14.2 vs 7.5%), composite (2.5% vs 0%), loop (50.8% vs 6.7%), and whorl (32.5% vs 28.3 %) patterns for the right-hand middle were also comparable between the Bukusu and Kabras (p = 0.054). The right-hand ring patterns were also comparable (p = 0.110), with the rates of the arch (14.2% vs 10.8%), composite (1.7% vs 3.3%), Loop (49.2% vs 60.8%, and whorl (35.0 vs 29.2%) between the Bukusu and Kabras, respectively. Similarly, the proportion of arch (14.2% vs 6.7%), composite (0.8% vs 1.7%), loop (50.0% vs 64.2%), and whorl (35.8% vs 27.5%) patterns for the right-hand pinkie were similar between the ethnic groups (p = 0.461).

The arch (15.0% vs 8.3%), composite (3.3% vs 3.3%), loop (50.0% vs 60.8%), and whorl (31.7% vs 27.5%) patterns for the left thumb were comparable between the Bukusu and the Kabras, respectively (p = 0.272). The arch (14.2% vs 7.5%), composite (1.7% vs 0%), loop (50.0% vs 64.2%), and the whorl (34.2% vs 28.3%) patterns for the left-hand index finger were similar between the ethnic groups (p = 0.065). The arch (14.2% vs 6.7%), composite (0 % vs 4.2 %), Loop (50.8% vs 61.7%), and whorl (35.0% vs 27.5%) patterns for the left-hand middle fingers were similar between the Bukusu and Kabras (p = 0.014). Similarly, the arch (14.2% vs 6.7%), composite (1.7% vs 3.3%), loop (50.0% vs 62.5%), and whorl (34.2% vs 27.5%) patterns for the left-hand ring were comparable across the ethnic groups (p = 0. 092). Finally, the arch (14.2% vs 6.7%), composite (2.5% vs 5.0%), loop (50.8% vs 61.7%), and whorl (32.5% vs 26.7%) patterns for the left-hand pinkie fingers were comparable between the Bukusu and the Kabras (p = 0.103).

The prevalence for the sub-patterns were (5.0% vs. 5.0%) for central pocket, (5.0 % vs 0.8 %) for double, (0.8% vs 3.3%) for loop arch sub pattern, (9.2 % vs 5.0%) for the plain arch, (20.0% vs 20.8 %) for plain whorl, (20.0 % vs 19.2%) for radial, (5.8 % vs 3.3%) for tented, (30.8% vs 40.8%) for ulnar, and (3.3% vs 0.8 %) for whorl arch in Bukusu and Kabras right-hand thumb, respectively. The distribution on the right-hand index was (0.8% vs. 0.8%) for the central pocket, (0 % vs 0 %) for double, (0.8% vs 2.5 %) for loop arch, (9.2% vs 4.2%) for the plain arch, (27.5% vs 25.8%) for plain whorl, (16.7% vs 18.3%) for radial, (5.0% vs 3.3%) for tented, for ulnar (32.5% vs 44.2%), and (2.5% vs 0.8%) for the whorl arch sub-patterns in Bukusu and Kabras, respectively. The right-hand middle finger sub-patterns rates were (0% vs. 0.8%) for the central pocket, (0.8 % vs 0 %) for double, (0.8% vs 0 %) for the loop arch, (11.7 % vs 5.0%) for the plain arch, (31.7 % vs 27.5 %) for plain whorl, (16.7% vs 20.0 %) for radial, (2.5% vs 2.5%) for tented, (34.2% vs 44.2%) for ulnar, and (1.7% vs 0%) for whorl arch between the Bukusu and Kabras, respectively. The rates for the central pocket (0% vs 0%), double (4.2% vs 0.8%), loop arch (0.8% vs 3.3 %), plain arch (11.7% vs 5.8%), plain whorl (30.8% vs 28.3%), radial (16.7% vs 18.3%), tented (2.5% vs 0.8%), ulnar (32.5% vs 42.5%), and whorl arch (0.8% vs 0%) sub patterns were recorded for the ring finger in Bukusu and Kabras, respectively. The right-hand pinkie fingers sub-patterns rates of central pocket (1.7% vs. 0%), double (3.3% vs 0 %), loop arch (0 % vs 0.8 %), plain arch (8.3% vs 3.3 %), plain whorl (30.0% vs 27.5%), radial (18.3 % vs 20.0 %), tented (5.8% vs 3.3%), ulnar (31.7 % vs 44.2 %), and whorl arch (0.8% vs 1.7%) were observed between Bukusu and Kabras, respectively

There was a prevalence of (5.8% vs. 4.2%) for the central pocket, (2.5% vs 1.7%) for double, (0.8 % vs 2.5 %) for the loop arch, (12.5% vs 8.3 %) for the plain arch, (23.3% vs 21.7%) for plain whorl, (20.0% vs 19.2 %) for radial, (2.5 % vs 0 %) for tented, (30.0% vs 41.7%) for ulnar, and (2.5% vs 0.8%) for whorl arch sub-patterns on the right-hand thumb between Bukusu and Kabras, respectively. The distribution for the left-hand index was (0% vs. 0.8%) for the central pocket, 0.8% vs 0.8%) for double, (0.8% vs 0 %) for the loop arch, (9.2% vs 5.0%) for the plain arch, (33.3% vs 26.7%) for plain whorl, (16.7% vs 20.0 %) for radial, (5.0% vs 2.5%) for tented, (33.3% vs 44.2%) for ulnar, and (0.8% vs 0%) for whorl arch sub patterns between the Bukusu and Kabras, respectively. The left-hand middle had rates of (0% vs 0%) for the central pocket, (0.8 % vs 1.7 %) for double, (0 % vs 3.3 %) for the loop arch, (11.7% vs 3.3%) for the plain arch, (34.2% vs 25.8%) for plain whorl, (16.7% vs 18.3 %) for radial, (2.5% vs 3.3%) for tented, (34.2% vs 43.3%) for ulnar, and (0% vs 0.8%) for whorl arch sub-patterns in the Bukusu and Kabras, respectively. Similarly, the prevalence for the sub-patterns were (0% vs 0%) for the central pocket, (1.7 % vs 0 %) for the double, (0.8% vs 1.7 %) for the loop arch, (11.7 % vs 4.2 %) for the plain arch, (32.5% vs 27.5%) for plain whorl, (16.7 % vs 19.2%) for radial, (2.5% vs 2.5%) for tented, (33.3 % vs 43.3 %) for ulnar, and (0.8% vs 1.7%) for whorl arch on the left-hand ring in the Bukusu and Kabras. The prevalence for the sub-patterns were (2.5% vs 0.8%) for the central pocket, (1.7% vs 0%) for double, (0 % vs 3.3 %) for the loop arch, (11.7 % vs 6.7 %) for the plain arch, (28.3 % vs 25.8 %) for plain whorl, (17.4% vs 18.3%) for radial, (2.5% vs 0 %) for tented, (33.3% vs 43.3 %) for ulnar, and (2.5 % vs 1.7 %) for whorl arch between the Bukusu and Kabras for the left-hand pinkie.

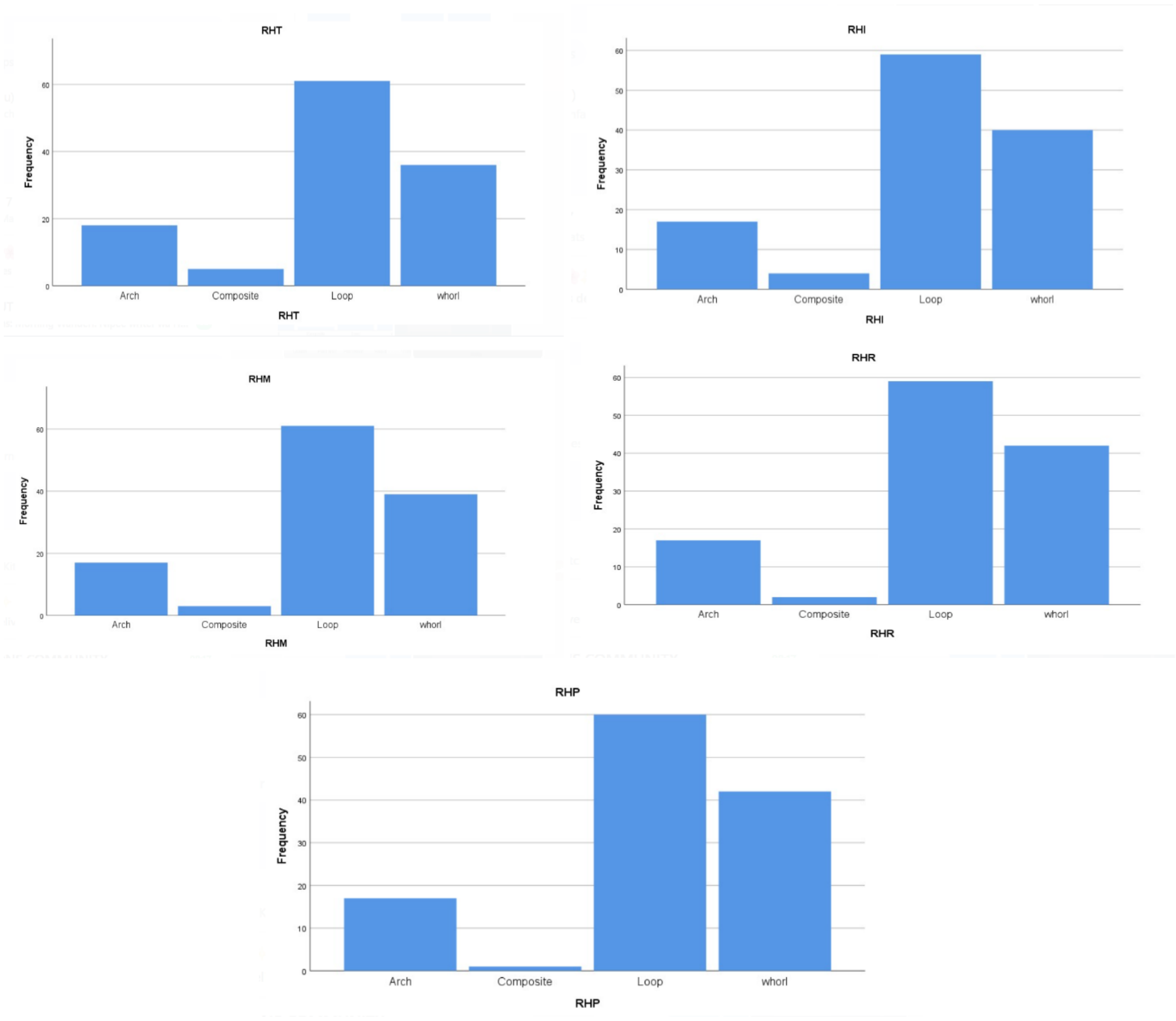


Figure 15: Distribution of arch, composite, loop, and whorl fingerprint patterns in the Right Hand Fingers of the Bukusu. A representation of the distribution of fingerprint pattern on the RHT, RHI, RHM, RHR, and RHP of the Bukusu. P-value = 0.318.

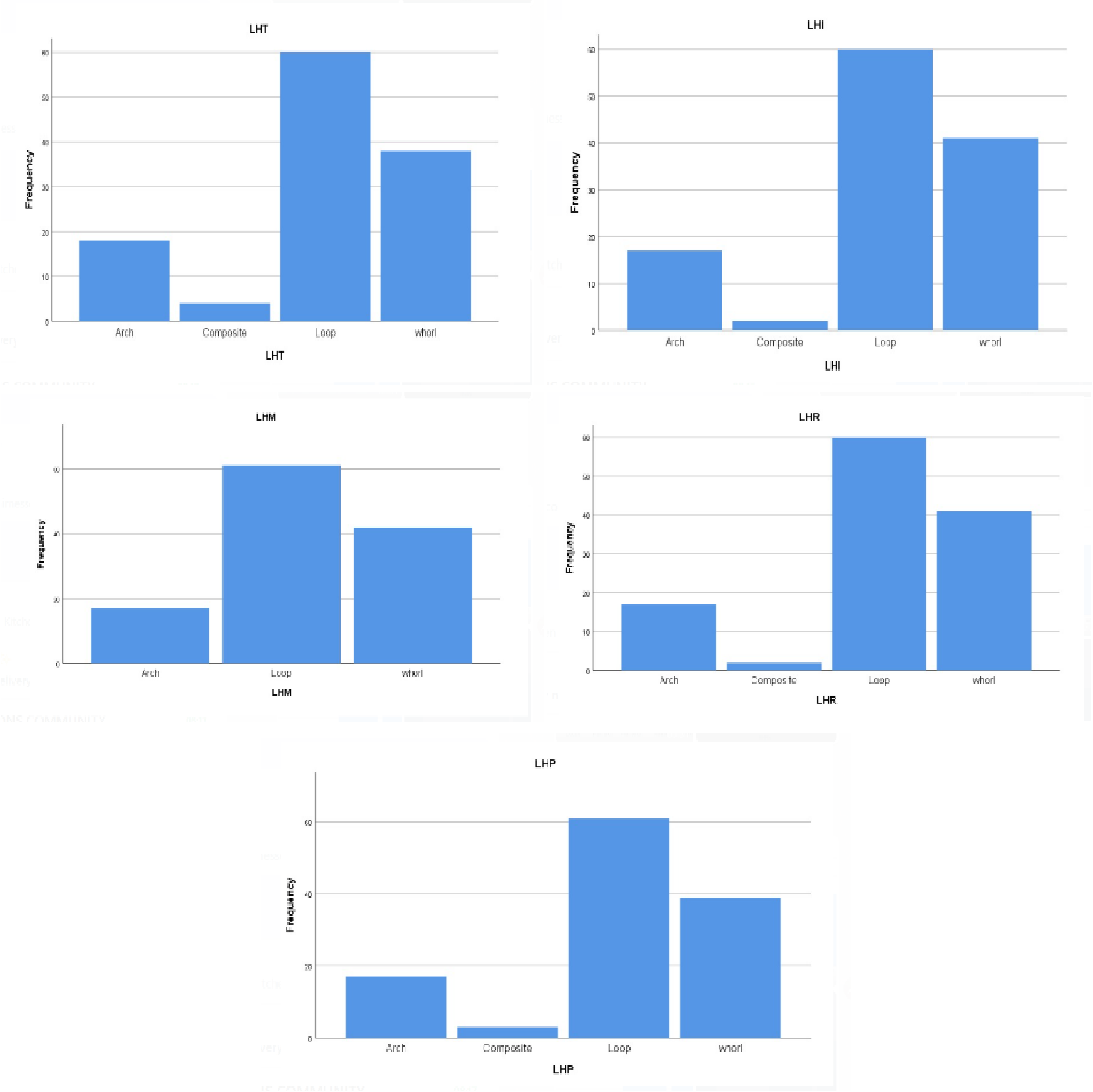


Figure 16: Distribution of the arch, composite, loop, and whorl fingerprint patterns in the Left Hand Fingers of the Bukusu. A representation of the distribution of fingerprint pattern on the LHT, LHI, LHM, LHR, and LHP of the Bukusu. P-value = 0.154

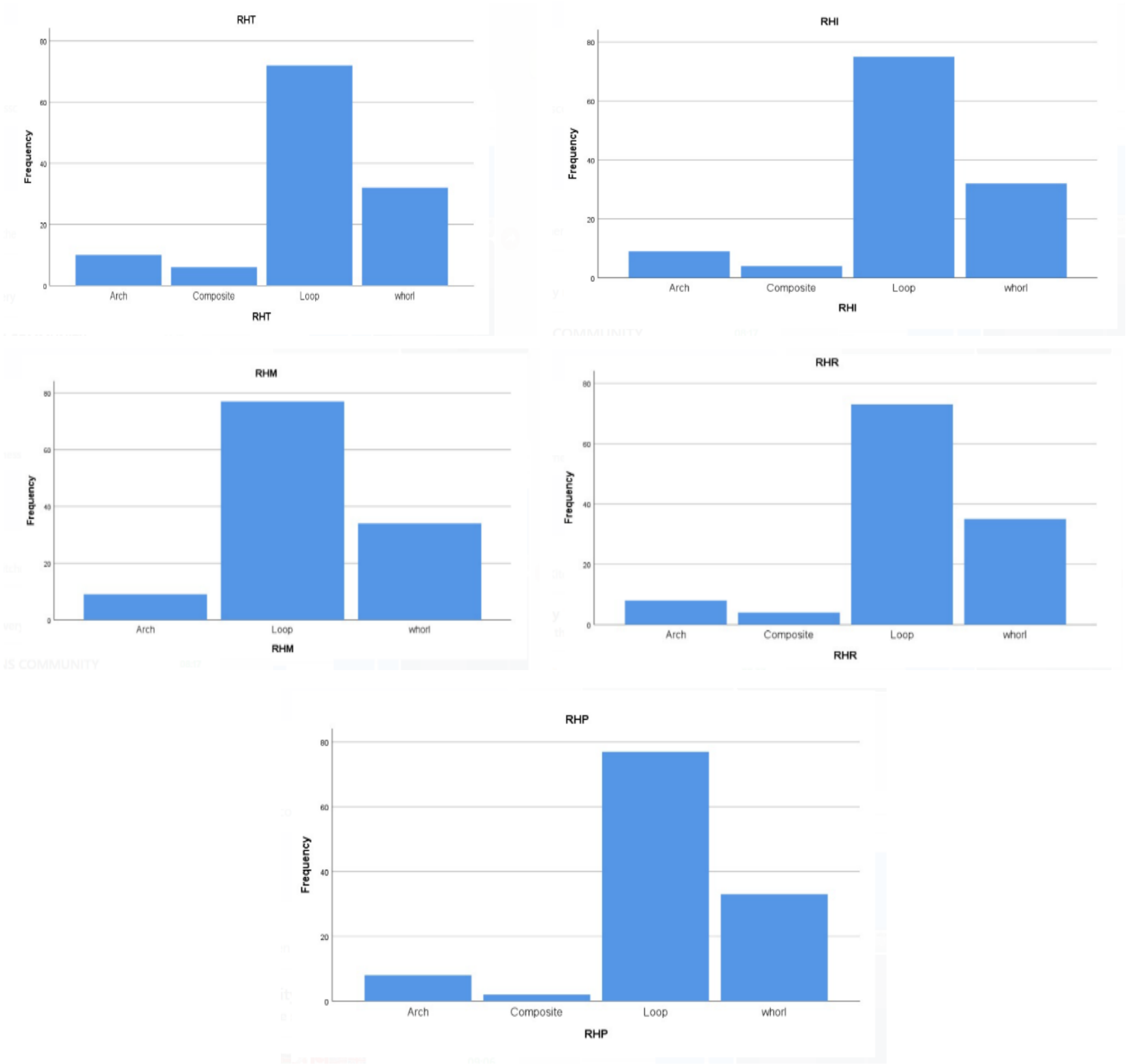


Figure 17: Distribution of the arch, composite, loop, and whorl fingerprint patterns in the right hand Fingers of the Kabras. A representation of the distribution of fingerprint pattern on the RHT, RHI, RHM, RHR, and RHP of the Kabras. P-value = 0.054

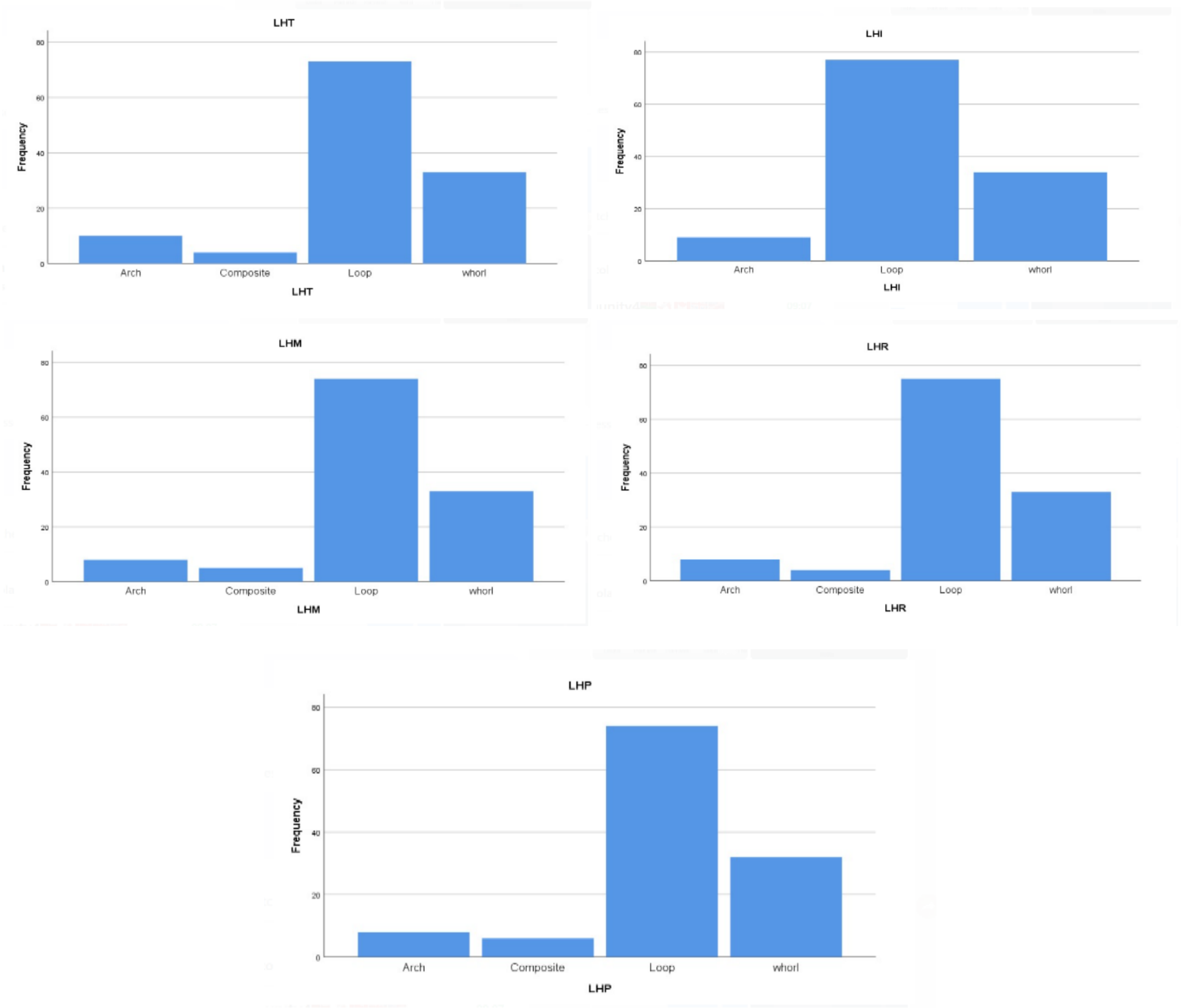


Figure 18: Distribution of the arch, composite, loop, and whorl fingerprint patterns in the left hand Fingers of the Kabras. A representation of the distribution of fingerprint pattern on the LHT, LHI, LHM, LHR, and LHP of the Kabras. P-value = 0.110.

The charts 15, 16, 17, and 18 above shows the distribution of fingerprint patterns in the right- and Left-hand Fingers in both the Bukusu and Kabras ethnic groups. The loop pattern appeared to have a higher frequency across all the fingers in both the ethnic groups. The composite pattern had the least occurrence in terms of numbers across all the fingers in both ethnic groups.

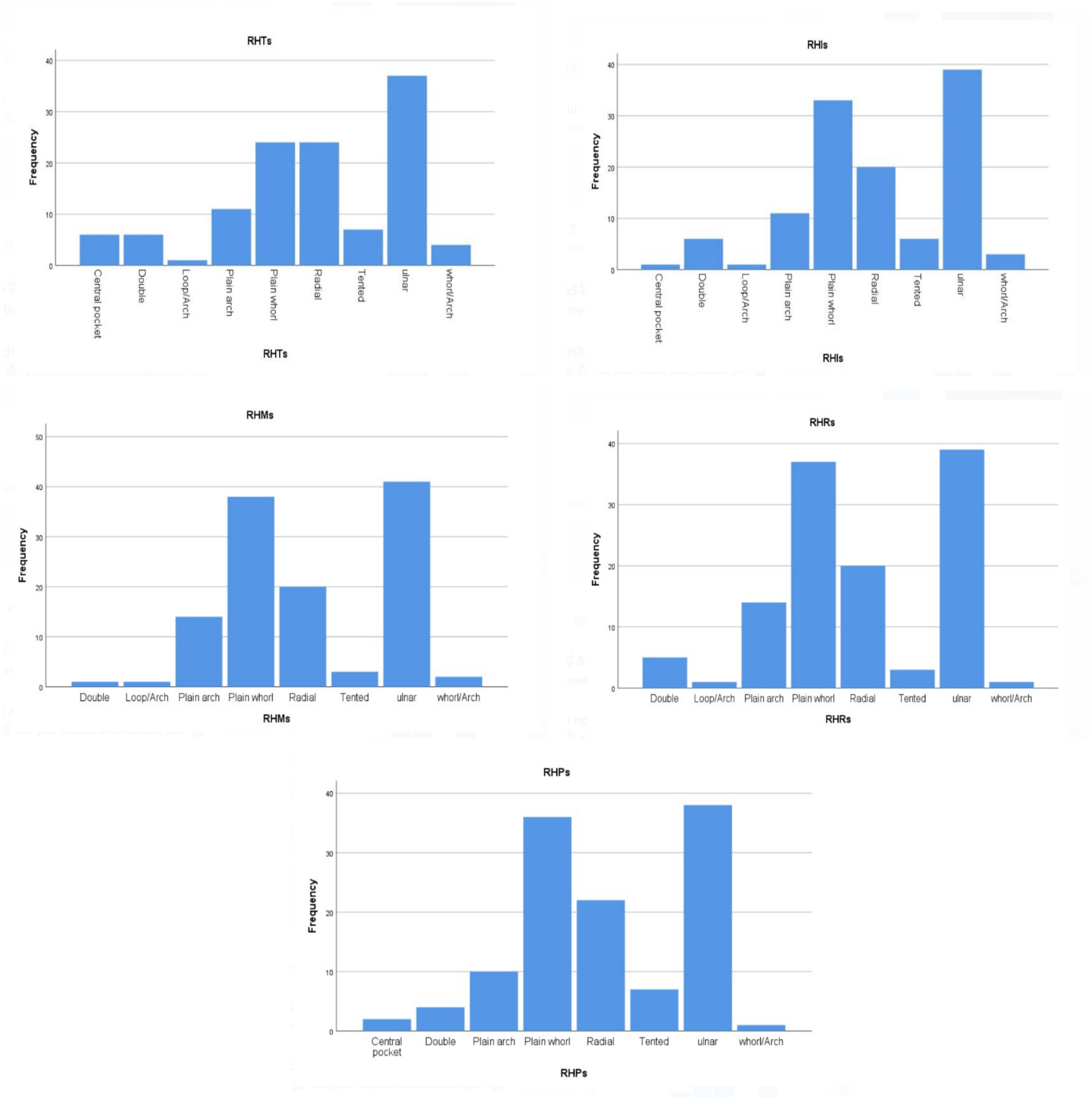


Figure 19: Distribution of fingerprint sub-patterns in the Right Hand Fingers of the Bukusu. A representation of the distribution of fingerprint sub-pattern on the RHT, RHI, RHM, RHR, and RHP of the Bukusu. P-value = 0.080

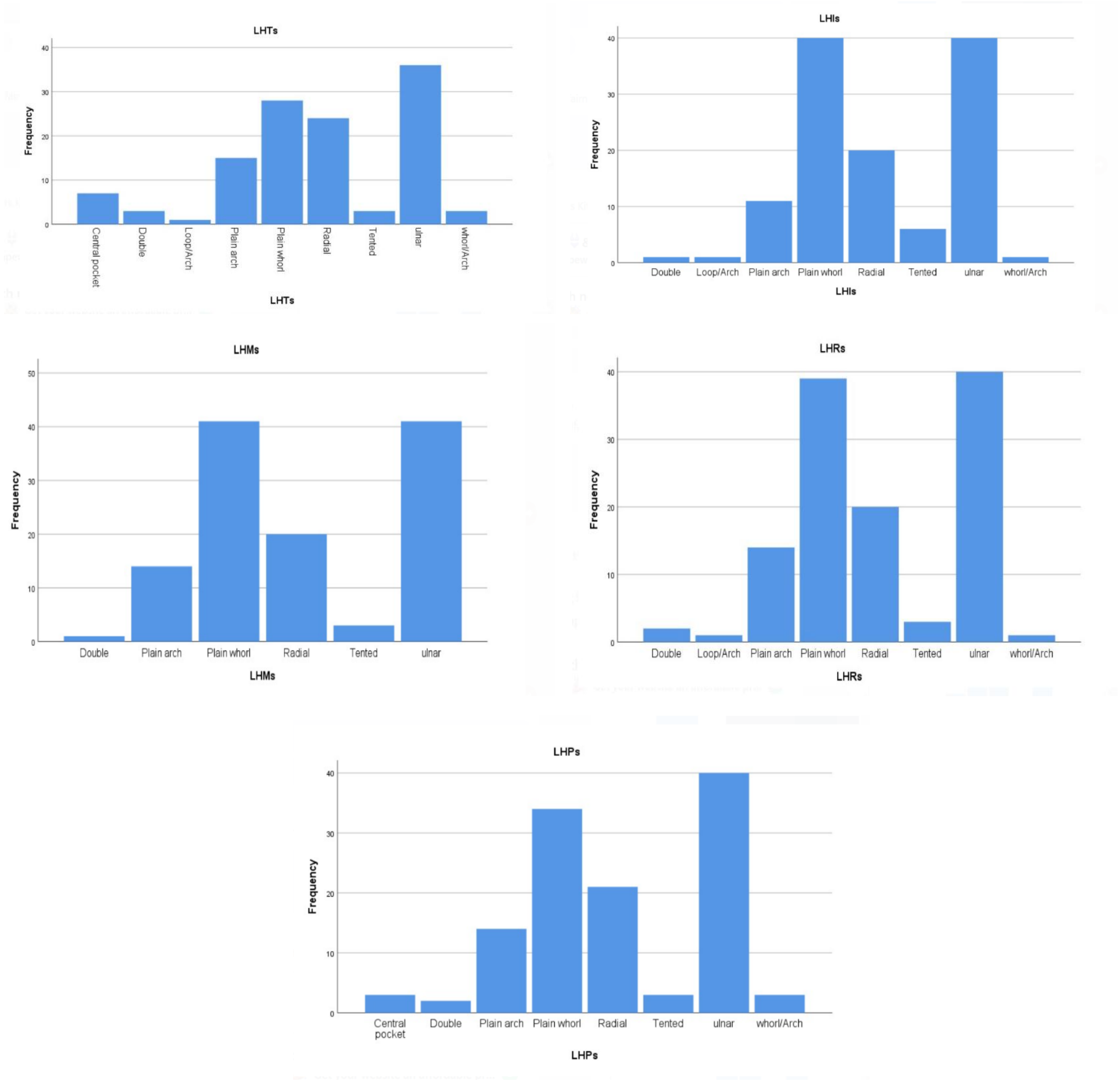


Figure 20: Distribution of fingerprint sub-patterns in the Left Hand Fingers of the Bukusu. A representation of the distribution of fingerprint sub-pattern on the LHT, LHI, LHM, LHR, and LHP of the Bukusu. P-value = 0.272

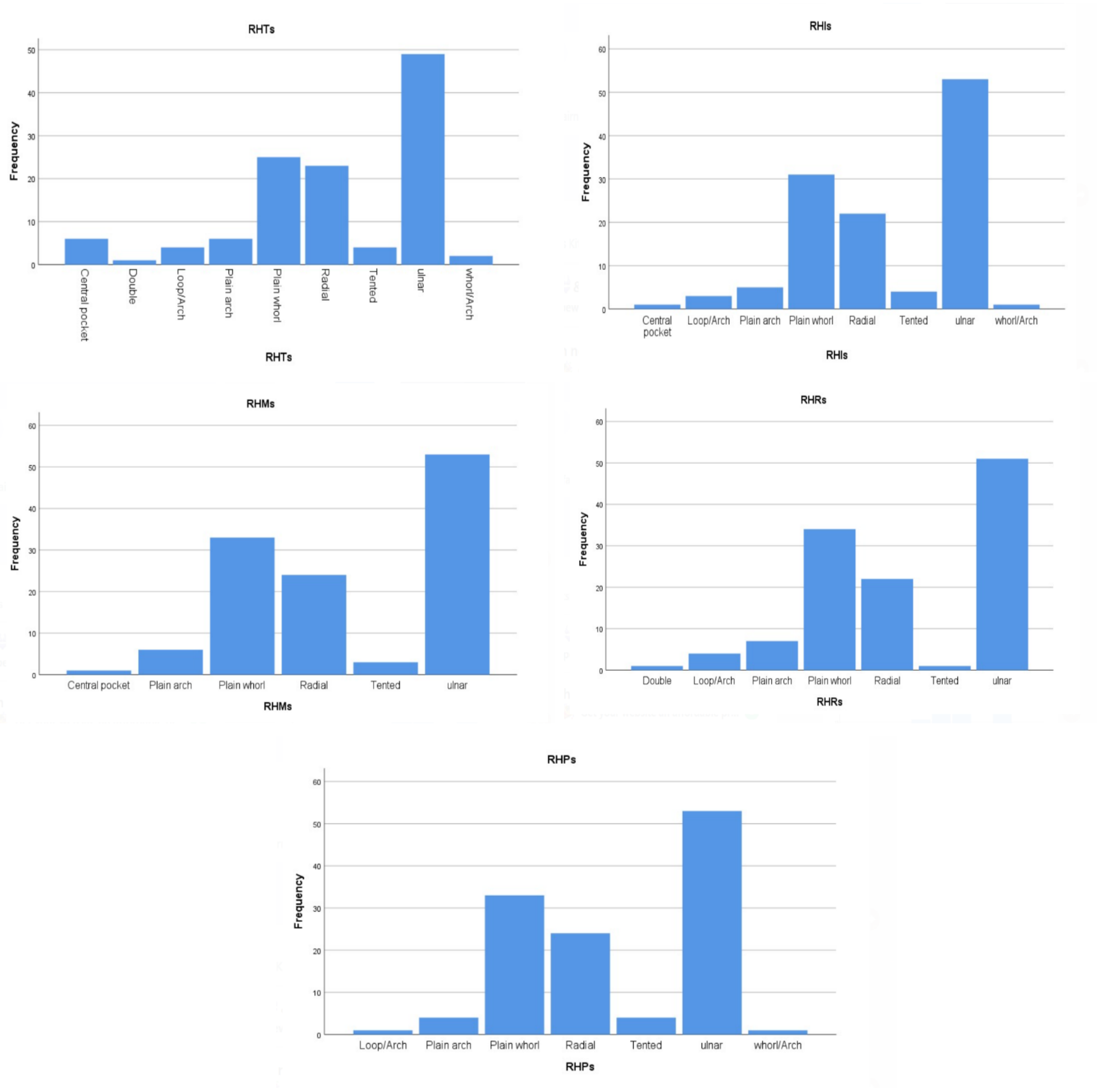


Figure 21: Distribution of fingerprint sub-patterns in the Right Hand Fingers of the kabras. A representation of the distribution of fingerprint sub-pattern on the RHT, RHI, RHM, RHR, and RHP of the Kabras. P-value = 0.065

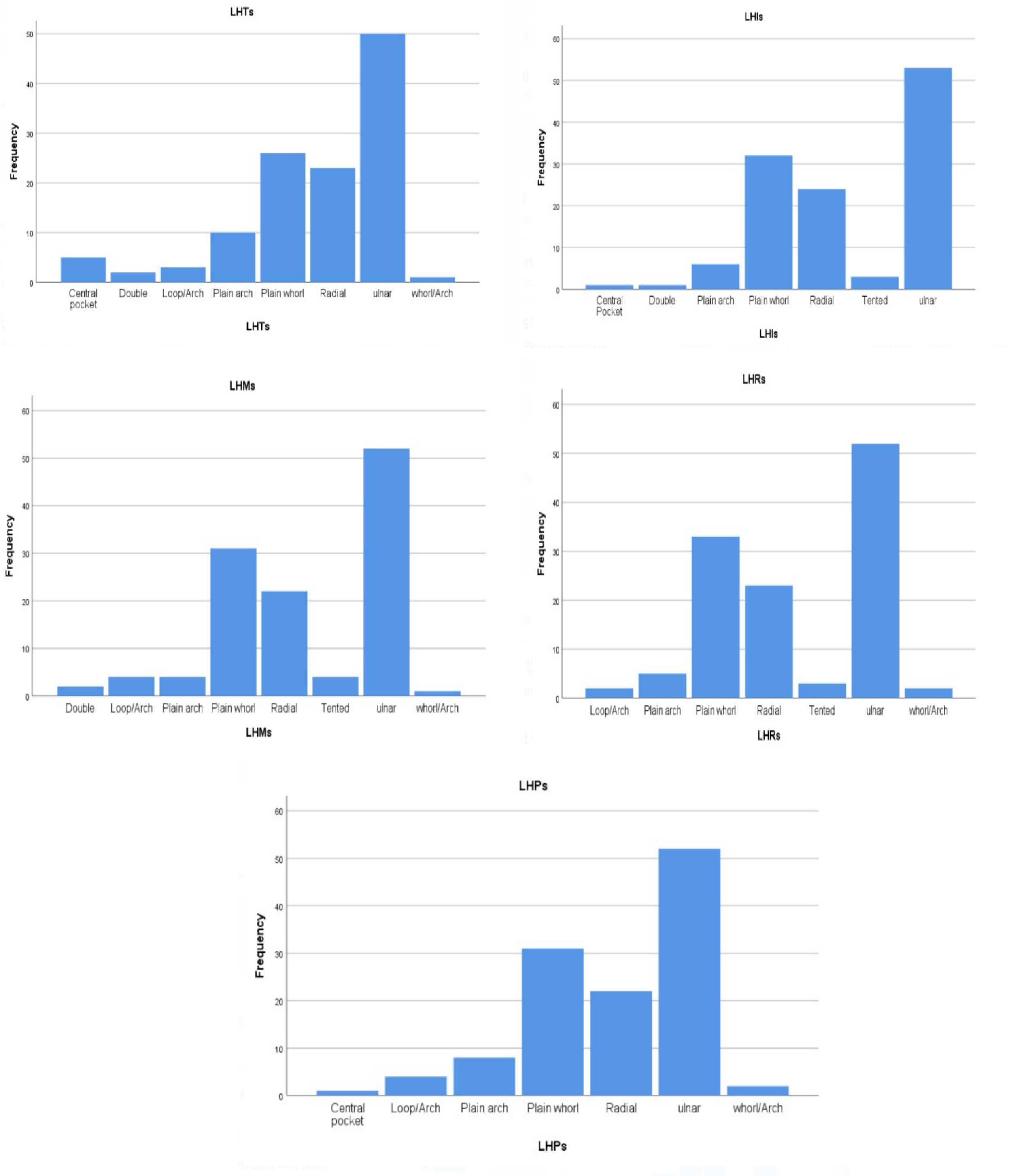


Figure 22: Distribution of fingerprint sub-patterns in the Left Hand Fingers of the Kabras. A representation of the distribution of fingerprint sub-pattern on the LHT, LHI, LHM, LHR, and LHP of the Kabras. P-value = 0.014.

The bar charts 19, 20, 21, and 22 above shows the distribution of fingerprint sub-patterns in the right and Left Hand Fingers in both Bukusu and Kabras ethnic groups. The ulnar loop sub-pattern appeared to have a higher frequency across all the fingers in both gender. The double loop, central pocket whorl and the composite based sub-patterns including the loop/arch and the whorl arch had the least occurrence in terms of numbers across all the fingers in both ethnic groups.

Discussion

The distribution of fingerprint patterns was similar between the Bukusu and Kabras for all ten fingers. These results were in agreement with the study conducted in Asia that revealed a similar distribution of arch, loop, and whorl patterns for Chinese and Malays people (Heng et al., 2018). Importantly, the results for the sub-pattern frequencies in the Bukusu and Kabras revealed that the ulnar loop sub-pattern had a high frequency across the five fingers of the left and right hands and the remainder being Plain arch, tented arch, Loop arch, Whorl arch, Radial, Ulnar, Central pocket whorl, Double whorls, and plain whorl, an observation which is consistent with a study (Jaiyeoba-Ojigho et al., 2019) in Nigeria, which found that the ulnar loop was the most common type of ridge pattern type among the study participants. The results however, are opposed by a descriptive study (Abimbola et al., 2021) in southern Nigeria which concluded that fingerprint patterns vary significantly among the ethnic groups of Urhobos and Ibos' residing in Warri, South Southern Nigeria. Also, the findings were in direct contradiction to the Costa Rican study's conclusions that there was a significant distribution in Arch, whorl, and loop fingerprint patterns (Segura-Wang & Barrantes 2009). The similarities and differences observed between the ethnic groups may be attributed to genetics, (Yang et al., 2016). For instance, certain genetic variants prevalent within a group can contribute to a higher occurrence of specific patterns. With this considered, fingerprint pattern distribution varies differently between different ethnic groups in different countries. Therefore, according to the study findings, the fingerprint patterns of the individuals in western Kenya may not be used to differentiate between Bukusu and Kabras.

4.4. Compare fingerprint patterns among siblings and non-siblings in a population in western Kenya.

Distribution of fingerprint patterns across siblings and non-siblings for the study participants is shown in bar charts 23, 24, 25, and 26 below. The rates of Arch (7.3 % vs. 19.1%), composite (4.6% vs. 4.5%), loop (62.9% vs. 42.7%), and whorl (25.2% vs. 33.7%) patterns for the right-hand thumb differed significantly between the siblings and non-siblings respectively (P = 0006). The prevalence of the arch (6.0% vs 19.1), composite (2.6% vs4.5), loop (63.6% vs 42.7%), and whorl (27.8% vs 33.7%) patterns for the right-hand index were significantly different between sibling and non-sibling (p = 0.002). The arch (6.0% vs 19.1%), composite (0.7% vs 2.2%), loop (66.2% vs 42.7%), and whorl (27.2% vs 36.0%) patterns for the right-hand middle were also significantly different between sibling and non-sibling (p = 0.001). The arch ((5.3% vs 19.1%), composite (3.3% vs 1.1 %), Loop (62.3 % vs 42.7%) and whorl (27.2 vs 37.1%) patterns for the right-hand ring differed differently between the sibling and non-sibling, respectively (p = 001). Similarly, the arch (5.3% vs 19.1%), composite (1.3% vs 1.1%), loop (64.9% vs 43.8%), and the whorl (28.5% vs 36.0 %) patterns for the right-hand pinkie were significantly different between sibling and non-sibling (p = 0.001). The prevalence for the arch pattern (7.3% vs 19.1%), composite pattern (3.3% vs 3.4%), loop pattern (62.9% vs 42.7%), and the whorl pattern (26.5% vs 34.8%) for the right-hand pinkie were comparable between sibling and non-sibling (p = 0.007). The prevalence of arch (6.0% vs 19.1%), composite (0.7% vs 1.1%), loop (65.6% vs 42.7%), and the whorl (27.8% vs 37.1%) patterns for the left-hand index finger were significantly different between sibling and non-sibling (p = 0.001). The patterns for the left-hand middle fingers were significantly different across the siblings and non-siblings (p = 0.001) with rates arch (5.3% vs 19.1%), composite (2.6% vs 1.1%), Loop (63.6% vs 43.8%), and whorl (28.5% vs 36.0%) reported between siblings and non-siblings. Similarly, the arch (5.3% vs 19.1%), composite

(2.0 % vs 2.4 %), loop (64.2% vs 42.7 %), and whorl (28.5 % vs 34.8 %) patterns for the left-hand ring were significantly different across the siblings and non-siblings (p = 0.001). Finally, the distribution of the arch (5.3% vs 19.1%), composite (4.6% vs 2.2%), loop (63.6% vs 43.8%), and whorl (26.5% vs 34.8%) patterns for the left-hand pinkie fingers differed significantly between siblings and non-siblings, respectively (p = 0.001).

The prevalence for sub patterns were (6.0% vs. 3.4%) for the central pocket, (2.0% vs 4.5%) for double, (2.6% vs 1.1 %) for loop arch, (5.3% vs 10.1%) for the plain arch, (17.2% vs 25.8%) for plain whorl, (20.8% vs 18.0 %) for radial, (2.0% vs 9.0%) for tented, (42.4% vs 24.7%) for ulnar, and (2.0% vs 3.4%) for whorl arch in siblings and non-sibling right-hand thumb, respectively. The rates of (1.3% vs. 0%) for the central pocket, (3.3 % vs 1.1%) for double, (2.0 % vs 1.1%) for the loop arch, (4.0% vs 11.2%) for the plain arch, (23.2% vs 32.6%) for plain whorl, (17.9% vs 16.9%) for radial, (2.0% vs 7.9%) for tented, (45.7% vs 25.8%) for ulnar, and (0.7% vs 3.4%) for whorl arch sub-patterns in sibling and non-sibling were recorded for the right-hand index, respectively. The right-hand middle had a prevalence of (0.7% vs. 0%) for the central pocket, (0.7 % vs 0 %) for double, (0% vs 1.1 %) for the loop arch, (4.6% vs 14.6%) for the plain arch, (25.8% vs 36.0%) for plain whorl, (19.2% vs 16.9%) for radial, (1.3% vs 2.5%) for tented, (47.0% vs 25.8%) for ulnar, and (0.7% vs 1.1 %) for whorl arch sub-patterns in male and female, respectively. The prevalence on the right-hand ring for the central pocket (0% vs 0%), the double (2.0 % vs 3.4%), the loop arch (2.6% vs 1.1 %), the plain arch (4.6% vs 15.7%), the plain whorl (27.2% vs 33.7%), the radial (17.9% vs 16.9%), the tented (0.7% vs 3.4%), the ulnar (44.4% vs 25.8 %), and whorl arch (0.7% vs 0%) sub-patterns were identified in siblings and non-siblings, respectively. The rates on the right-hand pinkie were (1.3% vs. 0%) for the central pocket, (1.3 % vs 2.2 %) for double, (0.7% vs 0 %) for the loop arch, (3.3% vs 10.1%) for the plain arch, (25.8% vs 33.7%) for plain whorl, (20.5% vs 16.9 %) for radial, (2.0 % vs 9.0 %) for tented, (44.4% vs

40.0%) for ulnar, and (0.7% vs 1.1%) for whorl arch sub-patterns in sibling and non-siblings, respectively.

The distribution for the left-hand thumb was (6.0% vs. 3.4%) for the central pocket, (2.0% vs 2.2%) for double, (7.3 % vs 15.7%) for the loop arch, (2.0% vs 1.1 %) for the plain arch, (18.5% vs 29.2%) for plain whorl, (20.5% vs 18.0 %) for radial, (0 % vs 3.4%) for tented, (42.4% vs 24.7%) ulnar, and (0.7% vs 0%) for whorl arch sub-patterns in sibling and no siblings, respectively. The distribution for the left-hand index for the central pocket (0.7 % vs. 0%), double (0.7% vs 1.1 %), loop arch (0 % vs 1.1 %), plain arch (4.6 % vs 11.2 %), plain whorl (26.5% vs 36.0%), radial (19.2% vs 16.9 %), tented (1.3% vs 7.9%), ulnar (46.4 % vs 25.8 %), and whorl arch (0.7% vs 0%) sub patterns were observed in the siblings and non-siblings, respectively. The prevalence for the left-hand middle for the central pocket (0% vs 0%), the double (1.3% vs 1.1 %), the loop arch (2.6 % vs 0 %), the plain arch (3.3 % vs 14.6 %), the plain whorl (27.2 % vs 16.9%), the radial (17.9 % vs 16.9%), the tented (2.0% vs 4.5%), the ulnar (45.7% vs 27.0 %), and the whorl arch (0% vs 1.1%) sub patterns were observed in sibling and non-sibling, respectively. There were (0% vs 0%) for the arch, (1.3 % vs 0 %) for the double, (1.3 % vs 1.1%) for the loop arch, (4.0% vs 14.6%) for the plain arch, (27.2% vs 34.8 %) for plain whorl, (18.5% vs 16.9 %) for radial, (1.3% vs 4.5%) for tented, (45.7 % vs 25.8 %) for ulnar, and (0.7 % vs 2.2 %) for whorl arch sub-patterns recorded in siblings and non-siblings for the left-hand ring. The distributions for the left-hand pinkie were (2.6% vs 1.1%) for the central pocket, (0.7% vs 0%) for double, (2.6% vs 0 %) for the loop arch, (5.3% vs 15.7%) for the plain arch, (23.2% vs 33.7%) for plain whorl, (18.5% vs 16.9%) for radial, (0 % vs 3.4 %) for tented, (45.0 % vs 27.0 %) for ulnar, and (2.0 % vs 2.2%) for whorl arch sub-patterns in sibling and non-sibling, respectively.

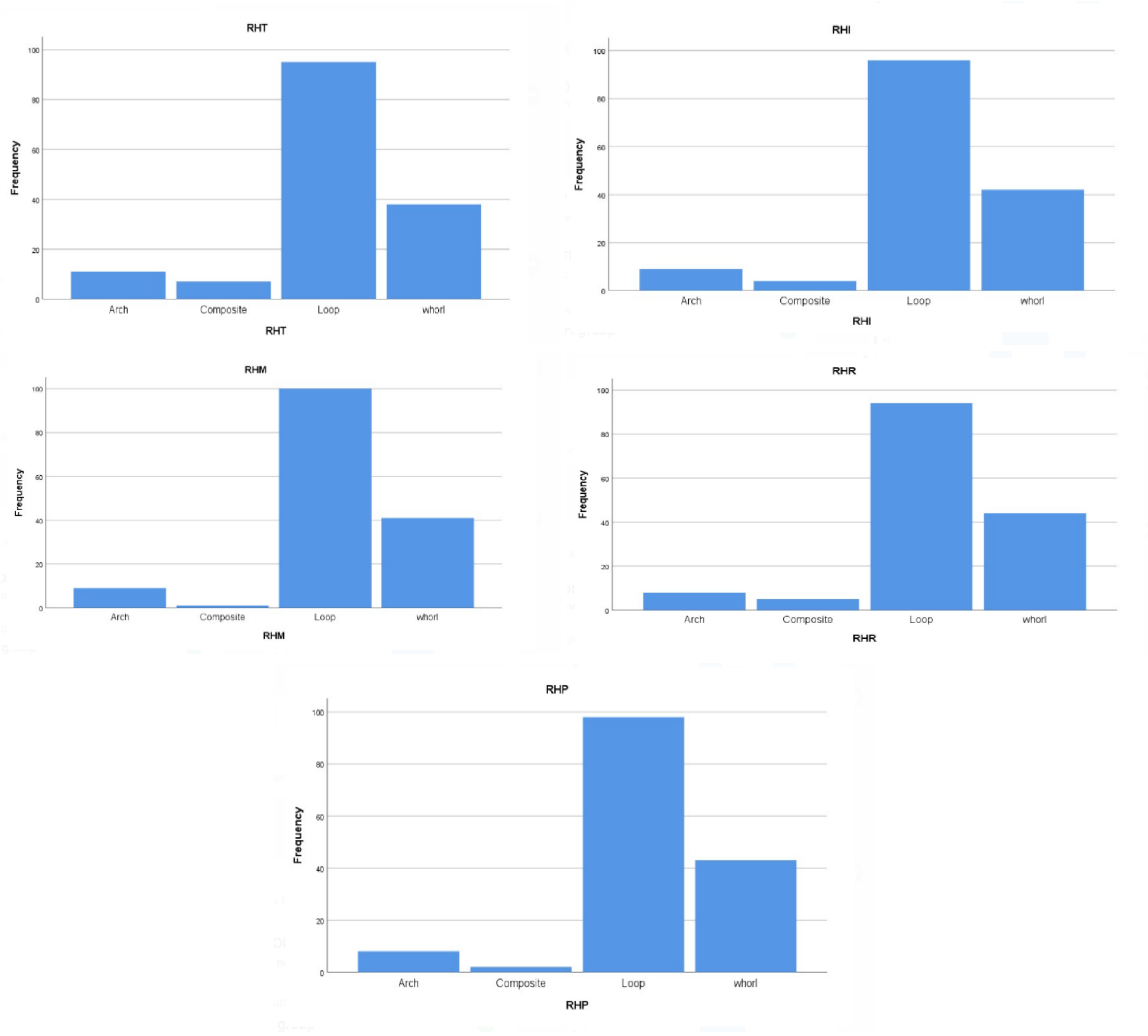


Figure 23: Distribution of fingerprint patterns in the right hand Fingers for siblings. A representation of the distribution of fingerprint pattern on the RHT, RHI, RHM, RHR, and RHP of the siblings. P-value = 0.006

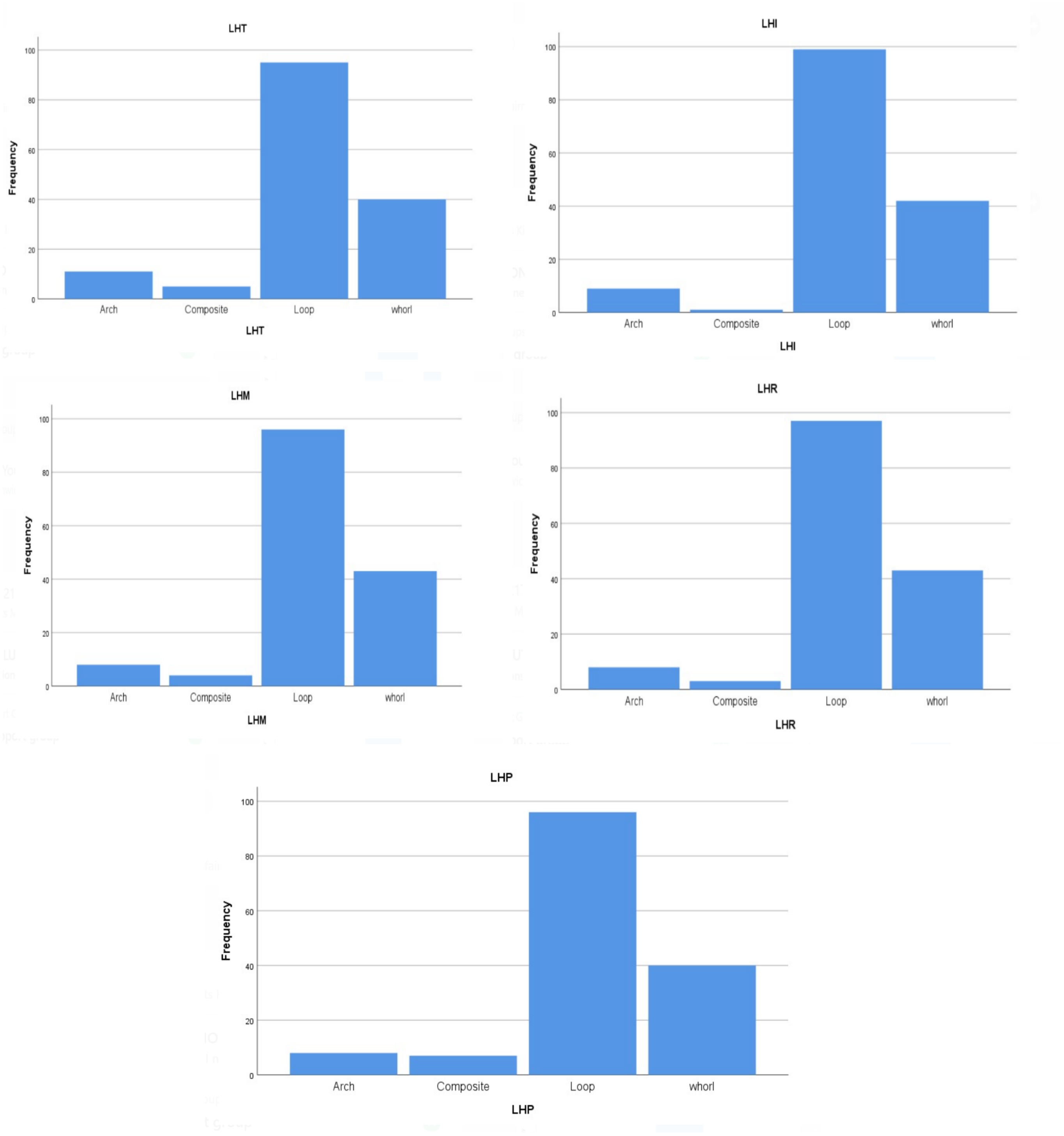


Figure 24: Distribution of fingerprint patterns in the left hand Fingers for Siblings. A representation of the distribution of fingerprint pattern on the LHT, LHI, LHM, LHR, and LHP of the siblings. P-value = 0.002

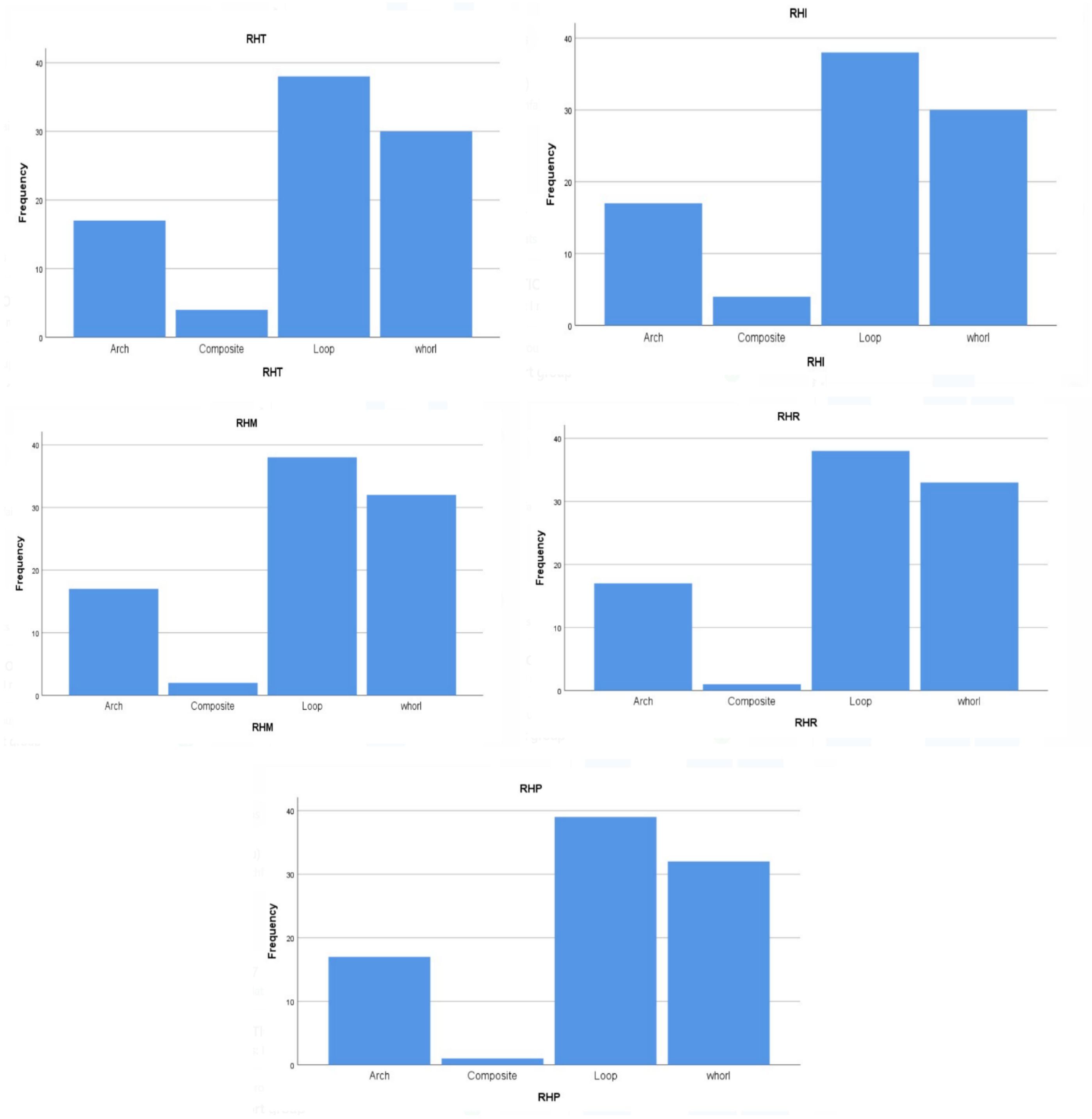


Figure 25: Distribution of fingerprint patterns in the right hand Fingers for non-Siblings. A representation of the distribution of fingerprint pattern on the RHT, RHI, RHM, RHR, and RHP of the non-siblings. P-value = 0.001

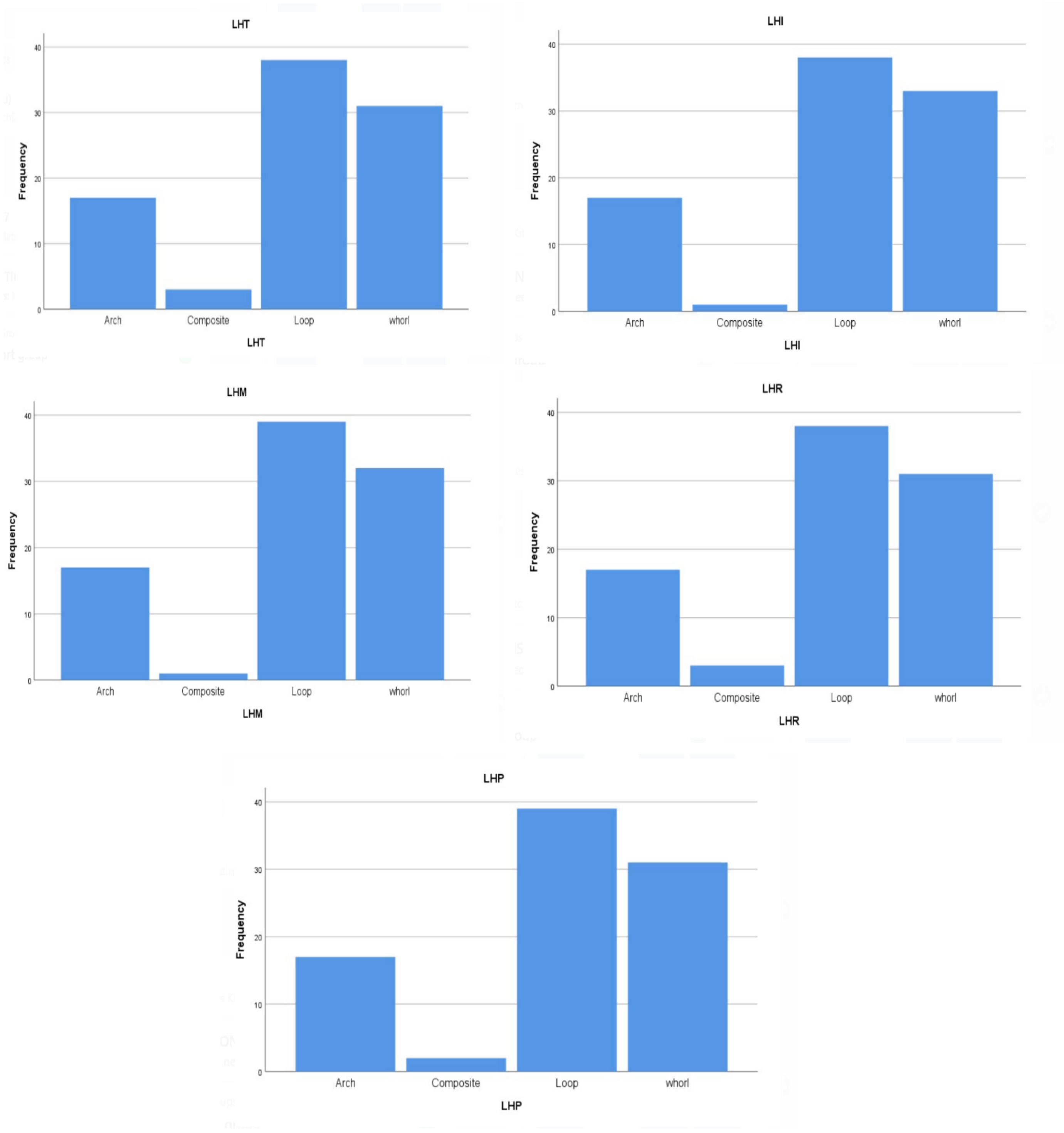


Figure 26: Distribution of fingerprint patterns in the left hand Fingers for non-Siblings. A representation of the distribution of fingerprint pattern on the LHT, LHI, LHM, LHR, and LHP of the non- sibling. P-value = 0.001

The bar charts 23, 24, 25, and 26 above shows the distribution of fingerprint patterns in the right and Left Hand Fingers in both siblings and non-siblings in the population of study. According the findings, loop pattern appeared to have a higher frequency across all the fingers in both siblings and non-siblings. The composite patterns had the least occurrence in terms of numbers across all the fingers in both siblings and non-siblings.

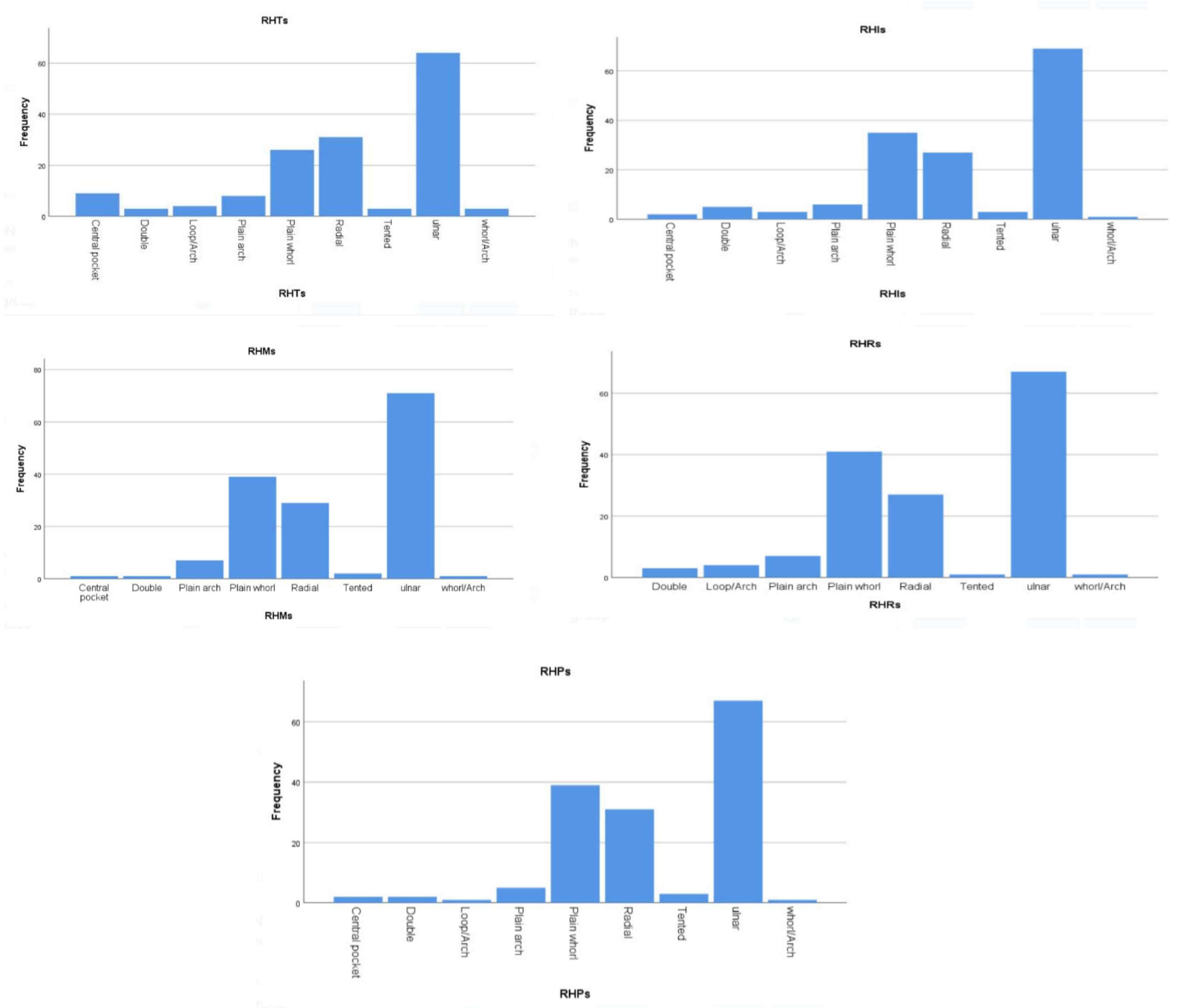


Figure 27: Distribution of fingerprint sub-patterns in the right hand Fingers for Siblings. A representation of the distribution of fingerprint pattern on the LHT, LHI, LHM, LHR, and LHP of the siblings. P-value = 0.001

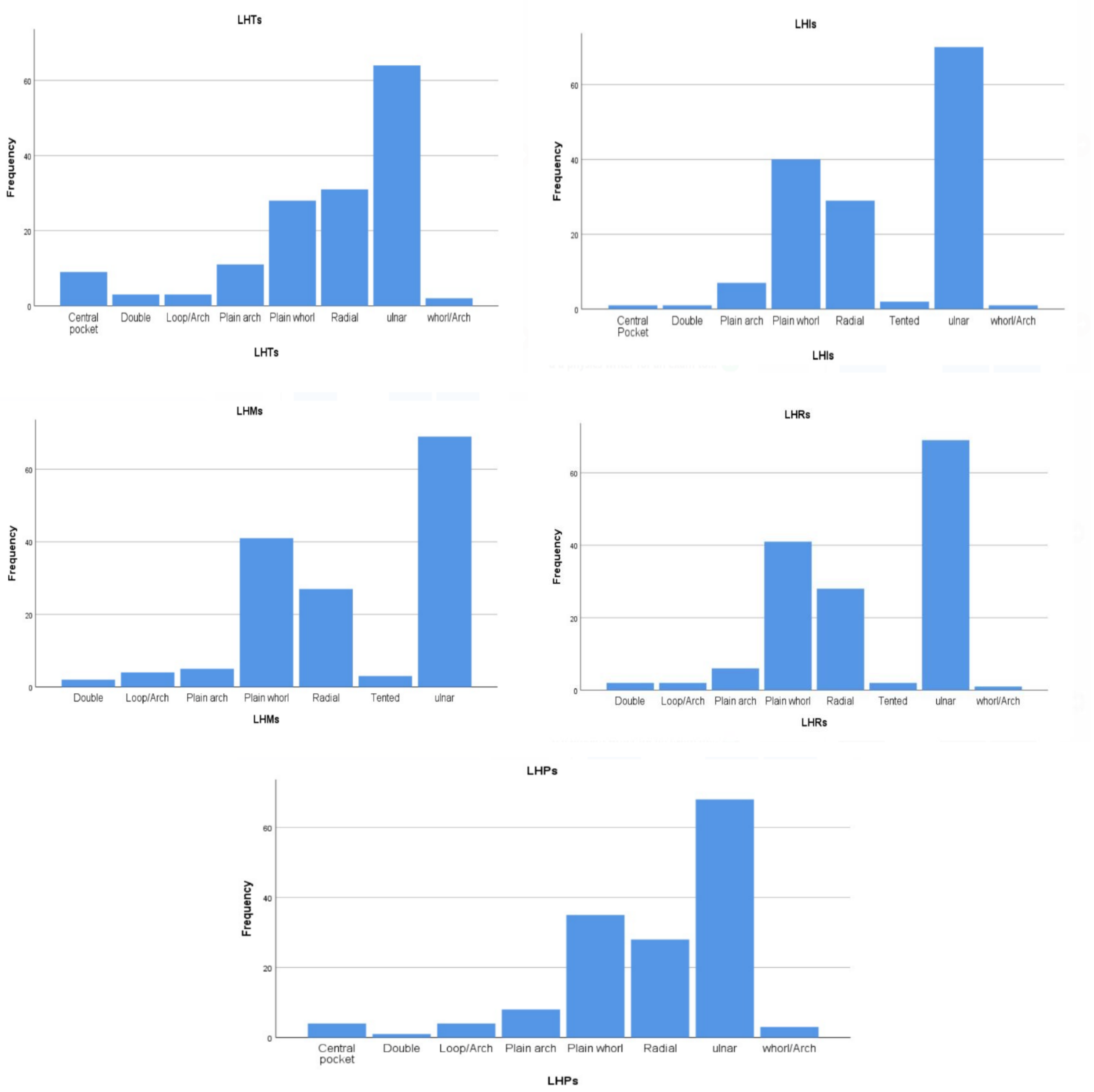


Figure 28: Distribution of fingerprint sub-patterns in the left hand Fingers for Siblings. A representation of the distribution of fingerprint pattern on the LHT, LHI, LHM, LHR, and LHP of the siblings. P-value = 0.007

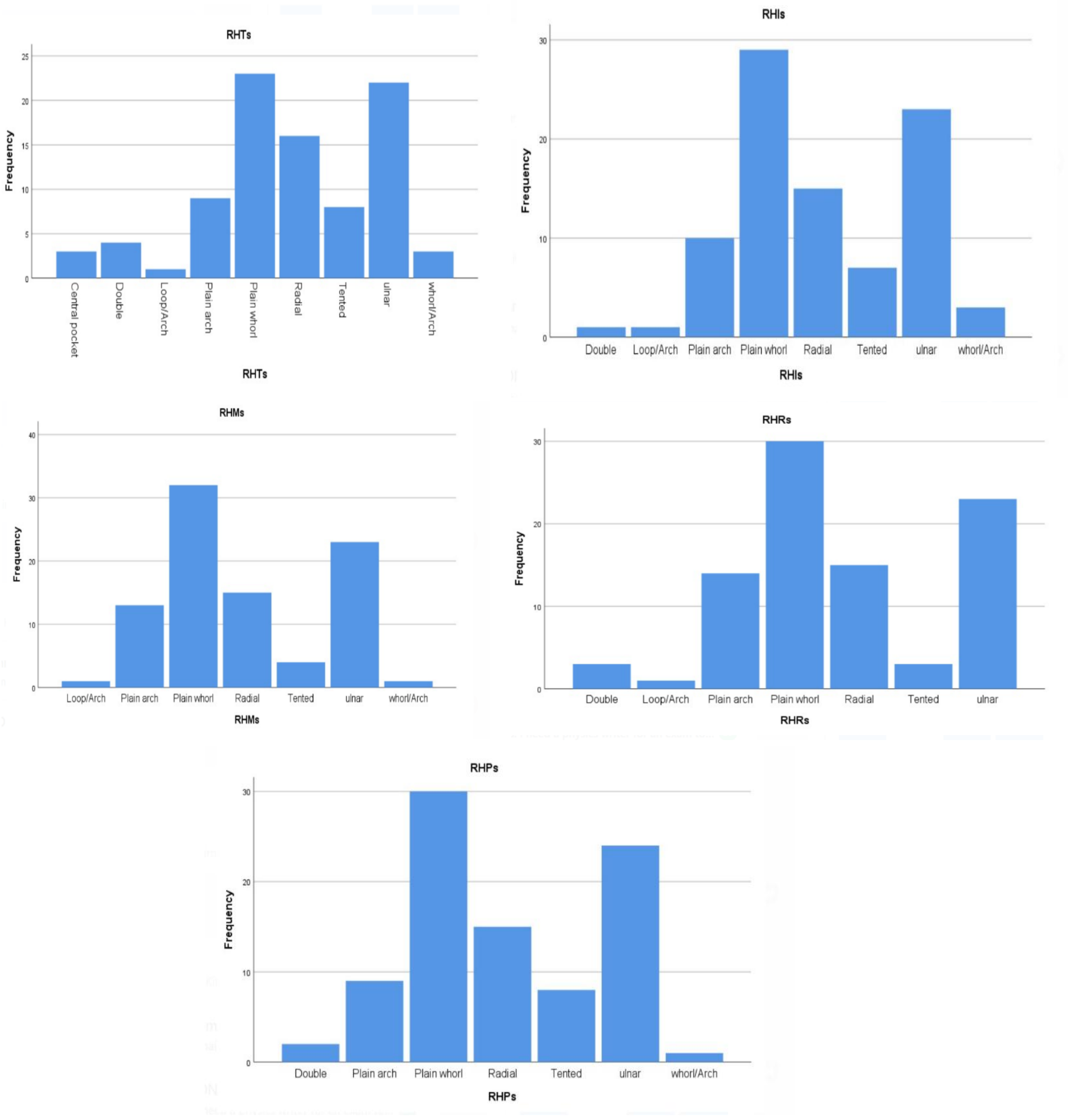
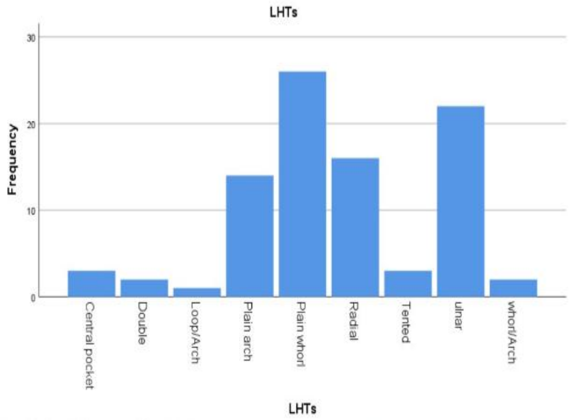
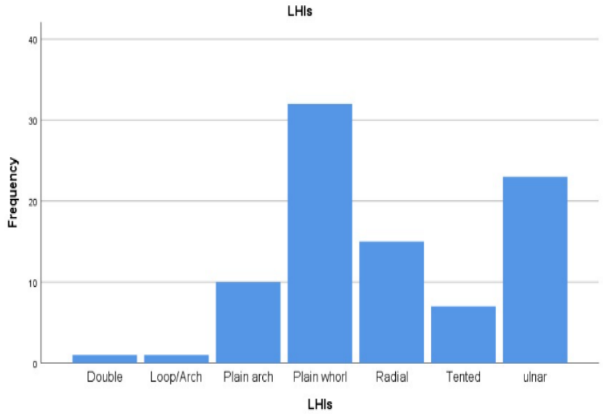
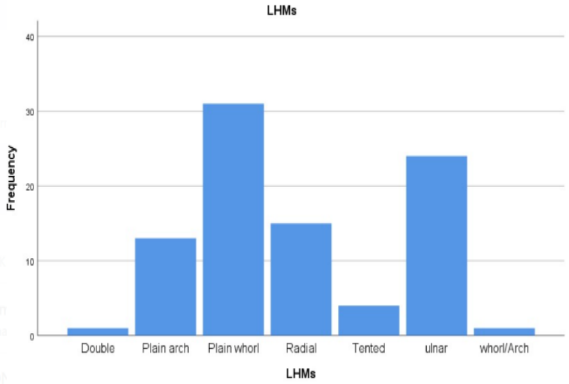
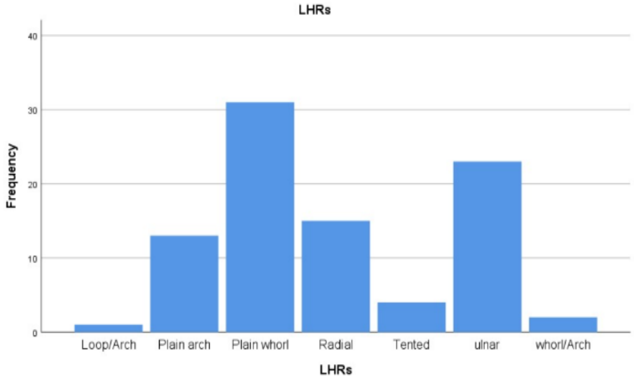


Figure 29: Distribution of fingerprint sub-patterns in the right hand Fingers for non- Siblings. A representation of the distribution of fingerprint pattern on the RHT, RHI, RHM, RHR, and RHP of the non- Siblings. P-value = 0.001


LHTs
Frequency
30
20
10
0
Central pocket
Double
Loop/Arch
Plain arch
Plain whorl
Radial
Tented
ulnar
whorl/Arch
LHTs


LHIs
Frequency
40
30
20
10
0
Double
Loop/Arch
Plain arch
Plain whorl
Radial
Tented
ulnar
LHIs


LHMs
Frequency
40
30
20
10
0
Double
Plain arch
Plain whorl
Radial
Tented
ulnar
whorl/Arch
LHMs


LHRs
Frequency
40
30
20
10
0
Loop/Arch
Plain arch
Plain whorl
Radial
Tented
ulnar
whorl/Arch
LHRs

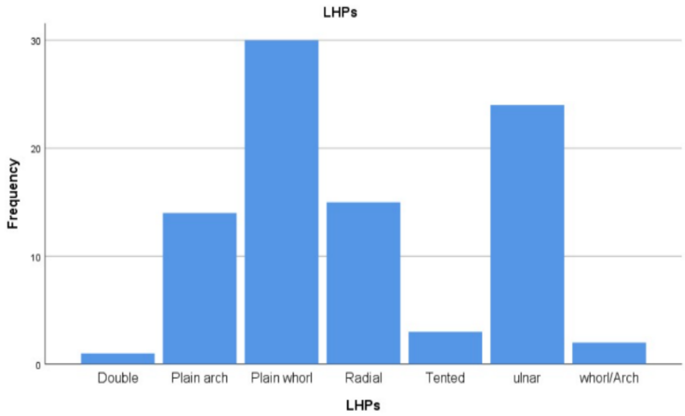

LHPs
Frequency
30
20
10
0
Double
Plain arch
Plain whorl
Radial
Tented
ulnar
whorl/Arch
LHPs

Figure 30: Distribution of fingerprint sub-patterns in the left hand Fingers for non- Siblings. A representation of the distribution of fingerprint sub-pattern on the LHT, LHI, LHM, LHR, and LHP of the non- Siblings. P-value = 0.001

The bar charts 27, 28, 29, and 30 above shows the distribution of fingerprint sub-patterns in the right- and Left-hand Fingers for both siblings and non-siblings in the population of study. The plain whorl and ulnar loop sub-pattern appeared to have a higher frequency across all the fingers in both siblings and non-siblings. The double loop, central pocket whorl and the composite based sub-patterns including the loop/arch and the whorl arch had the least occurrence in terms of numbers across all the fingers in both siblings and non-siblings.

Discussion

The results show a significant variation between sibling and non-sibling for both the right and left hand, with the sibling count being higher than the non-sibling count. The findings of this study are consistent with a study conducted in Nigeria, which found a substantial difference in the arch, whorls, and loop fingerprint patterns of siblings and non-siblings on both the right and left hands in Lagos (Iroanya et al., 2020). Moreover, the study also shows that siblings have a larger distribution of ulnar patterns throughout all ten fingers than non-siblings. On the other hand, research conducted in Pakistan comparing the fingerprints of siblings and non-siblings among the Pakhtun population of the Swat area revealed that siblings' fingerprints are somewhat more similar than those of non-siblings (Subhanuddin et al., 2022). Another partially contradicting study (Heng et al., 2018) in Malaysia concluded that siblings demonstrated similarities in all patterns to non-siblings except for the arch pattern. The differences and similarities may be a result of the genetic differences in siblings and non-siblings. Due to their common genetic makeup such us HOX Genes, TP63, and FOXC2 (Forkhead Box C2) siblings often exhibit a higher proportion of similarity between their fingerprint patterns than non-siblings (Heng et al., 2018). For instance, siblings inherit the genetic makeup responsible for fingerprint formation from their parents, therefore they will have the same patterns. Most importantly, an individual's Friction

Ridge Skin will always be unique because the precise arrangements of the ridges, minutiae, and other distinguishing features are random, not genetically linked, and therefore not inheritable (Kucken & Newell, 2005). Taken together, the study, therefore, showed a significant difference between siblings and non-siblings in their fingerprint patterns, with a higher prevalence of similar patterns among siblings. It is therefore possible that fingerprint patterns could be used to distinguish between siblings and non-siblings in a population.

CHAPTER FIVE: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1. Summary

The study revealed consistent fingerprint pattern frequencies across both right (P = 0.736) and left (P = 0.937) hands, with loops being slightly more prevalent across both hands. These results were found to align with findings in Nigeria and Thailand, but contradict those in Costa Rica, indicating global variation influenced by factors like maternal environment, blood group, and finger lengths.

Secondly, the study also found similar fingerprint pattern frequencies across genders for all ten fingers (P-values ranged from 0.173 to 0.857). Ulnar sub-patterns were most prevalent in both genders. Autosomal dominant inheritance, influenced by environmental factors, may explain global variations in fingerprint patterns between genders. Thus, fingerprint patterns alone may not reliably differentiate gender.

Thirdly, the study also found similar fingerprint pattern distributions between the Bukusu and Kabras across all ten fingers (P-values ranged from 0.014 to 0.318). This mirrored research in Asia on Chinese and Malays people. The ulnar loop sub-pattern was predominant, consistent with Nigerian findings. However, it contrasts with studies in southern Nigeria and Costa Rica. Genetic factors may underlie these variations, suggesting unique patterns within different ethnic groups.

Finally, the study found significant variation in fingerprint patterns between siblings and non-siblings for both hands (P-values ranged from 0.001 to 0.007), with siblings showing higher similarity. This aligned with Nigerian research but contrasts with findings in Pakistan and Malaysia. Genetic differences likely contribute, with siblings sharing more similarities due to common inheritance. However, individual fingerprint uniqueness remains, as patterns are not solely genetically determined.

5.2. Conclusion

The study concludes that the most significant variation in terms of fingerprint pattern distribution is between siblings and non-siblings, with no variations found when examining gender, hand of origin, or tribal lineage. These findings can be used as a tool to distinguish between siblings and non-siblings in the population in western Kenya

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APPENDICES.

Appendix I.

Introductory to the Questionnaire:

I am a student of MSc. Forensic Science from Kirinyaga University. I will be conducting research that will help determine the distribution of fingerprint patterns in the western region of the Kenyan population. The research will serve as an important tool to the forensic and law enforcement departments towards helping in specifying the type of distribution of fingerprints in the region. Therefore, I warmly encourage you to complete and fill out every part of this questionnaire and kindly avail your prints. The feedback that you will provide will be of very importance to this study. It is optional to either accept the process or deny it.

If you make a decision for the participant, it would mean a lot to the study and what the current research sought to achieve. The time needed for filling out this questionnaire will not be more than thirty minutes. In the section provided, kindly choose only one option that best fits your view from the list of other options to avoid misinterpretation. I will be very happy to hear your helpful thoughts and experiences regarding the questions asked.

Your data will be held confidential and will not be shared with anyone else and would only be used for the aim of research but may be shared with another researcher who might adopt secondary methods. The questionnaire does not request your name or any other identifiable personal details that could be used to track you by people outside this research.

Kindly fill out the questionnaire in the platform provided by January 15, 2023. Additionally, if there are any queries or would like to clarify anything concerning the research or the questions asked in this questionnaire, you can kindly reach me at mikelunani@gmail.com.

I want to thank you from the bottom of my heart for your assistance.

PART A: BASIC PERSONAL INFORMATION

Guidelines: Mark in the space(s) given, either with a tick (√) or mark (X).

Q 1. Please tick the box which represents your gender.

- Female { }
- Male {X}

Q 2. Please tick the box which represents your age range.

a) Below 24 years { }
b) 25 -34 years {X}
c) 35 - 44 years { }
d) 45 -54 years { }
e) 55 and above years { }

Q 3. Ethnic group: Bukusu

Q 4. What is your highest education level?

1. Secondary:{ }
2. College/University {X}
3. Master's Degree { }
4. PhD. { }
5. Other { } Please specify____________________

Q 5. What is your Occupation?

1. Farmer { }
2. Casual worker { }
3. Office-related jobs { }

4. [✓ Teacher]

5. Others { }. Please specify________________________

Q6. Sibling to study participant. 019

PART B: QUESTIONS PERTAINS DONATING YOUR FINGERPRINTS. TWO COPIES OF EACH PRINT ARE ADVISED TO INCREASE ACCURACY.

Right-Hand fingerprints

Right thumb print 1

Right thumb print 2

Right Index F1

Right index F2

Right middle F1

Right middle F2

Right ring F1

Right ring F2

Right pinkie F1

Right pinkie F2

Left-hand fingerprints.


Left thumb print 1


Left thumb print 2


Left Index F1


Left index F2


Left middle F1


Left middle F2


Left ring F1


Left ring F2


Left pinkie F1


Left pinkie F2

THANK YOU FOR YOUR PARTICIPATION!!

PART A: BASIC PERSONAL INFORMATION

Guidelines: Mark in the space(s) given, either with a tick (√) or mark (X).

Q 1. Please tick the box which represents your gender.

- Female { }
- Male { } ✓

Q 2. Please tick the box which represents your age range.

a) Below 24 years { }

b) 25 -34 years { } ✓

c) 35 - 44 years { }

d) 45 -54 years { }

e) 55 and above years { }

Q 3. Ethnic group: Kabarasi

Q 4. What is your highest education level?

1. Secondary: { }
2. College/University { } ✓
3. Master's Degree { }
4. PhD. { }
5. Other { } Please specify____________________

Q 5. What is your Occupation?

1. Farmer { }
2. Casual worker { } ✓
3. Office-related jobs { }

4. Teacher { }

5. Others { }. Please specify__________________________

Q6. Sibling to study participant P024

PART B: QUESTIONS PERTAINS DONATING YOUR FINGERPRINTS. TWO COPIES OF EACH PRINT ARE ADVISED TO INCREASE ACCURACY.

Right-Hand fingerprints

Right thumb print 1

Right thumb print 2

Right Index F1

Right index F2

Right middle F1

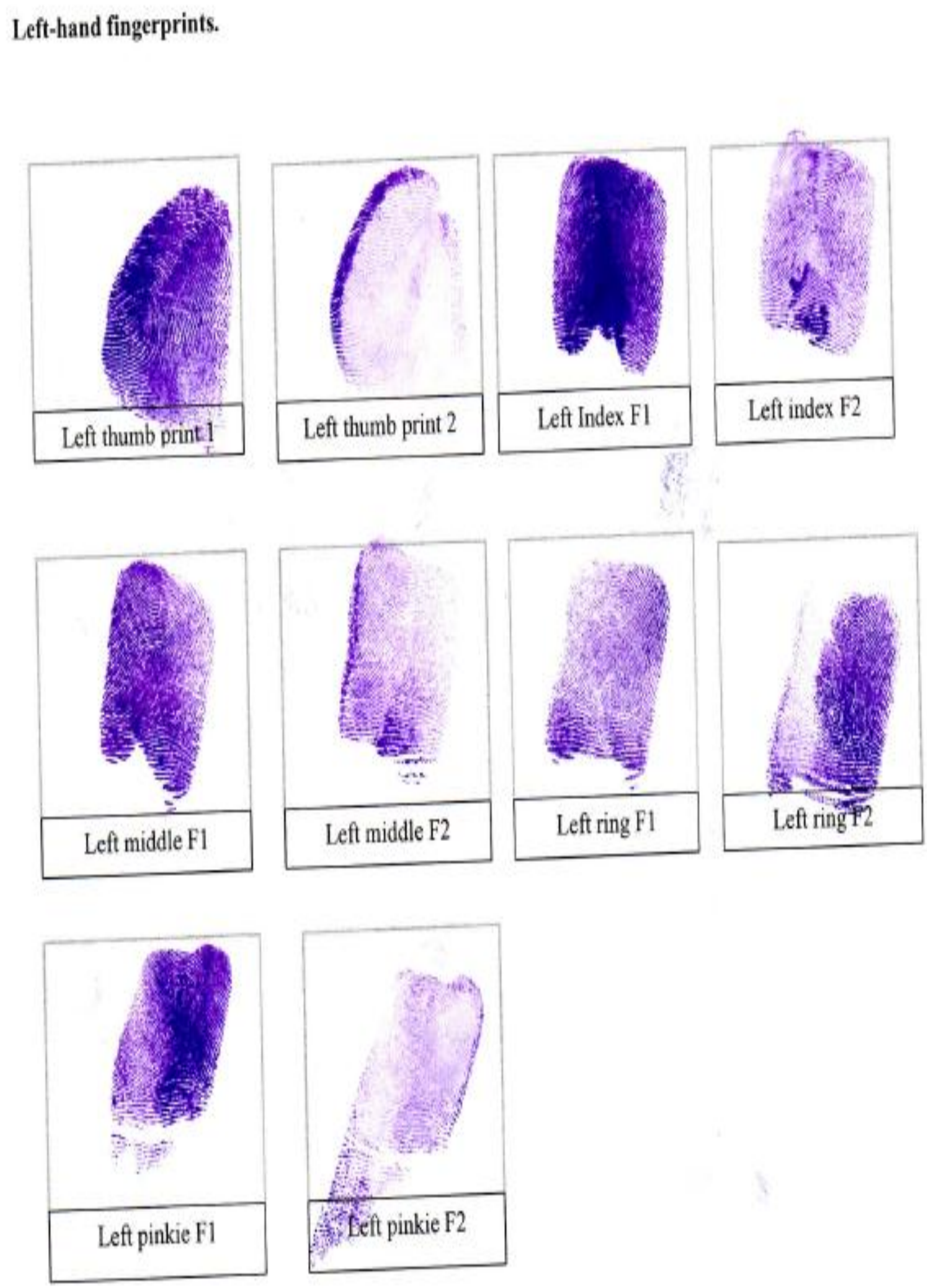
Right middle F2

Right ring F1

Right ring F2

Right pinkie F1

Right pinkie F2



Left-hand fingerprints.

Left thumb print 1
Left thumb print 2
Left Index F1
Left index F2
Left middle F1
Left middle F2
Left ring F1
Left ring F2
Left pinkie F1
Left pinkie F2

THANK YOU FOR YOUR PARTICIPATION!!

Appendices II.

TITLE OF STUDY

DISTRIBUTION OF FINGERPRINT PATTERNS IN THE KENYAN POPULATION WESTERN REGION.

PRINCIPAL INVESTIGATOR

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Phone: 0714552181 or 0765342278

Email: mikelunani@gmail.com

Co-investigators:

Dr. Mark Kilongosi

Dr. Godwill Munyekenye

PURPOSE OF STUDY

You are asked to take part in an investigation. Before you choose whether or not to participate, it is imperative that you understand the objectives and methods of the study. The content that follows should be read slowly. Do not hesitate to ask the researcher questions if something is unclear or if you would want further information.

The purpose of this study is to determine fingerprint pattern distribution in the Kenyan population. Fingerprints are the most predominant type of evidence found at a crime scene; therefore, understanding the print's patterns recovered is of great value to forensic Scientists in any Forensic case. There are three main fingerprint patterns that are distributed among the billions of people across the globe, which include arch, Whorl, and loop. These patterns vary differently for every individual, making it very difficult to classify a particular group of people by using the morphology of the prints. The variation in the patterns is caused by the small division of the fingerprint patterns that makes individualization possible. These divisions are referred fingerprint minutiae. The fingerprint minutiae include bifurcation, the lakes, termination, deltas, spurs, cross-over, point of the island, termination, etc. Therefore, classification of the patterns will help fingerprint departments in having classifications of the prints using the patterns. Classification of the individual in terms of ethnicity, gender, and age by simply analyzing the fingerprint patterns can be very helpful in the Forensic process. Therefore, this paper will analyze fingerprint patterns to determine their impact on gender, ethnicity, and the prevalence of fingerprint patterns in the Kenyan population.

STUDY PROCEDURES

Prior to fingerprinting, the individual's hands will be washed. For moist fingers, alcohol will be used in wiping the hands. For a hand that will be dry or flaky, a tiny amount of cotton will be used to wipe away any excess. The donors will be instructed to relax and gaze away from the fingerprint gadget. With the right hand, grasp the individual's right hand at the base of the thumb. Cup your palm over the individual's fingers, tucking beneath those that are not now being printed. Using your left hand, guide the finger being imprinted by rolling from nail edge to nail edge, catching the tip of each finger down to the first joint. The side of the finger bulb will be put on the card during the rolling imprint process. The finger is then rolled to the other side so that it points in the opposite way. A gentle, steady motion while rolling the finger will be applied. The maximum pressure required to capture a clean fingerprint is equal to the weight of the finger. When rolling each finger, the side with the highest resistance will be rolled first. Rolling will occur towards the body for the thumbs and away from the body for the fingers. When rolling the right index finger, for example, roll from left to right.

Following the individual fingerprints, the four-finger slap or simple print will be recorded. Press the inkpad with all four fingers of the right hand while keeping the fingers together.

You will then push the four fingers at a 45-degree angle into the appropriate area at the bottom of the card to capture all four prints simultaneously. This procedure will be repeated for the left hand. The two thumbs slap or simple prints will be taken simultaneously by putting both thumbs in the boxes at the bottom of the card. It will be ensured that all relevant demographic data is provided in the proper places and that the individual who is being fingerprinted signs the card.

RISKS

There are no risks that you will encounter during the procedure of data collection. You may decline to answer any or all questions, and you may terminate your involvement at any time if you choose.

BENEFITS

Participating in this study will be of great benefit to you and the people in your community as a whole.

- This study will deter crime rates in the communities as it will make it easy to classify fingerprint patterns and link them to a particular group of people hence making the investigation process easy.
- The study will help in classifying and linking cases of mistaken identity, lost individuals, or events in mass disaster cases, as the individuals could easily be linked to their origin using their fingerprint patterns

CONFIDENTIALITY

Your responses to this survey will be kept confidential. Avoid include any private information in your research. OR For the duration of this study, your answers won't be kept private. The researcher will take all reasonable steps to safeguard your privacy, such as the following:

- Giving participants identifiers or code names to use on all research materials and notes

- Preserving any personal notes, transcripts of interviews, and other data that may be utilised to identify a participant by the researcher.

Participant data will be kept confidential, unless the researcher is legally obligated to reveal specific occurrences. These situations include abuse cases and suicide risk cases, albeit they are not limited to them.

CONTACT INFORMATION

Contact the researcher using the information on the first page if you have any concerns about this study at any point or if taking part in it has caused you to suffer any negative consequences. Please get in touch with the Institutional Review Board at P.O. Box: 143-10300 Kerugoya if you have any queries about your rights as a study participant or if you run into issues that you don't feel comfortable discussing with the primary investigator. Email is info@kyu.ac.ke.

VOLUNTARY PARTICIPATION

Participation in this study is not compulsory. You are free to choose whether or not to take part in this study. If you would want to take part in the research, you will need to complete a consent form. Even after signing the permission form, you are free to revoke your consent at any time and for any reason. Should you want to withdraw from this study, it will not affect any interactions you may have with the researcher. If you withdraw from the study before the data collection is complete, your information will either be erased or returned to you..

CONSENT

I have read, understood, and had a chance to ask questions about the material presented. I am aware that my participation is entirely optional and that I may stop at any moment, for any reason, and without incurring any fees. I am aware that a copy of this permission form will be sent to me. I freely consent to participate in this research.

Participant's signature ________________ Date 10|03|2023

Researcher's signature ________________ Date 10|03|2023

Appendix III

Resesarch Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR
SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 989668

Date of Issue: 15/June/2023

RESEARCH LICENSE

This is to Certify that Mr.. Mike Wanyonyi Lumasi of Kirinyaga University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Bungoma, Kakamega on the topic: DISTRIBUTION OF FINGERPRINT PATTERNS IN A POPULATION IN WESTERN KENYA for the period ending : 15/June/2024.

License No: NACOSTI/P/23/26249

989668

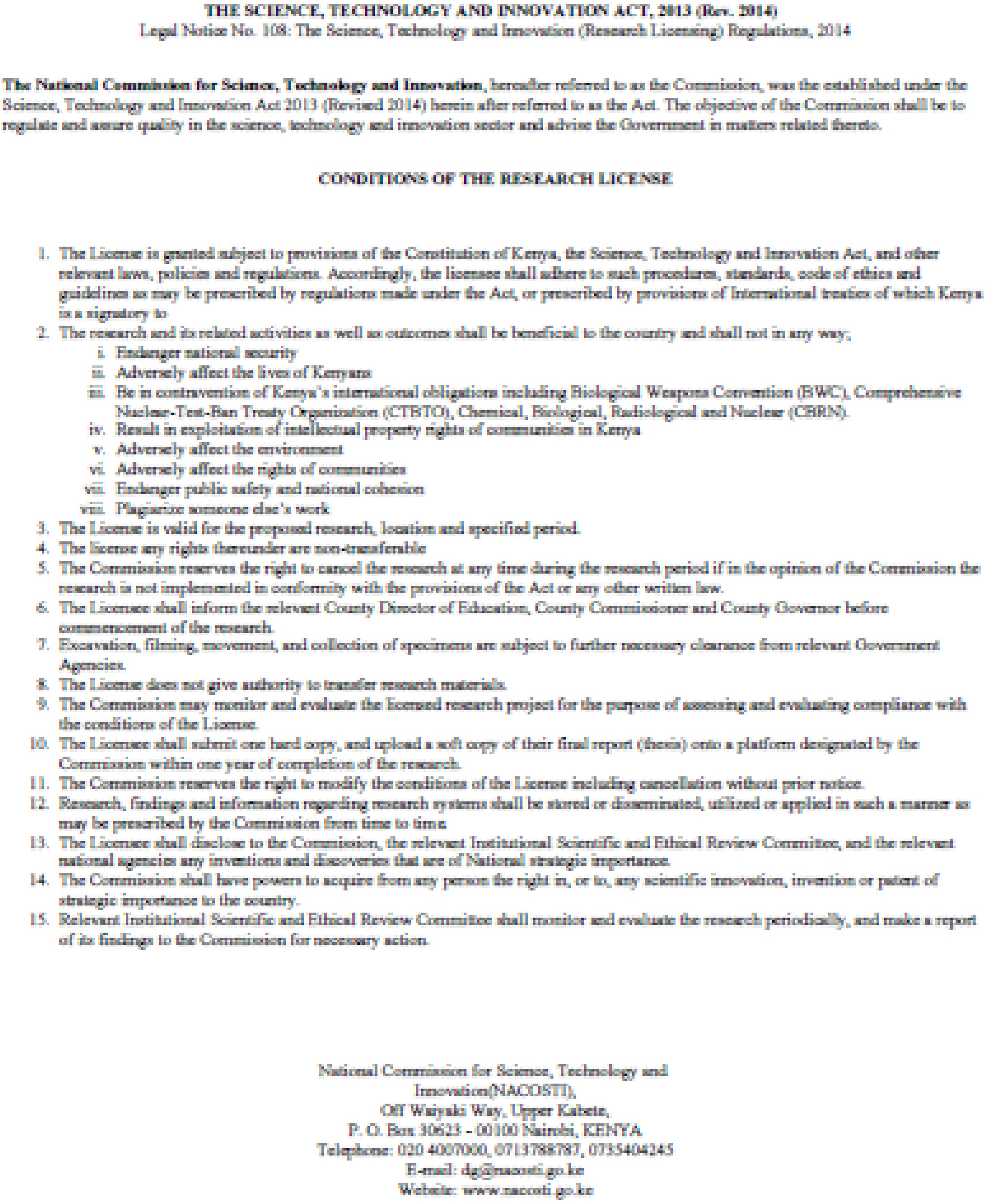
Applicant Identification Number

Director General
NATIONAL COMMISSION FOR
SCIENCE,TECHNOLOGY &
INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document,
Scan the QR Code using QR scanner application.

See overleaf for conditions



THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013 (Rev. 2014)
Legal Notice No. 108: The Science, Technology and Innovation (Research Licensing) Regulations, 2014

The National Commission for Science, Technology and Innovation, hereafter referred to as the Commission, was the established under the Science, Technology and Innovation Act 2013 (Revised 2014) herein after referred to as the Act. The objective of the Commission shall be to regulate and assure quality in the science, technology and innovation sector and advise the Government in matters related thereto.

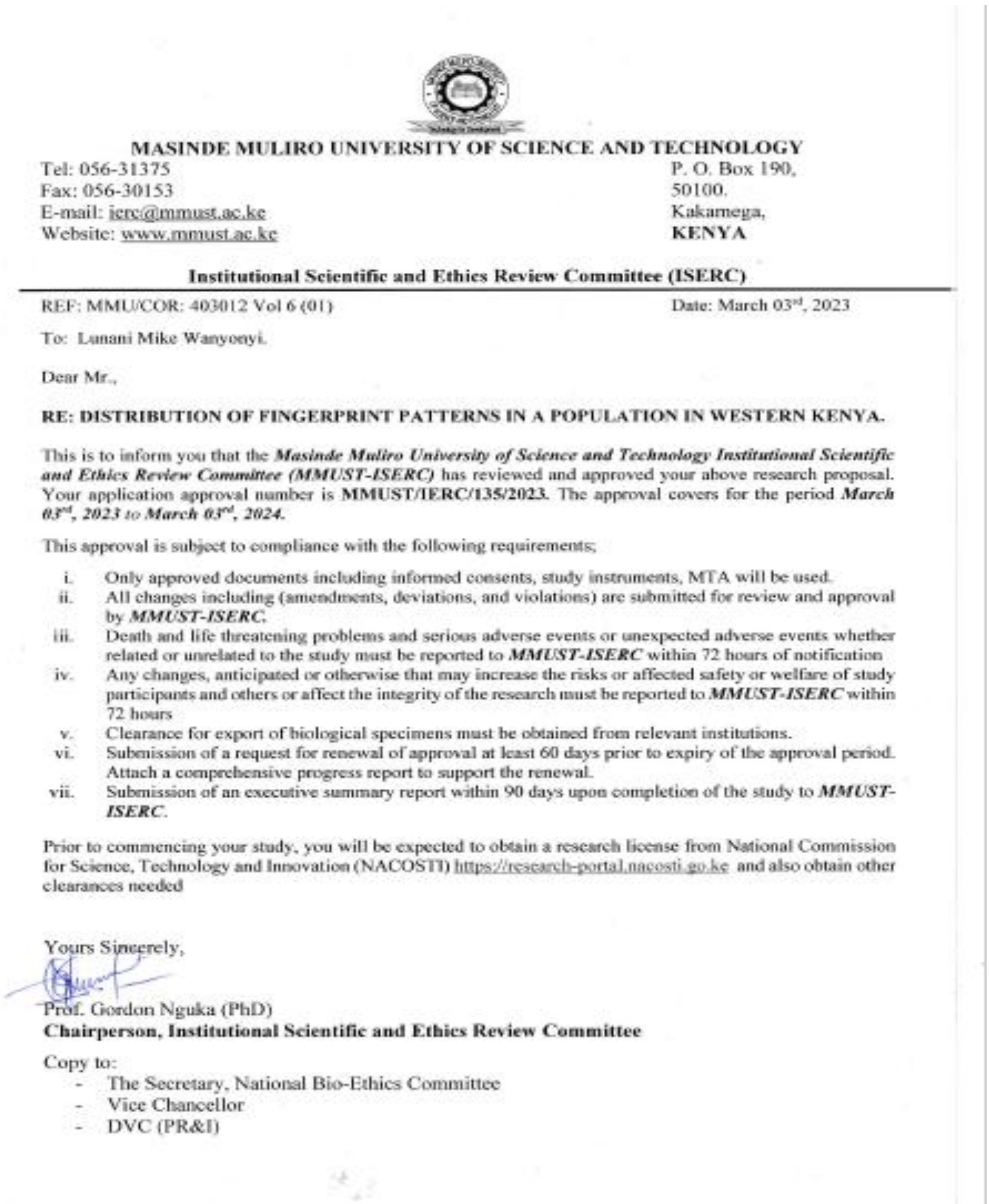
CONDITIONS OF THE RESEARCH LICENSE

1. The License is granted subject to provisions of the Constitution of Kenya, the Science, Technology and Innovation Act, and other relevant laws, policies and regulations. Accordingly, the licensee shall adhere to such procedures, standards, code of ethics and guidelines as may be prescribed by regulations made under the Act, or prescribed by provisions of International treaties of which Kenya is a signatory to
2. The research and its related activities as well as outcomes shall be beneficial to the country and shall not in any way;
   i. Endanger national security
   ii. Adversely affect the lives of Kenyans
   iii. Be in contravention of Kenya's international obligations including Biological Weapons Convention (BWC), Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Chemical, Biological, Radiological and Nuclear (CBRN).
   iv. Result in exploitation of intellectual property rights of communities in Kenya
   v. Adversely affect the environment
   vi. Adversely affect the rights of communities
   vii. Endanger public safety and national cohesion
   viii. Plagiarize someone else's work
3. The License is valid for the proposed research, location and specified period.
4. The license any rights thereunder are non-transferable
5. The Commission reserves the right to cancel the research at any time during the research period if in the opinion of the Commission the research is not implemented in conformity with the provisions of the Act or any other written law.
6. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research.
7. Excavation, filming, movement, and collection of specimens are subject to further necessary clearance from relevant Government Agencies.
8. The License does not give authority to transfer research materials.
9. The Commission may monitor and evaluate the licensed research project for the purpose of assessing and evaluating compliance with the conditions of the License.
10. The Licensee shall submit one hard copy, and upload a soft copy of their final report (thesis) onto a platform designated by the Commission within one year of completion of the research.
11. The Commission reserves the right to modify the conditions of the License including cancellation without prior notice.
12. Research, findings and information regarding research systems shall be stored or disseminated, utilized or applied in such a manner as may be prescribed by the Commission from time to time.
13. The Licensee shall disclose to the Commission, the relevant Institutional Scientific and Ethical Review Committee, and the relevant national agencies any inventions and discoveries that are of National strategic importance.
14. The Commission shall have powers to acquire from any person the right in, or to, any scientific innovation, invention or patent of strategic importance to the country.
15. Relevant Institutional Scientific and Ethical Review Committee shall monitor and evaluate the research periodically, and make a report of its findings to the Commission for necessary action.

National Commission for Science, Technology and
Innovation(NACOSTI),
Off Waiyaki Way, Upper Kabete,
P. O. Box 30623 - 00100 Nairobi, KENYA
Telephone: 020 4007000, 0713788787, 0735404245
E-mail: dg@nacosti.go.ke
Website: www.nacosti.go.ke

Appendix iv

Ethical Review



MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY

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P. O. Box 190,
50100.
Kakamega,
KENYA

Institutional Scientific and Ethics Review Committee (ISERC)

REF: MMU/COR: 403012 Vol 6 (01)

Date: March 03rd, 2023

To: Lunani Mike Wanyonyi.

Dear Mr.,

RE: DISTRIBUTION OF FINGERPRINT PATTERNS IN A POPULATION IN WESTERN KENYA.

This is to inform you that the ***Masinde Muliro University of Science and Technology Institutional Scientific and Ethics Review Committee (MMUST-ISERC)*** has reviewed and approved your above research proposal. Your application approval number is **MMUST/IERC/135/2023.** The approval covers for the period ***March 03rd, 2023*** *to* ***March 03rd, 2024.***

This approval is subject to compliance with the following requirements;

i. Only approved documents including informed consents, study instruments, MTA will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***MMUST-ISERC.***
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***MMUST-ISERC*** within 72 hours of notification
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***MMUST-ISERC*** within 72 hours
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to ***MMUST-ISERC.***

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://research-portal.nacosti.go.ke and also obtain other clearances needed

Yours Sincerely,

Prof. Gordon Nguka (PhD)
Chairperson, Institutional Scientific and Ethics Review Committee

Copy to:

- The Secretary, National Bio-Ethics Committee
- Vice Chancellor
- DVC (PR&I)