CHAPTER 5 – THE HUMAN NON-METRIC STUDY

5.1 Results 1 – Morphological traits

The sample size and percentile frequency for each variation from each group are contained in Table A5.1 of Appendix one. Histograms of the frequency of variation for each sex and group are contained in Figures A5.1 - A5.5 of Appendix two. The illustrations and definitions of the variations in morphological features are to be found in Chapter 2.

5.1.1 General trends

Comparison of the histograms in Appendix one, reveal that the general trends in the frequency of variation between the males and females of the three recent subgroups were very similar. As there was no obvious sexual dimorphism in terms of variation between these subgroups, they were compared with the pre-pastoral subgroup as a pooled-sex and sex indeterminate group as the numbers of individuals of known sex in this subgroup were too small for coherent comparison of frequency of variable traits. In the pre-pastoral subgroup, the trends were also very similar to the recent subgroups, consistently showing a greater frequency of typical descriptions in each bone of each subgroup.
5.1.1.1 Common morphological features

The first metatarsal head shape

A rounded or convex head shape (variation one) is by far the most common morphology in all the subgroups. In the Sotho and Zulu, this is followed by the square shape with a central ridge and the square shape. In the European female subgroup, the rounded head shape is notably the most common morphology, with only one specimen with a square shape and two specimens with a square shape and a central ridge. The European male subgroup presented with the rounded head shape, no square morphology and a few frequencies of square head shape with a central ridge. In the pre-pastoral subgroup, the common rounded head morphology is followed by the square shape and the least common, a square shape with a central ridge. Although the rounded shape is the most common in all the subgroups, the female Europeans have a slightly higher frequency of the common morphology.

The first metatarsal proximal articular surface shape

The kidney or reniform shape (variation one) is the most common morphology in all the subgroups. This is followed by the partially divided articular surface with the Sotho and European subgroups having a somewhat greater frequency than the Zulu and pre-pastoralists. Only the Zulu subgroup had an isolated completely divided (bipart) proximal articular surface.
The first metatarsal lateral base

A smooth area with indefinite margins (variation two) is by far the most common morphology in all the subgroups, followed by a smooth facet with well defined margins and no indication of an articular facet. Notably, both the European and pre-pastoral subgroups presented with a higher frequency of both an articular area with well defined margins (variation one) and no indication of an articular facet. However, in the European subgroup, most of these well defined articular facets had some indication of arthritic changes with a greater prevalence in the females. In all the subgroups there were a number of well developed articular facets that were also quite large in size and had a tendency to extend laterally in a slightly elevated position. In these, particularly with the afore mentioned arthritic changes, articulation of the first and second metatarsal bases gave a distinct impression that the facet was responsible for increasing the angle between the first and second metatarsals.

Though not described as a “new” variation, there was one isolated case of a small, well defined articular facet situated superiorly to the position of the common condition. This seems to indicate not a true variant from variation one, but variation one where the point of articulation with the second metatarsal is somewhat higher on the lateral basal aspect of the first metatarsal.

The second metatarsal medial base

Variation one is by far the most common morphology in all the subgroups. This is a facet on the superior part for the medial cuneiform bone. The next most common morphology is that of variation two, the superior facet for the medial
cuneiform extends distally and is gently concave. In the Sotho, variations four and five, in the pre-pastoralists, variations three and five and in the Europeans, variation five are absent. However, a sixth variant not previously described was found in the European subgroup. This is described later in this chapter.

The second metatarsal lateral base

Variation three represents by far the most common morphology in all the subgroups. There is a proximal beveled part of the inferior facet only, there being no inferior facet for the third metatarsal. In all subgroups, variation five was absent, in the Sotho and Europeans, variation seven, in the pre-pastoralists, variation nine were absent.

The third metatarsal medial base

In all subgroups variations one and two represent the most common morphologies. Variation one has two flat facets, superior and inferior, for the base of the second metatarsal. The facets reach the proximal margin to become continuous with the proximal articular surface for the lateral cuneiform. The superior facet is the larger of the two. The inferior facet is at times barely perceptible. In variation two, the inferior facet is absent.

In the Sotho and pre-pastoral subgroups, the frequencies of these common morphologies are almost equal, however, in the Zulu, variation one represents a slightly more common morphology. This is also the case with the European subgroup, however, the frequency of the variation one is more than twice that of variation two.
In the Zulus, a fifth variation not previously described was found. In the European and pre-pastoral subgroups, a sixth variation not previously described was identified. These are described later in this chapter.

The third metatarsal lateral base

Of the two variations found in the lateral base, the second is by far the most common in the Sotho, Zulu and pre-pastoral subgroups. In the female European subgroup, the frequencies of the two variations are identical; the male European subgroup having a slightly higher frequency of variation two than variation one. This is a facet on the superior part that reaches the proximal articular margin to become confluent with the area of the lateral cuneiform, and has the appearance of an oval with its proximal part cut off. The Sotho subgroup presents with an isolated variation not previously described and is dealt with later in this chapter.

The fourth metatarsal medial base

The third variation is by far the most common morphology in the Sotho, Zulu and pre-pastoral subgroups. The superior facet reaches the proximal articular margin to become continuous with the articular area for the cuboid. It is subdivided into proximal and distal parts. The common morphology is followed by the first variation, then second variation in these three subgroups. In contrast, the European subgroup presents with the first variation as the most common morphology followed by the third in the females and second in the males. However, the differences in the frequency of variations two and three between the sexes are marginal and do not represent any
significant “dimorphic” difference. The common morphology in the European
subgroup is an oval facet not reaching the proximal articular margin and is not
subdivided into a proximal and distal part. The articulation is only with the lateral
part of the base of the third metatarsal.

The fourth metatarsal lateral base

In no individual of any subgroup, variation from the typical description was
found. However, the size of the articular facet was considerably variable.

The fifth metatarsal medial base

In no individual of any subgroup variation from the typical description was
found. However, consistent with the lateral articular area of the base of the fourth
metatarsal, the size of the articular facet was considerably variable.

5.1.1.2 New variations

Five isolated variations were found that have not previously been described.
Illustrations of these may be found in Figure 5.1.

The second metatarsal medial base

An isolated variant was found on the medial base in a Zulu male. As in
variation one, this consisted of a superior articular facet, continuous with the proximal
articular surface for articulation with the medial cuneiform bone. Instead of an
Figure 5.1: Isolated new basal facet variations presenting in the second metatarsal medial and lateral base and third metatarsal, medial base.
inferior contact area, a small round contact area for the medial cuneiform was found proximal to the superior articular facet. This new variant represents a fifth variation of the medial basal facet. A sixth isolated variant was found in a European male. This was described as a facet on the superior part of the medial aspect of the base for articulation with the medial cuneiform and extends distally, being slightly concave and has an area immediately inferior to it that is elevated and slightly rough indicating an area of pressure. This may broadly be described as a combination of variations one and two.

The second metatarsal lateral base

An isolated variant was found on the lateral base in a Sotho female. There is no indication of contact with the lateral cuneiform or third metatarsal. In this individual, this variant corresponds with the medial base of the third metatarsal, where there is no indication of contact with the intermediate cuneiform or second metatarsal. This new variant represents the tenth variation of the lateral basal area.

The third metatarsal medial base

Two new variants were found in the medial base. An isolated variant was found in a Zulu male described as an inferior articular facet only, for articulation with the base of the second metatarsal. This facet was similar to the inferior facet found in variation one. This new variant represents a fifth variation of the medial basal facet.

Another isolated variant was found in a Sotho female. This presented as a superior facet that does not reach the margin of the proximal articular margin from
which it is separated by a non-articular strip, similar to variant three. In addition, there was an inferior articular facet that extended to the proximal articular margin. This new variant represents the sixth variation of the medial basal facet.

5.1.2 Chi-square tests for comparison of frequencies of variation between the subgroups

The Chi-square and P values for each variable feature for each subgroup comparison are to be found in Table 5.2. The lateral aspect of the base of the fourth metatarsal and medial aspect of the base of the fifth metatarsal have no variation from the typical description.

5.1.2.1 Between the Sotho and Zulu subgroups

With the exception of the three variations in the lateral basal facet of the first metatarsal between the Sotho and Zulu subgroups and three variations in the medial facets of the fourth metatarsal, all variations are significantly different at confidence levels 0.001 and in the first metatarsal head shape at a confidence level of 0.01.

5.1.2.2 Between the pre-pastoral and Sotho subgroups

Without exception all variations are significantly different at a confidence level of 0.001.
Table 5.1: The results of the Chi-squared tests for comparison of the frequency of variation in morphological features between the groups.

Chi-square: $X = P < 0.05$  $0 = P < 0.01$  $# = P < 0.001$
ns = not significantly different.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>METATARSAL 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head shape</td>
<td>Chi-squ. P</td>
<td>13.4</td>
<td>124.1</td>
<td>165.5</td>
<td>218.0</td>
<td>135.0</td>
</tr>
<tr>
<td>Base shape</td>
<td>Chi-squ. P</td>
<td>93.4</td>
<td>75.5</td>
<td>16.1</td>
<td>42.7</td>
<td>13.1</td>
</tr>
<tr>
<td>Lateral base</td>
<td>Chi-squ. P</td>
<td>4.35</td>
<td>78.2</td>
<td>48.8</td>
<td>52.7</td>
<td>75.6</td>
</tr>
<tr>
<td>METATARSAL 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medial base</td>
<td>Chi-squ. P</td>
<td>143.7</td>
<td>50.4</td>
<td>118.4</td>
<td>92.6</td>
<td>136.3</td>
</tr>
<tr>
<td>Lateral base</td>
<td>Chi-squ. P</td>
<td>76.1</td>
<td>148.6</td>
<td>118.5</td>
<td>353.2</td>
<td>268.8</td>
</tr>
<tr>
<td>METATARSAL 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medial base</td>
<td>Chi-squ. P</td>
<td>92.5</td>
<td>164.1</td>
<td>193.6</td>
<td>253.2</td>
<td>373.0</td>
</tr>
<tr>
<td>Lateral base</td>
<td>Chi-squ. P</td>
<td>23.8</td>
<td>49.8</td>
<td>9.20</td>
<td>0</td>
<td>159.2</td>
</tr>
<tr>
<td>METATARSAL 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medial base</td>
<td>Chi-squ. P</td>
<td>0.00</td>
<td>93.2</td>
<td>93.2</td>
<td>253.3</td>
<td>253.3</td>
</tr>
<tr>
<td>Lateral base</td>
<td>No variation</td>
<td>No variation</td>
<td>No variation</td>
<td>No variation</td>
<td>No variation</td>
<td>No variation</td>
</tr>
<tr>
<td>METATARSAL 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medial base</td>
<td>No variation</td>
<td>No variation</td>
<td>No variation</td>
<td>No variation</td>
<td>No variation</td>
<td>No variation</td>
</tr>
</tbody>
</table>
5.1.2.3 Between the pre-pastoral and Zulu subgroups

Without exception all variations are significantly different at a confidence level of 0.001 and in the third metatarsal lateral basal facet at a confidence level of 0.01.

5.1.2.4 Between the European and Zulu subgroups

Without exception all variations are significantly different at a confidence level of 0.001 and in the third metatarsal lateral basal facet at a confidence level of 0.01.

5.1.2.5 Between the European and Sotho subgroups

Without exception all variations are significantly different at a confidence level of 0.001.

5.1.2.6 Between the European and pre-pastoral subgroups

Without exception all variations are significantly different at a confidence level of 0.001 and in the first metatarsal lateral basal facet at a confidence level of 0.01.

Summary of morphological traits

The trends in frequency of the morphological traits were very similar between the sexes and subgroups, with the common descriptions of morphology having the greatest frequency. However, the combinations of frequencies of variants are
statistically significantly different in the vast majority of cases. Notably, the lateral articular facet of the fourth and medial articular facet of the fifth metatarsals, although variable in size, remain relatively consistent in shape. No obvious variations were detected here. A few isolated variations, not previously described were found in the second and third metatarsals. None of the subgroups could be clearly discriminated from each other on the bases of their non-metrical variation.

5.2 Results 2 – Pathological changes

The sample size and percentile frequencies for each pathological lesion from each sex and subgroup are contained in Tables A5.3 and A5.4. These are to be found in Appendix one.

5.2.1 Between the sexes of the subgroups

The Sotho subgroup

The first metatarsal presents by far with the most pathological changes, 63.3% of both males and females having these changes. This is followed by the fifth metatarsal, 26.6% of both males and females presenting with pathological changes. In the second and third metatarsals, 20% of the males and 26.6% of the females have pathological changes. In the fourth metatarsal, 16.6% of the males and 20% of the females present with pathological changes. The dominance of the frequency of pathological lesions in each metatarsal is expressed by the formula $1 > 5 > 2 = 3 > 4$ in males, and $1 > 5 = 2 = 3 > 4$ in females.
By far the most common pathological changes in the Sotho subgroup, are hypertrophy of the dorso-lateral aspect of the first metatarsal head in the females (27%) and hypertrophy of the medial and dorso-medial eminence of the first metatarsal head in males (20%). A ridge between the medial and lateral tubercles of all the metatarsals is also quite common. The first, second and third metatarsals in females generally present with a higher frequency of inter-tubercle ridges. Most of the remaining pathological lesions in both males and females present as isolated, or two or three incidences in each subgroup.

The Zulu subgroup

The first metatarsal presents by far with the most pathological changes, 50% of the males and 23.3% of the females having these changes. This is followed by the fifth metatarsal, 16.6% of males and 10% of females presenting with pathological changes. In the second metatarsal, 6.6% of both males and females have pathological changes. In the third metatarsal 13.3% of the males and 10% of the females have pathological changes. In the fourth metatarsal, 13.3% of the males and 6% of the females present with pathologic changes. The dominance of the frequency of pathological changes in each metatarsal is expressed by the formula 1 > 5 > 3 = 4 > 2 in males, and 1 > 5 = 3 > 2 = 4 in females.

By far the most common pathological changes in the Zulu subgroup, are hypertrophy of the dorso-medial eminence of the first metatarsal head in the males (27%) and hypertrophy of the dorso-lateral aspect of the first metatarsal head in males (23.3%). Osteophytes of all the metatarsal bases are more common in the males. As
in the Sotho subgroup, most of the remaining pathological lesions in both males and females present as isolated, or two or three incidences in each subgroup.

The European subgroup

The first metatarsal presents by far with the most pathological changes, 70% of the males and 66.6% of the females having these changes. This is followed by the third metatarsal in the males, being 20% and the fifth and fourth metatarsals in the females, being 13.3% respectively. The males presented with equal frequencies of pathological changes in the second, fourth and fifth metatarsals. In the second metatarsal, 3.3% of the females have pathological changes. In the third metatarsal 6.6% of the females presented with pathological changes. The dominance of the frequency of pathological lesions in each metatarsal is expressed by the formula $1 > 3 > 2 = 4 = 5$ in males, and $1 > 5 = 4 > 3 > 2$ in females. The European males present with a formula that differs considerably from those of the other subgroups. However, in addition to the general types of pathological lesions found in the third metatarsal of the other subgroups, the European male third metatarsal presents with traumatic callus formation, inter-tubercle ridging and deviation of the distal shaft. It seems as if a combination of trauma, epigenetic variation and mechanical factors played a role in contributing to the high frequency of pathological lesions in this bone. It should also be noted that, for presentation of percentile frequency, the sample is relatively small and any additional isolated lesion has the potential for making an impact on the overall pathological profile.
By far the most common pathological changes in the European subgroup, are hypertrophy of the dorso-medial eminence of the first metatarsal head in the males (40%) and hypertrophy of the dorso-lateral aspect of the first metatarsal head in males (20%). The females also have comparatively high frequencies of these lesions, 26.7% and 16.7% respectively. Unlike the other subgroups, there are also osteophytes on the medial articular margin of the first metatarsal head and erosion of the plantar extensions. As in the other subgroups, most of the remaining pathological lesions in both males and females present as isolated, or two or three incidences in each subgroup.

The pre-pastoral subgroup

As the numbers of individuals of known sex are comparatively small, serious consideration of the differences of pathological changes between males and females could not be undertaken. This is compounded by unequal numbers in each group, being eleven males and nine females. Nevertheless, as in the other subgroups, the first metatarsal in both sexes presented with the greatest frequency of pathological changes. In the males this was followed by the fifth and second metatarsals. In the females, the fifth, fourth and second metatarsals each had an isolated pathological lesion. Neither of the sexes presented with any pathological change in the third metatarsal. By far the most common pathological changes in the male and female pre-pastoral subgroups, are hypertrophy of the dorso-medial eminence and erosion of the plantar crista.
5.2.2 Between the recent and pre-pastoral subgroups

The percentile frequency of pathological changes between the recent and pre-pastoral subgroups are represented in Figures 5.2 and 5.3. It should be noted that the sample sizes are very disparate; recent subgroups, \( n = 180 \) and pre-pastoral subgroup, \( n = 34 \). The first metatarsal presents with the most pathological changes in all four subgroups. Of these, the Sotho and European subgroups had by far the greatest frequency (63.3% and 68.3% respectively), the Zulu and pre-pastoralists considerably less (36.65% and 35.29% respectively). This is followed by the fifth metatarsal, 26.6% in the Sotho, 13.3% in the Zulu, and Europeans and 6.45% in the pre-pastoralists. In the second metatarsal, 23.3% of the Sotho, 9.95% of the Zulu, 8.3% of the European and 3.3% of the pre-pastoral subgroups present with pathological changes. In the third metatarsal 23.3% of the Sotho, 11.65% of the Zulu, 8.3% of the European and 6.45% of the pre-pastoral subgroups present with pathological changes. In the fourth metatarsal, 13.3% of the Sotho and European, 9.95% of the Zulu and 3.12% of the pre-pastoral subgroups present with pathological changes. The dominance of the frequency of pathological changes in each metatarsal is expressed by the formula \( 1 > 5 > 2 = 3 > 4 \) in the Sotho, \( 1 > 5 > 3 > 4 > 2 \) in the Zulu, \( 1 > 5 = 4 = 3 > 2 \) in the European and \( 1 > 5 = 3 > 4 > 2 \) in the pre-pastoral subgroup.

Clearly, most pathological changes in these samples occur in the Sotho and European subgroups, followed by the Zulu and the pre-pastoralists having substantially less. The dominance of the frequency of pathological change in the
Figure 5.2: Bar chart comparing the percentile frequencies of pathological changes between the metatarsals of Sotho, European, Zulu and pre-pastoral samples. The sexes in all the samples are pooled.
Figure 5.3: Bar chart comparing the percentile frequencies of pathological changes between the metatarsals of Sotho, European, Zulu and pre-pastoral samples. The sexes in all the samples are pooled.
pooled recent (Sotho, Zulu and European) versus the pre-pastoral subgroups, revealed a formula of $1 > 5 > 3 > 2 = 4$ in both groups.

Of the pathological changes, a few are common to all four subgroups. These are; hypertrophy of the medial and dorso-medial eminence, dorso-lateral hypertrophy, dorsal lipping and eroded crista of the first metatarsal head, osteophytes of the bases of metatarsals three, four and five, irregular cortical lesions of the lesser metatarsal shafts and styloid process exostoses. The only pathological changes unique to the pre-pastoral and European subgroups are osteophytes on the medial margin and extensions of the first metatarsal head (5.71% and 8.35% respectively) and an eroded plantar extension of the first metatarsal (8.57% and 13.3% respectively). In the remaining pathologies, the pre-pastoral subgroup tends to have either no, or isolated cases of pathological lesions. However, it is notable that the Sotho, European and pre-pastoral subgroups share isolated individuals with ridges between the tubercles of the first to third metatarsals. These lesions were not noted in the Zulu subgroup. Also notable, are the lack of obvious periarticular erosions of the metatarsal heads. The exception to this was a few cases in the European first metatarsal head.

5.2.3 Trends in the frequency of lesions in the distal, shaft and proximal metatarsus

The general trends in frequency of pathological lesions in the three parts of each metatarsal for each subgroup are represented by bar charts in Figure 5.9. An examination of these trends reveals that the first metatarsal head is by far the most common site for pathological change. This was found to be the case in all four
Figure 5.4: Bar charts showing the comparative percentile frequencies of pathological lesions in the distal, shaft and proximal parts of the metatarsals.
subgroups. In contrast, the metatarsal shafts appear to have comparatively few lesions with dominance in frequency bearing no clear pattern between the subgroups or bones. However, the recent human subgroups showed a trend of at least a few cases where the second to fifth metatarsals had some forms of shaft irregularity. In contrast, the pre-pastoral subgroup presented with a comparatively high frequency of first metatarsal shaft irregularity. The Sotho were the only other subgroup to involve the first metatarsal shaft. These irregular cortexes were probably associated with either periostitis or post traumatic bone callus formation.

The proximal portions of the bones presented with some arthritic changes in all the subgroups. The Zulu subgroup had slightly more compared to the other subgroups, the trend being in the third to fifth metatarsal shafts. However, it should be noted that the samples were relatively small, particularly the pre-pastoral subgroup, and isolated lesions have an impact on the overall frequency of lesions. Nevertheless, the distal articular surface and head of the first metatarsal has by far the most incidences of pathological changes.

Summary of pathological changes

The trends in the dominance of pathological lesions between the five metatarsal bones were broadly similar in all the subgroups. In all these subgroups, the first metatarsal presented with by far the greatest number of pathological lesions; more specifically, at the first metatarsal head. The Sotho and European subgroups presented broadly with notably greater frequencies of pathological changes followed by the Zulu and pre-pastoral subgroups. However, the pathological lesions found in
the metatarsals of the three recent human groups, generally appeared to be more gross than those found in the pre-pastoral subgroup.

5.3 The morphological and pathological features together

Tables A5.5 – A5.9 contain summaries of the morphological features and pathological changes for each individual of each sex and subgroup. These may be found in Appendix one.

5.3.1 General trends

Scrutiny of the morphological features and pathological changes in each metatarsal in each individual of each subgroup, reveals no obvious correlation between them. However, where pathological changes are found in the first metatarsal head, the most common morphology is that of a rounded head shape (variation one), followed by a square head shape (variation two) and square head with a central ridge (variation three).

Of the total sample of 214 individuals, 98 present with pathological changes of the first metatarsal head. Of these, 72 had pathological changes out of the 145 associated with a rounded head shape (variation one). Fourteen have pathological changes out of 29 with a square head shape (variation two), and 17 have pathological changes out of 40 with a square head shape with a central ridge (variation three). In all three variations, less than half of the metatarsal heads have pathological changes; 49.7% of variation one, 48.3% of variation two and 42.5% of variation three.
5.3.2 The Sotho subgroup first metatarsal head

Variation one

Of the males, 17 have variation one of which 10 present with pathological changes. Two have hypertrophy of the medial/dorso-medial eminence, 2 have dorso-lateral hypertrophy, 3 have dorsal flattening and 2 have dorsal lipping.

Of the females, 17 have variation one of which 8 present with pathologic changes. Two present with hypertrophy of the medial/dorso-medial eminence, 4 with dorso-lateral hypertrophy and 2 with dorsal lipping.

Variation two

Of the males, 6 have variation two of which 4 present with pathological changes. One presents with dorsal head flattening, 1 with hypertrophy of the medial/dorso-medial eminence, 1 with dorsal lipping and 1 has an eroded plantar crista.

Of the females, 6 have variation two of which 3 present with pathological changes. Two have a hypertrophy of the dorso-medial eminence and one has an eroded plantar crista.

Variation three

Of the males, 7 have variation three, of which 3 present with pathological changes. Two have hypertrophy of the dorso-medial eminence and 1 has dorsal lipping.
Of the females, 7 have variation two of which 4 present with pathological changes. One presents with a hypertrophy of the dorso-medial eminence, 2 with dorso-lateral hypertrophy and one with dorsal lipping.

5.3.3 The Zulu subgroup first metatarsal head

Variation one

Of the males, 17 have variation one of which 10 present with pathological changes. Four present with hypertrophy of the medial/dorso-medial eminence, 3 with dorso-lateral hypertrophy and 2 with dorsal lipping.

Of the females, 17 have variation one of which 4 present with pathologic changes. One of each has dorsal head flattening, medial/dorso-medial eminence, dorso-lateral hypertrophy and dorsal lipping.

Variation two

Of the males, 7 have variation two of which 2 present with pathologic changes. One has dorsal lipping and 1 has an eroded plantar crista. Of the females, 4 have variation two of which 1 presents with a hypertrophy of the dorso-medial eminence.

Variation three

Of the males, 6 have variation three, of which 2 present with dorso-lateral hypertrophy. Of the females, 9 have variation three of which 2 presents with a
hypertrophy of the dorso-medial eminence.

5.3.4 The European subgroup first metatarsal head

Variation one

Of the males, 23 had variation one of which 17 presented with pathological changes. Nine had hypertrophy of the medial/dorso-medial eminence, 5 had dorso-lateral hypertrophy, 1 had a dorsal exostosis and 1 had a ridge between the tubercles.

Of the females, 27 have variation one of which 18 present with pathological changes. Eleven present with hypertrophy of the medial/dorso-medial eminence, 2 with dorso-lateral hypertrophy and 6 with lipping of the plantar extensions. One presented with cavitation of the distal articular surface.

A number of these had combinations of pathological changes. No were a number of metatarsal heads that had the rounded articular surface angled laterally as if to accommodate a laterally deviated hallux.

Variation two

Of the males, none presented with variation two. Of the females, only one had variation two of which presented with severe cavitation of the distal articular surface.

Variation three

Of the males, 7 had variation three, of which 3 presented with pathological changes. One had dorso-lateral hypertrophy and lipping of the plantar crista and 1 had
a dorso-medial cavity and another slight lipping of the medial articular margin.

Of the females, 2 had variation three of which one presented with lipping of the plantar crista and plantar extensions.

5.3.5 The pre-pastoral subgroup first metatarsal head

Variation one

Of the total sample of 34 specimens, 27 had variation one of which 7 present with pathological changes. Two had hypertrophy of the medial/dorso-medial eminence, 2 had eroded plantar extensions, 1 had an inter-tubercle ridge and 1 has osteophytosis.

Variation two

Of the total sample of 34 specimens, 5 had variation two of which 3 presented with pathological changes. One had an eroded plantar extension, and 2 had eroded plantar cristas.

Variation three

Of the total sample of 34 specimens, 2 had variation three of which 1 presented with an eroded plantar crista.
5.4 Discussion

5.4.1 Preamble

A study of pedal non-metric variation can only add to our understanding of modern human diversity. The relationship between metrics and non-metrics is further discussed in Chapter 6. Whereas the value of cranial non-metric traits in population studies has been established, particularly in regional populations, few similar studies have used postcranial bones (Donlon, 2000). It would seem imprudent to ignore a set of osteologic data that may prove valuable in addressing questions concerning population relationships and the pattern and amount of human variation, in this case, that of the metatarsus.

In the current study, two types of non-metric data were collected. The first was the identification and classification of epigenetic morphological traits or features. Berry & Berry (1967) stressed the advantages they thought non-metric variants possessed over measurements; they were unaffected by age, sex, side occurrence, and other traits. As in the morphometric study discussed in Chapter 4, the considerations of the possible reasons why morphological variation occurs are the same. They are influenced by genetics and behaviour or lifestyle during ontogeny and adult life.

The second, was the identification of pathological changes. It is noteworthy that these, as morphologically modified bone, differ from the metrics and epigenetic traits; they are pre-dominantly acquired and coincidental to the other data. As pathology may drastically alter epigenetic traits, even to the extent of obliterating them, many “pathological” bones were excluded. Thus the frequency of pathological
changes within these samples are not necessarily representative of the pathological changes *per se*, but rather occur within the samples that were suitable for combined metric and non-metric studies. This was done to determine if there was a relationship between them. A further noteworthy observation was that, of the pre-pastoral subgroup sample, none were excluded on the basis of pathological changes obliterating landmarks or deforming bone to such an extent that metrical measurement was not possible. In contrast, a number of individuals from each recent human sample were excluded for these reasons. There is no doubt that the recent human subgroups, although much larger in sample sizes, presented with much more pathology, both in frequency and extent.

5.4.2 The morphological features

An attempt is made to explain the variations in the morphological features.

5.4.2.1 General trends in variation

The trends in frequency of variation are very similar within and between the groups. This suggests that these morphological traits have an inherent tendency to be fairly consistently variable in the four human subgroups under consideration. This is in agreement with the opinions of Berry and Berry (1967), that non-metric traits are, at least to a great extent, not influenced by age, sex and side occurrence. Excluding the first metatarsal head shape, these findings are, in general, consistent with those of Singh (1960). Exceptions to this are, in cases of very low frequencies of some variations, these variations are occasionally not found in one, two or even all the
subgroups. The isolated “new” variations found in the current study, are also exceptions and were not previously described.

By far the greatest frequency of features in each bone are represented by the common descriptions in the literature, for example in those by Jones (1944), Sarrafian (1983) and Draves (1989). The greatest variability is to be found in the second metatarsal lateral base, where ten variations are described. No variations from the typical descriptions were found in the fourth metatarsal lateral base and fifth metatarsal medial base. It is tempting to suggest that there is a relationship between the second metatarsal, representing part of the medial (cranial) column of the foot, being more mobile, and the fourth and fifth, the anterior part of the lateral (caudal) column, being less mobile and more stable. However, as the second metatarsal is wedged between the medial and lateral cuneiforms, and is thus the most stable metatarsal in the foot, this is not a plausible explanation. Compared to the other bones, there is a greater interface between the cuneiforms and the second metatarsal; this may be associated with greater variation from the typical description as there is greater contact area medially and laterally of the cuneiforms on the metatarsal. To suggest that it may be associated with the inherent stability of the bone would be speculative. No significant number of any morphological feature was unique to any particular group, and these features can thus not be considered diagnostic for any particular human subgroup.
5.4.2.2 The first metatarsal

Head shape

The common morphology of a rounded head shape is found in all the subgroups and is consistent with the description by La Porta et al. (1994). This suggests that the first metatarsophalangeal joint is largely “unstable” with a tendency to hallux valgus formation according to Brahm (1988), Felner and Milson (1995), Du Vries (1973) and Landers (1992). It would be reasonable to presume that these authors are suggesting that the tendency to hallux valgus applies to shod feet, in which the hallux on the rounded articular surface is easily laterally deviated. However, there is sufficient evidence to indicate that hallux valgus may also occur in habitually and partially unshod populations (Barnicot & Hardy, 1955; Sim-Fook & Hodgson, 1958; Shine, 1965; MacLennan, 1966; Ashizawa et al, 1997).

A variation of the rounded or convex metatarsal head, often subtle, was a lateral deviation of the articular set angle. In this instance the distal articular surface lies obliquely to the lateral side, obviously indicating that the proximal phalanx will also lie laterally, in an abducted position. This morphology is reminiscent of the normal condition in the first metatarsal head of the apes. An example comparing a normal human and pathological human to a normal gorilla and bonobo is presented in Figure 5.10. This seems to suggest that when a human hallux and first metatarsal takes on a function more suited to an opposable hallux, this morphology further adapts to resemble more closely that of the ape first metatarsal head.
**Figure 5.5:** A comparison of the first metatarsal head of a normal human (a), pathological variant human (b), normal bonobo (c) and normal gorilla (d).
Proximal articular surface shape

The kidney or reniform shape is by far the most common in all the groups. This is in agreement with the findings by Singh (1960), although he further classified the typical description as having a common medial indent. This was not taken into consideration in the current study. Only a single specimen in the Zulu group had a completely bipartite articular surface. Both Singh (1960) and Ajmani et al. (1984) found this feature to be more common. Of course, the definition and identification of any non-metrical trait is often open to interpretation. In this instance the differentiation between a partially or completely divided proximal articular surface is somewhat ambiguous. As the metatarsocuneiform joint, as a rule, does not have any significant motion, it is not certain if this variation contributes to changing joint function. However, a number of workers (e.g. Waniwenhaus & Pretterklieber, 1989, Klaue et al., 1994; Fritz & Prieskorn, 1995) found to various degrees, some sagittal plane metatarsocuneiform motion to be present, more so in the presence of abnormal function.

Waniwenhaus and Pretterklierbe (1989) distinguished between two main groups of first tarsometatarsal joint; wide cartilage-covered joint surfaces that were only slightly narrowed in the middle, and narrow-waisted, high joint surfaces. Their findings suggest that the narrower articular surface may predispose the first metatarsal to some transverse plane movement. In the current study, both the univariate and multivariate results indicated that the breadth of the proximal articular surface is quite variable. There is also a suggestion that this variability is slightly greater in the pre-pastoral subgroup.
Lateral articular facet

This was the only feature of the proximal part of the bone that has a plausible functional correlation to variation (Greenberg, 1979; Wanivenhaus & Preterklieber, 1989; Romash, 1990). Consistent with the literature, both recent and ancient groups commonly have a transitional lateral facet for articulation with the second metatarsal. Wanivenhaus and Preterklieber (1989) found the well developed lateral facet to be predominantly in males. The current study shows no evidence for this. Notwithstanding, the few pre-pastoral first metatarsals with particularly well defined lateral facets, were all from relatively large bones that are probably from males. This was not the case in the recent subgroups. It is also noteworthy that the combined variations between the Sotho and Zulu were not significantly different at a 0.05 confidence level. The variation between these recent and ancient subgroups is thus bigger than the variation between the Sotho and Zulu alone. In the pre-pastoral subgroup, both the well developed and absent articular facets are more common than in the recent subgroups. This should however be considered within the context of the much smaller pre-pastoral sample size. This poses the question whether the presence or absence of an articular facet is an inherent epigenetic trait, or as a result of particular function of the first metatarsal ray? There is very convincing evidence in a number of the European specimens that suggests that the well developed lateral articular facet may, at least in some instances, be acquired. One reason for this is that most of these very prominent facets have degenerative arthritic changes to a greater or lesser extent. Another reason is that with articulation of the bases of the first and second metatarsals, a distinct impression is given of a wider first intermetatarsal
angle. Usually, it is imprudent to attempt to derive too much information through the articulation of dry bones as the influence of surrounding soft tissues is not present. However, in a number of specimens the articular areas on both bones were so obviously prominent, that articulation was possible (Figure 5.6). An example of a similar exercise is to be found in the examination of a mediaeval case of bilateral metatarsus primus varus (Anderson, 2003).

It is concluded that the variation in the lateral articular facet may occur in a number of ways. These are: 1) a facet with ill defined margins representing an epigenetic articular area for contact with the second metatarsal, 2) a facet with well defined margins that is an epigenetic variant, and is well defined due to the close proximity of the second metatarsal medial base, 3) the well defined contact area is acquired in response to a wide intermetatarsal angle (metatarsus primus varus) in order to stabilize the first metatarsal when hypermobility occurs at the metatarso-cuneiform or cuneio-navicular joint. This is not a true articular facet, but a “pseudo-facet” due to osseous modification. There is evidence from the literature that this may result in clinical symptoms around the base of the second metatarsal and thickening of the second metatarsal cortex (Kelekian, 1965; Prieskorn et al., 1996).

5.4.2.3 The second, third, fourth and fifth metatarsals

Even though the trends in variation between the subgroups are very similar, in the vast majority, the combined variations for each bone are significantly different between all the groups. The exception to this are the variations of the medial base of the fourth metatarsal between the Zulu and Sotho subgroups, and are not significantly
Figure 5.6: An example of a well developed lateral basal articular facet of the first metatarsal suggesting an association with an increased first inter-metatarsal angle.
different at a 0.05 confidence level. The fourth metatarsal lateral basal facet presents with no variation within and between the groups. The corresponding medial basal facet of the fifth metatarsal also has no variation, although the size of the facet is quite variable. Unlike the first metatarsal, no functional explanation for any of the variation is evident from the current study and excepting for the fourth and fifth articulation, no consistent correlation could be found between any of them. It is concluded that these variations are primarily genetically determined, probably with some as yet unexplained functional correlates particularly in those where isolated variants are found.

5.4.3 The pathological changes

The identification of pathological changes in bone is the most subjective part of the study. This poses a challenge in differentiating between bone modification that is normal, and that which is pathological.

5.4.3.1 General trends in pathological conditions

Considering the differences between the sexes of the recent subgroups, the Sotho generally do not show a discernable difference between males and females. The Zulu and European males, however, generally show a greater tendency to pathological changes than the females. In modern western cultures, the females generally have a greater tendency to foot pathology as a result of female footwear. A possible explanation for the Zulu males having greater frequencies of pathological changes may be related to occupation where most of the males have a history of being
labourers. This may or may not be the case in the European males, although most of the females also present with pathological changes. No explanation can be given for the Sotho and European subgroups presenting with considerably more pathological changes than the Zulu. The European females, however, present with more pathological changes of the first metatarsal head than the Bantu speaking subgroups. A plausible explanation for this would be that the European females probably tended to wear more “fashionable” footwear. Age is not a consideration, as the mean age of the Sotho males is 36 (SD 8) and Sotho females, 34 (SD 6.8). The Zulu are a little older; the male mean age being 49 (SD 15) and the females, 44 (SD 12). Similarly the European subgroup mean age is 45 (SD 7) for the males and 51 (SD 11) for the females. Although the age at death of the pre-pastoral individuals is unknown, it is estimated that their mean ages fall within the range of the recent subgroups, and in many cases, much older.

Regardless of these considerations, the patterns between the groups are very similar with the first metatarsal presenting by far with the greatest frequency of pathological changes, followed by the fifth metatarsal. Once again, a consideration is that the first ray is an important functional unit in the more mobile medial column, and the fifth ray in the more rigid lateral column.

5.4.3.2 A consideration of selected pathological lesions

An attempt is made to explain the reasons for some of the common pathological changes found in the four subgroups under consideration. The observed pathological changes are considered with reference to the literature in 2.2 of Chapter
2. Examination of the pathological lesions in the samples suited for both metric and non-metric analysis, suggest that most, if not all these lesions were as a result of a predominantly mechanical aetiology.

Hypertrophy of the medial/dorsomedial eminence of the first metatarsal

This represents one of the most common osseous modifications, particularly in the three recent human subgroups. In retrospect, few of these are true “medial eminences”, but rather a hypertrophy of the medial tubercle. Most were so large, that they could not be considered as normal variation in tubercle size. The pre-pastoral subgroup rarely had tubercles or medial eminences that were hypertrophied. As the recent subgroups are presumed to have been habitually shod, pressure from footwear and associated change in biomechanics is the most probable cause.

Osteophytes of the medial margin of the first metatarsal head

A few of the pre-pastoralists presented with this osseous modification which with the exception of a few Europeans, is not found in the recent subgroups. This suggests that there was a migration of sesamoid bones (Wilson, 1988), and may be associated with erosion of the planter crista. The only plausible explanation for this found by the author in the pre-pastoral subgroup is that these foragers had a lifestyle that required constant locomotion which resulted in “wear and tear” on the first metatarsal head that differs from that as a result of footwear.
Eroded crista and eroded plantar extension of the first metatarsal head

All subgroups presented with a few eroded plantar cristas, but the pre-pastoral subgroup presented with a comparatively high frequency of occurrence. This group also presented with the same number of eroded plantar extensions which were not present in any of the recent subgroups. Grode and McCarthy (1980) suggest that due to a medial deviation of the first metatarsal, there is a resulting displacement of the medial sesamoid that erodes the crista and medial plantar extension. Perhaps, even in the unshod pre-pastoralists, there may have been some extent of mechanical dysfunction of the first ray resulting in sesamoid subluxation. These lesions were completely eburnated in most instances and may simply represent normal degeneration over time and age of the individual.

Dorsal exostosis or lipping of the metatarsal head

This was found in all the subgroups, but to a lesser extent in the pre-pastoralists where the osteophytes were smaller than in the other three subgroups. This suggests that these individuals had advanced hallux limitus (Rzonica et al., 1984; Vanore, 1992; Klaue et al., 1994; Chang, 1996; Camasta, 1996). Roth (1992) classifies the hallux limitus associated with these exostoses or lipping as hallux limitus grade two.

Osteophytes of the metatarsal bases

These were found in all the subgroups. However, osteophytes of the base of the first and second metatarsals did not present in the pre-pastoral subgroup. This may
be important, as in the medial column this may indicate a functional adaptation due to a divergent first ray deformity, separating the base of the first metatarsal and the first and second cuneiforms (Klaue et al., 1994).

In both the recent and ancient subgroups, individuals with osteophytes of the third to fifth metatarsal bases were found. The exact nature of their pathology remains elusive.

**Fractures**

All four human subgroups presented with isolated first metatarsal shaft callus formation due to fracturing. This is usually as a result of direct trauma (Saraiya, 1995) or indirect hyperplantarflexion (Felder-Johnson et al., 1995).

Only the Sotho and European subgroups presented with an isolated bone callus formation each of the second metatarsal shaft. This represents the most common metatarsal fracture due to its recessed, therefore stable position. The Zulu subgroup presented with isolated bone callus of the third and fourth metatarsals of the same individual, probably as a result of direct trauma. The same occurred in a European individual, but also involving the fifth metatarsal. No fifth metatarsal styloid fractures were detected in any of the four subgroups.

**Ridge between the tubercles**

A number of individuals presented with prominent ridges between the lateral and medial tubercles from predominantly the Sotho, European and pre-pastoral subgroups. In the Sotho and European subgroups, this occurred in all the metatarsals
and in the pre-pastoralists in the first, second and third. Some occurred only in one bone, and others in two or three bones. Only a single Zulu female presented with a inter-tubercle ridge of the first metatarsal. There are two possible explanations for these ridges. They may be as a result of metaphyseal “scaring”, or as a result of habitual hyper-dorsiflexion of the metatarsophalangeal joints. In the first instance, a variation in epiphyseal ossification or damage may result in ridging. The first metatarsal has a peculiarity in growth, contrary to the classic anatomical descriptions (e.g. Gray, 2002) which claim only proximal ossification from the diaphysis, there is in fact also a common finding of a distal physis (Vilaseca & Ribes, 1980). In the second instance, the development of these ridges may be a signature for lifestyle related activities. As an archaeological sample was studied, this second possibility is of particular interest.

Uberlaker (1979) examined bony changes on the superior distal surface of metatarsals in a prehistoric sample from coastal Equador. The location and morphology of the alterations, as well as their association with femoral “squatting facets” strongly suggests they were produced by prolonged hyperdorsiflexion of the toes, probably resulting from a habitual kneeling posture. The morphology and location of these ridges in the current study are identical to those described by Uberlaker. This is especially true for those found on the first and second metatarsals. This could be considered as a “kneeling signature”, in much the same way that tibial and talar “squatting facets” strongly suggest a habitual squatting posture (Boulle, 2001). As these have been found in both the recent and pre-pastoral subgroups, inferences for specific differences related to culture or lifestyle cannot be made. This
may be a good example of similar mechanical function, even under very different circumstances resulting in the same osseous modification. An anecdotal example for this, may be that of a pre-pastoralist kneeling to perform a task of preparing food versus a recent human hyperdorsiflexing the toes while operating a motor vehicle.

Irregular thickening of the cortex

Irregular thickening of the cortex was found in all bones excepting the third metatarsal. Whether these can be considered as truly “pathological” is not certain. It is doubtful if any of these can be associated with osteomyelitis as they are merely a slight thickening and “roughening” of the cortex, most likely as a result of periostitis. Perhaps these lesions are a response to abnormal loading of the bones over time.

Periarticular bony erosions associated with rheumatoid arthritis

Although osteophytosis was identified in individuals from every subgroup under consideration which may have been as a result of rheumatoid arthritis, there was no conclusive evidence that this was the case. However, bony erosions associated with rheumatoid arthritis were found only in the first metatarsal of a few of the European individuals. No doubt, this degeneration of the subchondral bone will have resulted in dysfunction of the joint. When examining isolated bones, the distinction between severe rheumatoid arthritis and severe osteoarthritis is indistinguishable.
5.4.3.3 A consideration of pathological changes not found in the current samples

Most pathological changes initially listed in Table 2.2 of Chapter 2, were to be found in the current samples. However, there were a few that were not, as well as rare or unusual conditions. A few important ones are considered here:

**Chronic gout**

No obvious “punched-out” lesions (Rana, 1982; Roth, 1992; Rothchild & Heathcote, 1995) were found around the metatarso-phalangeal joints in the current samples that could suggest chronic gout. However, acute gout and gout that had not caused articular damage cannot be excluded.

**Osteomyelitis**

The typical involucrum of coarsely woven bone around the cortex as described by, for example, Ulrich-Bochler and Glowatzki (1982), Tighe & Davies (1984) and White (1991) was not evident in any of the specimens. However, some presented with irregular cortical thickening that may be associated with a number of differential diagnoses and have been discussed above.

**Primary tumours of the bone**

These, as described by, for example, Tighe and Davies (1984) were not evident in any of the specimens and are relatively rare.
Os intermetatarseum

The *os intermetataseum* is a relatively common heritable accessory bone of the human foot located at the tarsometatarsal border between the first and second metatarsals (Pfitzner, 1896; Sarrafian, 1983). It can occur as an independent ossicle or as an osseous spur projecting from the proximal ends of the first two metatarsals, or the distal end of the cuneiform. Case *et al.* (1998), found this anomaly to be particularly high in American Indian skeletons from various archaeological sites. This high frequency may, in part, be a higher degree of genetic relatedness among the individuals. In the 214 individuals examined in the current study, this inherited defect was not evident in any of the specimens.

Non-osseous tarsal coalition

Defects involving the common articular surface between the third metatarsal and third cuneiform have been reported in skeletal samples from both Old and New Worlds, with frequency ranging from 3.2 – 26.0% (Case, 1996; Regan & Case, 1997; Tenney, 1991; Wilbur, 1997). These defects are typically present as a circular or oval pit in the proximal facet of the third metatarsal and the distal facet of the third cuneiform. Regan and Case (1997), suggest that these lesions may be as a result of tarsal coalition. Tarsal coalition is thought to have a strong genetic component, suggesting that the pit defect may be useful as a skeletal nonmetric trait. The current samples did not display any obvious proximal articular pitting. However, in a number of what appeared to be nutrient foramina were observed. These should perhaps be more closely investigated in future studies.
5.4.4 Final remarks on the non-metric study

A considerable number of morphological traits found in the metatarsus are quite variable. In the four subgroups studied, the trends in variation were very similar and are comparable with the findings by Singh (1960). The typical descriptions, present consistently with the greatest frequency in both the recent and pre-pastoral subgroups. However, the traits that present with the least frequency are sometimes absent, and may be unique to the Singh study. By the same token, a few isolated, previously unidentified features were described in the current samples. This suggests, that it is likely that other isolated variants would be found in other samples; the larger the sample, the more of these “novel” variants become apparent. In the study by Singh (1960), no mention is made of the sample origins. With the exception of the European subgroup sample, all subgroups in the current study, although chronologically separated, were African. Whether the trend in frequency of variation changes when compared to more distantly related groups is as yet unknown. It is however suggested, that the differences in lifestyle between the recent and ancient subgroups do not obviously influence these morphological traits, but imply genetic variation common to all.

In terms of pathological changes, the results suggest that the unshod lifestyle of the pre-pastoral subgroup is associated with a lower frequency of osteological modification. No clear correlation between variation in the morphological features and pathological changes could be found. Notwithstanding, this does not rule out the possibility that certain morphological features predispose the metatarsus, or part thereof to a change in function and subsequent pathological changes.