Interpreting Diet by Age, Status, and Gender and Establishing Weaning Patterns Using Trace Element Analysis on Human Remains from Umm El-Jimal, Jordan

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INTERPRETING DIET BY AGE, STATUS, AND GENDER AND ESTABLISHING WEANING PATTERNS USING TRACE ELEMENT ANALYSIS ON HUMAN REMAINS FROM UMM EL-JIMAL, JORDAN

by

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Monica Shah
The intent of this study is to learn about the dietary patterns of early fourth century occupants of a Late Antique site in northern Jordan. Bone samples of 107 individuals from two distinct cemetery types, assumed to be status differentiated, were chemically examined for their trace element composition. Trace element analysis can potentially investigate groups of individuals to attempt to determine if gender, age, or status influenced access to food resources.

Statistical tests found that significant differences of trace element concentrations were evident in an interburial area study for all adults and subadults, and when examining intra-burial area males and females. No significant trace element levels were apparent when correlating age and diet or when attempting to establish weaning patterns for the site.
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CHAPTER I

INTRODUCTION

Traditionally, the diet of archaeological populations has been interpreted through the study of flora and fauna, collected from hearths, middens, or other areas of the site during excavation. More recently, however, chemical analyses of human skeletal remains are being used to assess past nutritional behaviors. Chemical tests, unlike floral and faunal studies, cannot determine a precise dietary breakdown, but they are useful for delineating proportions of habitually eaten food types that are specific to individuals at the site. Flora and fauna, on the other hand, assume a nutrition pattern for the entire site because these methods of analyses do not confirm an association between an individual and his or her dietary intake. Distinguishing individual nutrition practices may define what correlation, if any, existed in the diet between groups of people differing by age and burial areas. One goal is to ascertain whether this data can provide a measure of status in the community.
Eating can be a complex cultural activity, and foods may be distributed unequally throughout the community; hence, differences in diet may be status and/or age-related. Access to or denial of foodstuffs can be regulated along politically and socially imposed divisions. Trace element research relies on the assumption that the concentrations of particular trace elements correspond to dietary intake during life. If groups of individuals differed by their diet, it should be evident in the chemical composition of their bones. It is these differences which are sought to understand relationships between men and women, adults and children, individuals buried in Areas Z and AA or Area BB.1, and age cohorts.

This study focuses on nutrition at Umm-el Jimal, a Late Antique site, which is located in present-day northern Jordan (Figure 1). The remains from three contemporaneous burial areas, dated approximately to the fourth century C.E., were analyzed for their trace element concentration levels. These are Area Z, Area AA, and Area BB.1. Quality of preservation is variable and specific to each burial area due to local past and present depositional conditions. The age and sex of the individuals were determined by Cheyney (1997).
Figure 1. Location of the Site of Umm el-Jimal in Its Modern Setting (Drawing by Bert de Vries).
Area Z (Figure 2) is situated in an olive grove about 75 meters west of the southern edge of the principal Byzantine town ruins (Cheyney, in press; 1995). Area AA (Figure 2) is located near the Umm el-Jimal girls' school and is approximately 200 meters northwest of the main ruins (Brashler 1995). Cheyney (1997) suggests that Areas Z and AA represent one rather than two cemeteries. The apparent division is a result, most likely, of the present-day roads and buildings which physically separate the two burial areas. Stone-lined cists or simple pit burials with multiple and single in situ internments are characteristic of both Area Z and Area AA cemeteries. Basalt slabs are placed over both cist and pit burials at Z and AA and then sealed with chinking stones.

Area BB.1 (Figure 3), located approximately 1 Km southeast of the main Byzantine town ruins or 400 m south of Area R, the Early Roman/Late Roman Village, is a monumental tomb structure, containing numerous commingled remains from eleven loculi. The differences in the graves of BB.1 compared to those of Z and AA will potentially be borne out by disparities in the trace element results from their skeletal remains. Unfortunately, the
Figure 2. Umm el-Jimal Site Map Showing Area Z and Area AA Cemeteries (Drawing by Bert de Vries).
Figure 3. Umm el-Jimal Site Map Showing the Area BB.1 Tomb.
unprovenienced BB.1 remains make it difficult to reliably associate the commingled and disturbed skeletal elements to the age or sex of the person. An age was estimated for nearly every subadult, but it was rarely possible, in this project, to further classify the adults any more reliably than in early, early/middle, middle, or late age categories (Cheyney 1997). The inability to determine sex for the majority of adult skeletons in BB.1 restricts the testing of gender differences which may have been an important factor in accessing nutritional resources. Gender is examined only for Areas Z and AA adults.

Hypotheses

There are four main hypotheses tested in this project. The first, testing age relationships, is that there are no significant trace element concentration distinctions between early, early/middle, middle, and late adults in Areas Z and AA. Grave architecture and tomb contents do not indicate status differences at these age distinctions (Cheyney 1997). The second, testing status, is that there are significant element disparities between Area BB.1 individuals compared to Areas Z and AA based on architectural evidence and grave artifacts (Brashler, in
press; 1995; Cheyney, in press; 1997). The third hypothesis is that there is a statistically significant difference in trace element concentration levels of the two earliest subadult groups for Areas Z and AA combined compared to Area BB.1. This hypothesis may establish weaning patterns for the population. Even in populations where dairy foods form a significant portion of the diet, as is likely in this one, weaning age may still be calculable (Sillen and Smith 1984). The fourth and final hypothesis, testing for gender as a dietary influence, is that there are no statistically significant element differences between males and females in Areas Z and AA combined. Again, based on tomb architecture and grave artifact deposits, there is little to suggest that differences would be evident to indicate gender-related disparities in nutrition. Area BB.1 is not examined for the fourth hypothesis due to the lack of sexable individuals in the tomb.

The next chapter is a brief review of the literature on trace element research and offers a description of each of the elements utilized in the study and the food types with which they are associated.
CHAPTER II

BONE CHEMISTRY

Literature Review

Human bone is an active, dynamic substance which marks the life history of an individual. The skeleton's durability allows reconstruction of certain human behaviors, such as dietary patterns, from a specific time and place in the archaeological record (Crist 1995). As such, it can be a record of past social, economic, and environmental events. Similarities or differences that may have once existed in diet are retained chemically in an individual's bones; this conveys a message about past cultural practices that might otherwise remain unknown.

Fresh bone is composed of 70% mineral (inorganic), 20% collagen (organic), 8% water, and 2% noncollagenous material (Klepinger 1984). Bone mineral is not only the most significant component of bone, but the proportions of various minerals present in the bone structure are also positively correlated with diet. For trace element analysis to be a viable form of dietary interpretation,
the quantities of an element in the diet and in bone tissue must exist in adequate amounts and the relationship between the two must be established and documented (Beck 1985; see also Aufderheide 1989; Price 1989).

Research indicates that long bones offer a more controlled evaluation of representative trace element concentrations (Lambert et al. 1982). This is because long bones are composed mainly of cortical bone which remodels more slowly and is less susceptible to diageneisis due to its dense nature. On the other hand, ribs consist primarily of trabecular bone which remodels more quickly and is highly vulnerable to contamination because of its porosity. All bone remodels; however, the rate at which this occurs depends upon the age and health of the individual. In young individuals, approximately thirty to fifty percent of the bone is remodeled each year, and all of it is remodeled and replaced in six years (Rasmussen and Bordier 1974). As individuals age, the rate at which bone remodels decreases considerably (about two to four percent). Hence, several biogeochemical accounts are recorded during the individual's life (Ericson 1985). Chemical analysis of bone does not provide a chronicle of
that individuals entire nutritional history, but the older the age of the individual, the more comprehensive the picture becomes. In sum, trace element analysis of subadults indicates approximately the last six months of their life, whereas analysis of adults establishes the last ten to fifteen years of their life history.

The relationship between dietary trace elements and their evidence in the skeleton has been established on the knowledge that ions are continually exchanged within living bone; trace elements which enter the skeleton via food and the environment replace these ions in the hydroxyapatite, the dominant component of bone mineral (Crist 1995), resulting in certain measurable concentrations of the trace elements. These concentrations are dependent on the kinds of food the individual ate during life. However, they are altered by metabolic factors such as absorption, excretion, pregnancy, lactation, and growth (Sandford 1992). This is referred to as biogenesis. An issue of concern for most trace element researchers is that even after an individual's death, ionic transfer does not cease; it continues an exchange with the environment in which the body is interred (i.e., the soil), resulting in an ongoing alteration of the bones
known as diagenesis (see Lambert et al. 1985).

There are several studies which have attempted to survey how postmortem events alter the trace element proportions in bone. Despite recognition that diagenic change does take place, Kyle (1986), nonetheless, affirms that dietary interpretation is still possible. If dietary differences existed in life due to age- and/or gender-associated reasons, it is possible that biogenic processes, coupled with diagenic events, will magnify the differences postmortem (Sandford et al. 1988). This will aid in more clearly elucidating the differences being sought. In addition, diagenesis should be less of an issue in this analysis due to the comparative nature of the research. It would be more problematic in studies which emphasized the absolute rather than relative values of the results in the interpretation.

Klepinger (1984) states that the greater the number of variables examined, the greater the probability of more comprehensively reconstructing ancient diets. Several elements will trace many more aspects of the nutrition composite than one element alone. In addition, the importance of investigating several elements is critical in the light of detrimental diagenic factors. Multi-
element studies can potentially reduce errors which may occur from diagenesis or sample biases (Buikstra et al. 1989).

The trace elements that will be studied are expected to demonstrate a relationship to diet. These include barium, magnesium, calcium, copper, silicon, zinc, selenium, manganese, cadmium, and strontium. Furthermore, for subadults, calcium will also be analyzed as a ratio to strontium, magnesium, and barium, because as they are absorbed into the body, they compete with calcium, altering the existing ratio. Examining them as a ratio aids in standardizing the results (Beck 1985), another means of counteracting variable outcomes resulting from diagenic processes. The stability of each element is variable. In other words, some are more or less sensitive to diagenesis than others, but all correlate to diet. The following section details the plant food types which are correlated with the elements used in this study. All major foods associated with a particular element is mentioned even if it does not necessarily apply to the Umm el-Jimal population. For example, no evidence of seafood has been noted, but is included for the benefit of other researchers studying populations which do exhibit seafood
Barium (Ba)

Barium indicates vegetarian components (Subira and Malgosa 1992; Lambert et al. 1984). Concentration levels may be especially high for nonmarine vegetable foods (Klepinger 1984). Like strontium, barium competes with calcium once it enters the body, only more aggressively. Barium is not very easily absorbed, so if high amounts are present in bone samples, then, the individual was likely to have consumed a primarily vegetarian diet.

Magnesium (Mg)

Magnesium is found highly concentrated in nuts, seeds, and whole grains (Crist 1995; Subira and Malgosa 1992; Byrne et al. 1987; Gilbert 1985; Passwater and Cranton 1983). Green vegetables also contain fair amounts of this element. In addition, like barium and strontium, magnesium competes with calcium and can also be studied as a ratio of Mg/Ca.
Calcium (Ca)

Calcium is high in milk, cheese, and leafy green vegetables (excluding those of the goosefoot family). Meat, grains, and nuts are very poor stores of calcium (Passwater and Cranton 1983).

Copper (Cu)

The richest sources of copper, according to Underwood (1977) are in seafood and organ meats (see also Subira and Malgosa 1992). Nuts, dried legumes, dried vine, dried stone fruits, and cocoa also are good sources of copper. Dairy products, white sugar, honey, nonleafy vegetables, fresh fruits, and refined cereals are poor copper stores. Discretion is necessary because high levels of copper could be due to the suppression of zinc from cereal grain consumption (see description of zinc below).

Silicon (Si)

Silicon is important during early bone ossification (Underwood 1977). However, with increasing bone maturity, silicon drops in concentration and calcium in-
creases. Silicon is present in unpolished rice and grains (Crist 1995), as well as vegetables such as alfalfa, cabbages, lettuce, onions, and dark greens (Passwater and Cranton 1983). High fiber cereal grains, like oats, contain higher levels of silicon than low fiber grains, like wheat or maize (Underwood 1977). Also, whole wheat and unrefined sugar are better sources of silicon than white flour and white sugar because the majority of silicon is lost when milled. According to Passwater and Cranton (1983), only two percent of the original silicon concentration remains in milled flour.

Zinc (Zn)

Zinc is abundant in oysters, muscle meats, liver, egg yolks, and nuts (Subira and Malgosa 1992; Gilbert 1985; Passwater and Cranton 1983; Underwood 1977). A high amount of zinc in bone, then, is indicative of protein-rich fare. Although whole grains also contain a fair amount of zinc, much of the zinc is lost when foods are refined (Passwater and Cranton 1983; Underwood 1977). In fact, nearly eighty percent of zinc may be lost when milling wheat into flour. White sugar, pome (small, pulpy fruits) and citrus fruits, nonleafy vegetable and tubers,
and vegetable oils are very poor sources of zinc. Zinc is a good element to study because of its low sensitivity to diagenesis. However, cereal grains contain phytate, which if consumed, inhibit zinc absorption and lead to increased levels of copper (Crist 1995). Discovering low levels of zinc may be misleading and should be examined in conjunction with copper levels.

Selenium (Se)

In a diet that is dependent on products of animal origin, especially the organs of an animal, high levels of selenium are evident in bone (Passwater and Cranton 1983). The selenium content of meat, however, is highly dependent on the animal's nutritional intake; hence, selenium concentrations vary by region. In addition to organ meats, seafood, whole grains, garlic, onion, and yeast contribute to selenium concentrations in the body (Passwater and Cranton 1983; Underwood 1977). Fruits and vegetables are very poor sources; specifically, selenium in vegetables is lost when the water in which it may have been cooked is discarded.
Manganese (Mn)

Like magnesium, manganese is found in high concentrations in nuts, whole grains, and legumes (Crist 1995; Klepinger 1984; Passwater and Cranton 1983), variable amounts in vegetables, and low levels in meat, fish, and dairy foods (Schroeder et al. 1966).

Cadmium (Cd)

At birth, there is almost no cadmium present in the human body (Underwood 1977). It begins to accumulate with age. Seafood, especially oysters, are rich sources of cadmium. Concentrations of cadmium are high in vegetarian foods such as wheat and rice (Crist 1995). However, cadmium losses are evident in milled wheat. Dairy and meat products, with the exception of kidney, are poor sources of cadmium (Underwood 1977).

Strontium (Sr)

Strontium is one of the most widely studied and applied of the trace elements to dietary interpretations, most notably because it is the least affected by diagenesis. However, strontium still has not been confirmed as
an element essential to human nutrition (Passwater and
Cranton 1983). Nonetheless, it is correlated with strong
teeth and bones and Subira and Malgosa (1992) and Under­
wood (1977) states that strontium is associated with a
vegetarian diet. Strontium concentrations are found in
the bran of grains and in the peels of root vegetables,
which are commonly consumed by herd and dairy producing
animals. High levels of strontium, do not indicate con­
sumption of the animal or its by-products (milk, eggs,
and cheese); rather, it is evidence for an individual's
personal intake of a significant amount of plant matter.

Strontium competes with calcium once it enters the
body; therefore, strontium is often examined relative to
calcium. A diet high in dairy will exhibit a low ratio
of Sr/Ca, whereas individuals whose diet relies heavily
on plant foods, will consequently display a high Sr/Ca
ratio (Sillen and Smith 1984). Based on evidence from
Umm el-Jimal fauna (Toplyn, in press) and nearby contem­
poraneous sites, el-Lejjun (Toplyn 1987) and Tell Hesban
(Labianca 1990), the adult and subadult population at Umm
el-Jimal probably incorporated a significant amount of
dairy foods into their nutritional intake. As children
are being weaned, however, their Sr/Ca ratio will in­
crease due to the introduction of other foods (vegetables) into their diet.

In sum (see Table 1), high levels of zinc, copper, selenium, magnesium, and manganese indicate protein consumption; the first three are found in meat at high

Table 1

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x = High Concentrations, o = Intermediate Concentrations
concentrations, and the last two, in nuts. Strontium, barium, silicon, and cadmium, on the other hand, are prevalent in vegetarian foods. Calcium concentrations indicate dairy food intake, as well as, certain kinds of vegetables. The next chapter looks at foods specific to the region based on data from flora and fauna in order to be able to link foods or food types with the trace elements discussed above.
CHAPTER III

DIETARY EVIDENCE FOR COMPARISON

Through successive Islamic occupations, the original Roman names of the sites in the Hauran region have been lost (Miller 1995). Hence, records of agricultural production, taxation, and population are unavailable for ancient communities, including Umm el-Jimal (de Vries, in press; Butler 1913; see also de Vries 1986; 1985; 1981). What endures are structures, such as roads, walls, gates, and private and public buildings, constructed in antiquity from local basalt, many of which remain standing today. The type of structures present at the site were dependent upon the size, location, and utilization of the site. In general, customary to all were communal cisterns used to collect water from springs, run-off wadis, or wells. These cisterns confirm the importance of the sites as year-round dry farming settlements. The presence of grinding stones and storerooms attest to the production and processing of cereals. Finally, the existence of mangers with tether holes is indicative of past
populations stock-raising stall-fed animals. These kinds of structures signify that the sites' residents practiced both agriculture and animal husbandry.

It is unclear at this point whether the individuals interred in Areas Z and AA represent semi-nomadic peoples and Area BB.1 settled residents, or if Areas Z and AA signify a poorer sector of the community and Area BB.1 a wealthier district (Cheyney 1997; see also Haiman 1995; Banning 1986). From the architectural evidence discussed above, it is probable that both agrarian production and animal husbandry were practiced by the town's settled residents, resulting in a fairly balanced diet. If semi-nomadic tribes lived at the fringes of the settled community most likely they did not use their herds for meat but for trading or for milk and cheese. They should exhibit higher concentrations of calcium, as well as elements which point to primarily vegetarian fare. If, on the other hand, the distinction between Areas Z and AA versus Area BB.1 is not one of subsistence production but rather one of wealth or status, then, one would expect that diet between areas would demonstrate similarities in concentrations of all of the elements, except that the presumably higher status sector (BB.1) should exhibit
increased protein levels.

Trace element research will contribute to an understanding of the relative dependence of vegetable versus animal-product foods at Umm el-Jimal. Inclusion of floral and faunal data is critical to the research, however, because trace element concentrations express only proportions of vegetable-based to animal product-based foods rather than divulging specific foods that the ancient Umm el-Jimal occupants may have consumed.

The faunal assemblage from an Early Byzantine layer at Umm el-Jimal evidences a great number of skeletal elements from sheep and goat alone (Toplyn 1995). Successive periods exhibit additional animals such as chicken, cattle, camel, horse, dog, pig, and donkey, but these constitute a disproportionately small percentage of the total identified remains. That the Early Byzantine layer shows no other animal remains other than sheep and goat may not be dietarily significant; occupants from later periods may have partially cleared away the debris of earlier inhabitants (Toplyn, in press). From floral data, carbonized plant remains of barley, wheat, olive, lentil, vetch, pea, grape, fig, date, and some other unidentified cereals in the Late Roman and Early Byzan-
tine layers are present at Umm el-Jimal (Crawford 1995). Due to the preliminary nature of both studies, little more can be said about the plant and animal bone elements from Umm el-Jimal. Other site reports, however, may provide more information about the nutritional lifestyles of people living in the Late Roman and Early Byzantine periods of the Hauran region.

Flora and fauna recovered and studied from a nearby site, the fortress of el-Lejjun, contemporaneous with Umm el-Jimal, exhibits evidence of cereals, legumes, and fruits nearly identical to Umm el-Jimal in the Late Roman, Early Byzantine, and Late Byzantine layers (Crawford 1987). Butchered and burned faunal remains of Early and Late Byzantine periods indicate consumption of chicken, sheep, goats, and cattle. The occupants probably were eating animal by-products, such as milk, cheese, and eggs, as well (Toplyn 1987). The assemblages were all collected from the barracks and are probably indicative of the diet of the Roman soldiers rather than the native dwellers (Crawford 1987; Toplyn 1987).

The fauna of Tell Hesban, another nearby, contemporaneous site, indicate reliance on swine, poultry, and imported fish during the Roman period (Labianca 1990). In
addition, increases in camel meat consumption and a decrease in beef may reflect a return to camel nomadism. The principal field crops and fruits of this time period are again, essentially similar to both Umm el-Jimal and el-Lejjun. However, recovery of apricot, pears, and apples indicate a greater diversity in fruit consumption at Tell Hesban. The variety of foods in the diet at this site are probably a result of a Roman road network which made interregional trade both possible and efficient.

During the Early Roman period, semisedentary cultivators and pastoralists lived off the land. The Late Roman settlement, however, experienced intensified land use in the hinterlands; rapid urbanization transformed Tell Hesban from a small village into a town connected to and accessible by major highways. Admission into the trade network probably resulted in a diet which was both balanced and diverse.

The Byzantine diet at Tell Hesban continued similarly to the diet of the preceding Roman period. However, goat and sheep herding was on the rise due to decreasing grazing land in the valleys and plains for camels. Indeed, goat and sheep herding was more practical as a result of the animals' ability to access pastures on
steep slopes and ridges. Evidence of gardens and orchards suggest increased interest in fruits and vegetables, although cereals and legumes continued as staples in the diet. Spices and exotic foods may have become more commonplace in the Byzantine period because of convenient access to major trade networks.

Most dietary data available from the Near East is typically in the form of floral and faunal reports. Unlike those who work on sites in the United States, researchers in this region of the world have not really explored bone chemistry as a viable alternative to interpreting nutritional practices. A preliminary study available from a seventh-century Carthage population will be used loosely for comparative purposes. Due to its geographic proximity to the Near East, the types of food consumed by the Umm el-Jimal populace are expected to be more similar to that of the Carthaginians than U.S. Native Americans. However, the extremely small sample size (n=15) emphasizes its preliminary nature.

Sanford et al. (1988) tested six elements: magnesium, strontium, iron, zinc, copper, and manganese. With the exception of iron, all of the above are examined in the Umm el-Jimal study. Their sample size consists of
fifteen individuals, of which ten are adults and five are subadults. Due to high iron, and zinc levels and low strontium levels in both the adults and subadults, the authors conclude that the Carthaginians subsisted on a high amount of animal-protein foods in their diet. It is not really possible to compare the means of each of the element concentrations for subadults and adults of Carthage to the concentration levels of the Umm el-Jimal sample in the results and interpretation because of different preservation conditions at each site.

From the floral and faunal reports, it is evident that the people of Late Antiquity may have experienced diets and nutritional lifestyles which were relatively similar to one another. They grew a variety of fruits and vegetables and cereals and herded a significant number of goat and sheep for dairy foods, as well as for meat, perhaps. With the results of the chemical analysis, it will be possible to learn who relied more heavily on plant foods, who consumed more animal-derived foods, and consequently, what relationship may have existed between diet, age, and status. Together, the two types of data contribute to a more holistic picture of nutritional practices of the Late Roman and Early Byzantine
inhabitants from Umm el-Jimal.
CHAPTER IV

MATERIALS AND METHODS

The skeletal samples used for analysis were excavated from the 1993, 1994, and 1996 field seasons. For excavation reports, see Brashler (in press; 1995) and Cheyney (in press; 1997). For a detailed analysis of population demography, see Cheyney (1997).

Sample Population

A total of 107 individuals were analyzed in this project. All thirty-one excavated individuals from Area Z and all fifteen from Area AA were included in the sample population. However, from the total of ninety individuals in Area BB.1, only sixty-one were utilized in the trace element study due to the commingled and disturbed nature of the tomb. In other words, there was not always an associated humerus for every skeleton in BB.1. As for potential sample error in Areas Z and AA, it is possible that there are many more interred individuals which have not yet been excavated (Cheyney 1997).
Samples have been classified by age and corresponding cemeteries (Table 2). There are three subadult categories consisting of a total of forty-four samples age 0-1.5 years, 2-5 years, and 6-14 years. The average age at weaning in traditional Palestinian Arab communities takes place approximately between two and three years (Grin­quist 1930). A high mortality figure for children in the two to three year range then, may be indicative of inadequate weaning foods or poor nutrition, in general. There are sixty-three adults from all three burial areas classed into five categories: 15-24 years, 25-34 years, 35-45 years, 45 and older, and unknown. Thirty-nine of the sixty-three adults (sixty-two percent of the adult population) are of unknown ages.

Sample Preparation

A modified version of the traditional method of sample preparation initially developed by Szpunar et al. (1978) was used following guidelines provided by Crist (1995), Klepinger et al. (1986), and Pau et al. (1990). Inductively coupled plasma emission spectrometry (ICP), was the instrument used to test the samples because with it, it is possible to obtain results for many of the
<table>
<thead>
<tr>
<th>Age In Years</th>
<th>Cemetery</th>
<th>Total by Age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Z</td>
<td>AA</td>
</tr>
<tr>
<td>Subadults</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-1.5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2-5</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>6-14</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Total by Cemetery</td>
<td>19</td>
<td>5</td>
</tr>
<tr>
<td>Adults</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15-24</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>25-34</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>35-44</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>44+</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Unknown</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Total by Cemetery</td>
<td>12</td>
<td>10</td>
</tr>
</tbody>
</table>
simultaneously. Atomic absorption spectrometry (AAS), the more traditional method of trace element analysis, allows the examination of only one element at a time (Sandford 1992). In addition, the ICP demonstrates a high level of sensitivity to almost every element on the periodic table and determines concentrations of elements which are at exceedingly low levels, i.e., a few parts per billion (Fassel 1978). Finally, and perhaps most importantly, inductively coupled plasma emission spectrometry is highly valuable because it employs spectrochemically pure chemicals to create standards to which the samples are compared (Klepinger et al. 1986).

Samples were taken from the right humeral cortex where cross-sections adequately represented both the periosteum and endosteum of the cortex. The majority of the humeri were already fragmented prior to analysis. As a result, pieces from the midshaft were broken off by hand and weighed on a balance. When the humerus was found whole, a hand saw was utilized to cut out a triangular bone core to preserve the integrity of the bone. Approximately 5 g was extracted and pulverized from all adult bones. This has the effect of blending a relatively significant portion of bone to achieve greater
homogeneity for comparative purposes. From the subadult samples, only about 1 g was taken due to the less dense nature of their bones.

As a way to reduce diagenic hazards, the sample was abraded superficially with silicon carbide sandpaper (Lambert et al. 1989). This is a particularly useful for dislodging soil or other contaminants from pores and cracks in the bone (Sandford 1992). Using a mortar and pestle, the 5 g or 1 g sample of midshaft bone was ground to a fine powder. Once the full amount of the sample was crushed, 1 g from the 5 g adult sample, and 0.5 g from the 1 g subadult sample was taken for ICP preparation. Since the bone powder was not uniformly pulverized, it was wet-ashed by a perchloric-nitric acid digest and then gently heated until the nitric acid evaporated. Ashing is an important step for eliminating any of the organic content of the bone and consolidating the mineral (inorganic) constituent. Details of sample preparation follow below.

All glassware was washed in mild soapy water, rinsed with tap water followed by reverse osmosis (RO) water, and allowed to soak for at least one hour in 2% nitric acid. After it had soaked, the glassware was rinsed with
double distilled deionized water (milli-Q) and was then used. With a clean spatula, either 1 or 0.5 grams of samples was weighed out on a balance. It was not necessary for each sample to be of the same weight as long as the amount weighed was carefully recorded (Pau et al. 1990). The dry bone sample was transferred into 100-ml beakers and dampened with 2 ml of milli-Q using a volumetric pipette. Under a fume hood, 4 ml of concentrated trace element grade nitric acid measured by volumetric pipette and 10 drops of concentrated trace element grade perchloric acid were added to the beakers. Each of the beakers was covered with a watch glass so that the acids in the sample did not evaporate and cause the sample to go dry (which can potentially create an explosion). At this point, the samples looked cloudy and yellow-brown in color. The beakers were set on hot plates in the fume hood and allowed to heat evenly between 80 and 90 °C. Digestion time for each sample was variable but took approximately 1 to 1.5 hours. Beakers were agitated several times during heating. When digestion was complete, the samples looked pale yellow and clear.

After each sample completed the digestion process, it was allowed to cool. Then, it was vacuum filtered
with glass fiber filters of 1.5 micrometer pores. The filtered solution was transferred to a volumetric 100-ml flask and brought to volume with milli-Q. With parafilm sealing the opening, the flask was gently inverted several times to achieve homogeneity of the sample. Each sample was poured into clean 2% nitric acid soaked 100-ml polyethylene bottles for permanent storage.

Due to high absolute levels of calcium and strontium in the samples, the ICP was unable to analyze the concentrations to the level required. On each prepared sample, a 1:10 dilution was performed. Ten ml of sample was quantitatively transferred to a volumetric 100-ml flask. Four ml of concentrated nitric acid was added with a volumetric pipette and then brought to volume with milli-Q. Dr. M. Dziewatkoski (Western Michigan University, Department of Chemistry) was responsible for creating standard solutions of each element as well as for running the samples in the ICP.

Concentrations of trace elements in the digested samples are presented as parts per million (ppm) since trace elements contribute to only 0.01% of the total body make-up. All of the adult samples were approximately 1 g and all of the subadult samples were approximately 0.5 g.
In order to be able to use the data comparatively, all of the concentration levels were divided by the actual mass of the dry bone powder used so that each had a single reference point of 1 g.

Data Analysis

The collected data was entered into spreadsheets created by Microsoft Excel for Windows 3.1 version 5.0. The statistical program used to analyze the significance of differences of trace element concentrations between each of the adult categories to examine the role age may have played in nutritional intake and between each burial area for adults as a whole versus subadults as a whole to determine if the difference between cemeteries was one of status was one-way Analysis of Variance (ANOVA). A non-parametric test, Mann-Whitney-U, was used to determine significance between early and middle subadult age categories to attempt to establish weaning patterns and between males and females for understanding the relationship between gender and diet because of the smaller sample size. Both types of tests were performed by Maria Jean Urera, Western Michigan University Statistical Services.
CHAPTER V

RESULTS

A battery of ten elements, barium, magnesium, calcium, copper, silicon, zinc, selenium, manganese, cadmium, and strontium, were examined from three different burial areas (Areas Z, AA, and BB.1). Areas Z and AA were combined during statistical analyses based on the assumption that they probably represented a single cemetery in antiquity (Cheyney 1997).

The hypotheses tested are: (a) there are no significant differences in trace element concentrations between Z and AA early adults (n = 7), early/middle adults (n = 8), middle adults (n = 4), and late adults (n = 5); (b) there are significant differences in concentrations between Z and AA adults (n = 22) versus BB.1 adults (n = 41) and between Z and AA subadults (n = 24) compared to BB.1 subadults (n = 20); (c) there are statistically significant disparities in trace element levels between Z and AA early subadults (n = 5) and middle subadults (n = 7) when compared to BB.1 early subadults (n = 2) and
middle subadults (n = 9); and (d) there are no statistically significant differences in trace element concentrations between males (n = 9) and females (n = 5) in Areas Z and AA combined.

Age

The first hypothesis, that there are no significant differences in trace element levels between Z and AA adults classified as early (15-24 yrs.), early/middle (25-34 yrs.), middle (35-44 yrs.), and late (44+ yrs.), is accepted. None of the elements tested demonstrated a significant difference in relative concentrations between the four groups. The age categories examined included only adults of known ages.

Status

The second hypothesis, that there are statistically significant differences between Z and AA versus BB.1 in element concentrations, is accepted for both adults and subadults. In order to maximize the sample size and highlight cemetery differences, age categories were collapsed in this test. In other words, every individual was used to test dietary differences by burial area.
Tables 3 and 4 illustrate the trace element means detected from bone and p-values for adults and subadults, respectively, by burial area.

Table 3

Adult Trace Element Means by Cemetery: ANOVA Results

<table>
<thead>
<tr>
<th>Element</th>
<th>Area Z-AA n = 22</th>
<th>Area BB.1 n = 41</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barium</td>
<td>139.05</td>
<td>68.32</td>
<td>0.0952*</td>
</tr>
<tr>
<td>Magnesium</td>
<td>2158.79</td>
<td>2243.69</td>
<td>0.7999</td>
</tr>
<tr>
<td>Calcium</td>
<td>439,228.39</td>
<td>304,710.46</td>
<td>0.0000*</td>
</tr>
<tr>
<td>Copper</td>
<td>18.72</td>
<td>19.26</td>
<td>0.9159</td>
</tr>
<tr>
<td>Silicon</td>
<td>645.67</td>
<td>450.31</td>
<td>0.0004*</td>
</tr>
<tr>
<td>Zinc</td>
<td>282.08</td>
<td>162.24</td>
<td>0.0000*</td>
</tr>
<tr>
<td>Selenium</td>
<td>6.86</td>
<td>7.54</td>
<td>0.5598</td>
</tr>
<tr>
<td>Manganese</td>
<td>201.35</td>
<td>80.77</td>
<td>0.0048*</td>
</tr>
<tr>
<td>Cadmium</td>
<td>12.49</td>
<td>13.00</td>
<td>0.7188</td>
</tr>
<tr>
<td>Strontium</td>
<td>1106.81</td>
<td>682.74</td>
<td>0.0000*</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level.

**Significant at the 0.10 level.
Table 4

Subadult Trace Element Means by Cemetery: ANOVA Results

<table>
<thead>
<tr>
<th>Element</th>
<th>Area Z-AA n = 24</th>
<th>Area BB.1 n = 20</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barium</td>
<td>194.37</td>
<td>94.76</td>
<td>0.0629**</td>
</tr>
<tr>
<td>Magnesium</td>
<td>3462.49</td>
<td>2121.45</td>
<td>0.0001*</td>
</tr>
<tr>
<td>Calcium</td>
<td>501,119.02</td>
<td>255,556.63</td>
<td>0.0000*</td>
</tr>
<tr>
<td>Copper</td>
<td>124.39</td>
<td>89.36</td>
<td>0.5914</td>
</tr>
<tr>
<td>Silicon</td>
<td>1264.62</td>
<td>607.95</td>
<td>0.0001*</td>
</tr>
<tr>
<td>Zinc</td>
<td>406.44</td>
<td>240.88</td>
<td>0.0142*</td>
</tr>
<tr>
<td>Selenium</td>
<td>17.09</td>
<td>10.23</td>
<td>0.0622**</td>
</tr>
<tr>
<td>Manganese</td>
<td>225.98</td>
<td>135.38</td>
<td>0.0115*</td>
</tr>
<tr>
<td>Cadmium</td>
<td>12.49</td>
<td>13.00</td>
<td>0.0730**</td>
</tr>
<tr>
<td>Strontium</td>
<td>1123.60</td>
<td>668.44</td>
<td>0.0000*</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level.

**Significant at the 0.10 level.

In the following graphs, Figures 4 and 5 depict the means of the element levels measured for adults, while Figures 6 and 7 demonstrate mean values for subadults.
Figure 4. Adult Trace Element Means Excluding Calcium: Areas Z-AA and BB.1.
Figure 5. Adult Trace Element Means of Calcium: Areas Z-AA and BB.1.
Figure 6. Subadult Trace Element Means Excluding Calcium: Areas Z-AA and BB.1.
Figure 7. Subadult Trace Element Means of Calcium: Areas Z-AA and BB.1.
In all of the comparisons found to be statistically significant, it is evident that Areas Z and AA combined have greater values of calcium, silicon, zinc, manganese, and strontium. Although barium distinctions are not significant at a p-value of 0.05, the mean concentration is still greater in the Z-AA cemeteries; this is significant when the p-value is 0.10. For all other elements, the means appear quite similar in magnitude, and hence, it is this which is reflected by their p-values.

Results from statistically significant subadult mean concentrations indicate that all of the trace elements, with the exception of cadmium, exhibit higher levels in Areas Z and AA. Even copper, though not significant, is higher in Z and AA than in BB.1.

Weaning Patterns

The third hypothesis, that there are significant differences between the first subadult category (0-1.5 yrs.) and the second subadult group (2-5 yrs.) aimed at determining the effects of weaning within and between Z-AA and BB.1, is rejected. Only ratios of barium to calcium, magnesium to calcium and strontium to calcium are tested. In young children surviving solely on breast-
milk, levels of barium, magnesium, and strontium are very low when compared to calcium concentrations. With the introduction of solid foods, though, barium, magnesium, and strontium compete with and inhibit calcium absorption. Thus, weanlings should demonstrate higher Ba/Ca, Mg/Ca, and Sr/Ca ratios than solely breastfeeding youngsters. However, Mann-Whitney-U test results indicate that distinctions in levels of barium, magnesium, and strontium when compared to calcium are not significantly different between the early and middle subadult age groups.

Gender

The fourth hypothesis, that there are no significant differences between males and females when measuring trace element quantities in Areas Z and AA combined, is rejected. The following table (Table 5) summarizes the means of concentrations of males compared to females and p-values from the Mann-Whitney-U test. Figure 8, 9, and 10 represent trace element means when comparing sex at Areas Z and AA. Area BB.1 individuals are not included since sex was not determinable from the humerus alone (see Cheyney 1997 for the sex distribution of the entire
BB.1 sample population). Grave looting and burial reuse has resulted in highly disturbed and fragmented skeletal remains within the tomb’s loculi. The in situ internments at Areas Z and AA, however, resulted in reliable

Table 5

Adult Trace Element Means by Sex in Areas Z and AA: Mann-Whitney-U Test Results

<table>
<thead>
<tr>
<th>Element</th>
<th>Male n = 9</th>
<th>Female n = 5</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barium</td>
<td>103.75</td>
<td>98.06</td>
<td>0.4634</td>
</tr>
<tr>
<td>Magnesium</td>
<td>3099.58</td>
<td>1540.27</td>
<td>0.1615</td>
</tr>
<tr>
<td>Calcium</td>
<td>533,212.06</td>
<td>372,270.75</td>
<td>0.0388*</td>
</tr>
<tr>
<td>Copper</td>
<td>27.94</td>
<td>9.76</td>
<td>0.9468</td>
</tr>
<tr>
<td>Silicon</td>
<td>815.06</td>
<td>481.65</td>
<td>0.0388*</td>
</tr>
<tr>
<td>Zinc</td>
<td>342.64</td>
<td>200.57</td>
<td>0.0388*</td>
</tr>
<tr>
<td>Selenium</td>
<td>3.75</td>
<td>7.85</td>
<td>0.0174*</td>
</tr>
<tr>
<td>Manganese</td>
<td>251.45</td>
<td>122.03</td>
<td>0.7389</td>
</tr>
<tr>
<td>Cadmium</td>
<td>11.95</td>
<td>12.56</td>
<td>0.3173</td>
</tr>
<tr>
<td>Strontium</td>
<td>1186.86</td>
<td>1020.84</td>
<td>0.2471</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level.
Figure 8. Adult Trace Element Means: Area Z-AA Males and Females.
Figure 9. Trace Element Means of Calcium: Area Z-AA Males and Females.
Figure 10. Trace Element Means of Selenium and Copper: Area Z-AA Males and Females.
sex estimates of the individual.

Although means are used for parametric tests such as one-way ANOVA and not for nonparametric tests such as the Mann-Whitney-U test, they are included here in order to emphasize the direction of differences of specific trace element mean concentrations between males and females. With one exception (selenium), males demonstrate higher mean concentration for the elements indicated as statistically significant when the p-value is 0.05: calcium, silicon, and zinc. When the means are examined without concern for statistical significance, males still, in general, evince higher concentrations of nearly all of the trace elements (except cadmium).
CHAPTER VI

DISCUSSION AND CONCLUSIONS

As historical records which may have documented in detail early fourth century life at Umm el-Jimal do not exist, only inferences from the material and skeletal remains at the site can be made. The interpretations presented below are tentative because of the impossibility of attaining a thorough understanding of experiences and lifeways which no longer exist. The following sections are discussed by the major subjects of the thesis: age, status, weaning patterns, and gender in order to correlate the results with social factors that may have influenced the diet of Umm el-Jimal's residents in antiquity.

Age

Results indicate that no significant differences were found in trace element concentration levels between the four differing age groups of Z and AA adults when divided by ten-year intervals beginning at age fifteen.
This may be because each group consumed similar types and amounts of foods or different foods entirely, yet were still comparable in nutritive value. Another explanation for the lack of significant difference between age groups may be the small sample size for each age cohort. Potentially, a larger sample could elucidate differences in diet between the four adult groups. Furthermore, because the age groups were not divided by sex, detection of significant trace element differences between age cohorts may be less clear than if the samples had been made sex-distinct.

Status

Grave construction at BB.1 and Z-AA is indisputably distinct, but understanding reasons for this are less clear. It is assumed that individuals buried in the monumental tomb of BB.1 were either higher status or settled residents. Settled or wealthy groups have the time and/or resources to devote to substantial projects, such as an elaborate funerary structure which can accommodate a large number of people. Likewise, the simpler graves from Z and AA are presumed to have been the repository for lower status settled residents or semi-
nomadic individuals. It is unlikely that either relatively mobile or poorer groups would have been able to build complex tomb structures. For the purposes of this discussion, it will be assumed that the differences manifested in trace element concentrations between Areas Z and AA compared to BB.1 are a result of status due to the dearth of evidence which would indicate differences resulting from settled versus semi-nomadic lifestyles (Cheyney 1997). Future excavations at Umm el-Jimal, however, might indicate such a distinction, but at present, there is no such indication which could confirm this.

An analysis of diet which can be correlated to specific groups of individuals should elucidate where differences exist or do not exist. However, with the level of understanding of trace element that exists, it is only possible to suggest rather tenuous explanations. Further excavation to increase the sample size, use of microscopic aging techniques to achieve age classifications for all individuals, or an enhanced understanding of the trace elements associated with diet are required for more conclusive results. Even if the depth of knowledge and comprehension needed to understand diet through trace
element analysis could be achieved, there are other kinds of obstacles and personal biases which prevent complete faith. Room for error in the lengthy laboratory process or as a result of postmortem alteration of the remains is an ever-present danger. In addition, diet is not simply the intake of nourishment for survival. It is a cultural, political, and economic endeavor that varies by (a) social factors like lifestyle, age, status, and gender; (b) by region; and (c) through time. Potentially complex interactions make it virtually impossible to understand all of the components that make up "diet."

This is not meant to undermine the significance of trace element research, because clearly, it communicates something about the past; however, at this point, it may not be possible to fully comprehend the message. With continued data collection about trace elements from different regions and time periods of the world, the closer we may get to making appropriate interpretations with this type of research.

Statistically significant differences in trace element concentrations between the Z and AA cemeteries compared to BB.1 for adults and subadults indicate that, overall, the Z and AA occupants have higher element lev-
els than BB.1 individuals. Among adults from Areas Z and AA, levels of calcium, silicon, zinc, manganese, strontium, and barium were significantly greater than adults from BB.1. Each of these elements fall into different food classes, perhaps suggesting that they were providing for their nutritional needs from many sources such as dairy products, rice, whole wheat, muscle meats, nuts, legumes, and a variety of fruits and vegetables. Copper and selenium, two elements found in protein-rich foods were about equal in each of the burial areas; zinc, an essential element obtained through meat and nuts, however, was significantly higher in Areas Z and AA.

There are several possible reasons to explain why supposedly higher status individuals have significantly lower concentrations of many of the elements examined in this study. One is that the people interred in Z and AA were farmers who had access to field crops to supply their own, as well as, their families' nutritional needs. A more tenable interpretation could be that the higher concentrations of certain elements are due to diagenesis, or postmortem alterations of trace element levels. Since it is likely that preservation conditions varied between BB.1 and Z and AA, then the apparent differences do not
necessarily indicate dietary differences between burial areas.

The Z and AA skeletons exhibit higher measurable concentrations of barium, calcium, silicon, zinc, manganese, and strontium. From surveyed literature, there does not appear to be a significant amount of research exploring and documenting the direction diagenesis travels, i.e., whether concentrations in bone increase or decrease with time, although according to Klepinger et al. (1986), cadmium and manganese decrease with time whereas magnesium and calcium increase with time. Since cadmium and magnesium were not significantly different between burial areas, they are excluded for this discussion. Lower manganese levels in BB.1 could be the result of diagenesis. However, of the two burial areas, Z and AA would be more likely to undergo diagenic processes because the land is currently being irrigated (personal observation), and water leaching into the graves could alter the chemical composition of the skeletal remains. If diagenesis does not explain low manganese levels among BB.1 individuals, then Z and AA residents may have had high whole grain and nut consumption during life. The significantly high calcium levels in Z and AA could be a
result diagenic factors, as calcium is expected to rise through time. As for the stability of other elements, some researchers have noted that strontium and zinc are very resistant to diagenesis (Lambert et al. 1982), while others argue that zinc and manganese are the least affected (Nelson and Sauer 1984).

These contradictory statements further support previous arguments that trace element research as it stands, is still in its infancy, in terms of offering fully tangible results and explanations about archaeological diets. Nonetheless, it is evident that zinc, at least, is considered a highly reliable indicator of diet. Most other researchers would also argue that strontium is also reliable due to its stability in the environment (Blakely 1989; Klepinger 1984). Perhaps to be of better use, though, it may be necessary to take water and soil samples to test strontium concentrations in the environment. Hence, high strontium and zinc levels for the people from Areas Z and AA should suggest dietary differences from Area BB.1. Strontium is an element which is strongly correlated with vegetarian foods. Again, the possibility that the presumable poorer cemetery was better nourished is certainly perplexing and requires further investiga-
Similary, children from the Z and AA cemeteries demonstrate significantly higher levels of nearly every one of the tested trace elements when compared to BB.1 subadults. The children interred at Z and AA may be more likely to undergo diagenic processes which may have significantly altered the proportions of trace elements in the skeleton.

It is difficult to confidently argue that the trace element composition between the combined Z and AA cemeteries compared to BB.1 manifest dietary differences from antiquity. It is quite probable that there were foods unique to each subpopulation; however, it is unlikely that the people buried in the monumental funerary structure were eating more poorly than the residents buried in the simple graves of Z and AA, although the possibility cannot be completely eliminated because BB.1 individuals may have replaced nutritious staples with food items high in fat, which might have been considered as elite foods. Also, the postdepositional conditions at Areas Z and AA may have contributed to the significant differences in trace element composition. Testing soil chemicals from all three areas may assist in determining if the results
are a consequence of diagenesis. Finally, the possibility that the people interred in BB.1 are not higher status cannot be overlooked, or that the individuals present are not only from the Late Roman/Early Byzantine town. The BB.1 tomb has been disturbed through time, and poor villagers, centuries later, unable to afford the expense of furnishing a new grave may have buried the deceased in the BB.1 mausoleum (Melissa Cheyney, personal communication; Bert de Vries, personal communication). All of these explanations, rather than just one, may help in interpreting why the differences in trace elements in Z and AA compared to BB.1 are not only significant, but favor the residents of Areas Z and AA.

Weaning Patterns

Examining trace element concentrations between early subadults and middle subadults was expected to provide information about weaning patterns at Umm el-Jimal. Despite the very small sample size in each division, cemetery distinctions were made between Areas BB.1 and Areas Z and AA. However, no significant distinction could be made between children age 0 - 1.5 years and 2 - 5 years. Possibly, this indicates that children at ei-
ther burial area were weaned around the same age and that their intake of calcium (through dairy or dairy products) did not change significantly before and after they were weaned (gradual weaning). Also, the inability to establish weaning patterns could be the result of having divided the early from middle subadults between 1.5 and 2 years. It may have been more fruitful to have made the separation between 2 and 3 years or between 3 and 4 years. An increase in sample size and new age divisions may provide the data needed to establish weaning patterns for the site during the Late Roman/Early Byzantine occupation.

Gender

Finally, significant differences were found between males and females when only Areas Z and AA were examined. According to Lambert et al. (1989), with superficial abrasion of the bone samples, differences in trace element concentrations between males and females disappeared. During sample preparation in this project, the exterior surface of the bone was removed before analysis; hence, the disparities which are present should be a consequence of differences in dietary intake.
There are four elements which indicate significant differences between males and females: calcium, silicon, zinc, and selenium. The first three elements are found in greater concentrations in the male skeletons and the fourth element is higher in females. Calcium, silicon, and zinc all represent good protein sources. Silicon, found in rice and whole grains, is also a good source of carbohydrates. Zinc is abundant in nuts, as well as, skeletal muscle meat. Milk, cheese, and leafy green vegetables are all high in calcium. Possibly, males received nutrients which furnished them with greater energy output which may have been required for the types of work they performed. On the other hand, males may have enjoyed greater nutritional benefits if they were in a position of higher status over females.

Females were found to have significantly higher selenium levels in comparison to males. Selenium is found in organ meat as well as in whole grains. According to *The New Encyclopedia Britannica* (1994), whole grains are an excellent source of protein comparable to protein-rich foods such as meat or dairy products. In poor agricultural communities, cereals are often substituted for meat as comparable protein intake. In addition,
cereals provide an excellent source of carbohydrates. If females were restricted from foods which males had access to, they may have been eating foods that were less diverse, yet still provided for essential energy requirements. The lack of a well-balanced diet for females in Areas Z and AA, especially during their reproductive years, may be the cause of high mortality rates between the ages of fifteen and twenty-four years as was determined by Cheyney (1997). Another interpretation of the differences evident between the males and females in Areas Z and AA is that they may be eating various segments of the same prepared foods, not consuming entirely foods. Among modern Bedouin tribes, males have access to the choice portions of a meal, while females and children are given the remnants (Bert de Vries, personal communication). It is certainly tenable that gender hierarchies similar to the present, in terms of access to food resources, existed some 2000 years ago.

Concluding Remarks

Testing of both adults and subadults between Area BB.1 and combined Areas Z and AA reveal the lack of viability in comparing samples from two sites where preser-
vation conditions differ dramatically. Otherwise, it is difficult to interpret how Z and AA occupants had access to more nutritious food items. Intra-area comparisons, however, should reduce the interference of variable diagenic processes which may exist due to preservation conditions specific to each type of cemetery. An analysis of males and females from Z and AA demonstrate that there are some significant differences in their diet during life, and that the males were likely accessing more protein-rich resources like animal and dairy products, as well as rice and grains. Nevertheless, it can be argued that females made up for this by eating whole grains which offer both protein and carbohydrate benefits. The lack of a determinable weaning pattern may not be the result of diagenesis since an intra-area controlled study was conducted, but of other reasons which will require further investigation. Most agricultural communities in the world offer weaning foods to children which are hardly adequate in comparison to the nutrition they received when breastfeeding (Daniel Sellen, personal communication; David Tracer, personal communication). The small sample size for children in pre-weaning and weaning categories may contribute to the difficulty in establish-
ing patterns of weaning for the entire site and for each area.

The results of this project verify the need for a study with carefully controlled comparisons or soil testing in order to more exhaustively understand the effects of diagenesis on trace element concentrations in bone. Understanding dietary differences between Z and AA combined and BB.1 would have offered valuable insight about interactions between residents of the fourth century Umm el-Jimal population. Not controlling for preservation conditions, however, limits the value of inter-site comparisons. Interpreting how diet differs between age cohorts and establishing weaning patterns may be achieved still with more precise aging techniques and/or with an increased sample size. The differences in concentration levels between males and females, however, do provide knowledge about gender relationships in the past that, in some respects, may be not unlike existing ones in modern Middle Eastern rural communities.

It is very difficult to put the results of this study in the context of other ongoing trace element research. Mainly this is because very little chemical research on human remains has been attempted in Old World
archaeology, as well as generally small sample sizes that make it difficult to reliably accept others' reports when it is undertaken. This study examined 107 samples, a relatively large sample population for this type of research. However, not every individual could be included in the statistical analysis because the sex and/or age of the sample was unknown. More useful results would be expected with a solid age and sex estimate on every individual's humerus. Currently, little can be done to achieve a sex estimate for all adult humeri, but histomorphometry, or the determination of age microscopically on bone, is an option for future research. This would make it possible to include the maximum number of individuals in each age cohort. Finally, the fact that soil conditions at every site are unique, makes it nearly impossible to compare data from different studies. If trace element concentrations of bone were consistently presented as a ratio to trace element levels of the surrounding soil, then valuable parallels between sites could be a reality.
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