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Vlaar, Mathilde

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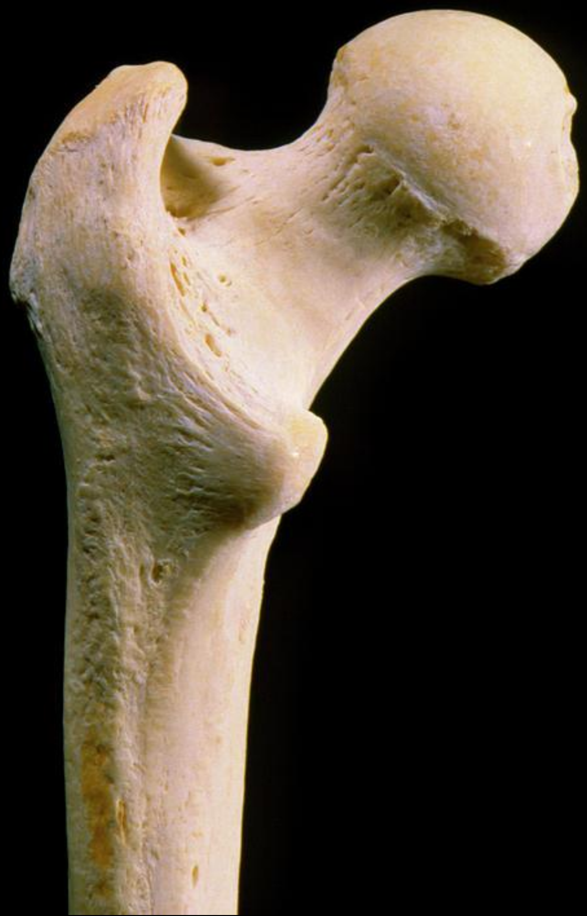

Mathilde Vlaar

Cover image: photograph of a femoral head (James Stevenson/science Photo Library)

Let them eat cake!

Correlating body mass to socioeconomic status in the post-medieval Netherlands by estimating body mass from femoral head breadth measurements

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1. Introduction

1.1 The Post-Medieval Netherlands

This thesis studies the relationship between socioeconomic status and body mass in the post-medieval period in the Netherlands using human skeletal materials from two archaeological sites and relating the outcomes to diet and lifestyle. The post-medieval period, often dated between 1650 and 1850 CE, in the Netherlands can be described as a turbulent period with many changes. The beginning of this period is characterised by great industrial growth and economic prosperity, mainly due to the fact that the Netherlands occupied a central and important position on the trade market with Dutch seafarers dominating the seas (Lintsen, 1995, p. 33). The industry mainly took place in the larger cities who were easily accessible over water. The surrounding lands provided peat as an affordable and available source of energy (Lintsen, 1995, p. 33).

There was a wide range of well-established industries, both in the rural and urban areas of the Netherlands. These industries produced a wide range of products from both domestic raw materials and the wide trade in products from abroad. Furthermore, the Dutch fishing fleet and the agricultural sector were the highly productive. In the agricultural industry new mechanical devices were introduced and existing ones were improved, enhancing the efficiency and quality of this sector. Similarly, optimisations happened in the fisheries and animal husbandry sectors as well. In the seventeenth century, the Dutch fishing fleet and the agricultural sector belonged to the European top (Lintsen, 1995, pp. 33-35).

However, the largest part of this post-medieval period, from the eighteenth century onwards, was marked by a period of stagnation and decline. As a result, not only the quantity, quality and price of once glorious industry products had a strong decline, lower employment rates led to higher rates of poverty than ever before (Bakker, 1995, p. 92; Lintsen, 1995, p. 36). The gap between the rich and the poor increased as the riches were centred in a smaller and smaller portion of society. “Pauperisme” (poverty), criminality and beggary became pressing matters (Jobse-van-Putten, 1995, p. 99).

During the post-medieval period, there was also a certain social order which the people living in this period can be assigned to. A distinction can be made between the different layers within post-medieval society in the Netherlands (see table 1). This is based on their socioeconomic status. The American Psychological Association (n.d.) defines socioeconomic status as “the position of an individual or group on the socioeconomic scale, which is determined by a combination of social and economic factors “ (Definition 1). In the case of this thesis, this corresponds to what jobs people were employed in and to what stability and riches they had access to.

Table 1 Overview of the social layers in the post-medieval society in the Netherlands (after de Vries & van der Woude, 1997, pp. 561-564)

Socioeconomic Layer	Description of Class	Occupation
Upper Class	The Elite	People in a governing position: mayors, council members and counsellors.
Middle Class	The Upper Bourgeoisie	Political and commercial leaders of the country, merchants, renters, the protestant clergy, the progressive professions, entrepreneurs, industrialists, people in high government positions and senior ranks of the officer corps
	The Middle Bourgeoisie	Lower ranked military officers, municipal officials, butchers, wine sellers, notaries, and the more successful traders, craftsmen and retailers.
	The Lower Bourgeoisie	Private-sector employees (tailors, officials, butchers and bakers) and a smaller portion consisted of public-sector employees (bookkeepers, inspectors and schoolmasters). Also specialised shopkeepers, midwives and certain surgeons.
		Low-ranking public officeholders, shopkeepers and craftsmen with limited turnover
Lower Class	People with increased job security	"Domestic servants, sailors, soldiers and numerous unskilled and semiskilled wage workers" (p. 562)
Lowest Class	People with little to no wealth	Majority of market- and street vendors
	The Dirt-Poor	Beggars, vagabonds and others without a steady stream of work

The lowest class formed the biggest group of post-medieval society; close to half of the urban population was probably part of the lowest rungs of the social ladder. For the poor, life was far from easy. They experienced higher levels of (biological) stress such as poor-quality or limited food, harsh living conditions with more exposure to pollution, and increased levels of disease. Furthermore, the poor often work in jobs that required long hours and demanding physical (and dangerous) tasks (de Vries & van der Woude, 1997, p. 562; Robb et al., 2001, p. 213). For the low bourgeoisie, socioeconomic security was also not a certainty. They were still bordering on the lower-class and misfortune could easily lead to a life in the lower socioeconomic class (de Vries & van der Woude, 1997, p. 563). The middle- and upper bourgeoisie would have a higher level of social- and economic security as they were able to accumulate (some) capital. The elite in the upper class could in comparison enjoy pleasantries such as country homes, exotic possessions, and art collections (de Vries & van der Woude, 1997, pp. 563-564).

1.2 Diet in the Post-Medieval Netherlands

As diverse as the social layers in the urban centres were, so was the diet they consumed. While it is difficult to make assumptions about the diet in the post-medieval Netherlands, some general remarks can be made. Cesspits, cookbooks, and personal historical documentation provide some insights in the post-medieval diet.

One of the first cookbooks to give an insight into the diet of the upper classes is "*Een notabel boecxken van cokeryen*" and was published in the early 16th century by Thomas Vander Noot. That this cookbook was aimed at the upper classes can be concluded from the expensive ingredients that made up these recipes. The cookbook shows that the very wealthy consumed large quantities of meat and fish, with a wide variety of animal species. They could also afford to consume (more) exotic animals and spices. Furthermore, the recipes contain a large amount of dairy products: butter, cream, milk, and cheese, as well as fat (lard, goose fat, rapeseed oil). Sugar was added to almost every dish, and sauces were also very important. Overall, many fatty foods were consumed (Jansen Sieben & van der Molen-Willebrands, 1994, pp. 10-11).

Later cookbooks, such as "*De verstandige kock*" (an elitist cookbook that first appeared in 1667), contain, besides a large amount of meat recipes, also a large number of vegetable recipes. Many of these vegetables were stewed in butter. This increase in vegetable consumption is partly due to the developments in market gardening in the seventeenth century (Strouken & Spapens, 1999, pp. 27-28). The consumption by the upper-class citizens of a lot of good meat, together with fresh vegetables or dried legumes, dairy- and cereal dishes, and fish, is further underlined by Burema (1953, p. 313).

According to Burema (1953), the general diet among the lower classes consisted mainly of peas and beans, coarse vegetables such as carrots and cabbage, and very little meat. From the mid-17th century onwards, the consumption of jenever took off among the lower classes, but still, a lot of beer was consumed (pp. 313-314).

Burema (1953) also states that breakfast, for both the rich and the poor, generally consisted of bread with butter and/or cheese with water, milk, mead or beer as drink. Rye bread was most commonly consumed within the lower social groups, whereas white bread was considered a luxury still. This breakfast of bread with dairy remains fairly constant throughout the post-medieval period. The poorer population also often ate carrots or potatoes for breakfast later in the 18th century (pp. 313, 315).

Furthermore, Burema (1953) notes the increased availability and popularity of sugar from 1750 onwards; a product that was soon found in every kitchen. It was used for conserving foodstuffs, but also consumed in drinks and in baked goods, as well as confectionary (pp. 315-316).

When discussing diet, it is also important to consider the periods of scarcity in the post-medieval period that led to differences and changes in the diet. Due to livestock epidemics in the 18th century, there was a downward trend in meat consumption; there simply was not enough meat to provide for the size of the population. As a result, the poor ate little or no meat, while the upper classes probably still consumed it in excess (Jobse-van-Putten, 1995, pp. 97, 99). In addition, the majority of the people in the post-medieval Netherlands suffered from the high grain prices in the last quarter of the 18th century, as a result of which bread and other grain products were no longer affordable for the lowest segments of the population either (Metelerkamp, 1804, in Burema, 1953, p. 222).

In this period of scarcity, the potato offered an affordable alternative. The potato was introduced first in the lowest layers of society after which it ascended to the higher segments. Potatoes also contain three times as many calories as grains, allowing it to become the main component in the diet of most people (Jobse-van-Putten, pp. 104-106). Especially among the lower classes of the population potato was the most commonly eaten food, sometimes two or three times a day (van Berkhey, 1776, in Burema, 1953, p. 133). This did however lead to an (even) more monotonous diet, which was not beneficial for people's health (Mulder, 1847, in Jobse-van-Putten, 1995, p. 103).

So, generally speaking, for the poor, the main focus seems to have been to put food on the table that was as cheap and as filling as possible (Bakker, 1992, p. 41). This did however often lead to an unvaried diet. The upper classes on the contrary, seemed to have had access continuously to a more varied diet, including meat in scarcer periods.

1.3 Research Problem

From the preceding paragraphs it is clear that there are large socioeconomic differences within urban centres in the post-medieval period, which appear to have been directly correlated to the diet each respective socioeconomic group had access to.

Diet, or to be more precise, calories consumed, impacts a person's body mass; if more calories are consumed than used by the body, one will gain weight and vice versa (Harvard T.H. Chan School of Public Health, 2023, Food and Diet section, para. 1). These changes in body mass are observable and could be used as a proxy for differences in diet between socioeconomic groups. Interestingly, although it might be expected that individuals with a lower socioeconomic status have a lower body weight, as they assumingly have fewer financial means to spend on food, in both the present-day United States and the Netherlands, low socioeconomic status leads to poor diet choices in terms of health and nutrition. This results in higher levels of obesity, thus a higher body mass (Geurts et al. 2017, p. 15; Larson & Story, 2009, p. S56).

Larson and Story (2009) describe the situation in the United States where it became prevalent that better access to supermarkets equals better access to healthy food choices, which consequently results in healthier diets. Whereas, at the same time, low-income neighbourhoods have poorer access to these supermarkets and are impacted more by this poor access than wealthy neighbourhoods (Larson & Story, 2009, pp. S62-S64, and sources therein).

Furthermore, it is not only accessibility, but also cost that plays a role in choosing foods. A study by Powell et al. (2007) suggests that price is the biggest determinator in choosing fast food over other options (in Larson & Story, 2009, p. S63). Lastly, and maybe most importantly, Jetter and Cassidy state that "in general, nutrient-dense foods cost more than foods that are higher in energy" (2006, in Larson & Story, 2009, p. S65). Therefore, when the choice has to be made between eating healthy or preventing hunger, the choice is often the latter (Dietz, 1995, in Larson & Story, 2009, p. S62; Darmon et al., 2003, in Larson & Story, 2009, p. S62; Steward & Blisard, 2006, in Larson & Story, 2009, p. S62). This is corroborated for the Netherlands, as presented by Geurts et al. (2017, p. 37).

So, even though poverty is often associated with starvation and being underweight, it has become clear that nowadays the contrary is true, at least in the United States and the Netherlands. However, we do not know much about this in the past. It can be imagined that in the post-medieval Netherlands, the situation could be similar to the current day patterns. As implied in the previous section, more energy dense foods might have been more readily available and accessible for poorer populations then as well. And, as Bakker (1992) suggests, the poor prioritised price over healthy-ness (p. 41). On the other hand, for the more wealthy a similar quantity of lower-fat food would result in a lower energy intake and a less positive energy balance (Institute of Medicine, 2003, p. 69). However, excessive consumption of lower-fat food would still cause a positive energy balance.

Therefore, it is interesting to study whether in the post-medieval Netherlands, the body mass of low socioeconomic status-individuals differed from individuals with a higher socioeconomic status. This will provide more information about the diet and lifestyle of these socioeconomic groups, and differences therein. This can be done by the means of skeletal proportions which are subject to change under differences in mechanical loading. These differences will be caused, in this case, by changes in body mass. In this thesis, methods based on this principle are used to determine body mass in past societies and link this to socioeconomic status. In the upcoming sections, socioeconomic status will be referred to with the abbreviation “SES”.

1.4 Research Questions

The main question to answer in this thesis is:

- To what extent does body mass correlate with socioeconomic status in the post-medieval Netherlands?

To be able to answer this main question, multiple sub questions have been formulated:

- What are the differences in body mass between male individuals with a high socioeconomic status and male individuals with a low socioeconomic status?
- What are the differences in body mass between female individuals with a high socioeconomic status and female individuals with a low socioeconomic status?

1.5 Aim and Approach

The aim of this thesis is to study whether there is a difference in body mass between individuals from the post-medieval period in the Netherlands with a high socioeconomic status and with a low socioeconomic status. This will be done by comparing two Dutch post-medieval case studies, a skeletal collection from Zwolle and one from Arnhem, one for each of the respective socioeconomic groups. By comparing the two, it is possible to study the impact of socioeconomic status on body mass.

1.5.1 Materials

The cemetery at Arnhem is located north of the Eusebius church. This northern part was named the “Old Cemetery” from 1444 on, and it was in use up until 1828 (Baetsen et al., 2018, p. 37), when all towns with more than a 1000 inhabitants needed to utilise a cemetery outside the city walls (Cappers, 1987, in Zielman & Baetsen, 2020, p. 112). The cemetery north of the church is known as the place where the poor were buried (Baetsen et al., 2018, p. 38), and it was used intensively. It seems however, as if there was no clear raster of burials with uniform depths and many graves cut each other. (Baetsen et al., 2018, p. 39). Unfortunately, it is unknown which specific individuals are buried here. Even though there are burial records from the seventeenth century onwards, they lack documentation on the location of each specific grave. (Baetsen et al. 2018, p. 37; Zielman & Baetsen, 2020, p. 95). There are also little grave goods associated with these burials, but as they are mainly Christian burials, this is not remarkable (Baetsen et al., 2018, p. 39).

The Broerenkerk in Zwolle was founded in 1465 by the Congregatio Hollandiae of the Dominican order. The church has been used for burial right from the start with Alanus de Rupe being buried in the choir of the Broerenkerk in 1475 (Aten, 1992, pp. 13-15). The individuals of this case study were buried inside the church. They were buried between the late 17th and early 19th century (Aten, 1992, p. 29). There is a lot of documentation on those who were buried here, and therefore there is abundant information on the background of these people. The individuals buried in the Broerenkerk, came from the middle-class. The highest socioeconomic groups could afford a grave in the "Grote Kerk". In the Broerenkerk, graves were less expensive, thus the middle-class could afford to be buried here (Bouts et al., 1992, p. 77).

1.5.2 Method

The method used in this thesis to determine body mass in the post-medieval individuals, is developed by Ruff et al. (2012) and uses the breadth of highest part of the thigh bone (the femur); the femoral head breadth (p. 603). Ruff et al. (1991) already established equations to estimate body mass with these measurements, but these were improved in the 2012 paper by Ruff et al. (p. 608). This method is based on the general principle of "bone functional adaptation" which entails that the structure of bone tissue is subject to change when the mechanical loading on the bones becomes different (Cowin, 2001, in Ruff et al., 2006, p. 485). In the case of this thesis, the difference in mechanical loading is equivalent to the body mass of the respective individuals. As the femur is the strongest bone in the body and is often recovered in archaeological context (White & Folkens, 2005, p. 255) the femur is ideally suited for this research.

The outcomes of the equations will be subjected to statistical analyses to determine whether there are significant differences between the body masses per group taking into account the sex of the individuals.

1.6 Thesis Outline

This introduction chapter will be followed by a background chapter with a more in-depth explanation on bone remodelling followed by a discussion of the development of body mass research within archaeology. The third chapter is the "Materials and Method" chapter, in which the materials and method will be clearly stated and explained. Then, the results will be presented in the "Results" chapter and discussed in the "Discussion" chapter. The latter will also include a critical evaluation of the results and the methods used to compile them. Attention will be given to the implications and points of attention that are important with this research on body mass. The last chapter will be the "Conclusion" chapter. Here, the research questions will be attempted to be answered. Recommendations and possibilities for future research will also be posed here.

2. Background

This chapter will present the theoretical background and framework of the methods and principles applied in this research. First, the principles behind bone functional adaptation and the way bones remodel will be discussed, followed by an in-depth overview of body mass estimation methods and how they make use of bone remodelling. In the sections on body mass estimation methods, the different types of methods will be discussed, as well as their origins, implementation in archaeological research, and their limitations. Examples will be given throughout the chapter to demonstrate the use of some of the mentioned concepts and research methods.

2.1 Body Mass and Bone Functional Adaptation

There are many factors that determine the body mass of an individual. One of them is that there needs to be a balance between energy intake and physical activity levels. When more energy is consumed than used, a positive energy balance will be the result. This will lead to an increase in body mass. Studies have demonstrated that modern obese people indeed have a higher energy intake than lean people. Factors that can cause differences in energy expenditure and energy intake are genetic factors and different activity patterns (de Castro, 1999, in Institute of Medicine, 2003, p. 69; Institute of Medicine, 2003, p. 69). Foods that result in a higher energy intake are high-fat foods as fat is more dense than other foods; the same quantity of lower-fat food would result in a lower energy intake and a less positive energy balance (Institute of Medicine, 2003, p. 69). However, excessive consumption of lower-fat food would still cause a positive energy balance.

Changes in body mass consequently lead to changes in mechanical loading on the body. The main idea is that bones respond to changes in mechanical loading through a certain feedback loop to regain its optimal strain level; if there is an increased strain (e.g., higher body mass), bone will be deposited to help withstand the strain. This will result in a decreased strain after which the optimum customary strain level is reached again. The same process will take place when the strain in decreased, only in the opposite way (Ruff et al., 2006, p. 485). This loop is illustrated in figure 1.

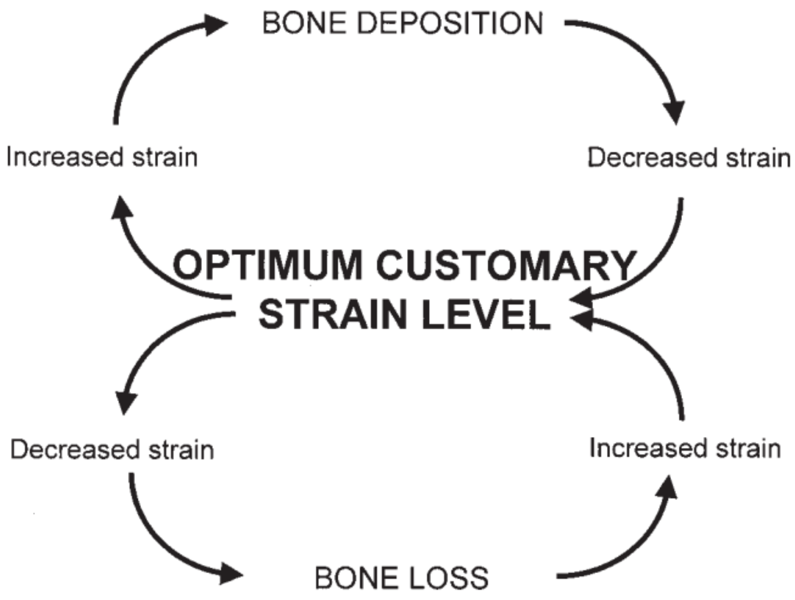

Figure 1 “Simple feedback model of bone function adaptation” (Lanyon, 1982 in Ruff et al. 2006, p. 485)

White and Folkens (2005) explain that “the reshaping, or remodelling of bones takes place at the cellular level” (p. 43). There are three cell types involved in creating and maintaining bone tissue: osteoblasts, osteocytes, and osteoclasts. Osteoblasts are the bone forming cells. Their role is to synthesize and deposit bone material. Osteocytes are in charge of maintaining the bone and they play a role in transporting nutrients. The osteoclasts’ role is the resorption (removal) of bone tissue. (White & Folkens, 2005, pp. 43, 46).

The principle described in figure 1 is often referred to as “bone functional adaptation”. The concept that mechanical loading influences living bone tissue over time, was originally often referred to as Wolff’s law. However, it is now generally agreed on that the term “bone functional adaptation” is more fitting (Cowin, 2001, pp. 30-31; Ruff et al., 2006, p. 485). Ruff et al. (2006) also includes the summarized writings of Roux (1881) by Roesler (1981) which states the following two important principles: “1) organisms possess the ability to adapt their structure to new living conditions, and 2) bone cells are capable of responding to local mechanical stresses.” (in Ruff et al., 2006, p. 485).

Bone functional adaptation is for example demonstrated in competitive tennis players for whom studies have shown that the rotational strength of the dominant playing arm is up to 70% greater than in their non-dominant arm (Stock, 2018, p. 1). Whereas on the other hand, when mechanical loading is reduced, for instance after a long period of bedrest or in space, bone will decrease (Gabel et al., 2022, pp. 1-2; Leblanc et al., 1990, p. 874).

2.2 Body Mass Estimation Methods

It has become clear from the previous section that strain and therefore body mass can influence bone morphology. This consequently means that body mass can be measurable in human skeletal material. Research on estimating body mass from skeletal elements has its origins in the late 1980s (e.g., McHenry, 1988 in McHenry, 1992; Ruff, 1987, 1988) and was further developed throughout the 1990s and continued to be improved in period after that. Most of these methods are formed by making use of regression analysis. With regression analysis, relationships between variables can be studied, in which an effect of one variable upon the other is estimated (Sykes, 1993, p. 1). This way, something that is seemingly unobservable will be justified by something that is observable (Konigsberg et al., 1998, p. 66).

The methods to estimate body mass can be subdivided in two main categories: “mechanical” methods and “morphological” methods (Auerbach & Ruff, 2004, p. 331). With the mechanical methods, it is assumed that there is a “functional association between a weight-bearing skeletal element and body mass” (Auerbach & Ruff, 2004, p. 331), in which the bones remodel as a direct result of the constrains put on the bones by the body mass of the individual (Lacoste Jeanson et al., 2017, p. 183.e2). The morphometric methods on the other hand, rely on the “direct reconstruction of body dimensions from preserved bone dimensions. The latter usually involve estimation of stature or body length, followed by estimation of body mass from stature, assuming some specified relationship between the two” (Ruff, 2002, p. 213).

Within these main categories, different methods developed. The most used methods make use of either the femoral head breadth (FHB) (Ruff et al., 1991; McHenry, 1992; Grine et al., 1995, Ruff et al., 2012), a combination of stature and bi-iliac breadth (STBIB) (Ruff, 1994; Ruff et al., 2005), or the estimated cortical area (CA) (Elliott et al., 2016). The FHB methods and CA method are mechanical methods, whereas the STBIB falls under the morphological methods (Lacoste Jeanson et al., 2017, pp. 183.e1-183.e2). This thesis applies the FHB method, as it can be applied to dry bone and only one bone is needed for the reconstruction of body mass.

2.2.1 Origins and Development of the Femoral Head Breadth Methods

As most of the body mass estimation methods, the three FHB methods currently most used were initially developed to estimate body mass in early hominids/ hominoid species. The benefit of using the femoral head, is that the femur is frequently available in the archaeological record (thanks to its sturdiness) and the measurements needed for the equations are simple to take and highly reproduceable (Auerbach & Ruff, 2004, p. 331).

To highlight the importance of knowing body mass of early hominids, McHenry (1992) mentions research done by Foley (1987) in which body size in early hominids has been related to variables “such as metabolic costs, mobility, thermoregulation, brain size, longevity, predator-prey relationship, home-range size, diet, foraging behaviour, and much else.” (p. 407). McHenry’s 1992 study aimed expand the “comparative dataset” in order to reassess body weight in early hominids. He did however also include a modern human sample. His dataset consists of equations for many skeletal elements, including the femoral head (p. 413).

The method by Grine et al. (1995) was created when miners found a mineralised femur in The Berg Aukas mine in 1991 (p. 152). In the 1995 paper, an attempt is made to determine to which species it belongs by comparing it to multiple early hominids. To determine its body mass, Grine et al. (1995) created an equation to use with the femoral head breadth, with the help of a reference sample of 10 large-bodied human samples (pp. 177-178).

Ruff et al. (1991) on the other hand, had a stronger focus on modern humans and used a sample of 80 living humans to improve Ruff’s (1988) hypothesis on skeletal changes trough mechanical loading (p. 397). Ruff (1988) aimed to investigate the relationship between hindlimb articular surface dimensions with body mass in both Hominoidea and Macaca as well as *Homo sapiens sapiens* samples (p. 687). The 1991 research by Ruff et al. led to sex- and race specific equations to estimate body mass in modern humans (p. 406).

In their 2012 paper, Ruff et al. aspired to create new, more accurate body mass estimation equations with the femoral head. For this study, a sample of 1145 individuals with a great variety in origins was accumulated. The improved equations were established after plotting the body mass, calculated by STBIB, to the femoral head breadth (Ruff et al., 2012, pp. 603, 608, 611). Because of the increased accuracy as a result of the large sample size, as well as the accessibility of the femoral head breadth measurements, this method is the best fit for this research. Therefore, it will be further discussed in the “methods” chapter.

2.3 Body Mass Research: Past and Present

Since the development of body mass research, these methods have been used extensively in a variety of research. As already touched upon in section 2.2.1, body mass research plays an important role in the study of human origins and evolution (see for instance Foley, 1987, in McHenry, 1992, p. 407; Ruff, 1997). Where in the latter, it has been used to compare body size to morphological changes such as when the increase in encephalization within *Homo* happened (Ruff, 1997, p. 173). This is only a small example of what body mass has been and can be used for within archaeology.

Furthermore, body mass reconstruction is also used outside of archaeology and paleo-anthropology. In the forensic field, body mass is important because it is not only part of the biological profile used in forensic anthropology where it can be used for human identification, it also influences decomposition processes (Baker & Newman, 1957, pp. 601-602; Byard, 2012, p. 403; Schaffer, 2016, p. 1431).

2.4 Limitations in Body Mass Estimation Methods

There are however also shortcomings within these methods as well as elements to be aware of. More recent evaluations showed that the currently available methods did not seem to be accurate enough to determine body mass on an individual level. Depending on the method, body mass might be over- or underestimated. It has furthermore proven to be difficult to differentiate between individuals with a normal BMI and people who are obese. Most methods do however estimate the sex-specific average on population level with good accuracy (Auerbach & Ruff, 2004, p. 335; Lacoste Jeanson et al., 2017, pp. 183.e5-183.e7). Therefore, these methods are reliable when saying something about a population on populational level and suitable for research like this thesis in which two populations are compared.

3. Materials and Methods

In this chapter, the methods and materials used in this research will be presented. In order to determine the difference in body mass between a post-medieval high-socioeconomic status (high SES) population and a low-socioeconomic status (low SES) population, two cases studies are used: one from Zwolle and one from Arnhem, respectively. The geographical locations of these sites can be seen in figure 2.

Figure 2 Geographical location Broerenkerk, Zwolle, and Eusebiuskerk, Arnhem (edited by Kroes, K., 2022, after www.openstreetmap.org)

3.1 Materials

3.1.1 The Broerenkerk in Zwolle

The high SES case study comes from the Broerenkerk in Zwolle (see figure 3). Excavations in the Broerenkerk took place from October 1987 up until February 1988. The reason for this excavation was that in the final phase of the restoration of the church, the existing tombstone floor and a layer of soil had to be removed for the installation of floor heating (Aten, 1992, p. 13).

Figure 3 Location of the Broerenkerk in Zwolle (edited by Kroes, K., 2022, after www.openstreetmap.org)

The Broerenkerk originates as a monastery which was founded in 1465 by the Congregatio Hollandiae of the Dominican order. The church knows three building phases and the first burial in the church took place in 1475 (Aten, 1992, pp. 13-14). Even though burials took place in the Broerenkerk right from the start, in the first period of use the convent must have been small and it is unlikely that the choir was used regularly for burials (Aten, 1992, p. 15).

The church has a turbulent history. In the 1570s, the Spanish phases of occupation of the city of Zwolle, led to damaging of the church (Aten, 1992, p. 15). In 1580, the monks were permanently driven out of the city and the Broerenkerk was partly sold and rented (Aten, 1992, p. 15). The next renovation of the church took place between 1639 and 1641 when the Reformed Church wanted to occupy the Broerenkerk after it had seriously fallen into disrepair (Aten, 1992, p. 15). Despite all this, burials still took place in the church in the period between 1580 and 1680 (van Mierlo & Streng, 1989, in Aten, 1992, p. 15). However, probably to a small extent. Since 1982, the Broerenkerk has been in the possession of the municipality of Zwolle and has been used for various purposes for a long time. In 2013, the church was transformed and given a new purpose as a bookshop, which is still is today (Van der Velde Boeken, 2023, para. 1).

During this excavation, 168 burials were studied. Ninety-seven of them were completely excavated. In total, the skeletal remains, or partial remains from 529 individuals were recovered, which were either completely or partially in anatomical context. In addition, an estimated 500 individuals that were not in anatomical context, were recovered as well (Aten, 1992, pp. 21-22).

The dating of the graves was done on the basis of the stratigraphy, the grave goods, and historical data. Throughout the entire church, a homogeneous brownish-yellow sand pack was uncovered in which all skeletal remains were found to be buried conform the most recently used grave pattern. It is likely that the sand pack, and thus the graves, date from after the Reformation as it is only interrupted by the choir screen and does not take into account other fixed inventory features. Coin finds have provided a more accurate date for the sand packet, which must have been deposited in the last quarter of the 17th century or the first quarter of the 18th century. The last burials in the Broerenkerk can be determined from the burial register for the period December 1819 to December 1828, with the last person being buried in the church on 31 December 1828 (Aten, 1992, pp. 23-24).

Because of this register, 141 individuals in 114 graves could be identified. It is certain that these individuals were buried in the above-mentioned period. The other burials in anatomical context were also grouped in one category, dating from before December 1819. It is most likely that they date from the last part of the 18th century and the first part of the 19th century, but in any case not older than the last quarter of the 17th century (Aten, 1992, pp. 28-29).

Due to notes of sacristans and the burial register, there is a good idea of the social status of those buried in the Broerenkerk. In both the 18th and 19th centuries, a large number of craftsmen were buried in the church, as well as sailors, and individuals of the lower military ranks; it was mainly the middle class that was buried here. These were the people who were wealthy enough to buy a grave inside of the church, but not wealthy enough to buy a grave in the “Grote Kerk” of Zwolle, where the upper bourgeoisie and the elite were buried (Aten, 1992, p. 77; Hagedoorn, 1992, pp. 42-43).

3.1.2 The Eusebiuskerk in Arnhem

The low SES population case study originates from the Eusebiuskerk in Arnhem (see figure 4). The excavation of the cemetery of the Eusebiuskerk in Arnhem took place from February up until September 2017 and was carried out by RAAP. The excavation was necessary because of the reconstruction of the historic "Sint-Jansbeek" (a watercourse) and the renovation of the sewage system (Baetsen et al., 2018, p. 36; Zielman & Baetsen, 2021, p. 3).

Figure 4 Location of the Eusebiuskerk in Arnhem (edited by Kroes, K., 2022, after www.openstreetmap.org)

It is suspected that people were buried at the cemetery of the Eusebiuskerk as early as the late 14th century. Already in 1444 this cemetery was given the name "het Oude Kerkhof" (Markus, 1908, in Zielman & Baetsen, 2021, p. 110; Zielman & Baetsen, 2021, p. 110). The archaeological record shows that somewhere after 1636, the cemetery was cleared and then reoccupied up until 1828 when by Royal Decree, burials were not allowed to take place inside the city anymore (Zielman & Baetsen, 2021, p. 110).

The former cemetery must have had a total surface area of 0.36 ha in 1821 and during the excavation in 2017, primary graves were found at three locations with a total of 630 primary burials (Zielman & Baetsen, 2021, p. 83). The cemetery of the Eusebiuskerk was used very intensively, with an average of 3.9 graves per square meter (Zielman & Baetsen, 2021, p. 84) and no clear raster of burials or uniform depths; some parts contain up to ten layers of inhumation graves. Furthermore, many graves cut each other (Baetsen et al., 2018, p. 39). Most relevant for this thesis are the 621 graves at the east end of Kerkstraat (WP10) (Zielman & Baetsen, 2021, p. 83), north of the church.

There are strong indications that the individuals in this northern part of the cemetery belonged to the less wealthy. The northern side is also called the cold side and was not favoured by religious people. This has several explanations; the north side of the church receives less sunlight, but there is also the biblical notion that the northern door of the church stood for heathens, sinners and plagues (Alberdink-Thijm, 1858, in Baetsen et al., 2018, p. 38). That the poor in Arnhem were also buried in the northern part of the cemetery is supported by the "*kerkhofoproeren*" (cemetery riots) of the 18th century in which there were protests against having to take into use a new cemetery for the poor outside the city instead of near the Eusebiuskerk (Zielman & Baetsen, 2021, p. 669). There is also documentation that the Eusebiuskerk contributed to the burial of individuals who could not pay for it themselves, in other words, from the diaconate (Gelders Archief, 2000, in Zielman & Baetsen, 2021, p. 668).

The precise dating and identification of the graves has proven challenging. Archive research has not yielded any documents with location indications of the graves. However, there are burial books that have been handed down which state who was buried and when, but they do not include the location of said grave. With a combination of some 14C-dating and find dating, the graves in WP10 have been periodised in the horizontal plane, dividing them into two time periods: graves from before 1650 and graves from after 1650 (Zielman & Baetsen, 2021, pp. 94-95, 99, 101). For this thesis, the graves from 1650 are relevant as this falls into the post-medieval period.

3.1.3 Sample

The method of how the samples were selected will be discussed in the forthcoming section. In both samples, probable males and probable females were included as males and females in order to perform relevant statistical analysis on the samples.

The first selection of the individuals was done by studying the skeletal forms present at the Osteological Laboratory at the Faculty of Archaeology in Leiden. On these forms, the completeness, sex, and age of each individual is listed. The individuals were selected on the following requirements: there needed to be at least one intact femoral head, the sex had to be (probable) male or (probable) female, and the individual had to be an adult (18+). the individuals who met these criteria were noted down in an excel sheet, per site, with their corresponding box-, feature-, and/or find number.

The second selection took place with the actual skeletal material. The boxes were retrieved from the depot at the Faculty of Archaeology in Leiden and the femoral heads were inspected on completeness and whether there were no pathologies that altered the femoral head, such as osteoarthritis.

For Zwolle, a sample of 46 individuals was selected, consisting of 25 males and 21 females.

For Arnhem, a total sample of 49 individuals was selected, which contains 23 males and 26 females.

3.2 Methods

3.2.1 Sex Estimation

Because the differences between high SES males and low SES males, and between high SES females and low SES females will be studied in this thesis, it is necessary to know the sex of each individual.

There are different methods to estimate the sex of an individual and they are based on the notion that there are skeletal differences between males and females. Generally speaking, female skeletal elements are characterised as smaller in size and with lighter construction, whereas males are typically considered to have larger and more robust elements. This estimation is most accurate when the individual has reached maturity (White & Folkens, 2005, pp. 385-386).

For both the Zwolle collection as the Arnhem collection, the estimation of sex had already been completed and noted on the skeletal forms present at the Faculty of Architecture, Leiden. The following paragraphs will give a short overview of the methods used for their estimations.

Both sites use both cranial and post-cranial elements to estimate sex, as established by the Workshop of European Anthropologists (WEA) in their 1980 publication. These elements are then given a score between -2 and +2, in which -2 is female, -1 is probable female, 0 is indifferent (neutral/indeterminate), 1 is probable male, and 2 is male (Rösing et al., 1980, p. 521).

As not all features are deemed equally sexually dimorphic, the features are weighted. When all features are scored, a calculation is done to determine the sexualisation rate which will be a score between -2 and +2. A negative score would then mean female and a positive score male (Aten, 1992, p. 69). Zielman and Baetsen (2021) summarised this in more detail, which can be seen in table 2.

Table 2 Sexualisation rate with corresponding sex determination (after Zielman & Baetsen, 2021, p. 362)

Score-interval	Sex estimation (code)
-2 to -1,001	Female (F)
-1 to -0,251	Probable Female (PF)
-0,25 to +0,249	Indeterminate (I)

+0,25 to +0,999	Probable Male (PM)
+1 to +2	Male (M)

There is also a difference in reliability between the cranial and postcranial elements. One of the most reliable skeletal elements to determine sex is the pelvis. This is due to the difference in function of the pelvis between males and females, as females often have a wider pelvis fit for childbirth (Aten, 1992, p. 68; Zielman & Baetsen, 2021, p. 361).

Sex of the Zwolle and Arnhem individuals was also estimated based on measurements. For Zwolle, several dimensions of the long bones were measured (as described by Dittrick and Suchey, 1986, in Aten, 1992, p. 70) and compared to the population standard of this site. The population standard was created first for this research by using measurements of individuals whose sex was known with certainty (Aten, 1992, pp. 70-71). Zielman and Baetsen (2021) applied the measurements as specified in Ubelaker (1999) to their population (p. 363).

Lastly, for both sites, the method by Phenice (1969) was also applied. These so-called "Phenice Traits" are comprised of three elements of the pelvis: the medial aspect of the ischiopubic ramen, the ventral arc and the sub-pubic concavity, that are either present or absent. Their presence of absence is the differentiating factor between female or male, respectively (Phenice, 1969, p, 298; Zielman & Baetsen, 2021, p. 363). This method has proven to be very accurate, with rates between 96% - 100% (White and Folkens, 2005, p. 398).

3.2.2 Femoral Head Breadth Method

The method used in this thesis uses the femoral head breadth (FHB) and was developed by Ruff et al. (2012). As mentioned in section 2.2, this is a "mechanical" method which assumes a functional relationship between the femoral head breadth and mechanical loading (body mass in this case). Ruff et al. (2012) aimed to develop new body mass equations by using a sample of 1145 individuals from all across Europe and dating from the Mesolithic up until the 19th century. They argue that this would lead to equations that can be applied to a wider range of European Holocene adult skeletal samples (p. 603).

To establish these new equations, body mass was first established by using the stature and bi-iliac breadth method (STBIB) (Ruff, 2005, p. 387). Then, these body masses were plotted against the superoinferior breadth of the femoral head (Ruff et al., 2012, pp. 605, 608).

This lead to the following equations (Ruff et al. 2012, p. 611):

Female equation: $2.18 * FHB - 35.8$ = body mass in kg

Male equation: $2.80 * FHB - 66.7$ = body mass in kg

Combined equation (males and females): $2.30 * FHB - 41.72$ = body mass in kg

It is important to note that equations are normally associated with a standard deviation. However, as these are not included in the paper by Ruff et al. (2012), it was not possible to apply a standard deviation to the data in this thesis.

For this research, it is relevant to analyse the difference in body mass between the males of both SES and the females of both SES separately (between sites). Therefore, the division between male and female is made and the corresponding equations will be used.

The measurements for this research are taken as the superoinferior breadth of the femoral head. The location of this measurement is shown in figure 5. When taking the measurements, a digital sliding calliper is used with an accuracy of one decimal. If present, the measurements of both femoral heads were taken. The measurement data was documented in a new excel sheet, with again the corresponding box-, feature-, and/or find number, the sex and age group of the individuals, plus the measurement data of the left and/or right femoral head, and when necessary comments. The data of both sites was stored separately. A list of selected individuals with their corresponding FHB can be found in appendix 1 (Zwolle) and appendix 2 (Arnhem). After taking all the measurements, the data was split per site on sex after which the sex-specific equations were applied.

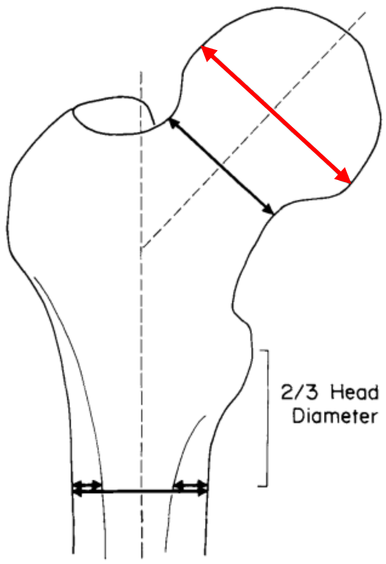

Figure 5 Location of where the measurements should be taken, indicated by the red line (after Ruff et al., 1991, p. 400)

3.2.3 Statistical Analysis

To determine whether there are significant differences in body mass between the high SES population and the low SES population, the data has been subjected to statistical analyses. These analyses will be done by using IBM SPSS 28 for windows. This will include descriptive statistics as well as inferential statistics.

Part of the data is nominal: male or female, and site/socioeconomic status (Zwolle/high SES or Arnhem/low SES). The femoral head breadth and body mass, on the other hand, are numerical values.

First, a demographic overview of both sites will be given. This will consist of descriptive statistics and the chi-square test for goodness-of-fit will be applied to determine whether there is an equal representation of the independent variables.

Secondly, the body mass data will be tested to determine whether the data for both the left and the right femur are normally distributed per site and per sex. For this, a Shapiro-Wilk test is used. This method is more fit for smaller sample sizes ($n < 50$). A p-value over 0.05 means the data is normally distributed (Statistisch Handboek Studiedata, 2021, para. 4.3.2). When the data is normally distributed, the independent T-test will be used to determine whether there is a significant difference between the groups. If the data is not normally distributed, the Mann-Whitney U-test will be used. The difference will be considered significant when the p-value is equal to, or lower than 0.05. If there is no significant difference between the femurs; the left and right femur will be combined to increase the sample size. The N-value will then stand for the amount of femoral heads, and not for individuals anymore. Then, the same steps will be applied to the measurement data to determine whether there is a significant difference between the samples on a site and sex-level, as well as inter-sample comparisons. Univariate analyses will be used to demonstrate the inter-sample relations.

When using inferential statistics, the following comparisons will be included:

- Comparison in body mass between the males from Zwolle and the males from Arnhem

- Comparison in body mass between the females from Zwolle and the females from Arnhem

The results will be presented with descriptive statistics such as tables, graphs, and boxplots. This way, the data can be clearly compared.

4. Results

In this chapter, the sample will be presented for both sites. Both the equalness of variation and several normality tests will be performed. Also, the make-up and general statistics of each site will be shown. Then follows the inter-sex comparisons in which the body mass (BM) data will be compared per sex, after which a univariate analysis will present the relations between the sexes. This chapter will end with a short summary of the findings.

4.1 Zwolle

The high SES sample, Zwolle, consists of 25 males and 21 females (see figure 6), with a total of 46 individuals. The chi-square test for goodness-of-fit showed that both variables are equally represented in this sample (χ^2 = 0.348, df=1, p= 0.555, N=46).

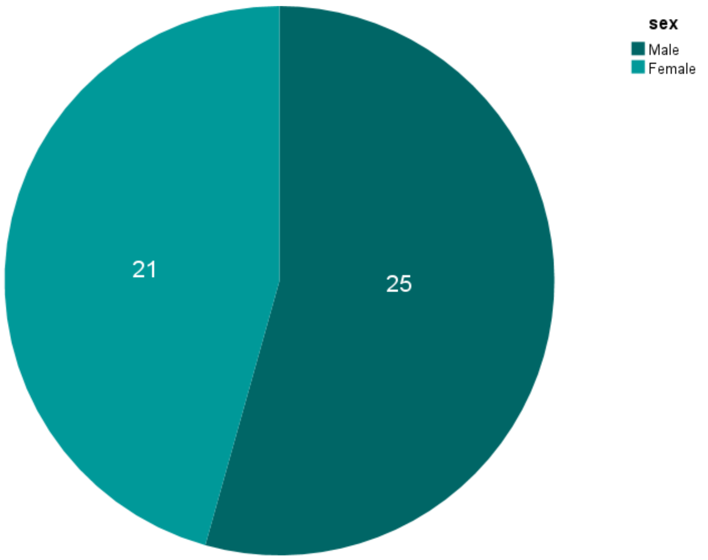

Figure 6 Pie chart with the sum of the males and the females in the Zwolle, high SES sample

To investigate how the data can be analysed, the distribution of the data is assessed. As can be seen in table 3, the BM data, for both males and females on both sides, is normally distributed.

Table 3 Normality test and mean BM for the Zwolle sample

Sex	Side Femur	N	Mean BM in kg	Normality
Male	L	24	66.0 ± 7.9	W=0.956, df=24, p=0.364
	R	21	67.8 ± 8.3	W=0.949, df=21, p=0.329
Female	L	18	57.1 ± 6.1	W=0,975, df=18, p=0.886
	R	18	57.4 ± 4.6	W=0.920, df=18, p=0.129

When comparing the BM data for the left and the right femur with an independent-sample T-test, it becomes clear that there is no significant difference for either the males or the females (see table 4). Therefore, the BM estimations following from the measurement data of both the right and the left femur, when available, will be used for the subsequent analyses of the high SES sample. Furthermore, the N-value will stand for the number of femoral heads in the further analysis of this sample.

Table 4 Results of the independent-samples T-test comparing the BM for the left and right femur by sex, of the Zwolle sample

Sex	N	Type	T-test
Male	45	BM	t=0.735, df=43 p=0.466
Female	36	BM	t=0.187, df=34, p=0.853

Re-analysing the normality of the distribution of this combined sample group with both the left and the right femur, per sex, shows that there is still a normal distribution (see table 5). Therefore, parametric tests can be used when processing the high SES sample set further.

Table 5 Results of the Shapiro-Wilk test for normality within the Zwolle sample

Sex	N	Type	Normality
Male	45	BM	W=0.959, df=45, p=0.113
Female	36	BM	W=0.963, df=36, p=0.268

As is shown in figure 7, the mean BM of the Zwolle males is 66.9 ± 8.1 kg, whereas the mean BM of the females is 57.3 ± 5.3 kg. As expected, this is a statistically significant difference (t=6.145, df=79, p=<0.001).

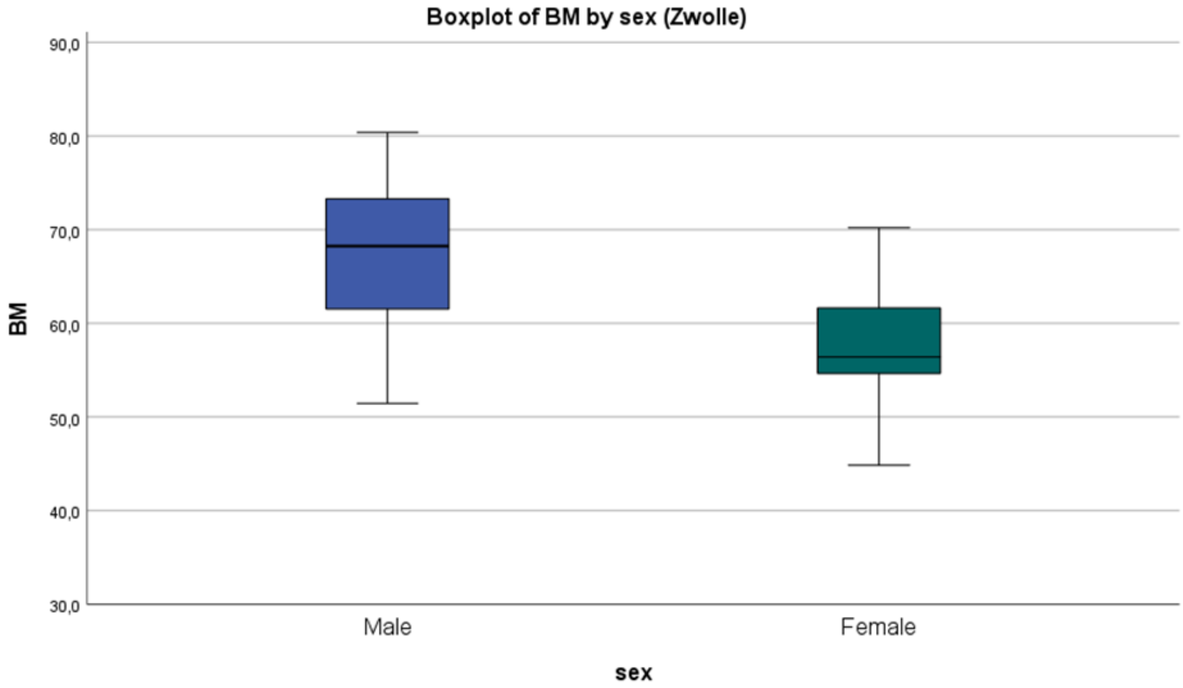

Figure 7 Boxplot with the mean BM (in kg) of the Zwolle males and females

4.2 Arnhem

For Arnhem, the low SES sample, the total sample contains 49 individuals of which 23 males and 26 females. This is visualised in figure 8. The chi-square test for goodness-of-fit shows that both variables are equally represented in this sample (χ^2 = 0.184, df=1, p=0.668, N=49).

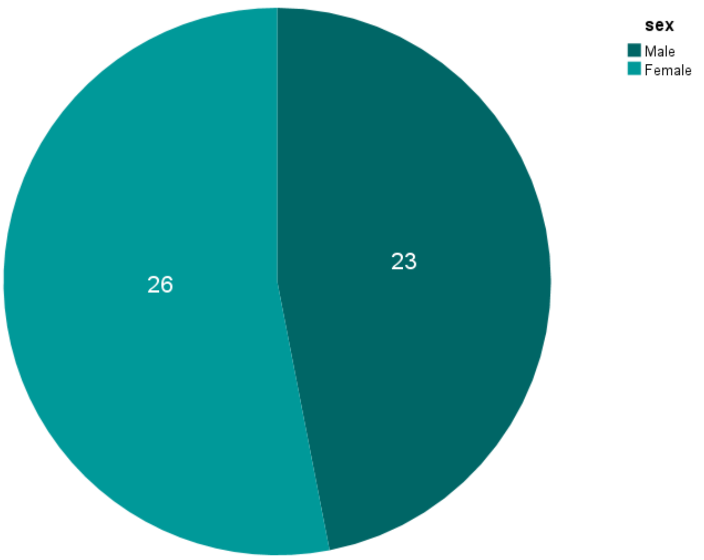

Figure 8 Pie chart with the sum of the males and the females in the Arnhem, low SES sample

Table 6 shows that the data for both the left and the right femur is normally distributed. Applying the independent-sample T-test demonstrates that there is no significant difference between estimations of the left and the right femur (see table 7). This means that for the analyses of the low SES sample, the data of both femurs will be used and the data sets will include both femurs when available. Consequently, the N-value will be the amount of femoral heads. And, male and female will be used when speaking about the male femurs and female femurs respectively.

Table 6 Results of the Shapiro Wilk test for normality, and mean BM for the Arnhem sample per side

Sex	Side Femur	N	Mean BM in kg	Normality
Male	L	20	70.0 ± 4.9	W=0.970, df=20, p=0.745
	R	19	70.4 ± 6.3	W=0.925, df=19, p=0.140
Female	L	22	57.0 ± 4.3	W=0,958, df=22, p=0,455
	R	22	57.6 ± 4.7	W=0.946, df=22, p=0.265

Table 7 Results of the Independent-Samples T-test per sex , for the BM of the Arnhem sample

Sex	N	Type	T-test
Male	39	BM	t=0.222, p=0.826, N=39
Female	44	BM	t=0.45, p=0.655, N=44

A second test for normality was executed and both the male as the female samples are still normally distributed when the data for the left and the right femurs is combined (see in table 8). As a result, parametric testing can be run to further analyse this sample.

Table 8 Results of the Shapiro Wilk test for normality per sex and side, for the Arnhem sample

Sex	N	Type	Normality
Male	39	BM	W=0.957, df=39, p=0.139
Female	44	BM	W=0.950, df=44, p=0.054

When studying the mean BM of the low SES sample (see figure 9). The mean BM for the males is 70.2 ± 5.6 kg and for females the mean BM is 57.3 ± 4.5 kg. As expected, this is a statistically significant difference (t=11.696, df= 81, p=<0.001).

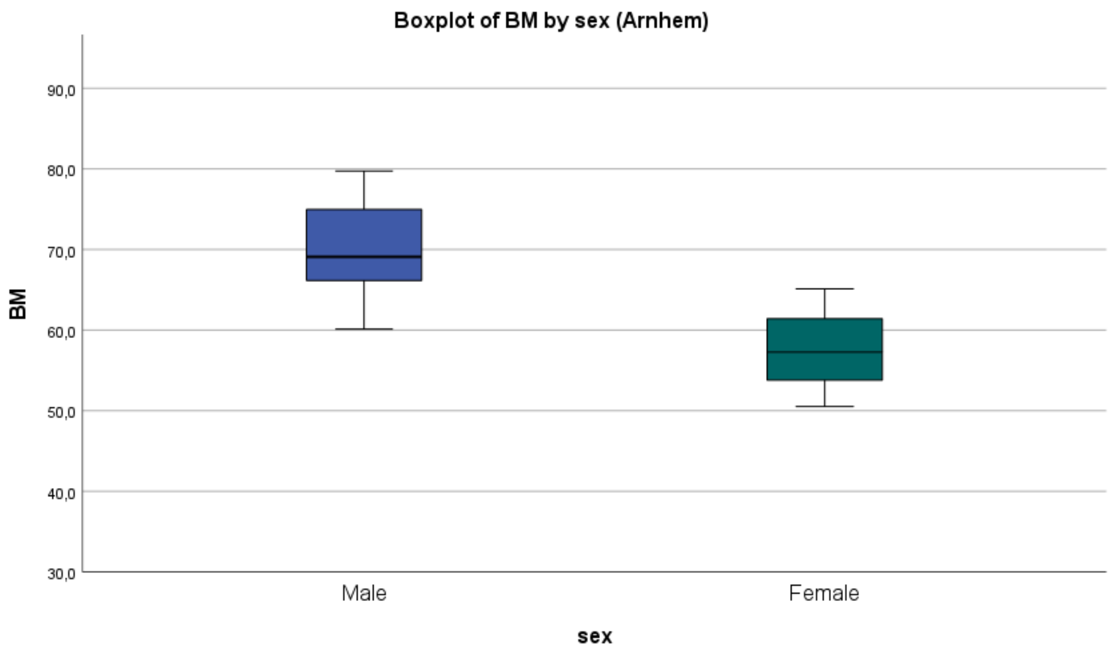

Figure 9 Boxplot of the mean BM in kg of the Arnhem males and females

4.3 Site Comparisons

In the following section, the sites will be compared. As the previous sections indicated clear differences between males and females, the sexes will be analysed separately. With these comparisons, the differences in mean body mass between the two status groups will be observable per sex.

The comparisons between the males will be covered first. When comparing the average BM of the high SES males (N=45) with the low SES males (N=39), it becomes clear that the low SES males from Arnhem have a higher estimated body mass (70.2 ± 5.6 kg) than the high SES male sample from Zwolle (66.9 ± 8.1 kg). There is a mean difference of 3.3 kg. This is visualised in figure 10. The independent-samples T-test indicates that this is a statistically significant difference between the two data sets (t=2.157, df=82, p=0.034).

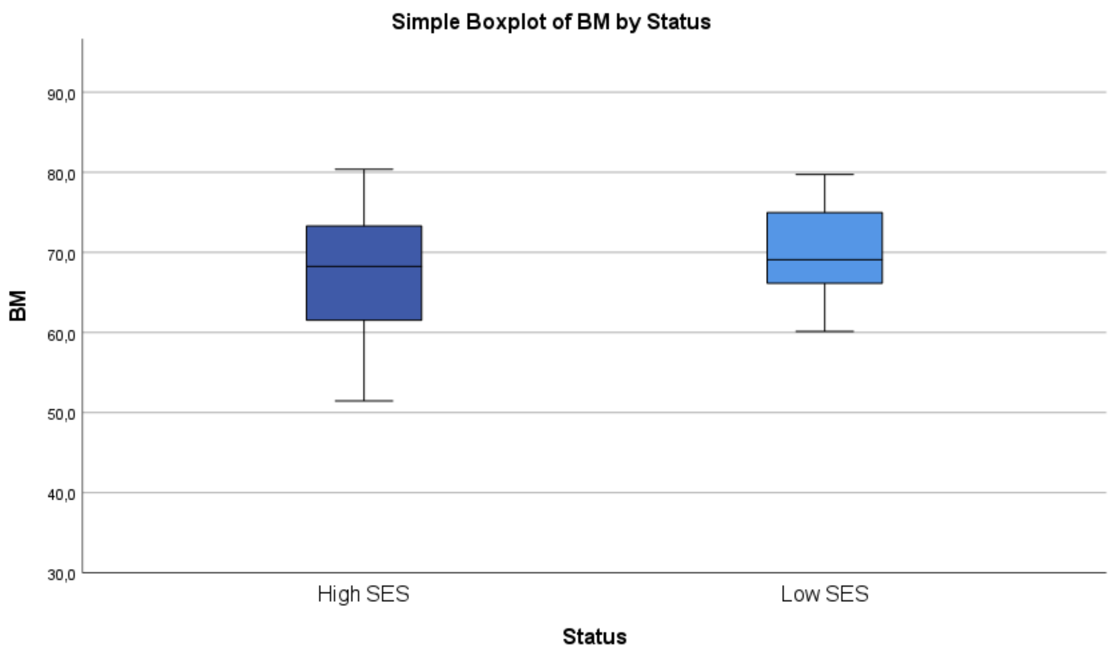

Figure 10 Boxplots of the mean BM in kg per SES group, for the male sample

Next, the results of the female analyses will be presented. The mean BM of both samples is visualised in figure 11. There is just a minimal difference in BM between the high SES females and the low SES females of 0.05 kg. The low SES females have a slightly larger BM, but as the independent-samples T-test confirms, this is not a statistically significant difference (t=0.046, df=78, p=0.963).

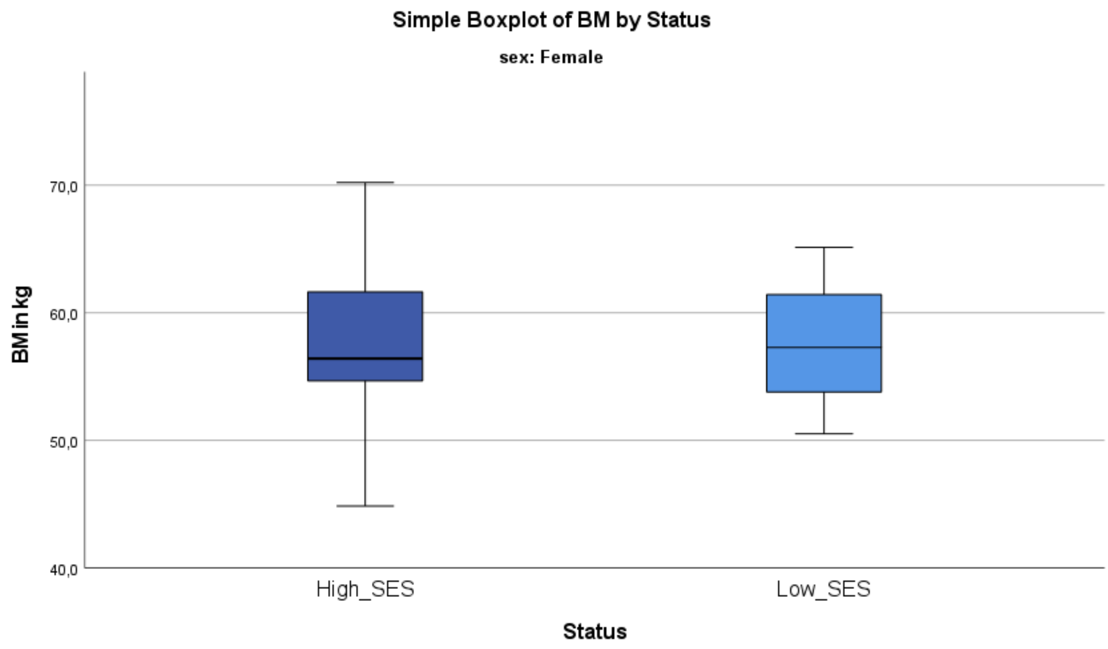

Figure 11 Boxplots of the mean BM in kg per SES group, for the female sample

When comparing the difference in the female samples to the difference in the male samples (see figure 12), the analysis shows an increased difference in BM; the males differ more in BM compared to each other than the females, as the lines in figure 12 do not run parallel to each other.

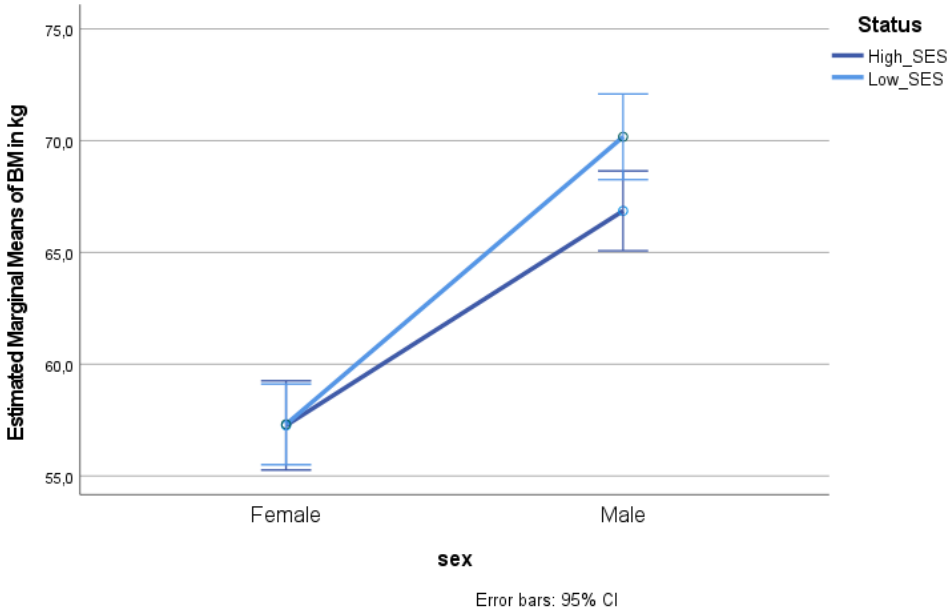

Figure 12 Univariate analysis of mean BM with error bars, inter-status and inter-sex comparison

4.4 Summary

The analyses showed that in all cases, the low SES sample has a higher mean BM than the low SES sample, but only for the male sample this is a statistically significant difference. Between the female samples and the combined sample, the differences are minimal and therefore not statistically significant.

5. Discussion

In this chapter, the results of the statistical analyses will be discussed. The aim of this thesis was to study to what extent body mass correlates with socioeconomic status by comparing a population with a high socioeconomic status (SES) with a population with a low socioeconomic status. As was demonstrated in the previous chapter, the general tendence in the data is that the low SES sample has a higher mean BM than the high SES sample. However, only between the males this difference is statistically significant.

The following sections will discuss the abovementioned trends in more detail. Possible causes for the differences between the samples will be presented. Implications of the limitations in the data and the methods will also be discussed.

Before the data will be further discussed, there is an important side note when discussing gender; sex ≠ gender. The archaeological skeletal record can only say something about the biological sex of an individual, but not about how someone identified or was perceived in the society they lived in. However, for this discussion, it is assumed that the individuals identified as their biological sex and that they were influenced by the general gender division of the post-medieval society.

5.1 Male Sample

First, the analytical results of the male sample will be discussed. The data from the statistical analyses in chapter 4 shows a statistically significant difference in mean body mass (BM) between the high SES male sample from Zwolle and the low SES sample from Arnhem. The low SES males from Arnhem have a mean estimated body mass of 70.2 ± 5.6 kg whereas for the high SES males from Zwolle, the mean estimated body mass is 66.9 ± 8.1 kg. Interestingly, this means that the low SES male sample has a mean body mass which is 3.3 kg higher than the mean body mass of the high SES male sample.

One of the explanations for this difference may lie in the dissimilar diets consumed between the two social groups. As described in chapter 1.2, individuals with a higher SES were able to consume a more extensive and varied diet, opposed to low SES individuals who were dependent on a more limited diet in terms of foodstuffs available and the quantity in which they were to consume certain foods. The low SES diet in the post-medieval Netherlands did however contain more high-calorie foods such as potatoes which were eaten in the majority of the meals (Jobse-van-Putten, 1995, pp. 104-106; Bakker, 1992, p. 41). A difference in consumed foods between high- and low SES males is not unique to this sample; another site where this seems to be the case, is the medieval population of Trino Vercellese. Dental microwear analysis and stable isotope analysis show that low SES males consumed a diet different from contemporary high SES males. The low SES males show a significantly bigger intake of millet and a smaller intake of animal proteins (Reitsema & Vercellotti, 2012, p. 597; Smith et al., 2019, p. 4790). Furthermore, there may not only have been a difference in the types of foods consumed, but also the availability and access to the foodstuff in the household may have contributed to the difference in body mass between the males from Zwolle and Arnhem. Smith et al. (2019) argue that because males have a higher rank in the household, they would therefore have more access to food (p. 4796). So, even though the males from Arnhem had a more monotonous diet, it is possible that they had a more unrestricted access to the high-caloric foods that are often ascribed to this social group. This in contrast to the high SES males who might have had the same access to food, but consumed a less calorie-dense and more varied diet. This would then lead to a larger increase in body mass for the low SES males in comparison to the high SES males which is in line with the results.

Additionally, there are other factors along with diet that can explain why the Arnhem males have a higher mean BM than the Zwolle males. For instance, the influence of occupation and level of labour. As body mass is made up of both body fat and lean mass (such as muscles) (Pomeroy et al., 2018, p. 56), the level of physical labour plays a role.

It is known that the lowest social classes were employed in labour intensive jobs, if they were employed at all. For the low SES males, jobs known to have been performed by people throughout the whole working class might be relevant to consider. The poorest people were beggars, vagabonds and others not steadily employed individuals. Slightly above them were petty traders who carried around a borrowed wheelbarrow each day to earn some money. But also domestic servants, sailors, soldiers and un-/ semi-skilled workers employed specialised industries (de Vries & van der Woude, 1997, pp. 561-562). It can be assumed that these employees were subject to significant psychical labour, with working days of twelve hours or more (de Pleijt & van Zanden, 2021, p. 634) requiring and leading to increased muscle mass. As mentioned in the preceding paragraph, this would explain a higher body mass.

Through documentation from sextons, more is known about the specific occupations that the individuals in the Broerenkerk fulfilled. Most were craftsmen and artisans, such as bakers, smiths, peat carriers, and carpenters, but also skippers and lower ranked military people, as well as teachers, preachers and doctors; a varied selection. It can be assumed that these professions required some physical labour, but not to the extent of the industries that the poor had to work in (Hagedoorn, 1992, p. 43). Therefore, the high SES males from Zwolle are expected to have a smaller muscle mass than the labourers from Arnhem and subsequently a lower body mass. Furthermore, as becomes clear from the introduction chapter as well as this section, the middle class can be characterised as a bit of a hodgepodge. As the middle class contains a variety of people employed in a subsequent wide range of occupations, this can explain why the mean body mass of the Zwolle males had a much wider range than that of the Arnhem males.

Furthermore, when looking at the method by Ruff et al. (2012), it is argued that the male equation does estimate body mass within acceptable limits (Elliot et al., 2016, p. 695). Femoral head breadth in males seems to respond rather closely to changes in body mass. Therefore, it is likely that the obtained data is representative for the mean body mass of the male samples and that the observed differences are a result of differences in diet and/or occupation and lifestyle.

So summarising, the low SES male sample from Arnhem having a higher mean body mass than the high SES male sample from Zwolle can be explained through the diets and occupations of the respective sample groups. The males from Arnhem could have had more access to the high-calorie foods associated with this social group because of their role in the household. The males from Zwolle would also have had similar access to food, but their varied diet was likely less calorie dense. Eventually this would mean that the low SES males had a more positive energy balance than the high SES males resulting in having a higher mean body mass. Furthermore, it can be expected that the heavy, physical labour of the low SES males led to a higher muscle mass. Although some of the professions known from Zwolle do ask for physical efforts, it does not compare to the twelve-hour, or more, working days of the unskilled labourers, explaining why the Arnhem male sample has a higher mean body mass than the Zwolle male sample. The variety of occupations in the Zwolle sample can explain why the range in mean body mass is larger compared to the Arnhem sample.

5.2 Female Sample

This section will discuss the results of the statistical analyses of the female samples. From the analyses, it has become clear that there is no statistically significant difference in mean body mass between the high- and low socioeconomic status (SES) females. The low SES female sample has a mean body mass of 57.31 ± 4.45 kg. The high SES female sample has a mean body mass of 57.26 ± 5.32 kg. Thus, the two female samples have an almost identical mean body mass.

There not being a difference in mean body mass between the high SES- and lows SES females could indicate that there was no difference in diet between these groups. This has also been observed at the site of Trino Vercellese where stable isotope analysis did not show a difference in diet between high SES- and low SES females. Their diet was also interpreted as more stable and consistent than that of their male counterparts (Reitsema & Vercellotti, 2012, pp. 597-598). Reitsema and Vercellotti (2012) argue that as women had roles in food preparation within the household, this may have granted them access to a larger range in foodstuffs as their routine was inside the home (p. 598).

Sociological research supports the notion of gender differentiation within households. However, according to Delphy (1979, in Beardsworth & Keil, 1997), women had a “duty to provide the best food for others” (p. 78) and therefore would consume only little of what they prepared food-wise. Being a woman can thus be considered as having a disadvantage when it comes to nutrition and food consumption (Beardsworth & Keil, 1997, p. 78; Delphy, 1979, in Beardsworth & Keil, 1997, p. 78).

Whether the female samples of Arnhem and Zwolle consumed a similar diet is difficult to say as no difference in mean body mass could also mean that there was no difference in consumed calories. As described in chapter 1.2, high SES and low SES individuals had access to different foodstuffs and the diet of low SES individuals in the Netherlands consisted of more energy dense foods (Jobse-van-Putten, 1995, pp. 104-106; Bakker, 1992, p. 41). Assuming that the high SES households generally had more to spend on more and better food than the low status households, this could mean that despite women having less access to food within the household, the high SES females were able to eat comparatively more than the low SES females. Due to the difference in calories between the diets, it is possible that both female samples consumed approximately the same number of calories and therefore had an almost equal average body mass. Thus, no difference in mean body mass does not necessarily implicate comparable diets regarding foods consumed, but it could be indicative of similar amounts of calories ingested.

Besides diet, differences in labour could have had an effect on the mean body mass of the two female samples as well. As for the male sample, the female body mass is made up of body fat and muscles (Pomeroy et al., 2018, p. 56). Although not much has been recorded on the contribution of women to the workforce, it seems that most housework was mostly done by women, both in the home and in institutions. Also, in the trade-sector, there were opportunities for women (de Vries & van der Woude, 1997, pp. 596, 601; Schmidt, 2005, p. 8). However, women also participated in heavy, dirty jobs in which physical labour and poor working conditions can be expected to some extend; it seems that women did the subsidiary tasks while their men fulfilled the core tasks when employed as unskilled workers in the industries (de Vries & van der Woude, 1997, pp. 596-597). Marriage also played a role in the employment of women. De Vries and van der Woude (1997) state that when married, the husband would gain guardianship of his wide and control her property (p. 598). In practise however, when the husband did not object, women could continue to work. On the other hand, in absence of a husband, women had to work (de Vries & van der Woude, 1997, p. 599; Schmidt, 2005, p. 5).

As this research did not find a significant difference in BM between the female samples, it is possible that the females in both samples performed similar tasks in for example housework. The social difference between the two female samples might thus allow for the interpretation that the type of work they were employed in would result in similar strain on the body, subsequently leading to a similar muscle- and body mass. But it is difficult to confirm the actual occupations of both the high SES as low SES women.

However, the body mass estimation equations for females are associated with some limitations. Research by Elliot et al. (2016, pp. 691, 699) applied the different BM estimation methods to a sample for which the body masses were known to compare the different methods. They report that none of the current methods predicts female body mass accurately (enough), thus this is also the case for the method by Ruff et al. (2012) applied in this research. Furthermore, according to Elliot et al. (2016), there is a less extensive relationship between FHB and BM in females than in males (p. 701). This is attributed to females having relatively more adipose tissue and less muscle mass in comparison to males. Weight in females also tends to fluctuate more and is distributed differently across the body (Power & Schulkin, 2008, in Elliot et al., 2016, p. 701; Shen et al., 2004, in Elliot et al., 2016, p. 701). As a result, the relationship between the FHB and BM might not be as tight. However, as Ruff et al. (2012) was developed from sex-specific groups, it should have performed better (Elliot et al., 2016, p. 701). Therefore, it should be taken into account that the body mass estimates for females might not accurately represent their actual body mass when alive. And, when the femoral head is less responsive to changes in BM in females, this could also be an explanation for the statistically insignificant difference between the females.

In conclusion, there was no statistically significant difference in mean body mass between the high SES females and the low SES females. This can be attributed to there being no difference in diet between the two samples, or perhaps more accurately, there not being a difference in consumed calories. Because of their similar roles in the household, both female sample groups would have limited, but similar, access to the foodstuffs in their homes. As the high SES females would generally have access to more food and the low SES females to more calorie dense foods, bottom line this would result in similar mean body mass between two groups. Furthermore, as the females from both samples were most likely mainly employed in, or assigned with, similar tasks inside the house, it is probable that because of these equal tasks, there will also have been little difference in muscle composition between these groups. Lastly, a less extensive relationship between body mass and femoral head breadth and methodological limitations could explain why there was no statistically significant difference in mean body mass between the two female samples.

5.3 Methodological Limitations

The abovementioned sections demonstrate how diet and occupation would have caused differences in body mass, or a lack thereof, between the high- and low socioeconomic status samples, as well as some methodological limitations related to the body mass estimation equations. There are however other factors that should be taken notion of when interpreting the results of the analyses conducted in this thesis. This includes limitations in the set-up of this research, as well as limitations in the methods available to estimate body mass in archaeological samples in general.

It is important to take into account the sample size and composition of the sample. The statistical analysis was performed on a total of 81 high SES femurs and 83 low SES femurs, but these are only from a limited number of individuals. 46 high SES individuals and 49 low SES individuals is still rather sufficient for statistical analysis, but a larger sample might give more conclusive results. Furthermore, it is possible that the difference in status between the samples is not distinct enough. The comparison has been made between a high SES sample that consists of (upper)middle class individuals, which were not the elite of the city of Zwolle (Hagedoorn, 1992, p. 43). It could be possible that the difference between these two groups would have been observable in the post-medieval period, but that this did not translate to the skeletal material of these groups.

Another question that can be posed is how big the influence of body mass really is on bone morphology. Sommerfeldt and Rubin (2001) argue that only a small portion of strain posed on the bone surface comes from axial loading. The largest part of the strain measured on the bone surface is caused by bending moments (p. S92). Therefore, putting pressure on bones by for instance heavy lifting or other intense physical labour might influence bone remodelling as well. This can be in combination with a change in BM, but might also be a factor on its own to consider.

5.4 Status and Body Mass

To summarise the findings of the discussion; there appears to be a positive relation between body mass and a low socioeconomic status. This can be attributed to differences in diet between the high SES sample and the low SES sample in which the low SES samples consumed more high calorie diet. Here, the role of the male as head of the household and therefor able to have access to more food, explains why there is a larger difference between the male samples than between the female samples. Furthermore, differences in labour could have caused differences in body mass. Mainly between the males, it was the low SES males who would have occupied very labour-intensive jobs, leading to larger muscle mass and consequently higher body mass than their high SES male contemporaries. Between the female sample groups, it is likely that the nature or degree of physical strain of their occupations was comparable, leading to no significant differences between the high-and low-status group. But, the notion that the body mass is predicted more accurately for males than for female samples, should also be considered when interpreting these results. Even though is it plausible that there was no observable difference between the female samples because of their similar places in the household and workforce, methodological limitations may have hindered to assess female body mass accurately enough to observe a difference. Lastly, even though the trend is for the low SES samples to have a higher mean body mass than the high SES sample, this does not automatically mean that they also enjoyed better health.

6. Conclusion

The aim of this thesis has been to study the relationship between body mass (BM) and socioeconomic status (SES). This has been done through body mass estimation methods making use of femoral head breadth (FHB). The main question to be answered was:

- To what extent does body mass correlate with socioeconomic status in the post-medieval Netherlands?

To be able to answer this main question, multiple sub questions were formulated:

- What are the differences in body mass between male individuals with a high socioeconomic status and male individuals with a low socioeconomic status?
- What are the differences in body mass between female individuals with a high socioeconomic status and female individuals with a low socioeconomic status?

For this, two case studies were selected. For the low SES sample, this were individuals from the Eusebiuskerk in Arnhem. For the high SES sample, the individuals came from the Broerenkerk in Zwolle. The conclusions of this research will be presented in this chapter, as well as recommendations for future research.

6.1 Body Mass between the Male Samples

Statistical analysis showed that the BM of the low SES males was significantly higher than the body mass of the high SES males. This mean difference was 3.3 kg and statistically significant. This is interesting as the general assumption is that high SES individuals have more access to better foods. When considering diet, it is plausible that there has been a difference in foodstuffs consumed. Furthermore, it is implied that males as the head of the household had more access to food than the females. Thus, the low SES males could have had more access to the more calorie dense foods whereas the high SES male might have consumed similar quantities, but their varied diet was likely less energy dense. Eventually this would mean that the low SES males had a more positive energy balance than the high SES males resulting in having a higher mean body mass. Another factor that could play a role in the larger BM of the low SES males are working conditions. The low SES males had to perform more, and heavier physical labour than their high SES counterparts. This might have led to an increased muscle mass and therefore body mass.

6.2 Body Mass between Female Samples

Between the female samples, there was no statistically significant difference in BM between the high SES sample and the low SES sample, but the low SES females had a slightly higher mean BM than the high SES females. This could mean that both female groups consumed about the same amount of calories, even though their diets differed. Here, gender differentiation in the household leading to women having less access to food should be taken into consideration. Furthermore, the type of labour could be similar, although it is more likely that women of low SES had to work under tough circumstances. This explains why there was no difference in BM between the two status groups, but methodological inaccuracies might also play a role in these results. Not only are the equations for females not as reliable as for males, it was also noted that the FHB might not be as closely related to actual BM in comparison to the male sample. Therefore, it is difficult to make a final statement on the similarities in BM between the female samples.

6.3 Relationship between Body Mass and Status

To answer the main research question: from the abovementioned sections it can be concluded that BM correlates to SES to some extent. Throughout the whole sample, the low SES sample showed consistently a higher body mass than the high SES sample. Between the male samples this relation was most distinct. For the female sample, the trend was observable, but not statistically verifiable. It thus seems that body mass can change as a result of status-differences in diet, labour, and other strain inducing activities. The notion that in males, the FHB is related more closely to BM than in females should be taken into consideration however when interpreting the results. In conclusion, low status in the post-medieval Netherlands shows a trend towards positively influencing body mass in comparison to having a higher status. However, this does not mean that the low socioeconomic status individuals were healthier than their high socioeconomic status counterparts.

6.4 Recommendations for Future Research

In future research it would be interesting to apply and combine other body mass estimation methods. In this study, stature is not taken into account due to the limited scope of this thesis while it might be useful to investigate whether including body proportions will give different results or other insights as body shape influenced the way weight is distributed on the body. The same body mass looks different when stature is different and will have other implications.

Furthermore, age has not been factored into this study. Differences in age might account for changes in body mass as well. It would be valuable to study whether differences in mean body mass between two status groups can also be observed when comparing age groups.

Another theme that could be further explored is the relationship between female skeletal elements and their relation to changes in body mass. A better understanding of this relationship might lead to more accurate body mass estimation methods for females.

Moreover, as body mass does not necessarily say something about health, it would be valuable to study how health relates to body mass and socioeconomic status. Combining this information with data on diet and labour would provide a more complete picture of post-medieval society in the Netherlands and how individuals from different layers of society lived.

Lastly, it has become clear that research on body mass in relation to status in the post-medieval period is limited. More research projects on this theme and in this period would provide a more extensive framework in which the results of this thesis could be placed and more accurately interpreted.

Abstract

In the post-medieval Netherlands (c. 1650 to 1850 CE), large socioeconomic differences within urban centres existed, which appear to correlate with the diet each socioeconomic group had access to. While low socioeconomic status (SES) often evokes the association of low body mass as a result of having little access to food, modern-day studies show that people living in poverty actually have a higher body mass than contemporaries of higher socioeconomic status. This thesis aims to study to what extend the relationship between body mass and socioeconomic status existed in the post-medieval Netherlands, with a focus on the role of diet and lifestyle.

This was done by studying two post-medieval urban populations: one with a low SES from the Eusebiuskerk in Arnhem and one with a high SES from the Broerenkerk in Zwolle. Body mass was estimated by applying body mass estimation equations developed by Ruff et al. (2012) to measurements of the femoral head breadth. Statistical analyses were applied to compare the mean body mass between the high- and low SES samples. The males and females were compared separately.

The results showed a positive relation between body mass and low SES. However, this relation was only statistically significant between the male samples. As males had more access to food because of their role in the household, the calorie-dense diet of low SES males could have allowed them to consume more calories than their high SES male counterparts who had access to a more varied diet with overall less calories. Low SES males furthermore performed more physically intense labour than the high SES males, increasing their muscle mass. Both female groups likely had less access to food in general, thus it is plausible that bottom line they consumed similar amount of calories. Also, both female groups would have mostly performed similar household tasks leading to no difference in muscle mass. Lastly, the femoral head is less responsive to changes in body mass in females which could attribute to these results.

It can thus be concluded that that body mass can change as a result of status-differences in diet and labour. Based on the sites of Zwolle and Arnhem there seems to be a positive relation between low socioeconomic status and body mass in the post-medieval Netherlands.

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Appendices

Appendix 1. Measurements individuals Zwolle

Find nr.	Age	Sex	Measurements left in mm	Measurements right in mm
2	Middle Adult (40-50)	M	50.7	50.5
3	Old adult (50+)	M	49.7	50.9
12	Middle Adult (36-49)	F	44.4	44.3
13	Middle/older adult	M	45.8	
14	Old adult (50+)	M	46.5	46.9
20	Middle Adult (36-49)	M	45.3	46.6
22	Old adult (50+)	F	44.1	43.9
26	Late young adult (26-35)	M	48.2	47.7
29	Middle Adult (36-49)	F		43.5
31	40+	M	49.6	49.4
32	Middle Adult (36-49)	F	41.1	41.6
34	Early young adult (18-25)	M	44.2	
35	Late young adult (26-35)	M	45.6	
36	Middle Adult (36-49)	F	42.1	41.6
38	Old adult (50+)	M	49.2	48.6
39	Late young adult (26-35)	M	43.2	43.2
44	Early young adult (18-25)	M	50.7	52.2
45	Old adult (50+)	F	39.9	39.7
49	Middle Adult (36-49)	M	42.2	42.8
50	Middle Adult (36-49)	M		46.7
51	35+ (MA or OA)	F		41.6
53	Middle Adult/Old adult	M	52.5	52.5
54	Middle Adult (36-49)	M	49.2	50.1
68	Middle Adult (36-49)	F	41.5	41.5
69	Old adult (50+)	F		44.8
70	Old adult (50+)	M	45.9	46.1
77	Middle Adult (36-49)	M	48.9	
86	Late young adult (26-35)	M	45.4	45.8
87	26+	F	44.9	45.2

90	Old adult (50+)	M	46.0	46.4
94	Middle Adult (36-49)	M	50.2	50.8
99	Middle Adult (36-49)	F	42.1	42.7
105	Middle Adult (36-49)	F	42.3	41.6
112	Old adult (50+)	F	44.6	45.0
114	Late young adult/Middle Adult	F	41.1	43.2
115	Middle Adult (36-49)	F	45.7	44.8
117	Late young adult (26-35)	F	48.6	
118	Old adult (50+)	F	37	37.5
119	Middle Adult (36-49)	F	38.5	
121	Old adult (50+)	F	42.3	
125	Middle Adult (36-49)	M	50.0	51.5
130	Late young adult (26-35)	F	41.5	41.7
131	Old adult (50+)	M	42.4	42.5
205	Middle Adult (36-49)	M	47.6	48.2
207	Middle Adult (36-49)	F	45.3	45.6
247	Middle Adult (36-49)	M	48.8	49.5

Appendix 2. Measurements individuals Arnhem

Box nr.	Feature nr	Find nr.	Age	Sex	Measurements left in mm	Measurements right in mm
8	280	218	Middle Adult (36-49)	F	45.7	45.7
12		1743	18+	F	39.9	39.6
14	258	246	middle adult (36-49)	M	48.4	
25	371	481	middle adult (36-49)	M	49.0	48.5
26	374	490	Old adult	M	48.1	48.4
27	370	492	middle adult (36-49)	M	48.3	48.3

35	418	560	middle adult (36-49)	M	51.9	52.0
48	438	687	Late young adult (26-35)	F		40.6
58	520	814	Old adult (50+)	F	43.0	
61	539	855	Late young adult (26-35)	F	43.3	43.3
63	537	868	middle adult (36-49)	M	47.1	47.1
80	597	1043	Old adult (50+)	M	51.4	51.0
82	604	1087	middle adult (36-49)	F		45.9
94	643	1253	Late young adult (26-35)	M	51.3	52.1
98	659	1298	Old adult (50+)	M	48.1	47.8
99	660	1299	middle adult (36-49)	M	50.9	51.2
103	669	1318	middle adult (36-49)	M	49.5	49.4
113	697	1375	middle adult (36-49)	M	49.5	
118	710	1401	middle adult (36-49)	F	45.6	45.1
124	722	1434	early young adult (18-25)	F	41.5	41.7
128	730	1454	early young adult (18-25)	F	42.0	
133	750	1495	Late young adult (26-35)	M	47.4	47.1
134	752	1500	26-35	M	45.8	46.1
135	754	1506	late young/middle adult	F	41.3	41.8
140	762	1530	Early young adult	F	40.4	39.6

145	773	1561	middle adult (36-49)	M	45.7	45.3
148	711	1585	Late young adult (26-35)	F	40.6	41.0
143	781	1588	middle adult (36-49)	F	42.6	42.8
141	782	1596	Late young adult (26-35)	M		51.9
152	790	1621	Late young adult (26-35)	M		46.4
149	801	1638	Late young adult (26-35)	F	42.1	42.0
157 a+b	806	1655	36-49	F	46.0	46.3
168	862	1752	middle adult (36-49)	F	39.6	39.8
170	864	1754	middle adult (36-49)	F	43.4	42.9
179	871	1802	middle adult (36-49)	M	48.5	47.5
189	905	1840	middle adult (36-49)	F		43.6
192 ab	911	1856	middle adult (36-49)	F	44.6	45.5
232 ab	1021	2062	early young adult (but c. 25)	M	49.6	
233	1022	2064	middle adult (36-49)	M	48.8	
239	1045	2101	Late young adult (26-35)	F		44.9
242	1055	2114	Early young adult	F	41.0	41.2
286	1245	2433	middle adult (36-49)	F	42.5	41.7

291	1255	2451	Late adult (50-60)	M	49.9	50.3
294	1269	2481	middle adult (36-49)	F	39.6	
284	1272	2489	17-30	F	44.0	44.6
199ab	919	1883	Late Young Adult (26-35)	F	43.1	43.2
90	639	1247	Late Young Adult (26-35)	F	44.8	
117	708	1399	Middle Adult (36-49)	M	47.1	47.5
123	707	1432	Early Young Adult	M		52.3