Disability Beyond Disease: A Bioarchaeological Study of Access and Inequality at the Rural Medieval Italian Sites of Villamagna and Pava

By

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Abstract

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In this dissertation project I use multiple lines of evidence to investigate the ways in which inequality and access shape disease outcomes, mobility and movement, and experience in two rural Medieval sites in the Italian peninsula (San Pietro di Villamagna, Lazio; Pieve di Pava, Toscana). I question the nature of disability itself, examining it from multiple angles and in terms of a vibrant body of critical disability studies scholarship, biological anthropology research, and feminist new materialisms. Medieval Europe, and the Italian peninsula in particular, is a dynamic and diverse period for understanding the body and its role in daily life, due to the complexity of changing religious ideology and practice, as well as turbulent political transformation. Biological anthropologists have considered disability, impairment, and the body as an object of study for decades; in contrast, the framework implemented in this dissertation thinks *with* disability about the influences and intersections of social inequalities, access to economic privilege, and agricultural work in the rural Medieval landscape. In this project I use population-level skeletal indicators from the spine and femur alongside individual-level descriptive paleopathology analysis to examine these issues. The spine elements from 265 individuals (Villamagna n=128, Pava n=137) were examined for skeletal indicators of degenerative joint disease in the apophyseal and zygapophyseal joints and scored according to an ordinal scale; cross-sectional geometry properties of the femur for 233 individuals (Villamagna n=114, Pava n=119); and a descriptive paleopathological analysis of one individual from Villamagna results are presented in this dissertation. Degenerative joint disease data from the spine suggest that economic access plays a role in disease outcomes at Villamagna, and that subtle intersectional differences in economic experience (intra-class differences) are important factors alongside physical activity in predicting spine disease outcome. Cross-sectional geometry data from the femur suggest differing baseline levels of terrestrial mobility between Pava (Tuscany) and Villamagna (Lazio), greater sample dispersion (variation) amongst older age people, and higher bending strength and rigidity at Villamagna compared to Pava. Females with less access to economic resources are have significantly higher medullary area (endosteal bone loss) and significantly less cortical area than other groups, in addition to higher prevalence of spine disease. The case of one particular individual from Villamagna highlights the trouble with diagnosis and purposes a methodology of counter-diagnosis for expanding traditional

paleopathology and osteobiography approaches to human skeletal remains and disease. These results demonstrate one way in which bioarchaeological data and biological anthropology can be ethically oriented towards social justice and liberation, expanding the ways in which disability and disease are conceptualized broadly and more specifically in the archaeological and recent past. The results of this project prompt us to think with an intersectional and critical disability perspective about any number of bioarchaeological and biological anthropology questions, not only about identity—but also about human variation, adaptation, and biology.

This dissertation is dedicated to my family,
and to my grandmothers: Helen, Mildred, Lea, Loretta, Marjorie June,
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Chapter 1:

Introduction

This is a study that traces the experiences of the people from two Medieval cemeteries in the Italian peninsula: San Pietro di Villamagna, in Lazio, and San Pietro di Pava, in Toscana. My narrative and examination of these people and their lives is certainly fragmentary—as is the nature of any bioarchaeological study that relies on archaeological materials. In what follows, I approach an archive, archaeological sites, and skeletal assemblages from microhistorical, queer-crip, and biocultural orientations in order to investigate the ways in which inequality is embodied, institutions enforce normalcy (or not), and movement and mobility have been simplified and homogenized.

In this dissertation, I investigate chronic degenerative spine disease alongside mobility and limb use first at the level of the population, then with specific attention to individuals within the populations. A central theme to the studies presented forthwith is variation and difference. Using a critical crip-disability orientation, I examine variation in spine disease along various axes of identity and find that economic inequality and gender intersect in multiple ways to produce health disparities amongst medieval peasants in rural Central Italy. Building on these results, I extend my analysis to population-level trends in mobility—building population baselines for the people of Villamagna and Pava. Finally, I utilize these baseline understandings of these medieval peasants to examine people who would typically be considered outliers and excluded from traditional analyses. Through a close examination of a few individuals, I draw on skeletal, art-historical, material, and documentary evidence to explore medieval piety and experiences of the body for medieval peasants.

This dissertation practices multi-disciplinarity in order to investigate questions about how social and economic inequalities are embodied in the medieval period; and how ableist biases shape theoretical, material, and biological understandings of the "nature" of disability. My approach is inspired by the work of intersectional-feminist materialists, disability studies scholars, critical historians, and social bioarchaeologists. In this dissertation, I rematerialize bodies, in their queer, fragmentary, skeletal, and otherwise disruptive matter – repopulating and reimagining the stories of Villamagna, Pava, and of medieval life through an intersectional lens. My research continues on the path of many other feminist, queer, and critical disability studies scholars, and brings to bear the stories embedded in the dynamic and plastic tissue of bone—the skeletons of medieval peasants and the case of an older woman with an unusual gait. In this narrative, I do not attempt to homogenize these bodies into a fully cohesive narrative, nor do I attempt a full reconstruction or comparison where it is not possible. Disabled bodies are themselves disruptive, subversive, and their refusal to conform with normative standards of analysis and narrative is a potent site of discussion that I will address at length in future writing.

One of these disruptions that repeatedly materializes in bioarchaeology is an issue of scales of analysis: the relationship between population-level results and the experiences of individuals, and the ways in which the collective might represent (or not represent) the individuals within it. This dynamic quality, where disability is both a unifying political identity and also an individual experience is well theorized and has a long history of scholarship in disability studies (e.g, Kafer 2013, Samuels 2014, Siebers 2008a, 2010); and remains an important topic of discussion within the Disability Rights and Disability Justice movements. Siebers (2008a) notes that this insistence on a stable identification is a product of the ideology of ability, writing that

> "ideology does not permit the thought of contradiction necessary to question it; it sutures together opposites, turning them into apparent complements of each other, smoothing over contradictions, and making almost unrecognizable any perspective that would offer a critique of it" (Siebers 2008a:8).

In this dissertation, I will address assumptions that shape most biological anthropology studies of people in the past. The first is the conclusive statement made by many paleo-epidemiological studies that, *these results are representative of the population*; while it is clearly stated in the methodological portion of the paper that individuals with "pathology" or "disease" were *a priori* removed from the study sample. This contradiction is an enactment of typical scientific ableism (and violence), whereby a boundary is made around personhood and disabled people are dehumanized as nonpersons—not part of the population. Disabled people do not fit in biological anthropology's evolutionary and historical narratives of *Homo sapiens* because they have been intentionally removed. That being said, there is an argument for removing outliers from statistical analyses—and I am not arguing against statistical approaches to empirical data, but rather for a more complex approach to multifactorial and imperfect datasets (a hallmark of archaeological research). I am not a statistician, and my purview is not (yet) to completely dismantle statistical methods in biological anthropology. I critique the "representative" population and epidemiological notions of normal populations, but I will also demonstrate that economic and class inequalities contribute to differential health outcomes and differentially and intersectionally debilitate medieval peasants (Chapter 3), using a more critical epidemiological approach. In order to measure this effect across the population, I use a variety of statistical methods—where I remove individuals who had *skeletally recognizable diseases* from my initial analysis. I temporarily remove these individuals, in order to look at the compounding effects of economic, gender, and age on spine disease in the population and to control for confounding effects of disease or disability, which also alter physiology and experience (as any aspect of identity might). Rather than relegating disease to the margins, by considering it as a disruption to the analysis—its effects are examined both as a result of inequality, but also as a generating factor in *producing* inequality.

Statistics, as a field of knowledge, began formulating the concept of an "average," or "normal," human in the early 19th century (Davis 2013). These notions of an average human rely not on individual configurations (or particularities) of bodies, but rather on abstract generalizations that cannot be reproduced at the scale of the individual, as no single individual embodies this average ideal. The concept of a *norm* implied that it was the condition for a majority of a given population, and in constituting an average—it materializes deviant subjectivities. As Davis writes, the relationship between statistical science and eugenic concerns is a symbiotic one (2013:3). I do not solve this problematic relationship, between statistics and eugenics, in this dissertation—as much as I would like to provide a substantive and rigorous alternative. The feminist practice of reflexivity emphasizing disruptions and particularity, moves against the ideology of ability and its liberalist tendency to homogenize experience (Siebers 2008a, Kafer 2013). As such, even though I inhabit an orientation that centers disability as human variation, prioritizes access, and emphasizes intersectionality in establishing population baselines, I make an effort in Chapter 5 to examine the exceptions to the generalizations I make about medieval peasants in Chapter 3 and 4 and provide a less-homogenous narrative.

A second assumption I engage with lies near the heart of this dissertation: although I argue that disability does not appear (based on my evidence) to exist in the medieval period as a cohesive, agential, or conscious social identity, I will employ a disability-centric framework to examine disease in the past. I do not take disease and disability as synonymous, nor am I asynchronously applying contemporary structures and ideologies about disability onto the past. My rejection of a “disability” interpretation of bodily difference and disease amongst these medieval peasants is a defiant act of reframing and centering disability as a rigorous theoretical orientation to the body, where disease and difference do not diminish personhood. I choose to center disease experience and the ways in which inequalities differentially affect disease outcomes because these narratives have historically been suppressed or tokenized within biological anthropology. However, I also reject the notion that a disability orientation must take up the question of, “is this disability or not?”.

Just as Disability Anthropology is not an anthropology *of* disability per se (Hartblay 2019), disability-oriented Bioarchaeology is not merely an examination of disabled bodies, disease, or pathology in bioarchaeology contexts, nor is it necessarily a bioarchaeological analysis of physical impairment as disability. It is a theoretical and practical commitment to Disability Justice (see Berne 2016, Berne et al. 2018, Block et al. 2015, Piepzna-Samarasinha 2017). Framed by and in terms of disabled peoples lived experiences, it makes a formal contribution to Disability Studies as a multi-disciplinary academic field (see Hartblay 2019 for more). A primary tenent of disability oriented Bioarchaeology is decentering disability as an *object* of study and centering the experiences and needs of the Disability Community and disability liberation in our approach to the body in the past. This emancipatory and intersectional orientation operationalizes the demand for *thinking with disability* in the social sciences. Therefore, the primary goal of this framework is not to better understand disability, but rather to rehumanize disabled people—broadly conceived—in our narratives of the past, present, and future.

In this dissertation, I draw on scholarly work from multiple disciplines including Anthropology, Disability Studies, and History. Here I provide an overview of some concepts I draw on for the foundation of my research, with brief discussions of how these concepts influence this dissertation. At the beginning of Chapters 3, 4, and 5 I provide a brief “orientation” to the ideas, theories, and political activism that inform the research design, questions, hypotheses, and interpretations for those chapters. I draw on Sara Ahmed’s *Queer Phenomenology* concept of “orientation,” which I use to generate a description of the embodied, political, and biocultural arrangement of myself as an observer within the phenomena I study (Ahmed 2006). These “orientations” are themselves an enactment of my own re-orientation or dis-orientation from the bodies I study, as well as my own body (Ahmed 2006). This relational approach is also informed by the writings and ideas of Karen Barad (2003, 2007) and other so-called (sometimes-called) “new” materialists (e.g., Coole & Frost 2010, Chen 2012, Dolphijn & Tuin 2012, Delanda 1997, 2013, Joyce 2015a, 2015b, 2015c, 2020, Povinelli 2016). Although my engagement with new materialists is not necessarily fore-fronted amongst the Chapters presented here, my orientation to the material-discursive (Barad 2007) practices of research were built within this foundational scholarship.

Orientations

Normalcy

A disability orientation in biological anthropology requires the mobilization of the power of scientific inquiry and empirically derived data *against* normalcy (Davis 1995; Clare 2001, 2015; Garland Thomson 1996, 2005, 2011, 2017), compulsory able-bodiedness (McRuer 2010; Davis 2013), and the ideology of ability (Siebers 2008a, 2010, 2013). In this research, the tools of scientific inquiry and research, which have historically been weaponized against disabled people in order to benefit "society" writ-large, are re-aligned for the benefit of the Disability Community. The relationship between statistical "norms" and compulsory able-bodiedness has historical roots: Robert McRuer convincingly argues for the emergence of compulsory able-bodiedness alongside industrial capitalism of the 19th century (2013). As a historical bioarchaeologist this provokes the question—what about before the 19th century?

For further context: McRuer is writing against a 1999 article in *Salon*, which attacks disability studies in favor of normalcy; Norah Vincent writes that the "human body is a machine…that has *evolved* functional parts" (emphasis mine, in McRuer 2006:7). The possibility for Vincent's writing this absurd misrepresentation of the body, as an *evolved machine* begins more than a century earlier with the institutionalization of eugenics in academic discourse, but also reflects widespread misconceptions about the body and about the mechanisms and processes of evolution itself. These are the same misconceptions that inform biological anthropologists who partition people into persons and nonpersons. McRuer to resists globalizing disability studies, writing that disability cannot be "*the* subject position," that is transcendent or glorified as emblematic of a post-identity politics due to its instability (2006:202), especially given the complex relationship between inequality and pain, debility, and disability in late liberalism (Puar 2017).

In this dissertation, I provide three examples of biological anthropology research grounded in a robust scientific approach with emancipatory aims against the naturalization of Ability and against normalcy. In the first of these cases, I take up degenerative spine disease, a leading cause globally of disability-related leave from work and remains one of the most ubiquitous and widespread chronic diseases to affect humans. It is not understudied in and of itself by biological anthropologists (Klaus et al. 2009, Snodgrass 2004, Lieverse et al. 2007, Sofaer 2000, Zampetti et al. 2016), but remains un-accounted for more broadly. Although it is a ubiquitous disease, its effects are never considered on other diseases, metabolic indicators, or with regard for large scale trends in human mobility. Molly Bloom, a disabled linguistic anthropologist and expert on spinal cord injuries and disability anthropology (Bloom 2019), once told me that she had never given much thought to the disabling effects of degenerative joint disease in the spine because of the emphasis in Euro-American culture on spinal cord injuries. Most popular culture visibility and disability research on the spine is related to spinal cord injuries and their affective qualities (Dillaway & Lysack 2015, Shildrick 2002, Thomas 1999). Unlike degenerative spine diseases, spinal cord injury is not typically a chronic event associated with aging. These disparate treatments of spinal cord injury and degenerative spine disease reveal a eugenic ideal to prop up health in binary opposition to disability, and a denial of the instability and flexibility of the body over the life-course, particularly in the aging body.

Crip

Throughout this work and in more widely in disability studies research from the past decade, a critical contradiction has surfaced as a vital point of discussion. In her 2013 book, *Feminist Queer Crip* Alison Kafer begins by foregrounding a contradiction that troubles disabled practitioners of disability studies: valuing disability as a subjectivity, while recognizing the ways in which physical impairment is weaponized against and unevenly distributed among the global populous. She remarks, that although she is “not interested in becoming more disabled than [she] already [is]” she values disability and illness as part of a shared human experience. Recalling Siebers (above) on ideology, he writes that ideology does not permit contradictions; and by extension we might then propose that contradictions are against ideology and against normalcy. There is no resolution to this contradiction: disability can be a positive and valuable subject position; and disability can be the material embodiment of inequalities.

Disability, as a political and material phenomenon is embedded in larger landscapes of inequality that heterogeneously and intentionally target some subjectivities (often along other axes of marginalization). Discourse on toxins, and their role as agents of late liberalism and industrial capitalism were taken up by environmentalist Rachel Carson in her 1962 book *Silent Spring*; and have subsequently featured as material-discursive focal points in Nirmala Erevelles’ *Disability and Difference in Global Contexts* (2011), Mel Chen’s Following Mercurial Affect (2012), in Elizabeth Povinelli’s *Horizons and Frontiers* (2018a), and in Sunaura Taylor’s 2019 talk at UC Berkeley, “Disabled Ecologies: Living with Impaired Landscapes”. Erevelles (2011) argues that disability is produced by the structural and material violence that is foundational to transnational capitalism, rooted in the physical (impairing) violence slavery inflicted on the bodies of enslaved peoples. Following Erevelles’ logic the medieval European feudal mode, refined from Roman agrarian slave mode, may have had social and ideological phenomena that are especially legible through a disability orientation and may even share some continuity. Although I do not attempt to read contemporary disability discourse or materiality onto the medieval period, I am interested in how bodies and difference have been understood, (re)produced, and enforced in this historic time period.

There is linguistic, textual, and material evidence to suggest people with similar bodily conditions may have consciously formed social-political coalitions and/or experienced institutionalized, structured, and systematic discrimination and violence historically (e.g., Garland 1995, Metzler 2006, 2013, Wheatley 2010). Historical documents from the Roman period suggest that Romans paid higher prices for impaired slaves at the markets, where “*moriones*” were considered an amusing or fashionable addition to high-status household (Garland 1995). A significant amount evidence suggests that the medieval leprosy, encompassing a variety of modern infectious chronic diseases, was another embodied experience that held considerable political, economic, religious, and cultural attention (e.g., Moore 1983). This is especially true in Italy, where Saint Francis and the Franciscan monastic order were known as caregivers for lepers, and where social and political apparatuses of ostracism and poverty were enacted against Lepers, as well as Jewish people and Heretics (Melville 2016:170-174, Moore 1983:18-28). It is clear from literary, religious, and material sources that from the beginning of the Medieval period onwards, people’s lives and experiences across society were shaped and transformed by the enforcement of difference, especially in the body.

In Chapters 4 and 5, I investigate the possibilities of alternative bipedalisms. The shared evolutionary history past people encompasses a wide range of “healthy” and “pathological” biomechanical modes are central to our understanding of contemporary health and normative bipedal gait and movement, and yet the gait, kinematics, or biomechanics of “unhealthy” people have remained at the margins of biological anthropology research. I use the concept of crip futurity and Kafer’s articulation of a feminist-queer-crip approach to address a gap in our understandings of limb use and biomechanics in past populations, and how these gaps contribute to the othering of disabled people in contemporary global contexts.

Debility

Building a future where disability is political, valuable, and integral cannot be successful if it denies the structural, systemic, and historical violences associated with some of the material causes of impairment and disability (Kafer 2013). This tension, between etiology and futurity is a central tenant of Kafer's (2013) political/relational model of disability, which remedies a fundamental flaw in the politics of late liberalism and in neoliberal economics: to place the burden of care and healing from itself "onto those it has already harmed" (Povinelli 2018a). In a talk "The Four Axioms of Existence," given at UC Berkeley in 2018, Povinelli explicitly discussed the implications of the late liberalism's heterogeneous effects of power and power to affect a given "terrain of existence," converging on a point that necessarily draws together theorists from across academic disciplines: the intersectional and compounding effects of inequality. The critical conceptualization of people who are "multiply marginalized" is not new, and like many phrases, the term has been reclaimed from the biomedical community by queer crip and disability theorists (e.g., Schalk 2013, Berne 2016, Berne et al. 2018). Rosemarie Garland-Thomson draws particular attention to the ways in which the hierarchical organization of abled and dis-abled bodies is used to justify the unequal distribution of "resources, status, and power" (2005).

Critical to any (re)theorization of disability within in a crip framework, is Jasbir Puar's important and recent book on the intersections of disability studies with post-colonial and critical race studies. In *The Right to Maim,* Puar elaborates the concept of debilitation, or debility, to emphasize the ways in which racialized (and multiply marginalized) bodies have been forced to endure pain, suffering, and injury (2017). Debility emphasizes biopolitical risk in triangulation with the ability/disability binary, in an effort to account for the ways in which privilege and access (to rights, to identification, to resources) are differentially distributed. Puar writes that "capacity, debility, and disability, exist in a mutually reinforcing constellation, are often overlapping or coexistent, and that debilitation is a necessary component that both exposes and sutures the non-disabled/disabled binary" (2017:xv).

Building on this concept, I particularize debilitation in the context of biological constraints and affordances, with attention to the synergies between physiological and political processes. Biological-material constraints and affordances exist on the individual, community, population, species, and genus level (and up through taxonomic orders) and provide a plane of immanence on which evolutionary and political processes, histories, and futures are enacted. Conceptualizing of organisms' materiality through a lens of constraints, affordances, and virtualities accounts for multiple temporalities and spatialities in our understanding of lived experience (from genetic to microbial to physiological). This orientation to the body illuminates ideological boundaries of human subjectivity that have been electrified in order to delineate and maintain hierarchies of power. In this dissertation I examine how political and economic privilege effects disease outcomes and show that the spine disease is most severe and widespread amongst the medieval peasants who incur the most biopolitical risk (i.e., sharecroppers, and people buried without grave materials associated with wealth). This is the result of an accumulation of intersectional biopolitical risks, which interact with physiological vulnerability to differentially debilitate medieval peasants and are an embodiment of economic, gender, and religious inequalities.

Anthropology of Disability

Studying disability (as an object of inquiry) through material culture, archaeology, cultural anthropology, biological anthropology, and even bioarchaeology is not a novel line of inquiry. There are numerous studies that examine disability-as-identity (e.g., Marstellar et al. 2013), as physical impairment (e.g., Trinkaus et al. 1983, Lovell 1994), and through the perspective of care and caregiving (e.g., Chamoun 2020, Tilley & Cameron 2014, Tilley 2015, Powell et al. 2016). But ultimately there remains a critical gap, where the experiences and embodied knowledges of disabled, chronically ill, Neurodiverse, Deaf, and Blind people have been largely excluded from the interpretive processes that generate our knowledge of the archaeological past. The 2017 volume, *Bioarchaeology of Impairment and Disability* includes a chapter by Russell Shuttleworth and Helen Meekosha titled "Accomodating Critical Disability Studies in Bioarchaeology," these Critical Disability Studies (CDS) scholars outline a general overview of CDS and explicitly discuss the ways in which a CDS perspective might be implemented in Bioarchaeology. Although their perspective is primarily aimed at scholars who are studying disability as on object of inquiry, they reiterate the importance of a contextual approach that considers the body in terms of impairment and disability (Shuttleworth & Meekosha 2017). The approach taken up in this dissertation, draws on biocultural and political models of disability and queer-crip orientations to disability in order to address the rampant disembodiment of disability in early social-model theorizations, and the relentless medicalization of the body in bioarchaeological research.

Any study of disability in the archaeological past, must begin by foregrounding disability as a historically and culturally contingent arena of experience. To cast disability as an ahistorical category of personhood is to place it outside of the realm of culture and therefore to naturalize discrimination against disabled people and against impaired bodies. The concepts of local biologies (Lock & Kaupert 2001) and temporal biologies (Gilchrist 2012) help elucidate the geographically and temporally unique condition of the biocultural body. The body shapes and is shaped by cultural practice; the body emerges through physiological, mechanical, and biological processes. This biocultural body continuum is generated through genetic regulation, physiological function, and biological forms, and is continually modified during the life course through bone's innate plasticity (see Agarwal 2016, Agarwal & Beauchesne 2011 on plasticity).

Further, in order to investigate the disabled body in its Medieval context, it is necessary to consider medical knowledge, religious and astrological conceptions of the body, and natural philosophy. These historical bodies of knowledge provide a more complete sense of what constituted difference, and how people may have had differential social experiences because of their actual or perceived bodily difference. Many historians of disability view physical, sensory, or psychological *impairment* as a "non-negotiable reality," and disability-identity as a "matter of perception" (Metzler 2006). This misconception of the body and of disability is due in part to pervasive historical and eugenic biases in human biology and skeletal biology, where the human body is framed as natural and ahistorical and biology is described as a transcendental truth—above the influence of culture. This bias is apparent in the dialectical distinction between "biological sex" and social "gender," as if "biological sex" itself were not also a culturally embedded phenomenon. Although feminist theorists of all stripes have largely adopted the language of a biocultural approach to the body (Bennett 2004, Frost 2014, 2016), these versions of body materialism emphasize a simplistic, deterministic, and speculative biology that is illegible to practitioners of human, skeletal, or organismal biology, and lacks an empirical foundation. This is a critical gap that can be addressed by feminist biologists, and other practitioners of science, who can reflexively attend to the complex biology of biocultural bodies and build more robust and radical biocultural frameworks with emancipatory goals.

Microhistoria

The historical tradition of *microstoria*, or microhistory emerges from Italian scholars in the late 1970s, the classic example being *Il formaggio e i vermi* by Carlo Ginzburg (1976, 2013). In *Il formaggio*, Ginzburg narrates the story of Menocchio, a 16th century miller in Friuli, in Northern Italy, who is accused of heresy during the Roman Inquisition, based on his fermentative reading of the creation of the world in Genesis (Ginzburg 2013). Through a close reading of archival documents from the Roman Inquisition in northern Italy, Ginzburg traces the idiosyncrasies of Menocchio's readings of books such as the Bible, Boccaccio's *Decameron*, Mandeville's *Travels*, and likely the *Qur'an* in order to investigate daily life, oppressive economic systems, and larger-scale trends in medieval history (Tedeschi in Ginzburg 2013). Later Ginzburg (1986) published an essay where he elaborated upon the new microhistory narrative strategy, he employed in *Il formaggio,* the "method of clues," writing about the analogous approaches of Giovanni Morelli, Arthur Conan Doyle, and Freud in building a narrative (Peltonen 2001). Thus, the *new* microhistory was fomented, and conversations in historiography shifted (e.g., Le Roy Ladurie 1974, 1978, 1979, Schmitt 1983, Levi 1985, 1991, see Chapter 5 for further discussion).

The language of microhistory has been utilized widely since Ginzburg's original book, even by bio/archaeologists (e.g., Beaudry 2008, 2011, Darnton 1984, Donati 2019, Hosek 2019, Novak 2017, Sheptak 2013), although some of these approaches take up a more biographical approach. Tracing the Italian historiographical tradition of *microhistoria*, it is clearly antithetical to positivist approaches in French historiography and has roots in anthropological approaches to the everyday (see Brewer 2010, Iggers 1997, Revel & Hunt 1995, Sheptak 2013, Trivellato 2011). Like feminist, queer, and disability frameworks, reflexivity is central to the practices of microhistory in bioarchaeology (Joyce 2017). Microhistory, an endemic historiographical tradition in Italian scholarship, focuses on tensions of scale and temporality—examining the peculiar, contextualizing particularities, and drawing out the contradictory elements of normative ideological systems. As a subversive historiographical technique, microhistory is a sometimes-Marxist practice that has focused attention on the histories of class-oppression, as well as the elitisms that shape the discipline of history itself. The apparatuses that have worked to erase and invalidate the experiences of non-elite, common, and/or peasant peoples, have simultaneously positioned the past (be it archaeological or archival) as an inevitable scaffold for the future. This (multi-scalar and non-linear) apparatus of class oppression has held archaeological interpretations of physical difference and variation in stagnation, in an attempt to prop up ableist, capitalist, and oppressive presents which are positioned as inevitable.

Although I do not employ a Marxist or even neo-Marxist approach, (favoring instead a queer-crip-materialist orientation), I find that the methodological commitments of microhistory complement the theoretical commitments of a queer-crip project. Crip theory's emphasis on futurity and particularity indirectly questions archaeological pasts. Crip futurity looks towards alternative imaginations of the future, seeking liberation and justice across intersectional embodiments, while microhistory examines the actual as an access point for more critical readings of the past (with emancipatory aims). In this attention to temporalities and scales, the fragmentary archaeological past is often conjured in present-futures as an means of justifying ideology and inequality. I see this theoretical orientation as occasionally tangential to the so-called "speculative turn" in philosophy (e.g., Badiou 2008, Byrant et al. 2011, Meillassoux 2010), however my particular orientation to futurity is grounded in the agential realism of Karen Barad (2003, 2007) and feminist/new materialists (Alaimo &

Hekman 2008, Braidotti, 1994, 2013, DeLanda 1997, 2002, Dolphijn & van der Tuin 2012, Grosz 1994, Oyama 2000, Stengers 2010).

I propose that crip futures might draw on past landscapes as speculative imaginaries, and that bio/archaeological interpreters might take note of the alternative (virtual) possibilities that crip theory and disability ethnography, art, and life-writing conjure, when writing about and analyzing human skeletal remains. In practice, the statistical analyses I employ in Chapters 3 and 4 are disrupted and rehumanized using a diffractive (Barad 2007) and microhistorical orientation in Chapter 5. In Chapter 5, I begin to foment a critical, ethnographical account of alternative bipedalisms based on multi-scalar accounts of cross-sectional geometry data and the particular case of one individual from Villamagna.

Historical Background

Rural Economies

The rural economies of medieval Europe depended on a system of feudal, or manorial system of landownership and agriculture, and in Central Italy sharecropper laboring. Sharecropping and medieval serfdom have been analyzed by Marxist historiographers in terms of their politics, ideology, and institutions (e.g., Bois 1976, Kula 1970, Wickham 1984, 2008). According to Wickham (2008), the economic logic of feudalism centers on the forcible extraction of surplus resources from peasant families by both the local landowners, as well as the state or regional governing institution. Historians of feudalism, particularly medieval feudalism, have tended to take up a Marxist or neo-Marxist approach (e.g., Bois 1976, Brenner 1978, Hilton 1976, Epstein 1989, 2000, 2007; Kula 1970, Wickham 1984, 1994, 2008). These analyses take up the productive forces (i.e., tools, techniques, knowledge, and organization of the labor process) and the relations of production (i.e., property, exploitation, resistance, class struggle) that characterize medieval feudalism with the aim of either understanding medieval economic logic *or* for delineating the foundations of early capitalism and industrialization in Europe (Wickham 2008). Feudalism, the hierarchical mode of the earlier medieval period, is characterized by a reciprocal, albeit exploitative and coercive relationship between feudal lords and peasantry. During the 12th and 13th centuries, many cities in northern and north-central Italy divested from the Papal State as a result of the Investiture Conflict (Wickham 2015), and autonomous *communes* were formed, for example the Tuscan cities of Siena, Lucca, and Arezzo (Scharf 2014, Wickham 2011). Italian communes have been proffered as a type of early democracy, however these sometimes-chaotic governing entities often verged towards authoritarianism, known in Italy as the *signoria* system (Wickham 2011, 2015). Across Italy the specific political, economic, and social powers of the *signoria* varied as the seignorial system came to dominate parts of the European continent from the 15th century onward (see Vaquero Piñeiro 2013, Scharf 2014). This urban centralization of power by communes took place alongside the continued extraction from the peasantry in the rural economy. Rural economies were driven by landholding and serfdom until the 14th and 15th centuries when agrarian economies were commercialized.

Medieval economies have been stereotyped in terms of strict gendered divisions of labor, and generally there were strong gendered expectations and intersectional trends of inequality that shaped medieval culture. However, feminist medieval scholarship focused not only on defying stereotypes of female domesticity—but also on examining the diverse ways in which many people, particularly women and children participated in the economy both in the domestic and commercialized spheres (e.g., Bennett 1996, 2006, Bennett & Karras 2013, Cadden 1993, Goldberg 1993, 1997, Hatcher 2001, Karras 2004a, Park 2010, Whittle 2013). Further, the trivialization of domestic labor (performed by any gendered person) is also a problematic legacy of masculinist historiography (Bennett 2006, Karras 2004a, 2004b).

Art historical evidence for the medieval period depicts women performing a variety of tasks in, around, and outside domestic spaces. The Luttrell Psalter, an illuminated book of psalms dated to c. 1320-1340 commissioned by Geoffrey Luttrell in Lincolnshire, England (Backhouse 2000). The Psalter contains a calendar, Latin psalms and canticles, a litany, and an antiphon for the dead and is widely discussed by scholars for in terms of its own material history and for its illuminated depictions of everyday rural life in medieval England (Figures 1.2-1.9, Backhouse 2000, Wieck 2002). The manuscript is unique for its minimal text and elaborate and opulent use of illuminations in the margins depicting Geoffrey Luttrell's life, daily medieval life, and the usual hodgepodge of animal-human figures, naturalistic motifs, saints, and fantasy scenes (Backhouse 2000). Most notably, there is an 8-folio-page sequence depicting a typical rural harvest season, from plowing to carting (Figures 1.2-1.9, Rentz 2010). This sequence has been understood by medievalists to demonstrate the spiritual enterprises of farming, an idyllic and romantic interpretation that ignores the implicit economic anxieties and embodiments of labor inequality that accompany the sequence. Importantly, the sequence depicts men and women participating in the harvesting and displays a variety of bending and weight-bearing agricultural activities that remain common amongst European farmers today and often result in chronic back pain, disc herniation and degeneration, and spine disease (Figures 1.2-1.9). The interpretation of the book as a public liturgical device, used by multiple readers at the same time for the (public) performance of prayers and devotion (Rentz 2010), suggests that the Psalter was used to quietly but materially reinforce class hierarchies as much as it might have facilitated devotional practices. Particularly salient is a series that depicts a peasant succumbing to the sin of idleness (Figure 1.1); a moral designation that conveniently affirms a feudal lord's (Geoffrey Luttrell's) moral and economic position, as well as his entitlement to peasant labor. Images such as Figure 1.1 and its cultural and textual context helped to naturalize of the role of peasants in providing labor to elites, framing it as a necessary act of spiritual devotion and humility (Camille 1987).

Although the Luttrell Psalter was created in Northern England and reflects medieval farming life based on multiple artists' interpretations of 14th century England, these images are commensurate with illuminations from other manuscripts from Italy, and more widely across medieval Europe. For example, the *Tacuinum Sanitatis* is a series of Latin translations of an 11th-century Arab medical treatise (*Taqwīm as-siḥḥa bi al-Ashab al-Sitta*) written originally by the Christian physician Ibn Butlan (Hoeniger 2006, Wickersheimer 1950). The wheat harvest was a central to many Medieval economies, in particular the rural Italian economy (Carroci 2016, Flascassovitti 1997) and is widely depicted in also in various versions of the *Tacuinum Sanitatis* (Figures 1.10-15). Four *Tacuinum Sanitatis* manuscripts from Lombardy survive at libraries in Vienna, Paris, Liège, and Rome; one of these manuscripts has an illumination of women making pasta (Figure 1.10), while others depict the garlic harvest (Figure 1.11), wheat threshing (Figure 1.12), wine making (Figure 1.13), and many other daily life activities accompanied by text describing the health benefits and harms of these various activities (Hoeniger 2006, Givens et al. 2016). Drawing on these depictions of farming and agricultural labor, it is clear that both men and women participated in the broader rural economy outside the "domestic sphere," including and especially the rural harvest economy. Drawing on these visual representations of medieval life, as well as critical feminist historiography (e.g., Bennett & Karras 2013), we expect that there may be gendered differences in the types of labor performed on a daily, annual, or semi-annual basis, but that these differences in labor do not buffer medieval women from the consequences of intensive agricultural labor.

Pieve di Pava

Pava is located in the Val d'Asso between Siena and Arezzo, between the Val d'Orcia and the *Crete Senesi* of Southern Tuscany, in *Tuscia suburbicarian* (Campana et al. 2007a, 2007b, 2008a, 2008b, Felici 2016a, Felici et al. 2010, Mongelli et al. 2011, Riccomi 2020). Pava lies about 250km northwest of Villamagna, west of the Apennine Mountains. Although there is evidence of continual use and occupation of the site from the 2nd century AD, the first records of the site emerge in the 8th century. Like Villamagna, Pava has its origins as a Roman villa (from the 5th century AD)—and was later transformed into a paleo-Christian church (*pieve*) in the beginning of the 6th century (Cantini 2012, 2013, Felici 2016b, 2016c, Riccomi 2020). In 714 AD, a *giudicato* lists the *baptisterium Sancti Petri in Pava*, as one of many *plebs* involved in a controversy between the bishops of Arezzo and Siena (Schiapparelli 1929:n.19, Ricci et al. 2016). What follows this dispute remains relatively unknown based on current archival research, although we know from other work on the history of Tuscany that after the Lombard and Frankish marquisate and governance by episcopal bishopric governance, many Tuscan city-states functioned independent of clerical rule (Bowsky 1981). Both Siena and Arezzo supported Ghibelline, or pro-imperial (Holy Roman Empire) factions, in opposition to Guelph-controlled Firenze, although each city-state has a unique and complex history (see Bowsky 1981).

Previous archaeological excavations revealed a large parish church (33m by 10m) with apses at the east and west aspects (Campana & Francovich 2006). The cemetery that surrounds the church had over 1000 excavated burials and in the center of the church, under the high alter, the remains (relic-remains) of a suspected Saint were recovered (Ricci et al. 2012). This so-called Saint has been the focus of much research, because their remains show signs of *acromesomelic dysplasia*, commonly known as short-limbed dwarfism (Ricci et al. 2012). Skeletal evidence from the clavicle and humerus suggest this person may have used crutches, and further osteological analyses suggest this person was a young (18-20-year-old) male, whose remains had been transported to the church for its consecration in the late 8th century (Ricci et al. 2012). A study of dietary variation at Pava, focused in particular on the Saint-burial, found that his diet was rich in animal proteins compared to the other individuals sampled (Ricci et al. 2012). This finding has been used to suggest that this man was part of a prominent local Tuscan family; not unlike many other Saints from the region of Tuscany, such as Catherine of Siena (Ricci et al. 2012). Stable isotope analysis of ^{18}O attest to his membership in the local community, however radiocarbon dating provided an estimate of 645-690AD, and the burial was determined to be a secondary burial by excavators (Ricci et al. 2012). This evidence supports the hypothesis that the Saint was moved to the church later, as part of a dedication or consecration event—a common practice amongst medieval Christians that persists in the Church today.

Although the history of the Pieve di Pava is relatively unknown based on historic documents, the region of Tuscany is well studied by historiographers of agriculture and economics (see Dameron 2017 for an exhaustive review). Tuscany was one of the most densely populated regions of Europe before a series of *Yersinia* plagues; and Epstein (2000) suggests that Tuscany supported 60 people per square kilometer by around 1300AD. After the emergence of several communes in Tuscany during the 12th century, the area suffered from food hoarding and nearly constant warfare as the *popolo* (non-noble, urban elites) of these *communes* struggled to consolidate their power (Dameron 2017). The relationship between the urban *communes* and the surrounding countryside has been documented as a contentious and sometimes violent relationship (see Curtis 2012).

Typical medieval Tuscan diets consisted of millet, wheat, barley, olives, wine, wild boar, deer, sheep/goat, and birds, although there is historic and archaeological evidence for variation in Tuscan diet across the region (Buonincontri et al. 2017, Dameron 2017, Riccomi 2020). Recent research from an additional sub-sample of individuals from Pava (n=51) shows that their diet was dominated by C^3 plant consumption and terrestrial animal proteins, and that there were not differences in diet based on skeletal sex (Riccomi 2020, Ricci et al. 2012). Differences in dietary staples have been demonstrated archaeologically as well as historically within the region of Tuscany, where it is expected that millet was more frequently consumed in Northern Tuscany, as opposed to wheats in southern Tuscany. Linguistic differences in the types of *frumento*, or wheat (*grosso*, *siciliano*, *calvello*, *comunale*) compared to the types of *biade* (including *saggina*, *segale*, *miglio*, *orzo*, *fave*, *spelta*) point to historical and economic differences in the cultivation of grains in Italy (Buonincontri et al. 2017, Dameron 2017); for example, in Tuscany breads made from *frumenti* were preferred over the darker breads made from *biade* (Buonincontri et al. 2017, Dameron 2017). Generally, medieval diets depended on local availability and culture and differences in diet were more related to class-differences than to sex or age differences.

San Pietro di Villamagna

Villamagna is located across a valley from Anagni, near Frosinone in central Lazio and lies approximately 60km southeast of Roma. After the fall of the Roman Empire, the Villa Magna, a residence frequented by Marcus Aurelius, was transformed into a Byzantine church in the sixth century. Later it became a residence for a few elite (but unknown) families in the Early Medieval 8th and 9th centuries, and finally in the 10th century was established as a Benedictine monastery, known in its time as *San Pietro di Villamagna*. *San Pietro's* beginning foreshadows its end: material evidence recovered during archaeological excavations (2006-2010) are evocative of the powerful *domuscultae*, or medieval papal estates—that fill the countryside of Lazio and center of the *Stato Pontificio* (Papal State). Although Villamagna is explicitly and definitively not a *domusculta*, the proliferation of liturgical stone, ceramics, and other fine materials suggests Villamagna had strong ties to the papacy and benefited from its power and protection under sympathetic popes. The formation of the Benedictine monastery comes about during a time when monastic-life, that is spiritual life, is bourgeoning across Europe and especially so in Italy in sanctioned and unsanctioned forms.

It is clear from the vast historical archive at the center of the Villamagna assemblage that starting in the Central Medieval period, the men of Villamagna were not *de vili et servili conditione*, or of servile condition to the monastery (Carocci 1997a, 1997b, 2016, Flascassovitti 2007:n142-143). The men of Villamagna were free men, described as *vassali* to the monastery. In other words, the men of Villamagna were not legally bound as agricultural workers to the monastery as serfs (Bailey 2014, Wickham 2008). As part of this vassalage, the men of Villamagna paid rent for farmland, although not for their gardens, in variable quantities of wheat and barley; in *spatula porci*, or pork shoulder cuts ideal for making prized dried meats such as a *prosciutto*; and with 60 days of free labor to the monastery at harvest time (Carocci 1997a, 1997b, 2016, Flascassovitti 2007, Goodson 2019). Carocci (2016) notes that one of the most distinct characteristics of the monastery San Pietro at Villamagna is the relatively compact size of the monastic estate. Rather than a mosaic of holdings across the landscape, San Pietro's estate extended for about 2 km in every direction.

Another distinctive characteristic of Villamagna is the conservation of the *feudum* in organizing labor and production, and in this sense was more similar to the rural monastic estates of the Norman kingdom starting approximately 25km south of the site (Carocci 2016). Medieval *feudum* consisted of a house, vegetable garden, a vineyard, and a number of agricultural plots in the seigneurial territory. Elsewhere in Italy, the *feudum* was no longer an operational unit of farming, but rather a means of control and extraction from the elite rural class of *signoria*. It was common for multiple tenant families to farm various plots within a single *feudum*, and to collectively pay rent for that land. Within Villamagna however, the *feudum* persisted as an organizational unit; for example one of the *feuda* of Villamagna belonged to Giovanni di Preite, and was comprised of 9 agricultural parcels, two large gardens, a bed of reeds, a vineyard, a house, and a kitchen garden (Flascassovitti 2007:n.56, Carocci 2016). Archaeological research at Villamagna points generally to a centralized settlement, where farming peasants largely did not live on their *feudum*. Carocci (2016:405) makes the case based on archaeological remains and historical documents that the peasant farmers of Villamagna lived in a communal centralized residence, rather than in a more typical dispersed manner.

Further evidence from Villamagna suggests a variety of occupations and labor undertaken by its peasant inhabitants; Trombley et al. (2019) found dental evidence for the production of hemp textiles that corroborates archaeological evidence of spindle whorls, spindle hook, and sewing needles recovered at the site. More broadly, it is expected that textile production, animal husbandry, wine production, and crop farming were part of the daily life activities of the people at Villamagna. Archaeological evidence from the site suggests that many properties grew grapes for wine, wheat, barley, olives, fruit trees, and *cannapinae* (hemp groves); and micro-paleobotanical remains suggest estate workers ate leafy greens, elderberries, buckwheat, sheep or goat meat, and birds (Goodson 2016). A stable isotope study conducted at the site showed a difference in δ^{15}N for infants and juveniles, indicative of expected trends for weaning and differences in diet between juvenile and adult individuals. Stable isotope data from adults at Villamagna suggest that their diet was relatively consistent with what is broadly expected for Italian medieval peasants (e.g., millet, wheat, barley, legumes) (Nitsch 2016), and the dietary trends seen at Pava (Riccomi 2020). Nitsch's (2016) elaboration of dietary differences, based on Villamagna results suggests that in addition to religious identity and chronological distinctions, there are important differences in diet that relate to larger trends of inland versus coastal diet and urban versus rural diets, and males had slightly higher δ^{15}N and δ^{13}C compared to females, indicating that perhaps they had more access to more proteinaceous food sources.

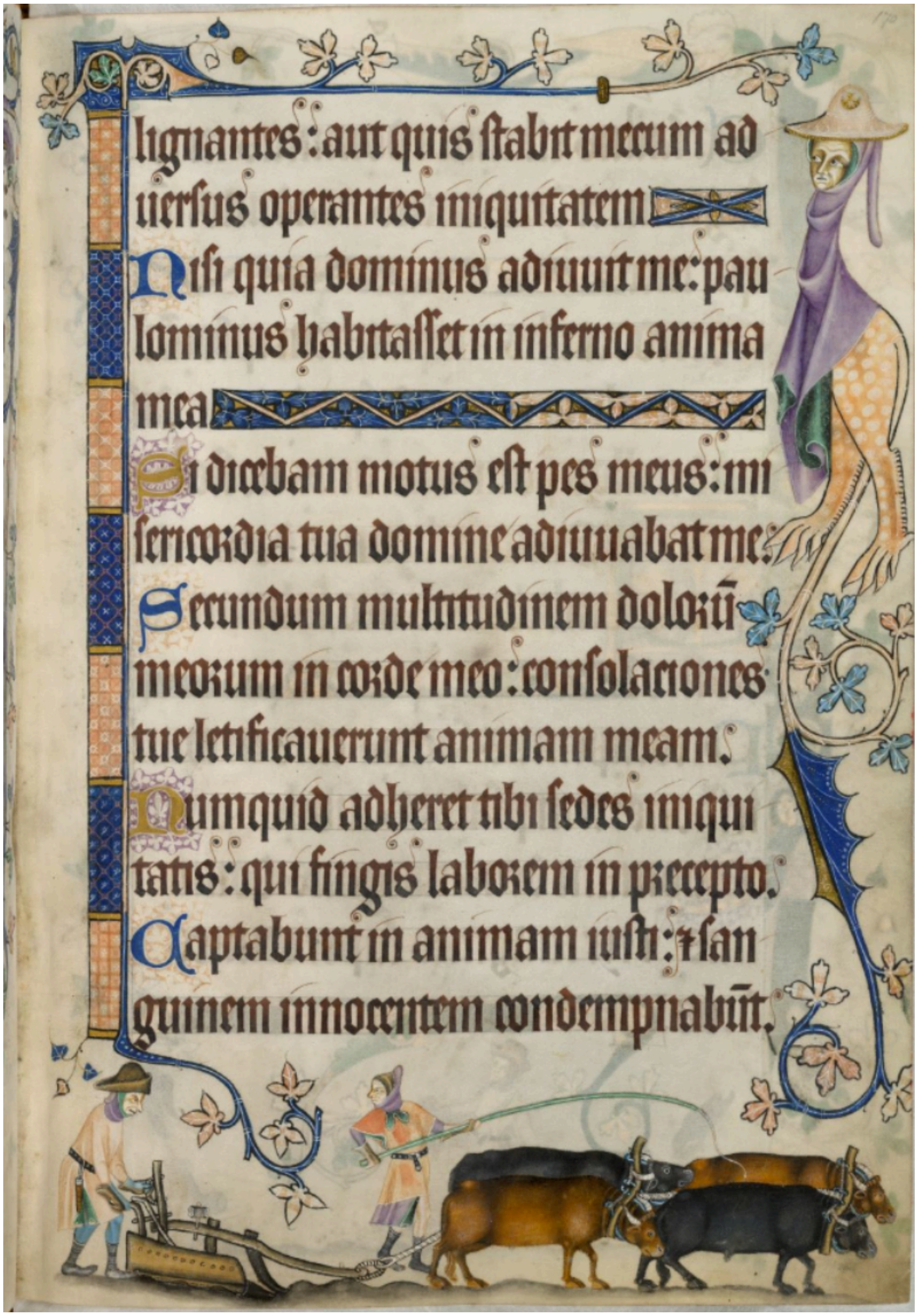
Opening Thoughts

In Chapters 3-5 of this dissertation, I examine markers of labor, movement, and inequality at these two Medieval sites. Medieval Italy is a compelling place and time period for investigating how inequality is embodied, particularly amongst rural people due to the abundant scholarly work that has been done on medieval disability (e.g., Eyler 2016, Metzler 2006, 2011, 2013, Pearman 2010, Singer 2010, Wheatly 2010), saints (Booth 2011, Bynum 1988, Sanok 2007, Lewis 2012), medicine (Dendle & Touwaide 2015, Green 1989, 2009, Skinner 1997) and material culture (e.g., Gilchrist 1997, 2008, Smith 2009, Stanbury 2015), and bioarchaeology (Agnew 2014, DeWitte 2014a, 2014b, 2015, Mant & Roberts 2015, Lewis 2016, Roberts 2017, Sofaer-Derevenski 2000, Trombley et al. 2019). Moore (2003) a critical medievalist, links discrimination in contemporary Euro-American culture to the Late Medieval period, citing growing anxiety about the body in relation to the plague, leprosy, Jews, and heretics—and the legal enforcement of social hierarchies along lines of sex and gender, religious belief and practice, and even regional ethnic identities. Framed in terms of biopolitical risk, there is ample contextual evidence for the variety and nature of biopolitical risk exposure amongst medieval peasants, although considerably different from any contemporary context. Rather than explaining contemporary disability or tracing a continuity between the medieval period and the present, I look to the medieval period with a disability orientation—reconfiguring the ways in which medieval daily life, inequality, and bodies are understood. For this work, I examine the bodies of medieval peasants (n=276) from two populations (Villamagna and Pava) using a crip-materialist framework that builds on previous historiographical analyses of economic change, political economy, and the agricultural milieu of Medieval Italy. I infuse critiques of class struggle, feudalism, and labor inequality with the evidence of the embodied consequences of these inequalities, moving against the notion that the body and its materiality can be taken for granted in our studies and writings of the past.

Figure 1.1 Prowess and Idleness, David and Goliath, a sower, Somme le Roi, Central France c. 1295 (BL Add. 54180 f.121v)

Figure 1.1 – This figure is an image from the Luttrell Psalter (British Library Add. 54180 f.121v) that shows four scenes, including on the right top an "idle" farmer laying on the dirt in the field he is supposed to be plowing. He is idling next to two horses who are attached to his cart. There is a small oak tree trunk with re-growth next to him. In the lower right scene shows an "industrious" sower with a bib full of seeds to be planted around his neck; he is sowing seeds with his right hand and holding the bib with his left.

Figure 1.2 Two men ploughing with four Oxen, Luttrell Psalter, Northern England c.1350 (BL Add 42130, fol. 170r)



lignantes: aut quis ſtabit mecum ad
uerſus operantes iniquitatem
Niſi quia dominus adiuuit me: pau
lominus habitaſſet in inferno anima
mea
Si dicebam motus eſt pes meus: mi
ſericordia tua domine adiuuabat me:
Secundum multitudinem dolorū
meorum in corde meo: conſolaciones
tue letificauerunt animam meam.
Numquid adheret tibi ſedes iniqui
tatis: qui fingis laborem in precepto.
Captabunt in animam iuſti: ⁊ ſan
guinem innocentem condempnabūt.

Figure 1.2 – This figure is an image of page f.170r from the Luttrell Psalter (British Library Add. 54180) that shows two men using four oxen and a blade-style plough to turn the soil in a field. One man is holding a long whip, while the other man holds onto the plough with his back bent forward slightly. This style of ploughing is very physically intensive and could result in disc herniation or injury from sustained practice.

Figure 1.3 Man sowing seeds with guard dog and crows stealing seeds, Luttrell Psalter, Northern England c.1350 (BL Add 42130, fol. 170v)

Et factus est michi dominus in re
fugium: et deus meus in adiutoriū
spei mee
Et reddet illis iniquitatem ipsorū:
et in malicia eorum disperdet eos: dis
perdet illos dominus deus noster.
Venite exultemus domino:
iubilemus deo salutari
nostro.
Preoccupemus faciem eius in con
fessione: et in psalmis iubilemus ei.
Quoniam deus magnus domi
nus: ⁊ rex magnus super omnes
deos.

Figure 1.3 – This figure is an image of page f.170v from the Luttrell Psalter (British Library Add. 54180) that shows a man with a basket or wooden box worn like a purse across his chest full of seeds. There is a large sack of seeds behind him. He uses a cup or scoop to throw seeds on the ground from his box as his guard dog chases one crow and another crow eats seeds from the sack on the ground. Carrying the weight of the seed box across the neck and shoulders, as shown here could result in arthritis or neck strain with continual use.

Figure 1.4 Two men tilling soil using a horse being pestered by crows, Luttrell Psalter, Northern England c.1350 (BL Add 42130, fol. 171r)

Quia in manu eius ſunt omnes fi
nes terre: et altitudines moncium
ipſius ſunt.
Quoniam ipſius eſt mare et ipſe fe
cit illud: ⁊ ſiccam manus eius forma
uerunt.
Uenite adoremus ⁊ procidamus et
ploremus ante dominum qui fecit
nos: quia ipſe eſt dominus deuſ noſt'.
Et nos populus paſcue eius: ⁊ oues
manus eius.
Hodie ſi uocem eius audieritis: no
lite obdurare corda ueſtra.
Sicut in irritacione: ſecundum diē

Figure 1.4 – This figure is an image of page f.171r from the Luttrell Psalter (British Library Add. 54180) that shows two men tilling soil using a horse that is pulling a till. One man is holding a sling shot to throw rocks at two crows, while the second man is leading the horse and holding a small whip in one hand.

Figure 1.5 Man and woman breaking up clods in a field using mallets, Luttrell Psalter, Northern England c.1350 (BL Add 42130, fol. 171v)

temptacionis in deserto
Ubi temptauerunt me patres uestri:
probauerunt ⁊ uiderunt opera mea.
Quadraginta annis offensus fui
generacioni illi ⁊ dixi semper hii er
rant corde
Et isti non cognouerunt uias me
as: ut iuraui in ira mea si intrabũt
in requiem meam
Cantate domino canticum
nouum: cantate domino
omnis terra
Cantate domino ⁊ benedicite no
mini eius: annunciate de die in diẽ

Figure 1.5 – This figure is an image of page f.171v from the Luttrell Psalter (British Library Add. 54180) that shows a man and woman breaking up clods in a field. They are each holding a mallet, used to hit the clod to break it up. They are both bent over in a way that would result in lower back pain and possibly arthritis with sustained practice.

Figure 1.6 Two women cutting weeds from a crop field, Luttrell Psalter, Northern England c.1350 (BL Add 42130, fol. 172r)

ſalutare eius
Annunciate inter gentes gloriam
eius: in omnibus populis mirabi
lia eius
Quoniam magnus dominus et
laudabilis nimis: terribilis eſt ſuper
omnes deos
Quoniam omnes dii gencium de
monia: dominus autem celos fecit.
Confeſſio ⁊ pulcritudo in conſpectu
eius: ſanctimonia ⁊ magnificencia
in ſanctificacione eius
Afferte domino patrie gencium af
ferte domino gloriam ⁊ honorem:

Figure 1.6 – This figure is an image of page f.172r from the Luttrell Psalter (British Library Add. 54180) that shows two women cutting weeds from a field of wheat. They are using two long poles with small scythes attached to the ends to cut and remove these weeds. They are bent over from the lower back, suggesting this type of weeding activity could affect the joint health and stability in the lower and low back regions of the spine.

Figure 1.7 Three women and a man harvesting wheat in the field using hand-scythes, Luttrell Psalter, Northern England c.1350 (BL Add 42130, fol. 172v)

afferte domino gloriam nomini eius.
Tollite hostias ⁊ introite in atria
eius: adorate dominum in atrio
sancto eius
Commoueatur a facie eius uniuer
sa terra: dicite in gentibus quia do
minus regnauit
Etenim correxit orbem terre qui nō
commouebitur: iudicabit populos
in equitate
Letentur celi et exultet terra: com
moueatur mare et plenitudo eius:
gaudebunt campi ⁊ omnia que in
eis sunt

Figure 1.7 – This figure is an image of page f.172v from the Luttrell Psalter (British Library Add. 54180) that shows three women (right) and one man (left) threshing wheat in a field using hand scythes. Two women are on the ground threshing, while another woman stands with a scythe nearby. The man walks behind them, gathering the wheat into bundles. Threshing activities performed in this manner would likely affect the shoulders, neck, upper back, and lower back.

Figure 1.8 Five men hauling and stacking bundles of wheat after harvest, Luttrell Psalter, Northern England c.1350 (BL Add 42130, fol. 173r)

Tunc exultabunt omnia ligna sil
uarum a facie domini: quia uenit
quoniam uenit iudicare terram
Iudicabit orbem terre in equitate: ⁊
populos in ueritate sua
Dominus regnauit exultet
terra: letentur insule multe:
Nubes ⁊ caligo in circuitu eius: ius
ticia et iudicium correccio sedis eius.
Ignis ante ipsum precedet: ⁊ inflam
mabit in circuitu inimicos eius.
Illuxerunt fulgura eius orbi terre:
uidit ⁊ commota est terra
Montes sicut cera fluxerunt a facie

Figure 1.8 – This figure is an image of page f.173r from the Luttrell Psalter (British Library Add. 54180) that shows five men hauling and stacking bundles of wheat. Some of the men wear gloves on their hands or have them at their belts. Two men hauling wheat bundles (left) are carrying the bundles on or above their shoulders/upper back; the men who are stacking the wheat (right) have slightly bent backs and pile the bundled wheat in a large stack.

Figure 1.9 Four men carting wheat with three horses, Luttrell Psalter, Northern England c.1350 (BL MS Add 42130, fol. 173v)

domini: a facie domini omnis terra.
Annunciauerunt celi iuſticiam eiuſ:
⁊ uiderunt omnes populi gloriam
eius.
Confundantur omnes qui ado
rant ſculptilia: ⁊ qui gloriantur in
ſimulacris ſuis.
Adorate eum omnes angeli eius:
audiuit et letata eſt ſyon.
Et exultauerunt filie iude: propter
iudicia tua domine.
Quoniam tu dominus altiſſimus
ſuper omnem terram: nimis exalta
tus es ſuper omnes deos.

Figure 1.9 – This figure is an image of page f.173v from the Luttrell Psalter (British Library Add. 54180) that shows four men carting the bundled wheat, presumably from the field to storehouses, granaries, or mills elsewhere. One man is driving the cart with 3 horses. He has a long whip in both hands. Two other men are pushing the back of the cart, using their knees, upper thighs, and lower and low back to bear the weight of the loaded cart. The fourth man (right) is using a long pole to keep the wheat stacked higher on the cart from falling as the other men push the lower part of the cart.

Figure 1.10 Two medieval women making pasta, Northern Italy c.1390 (Biblioteca Casanatense 4182, f.84)

Figure 1.10 – This figure is an image of folio 84 of the Tacuinum Sanitatis (TS) (Biblioteca Casanatense, MS 4182, f.84) that shows two women making pasta. The woman (left) stretches strands of pasta on a wooden rack to dry, while the woman (right) is shown kneading pasta dough. The author of the Arab author of the original text (Ibn Butlan) wrote that pasta was good for the throat and chest; generally, the images from this manuscript depict an idealized view of agricultural practice, food production and the ideal medieval lifestyle. The TS manuscript at Casanatense in Roma was likely commissioned by Giangaleazzo Visconti the Count of Milano or another member of the Milano nobility in the late 14th century.

Figure 1.11 The garlic harvest, Northern Italy c.1375 (BnF Ms. Lat 9333, f.23r)

Figure 1.11 – This figure is an image of folio 23r the Tacuinum Sanitatis (Bibliothèque nationale de France, MS Lat 9333 f.23r) that shows two men harvesting garlic (Allium sativum), labeled "Alea". One man (left) is carrying two bundles of garlic over his shoulder, and the other man (right) is harvesting garlic from the field, while crouching on the ground. The text below the image describes garlic as effective against poisons, but possibly damaging to the brain (Daunay et al. 2009).

Figure 1.12 Spelt threshing, Northern Italy c.1390 (Biblioteca Casanatense 4182, f.87)

Figure 1.12 – This figure is an image of folio 87v from the Tacuinum Sanitatis (Biblioteca Casanatense 4182) shows a man and woman threshing grain (spelta) in a field, there is an open granary behind them with bundled spelt stacked in it. The woman is demonstrating a standard posture for threshing, bent forward from the waist and holding a heavy hand flail; it is likely that activities such as threshing or reaping would contribute to disc or back pain or spine injury.

Figure 1.13 Wine making, Northern Italy c.1390-1400 (Biblioteca Casanatense, MS 4182 f.102)

Figure 1.13 – This figure is an image of folio 102 the Tacuinum Sanitatis (Biblioteca Casanatense MS 4182) that shows the autumn harvest. Although this illumination is part of a folio that discusses the benefits and detriments of the autumn season, it also depicts the vindemia, or annual grape harvest and first step in the wine-making process. In this image there is a young person of ambiguous gender (left) crushing grapes with their feet in a large vat, a woman (center) who is lifting a basket with grapes to add them to the vat, and a man (right) who is harvesting grapes from the vine. It is likely that lifting heavy baskets of grapes and carrying those baskets on top of the head (as seen in other imagery) would contribute to arthritis and degeneration in the neck region of the spine.

<u>Chapter 2:</u>

Materials & Methods

Orientation

This chapter provides an overview of the skeletal indicators and methodologies used to assess disease and mobility in the Villamagna and Pava samples, with some discussion of the current state of research amongst practitioners of bioarchaeology and a critical orientation. More precise details of sampling and methodological approaches, particularly analytic approaches are presented with each case (Chapter 3, 4).

This dissertation takes up an ethical and political orientation to disability that centers Disability Justice and disabled people. Visualizations of data presented in this dissertation were designed in R using the *viridis* package color maps (Garnier 2018), which is designed not to exclude color blind readers. These color scales are perceptually identical when converted from color to black and white and are designed to be equally visually distinct for viewers with various forms of color blindness (Garnier 2018). Throughout this text I primarily use identity-first language (i.e., disabled) as opposed to person-first language (i.e., people with disabilities). Identity-first language is contentiously preferred by many in the Disability Community in the United States (e.g., Brown, 2011, Longmore 1985a, 1985b, O'Toole 1996, Sinclair 2013) and is my personal preference as well. Although the use of person-first versus identity-first language remains hotly debated amongst the Disability Community and within academic discourse (e.g., Haller et al. 2006, Zola 1993). A politics of practice (e.g., Hunter 2019), requires an attention to the material-discursive components of embodied practice. The incorporation of identity-first language and of accessible color maps are a material-discursive enactment of the ethical work of this dissertation and demonstrate the real materiality of disability itself.

Materials

Skeletal Sample

Overall 265 individuals from the medieval cemeteries of Villamagna in Lazio (n=128) and Pava in Toscana (n=137) were selected for analysis in this study across all sex groups and adult age cohorts. Initial criteria for sampling included individuals with good preservation of the study skeletal site (spine and femora) as well as the pelvis and skull for estimating morphological sex and skeletal age-at-death. Sample sizes for individual analyses are contingent on preservation, therefore there are slightly reduced sample sizes for particular analyses of the datasets.

At Villamagna a stratified random sample of adult individuals with good to excellent preservation from all periods was used for analysis, with the target being relatively equal distributions of male and female individuals. The site was stratigraphically excavated, and high-quality GIS and CAD maps were made of the site and skeletal assemblage during excavations (Figure 2.1-2.3). A relatively high percentage of the individuals available for analysis were studied. The observational data from Villamagna that is the basis of a large part of this dissertation was collected at the University of Rome, La Sapienza during in 2015 and 2016.

The Villamagna sample was cleaned and field osteological analyses were completed by Francesca Candilio and a team of master's students and volunteers on the project. The project initially sought to excavate the remains of a Roman Villa in order to address pertinent questions to about Imperial Rome and Latium Villas (Fentress 2016), but when excavations revealed medieval human remains in addition to expected archaeological and architectural remains, the project transformed to incorporate a bioarchaeological component. The effort was sponsored by three international institutions: the British School at Rome, the University of Pennsylvania, and the *Soprintendenza ai Beni Archaeologici del Lazio*, and the project incorporated a team of archaeologists, architects, and historians from many countries.

At Pava the skeletal assemblage observed for this dissertation was created by a stratified random sampling strategy (for individuals from the part of the cemetery dated to the 10th-13th century), that targeted equal proportions of male and female individuals distributed across all age groups. The Pava skeletal remains are housed at the Università di Pisa and were analyzed between 2018 and 2019. The Pieve di Pava, a rural *baptisterium*, was excavated as part of a landscape archaeology study of Tuscany, directed by Stefano Campana at Università di Siena. Over 1000 individuals from the Late Antique to Medieval period were excavated from the site (Figure 2.4). Osteological research has also been completed by Valentina Guiffra (Guiffra et al. 2019), Valeria Mongelli (Mongelli et al. 2008, Mongelli et al. 2011), Simona Minozzi, Paola Ricci (Ricci et al. 2012), and Giulia Riccomi (Riccomi 2020, Riccomi & Guiffra *forthcoming*, Riccomi et al. 2018), in addition to research completed as part of the master's program directed by Valentina Giuffra at the Università di Pisa.

Figure 2.1 Plan of Early Medieval Cemetery at Villamagna

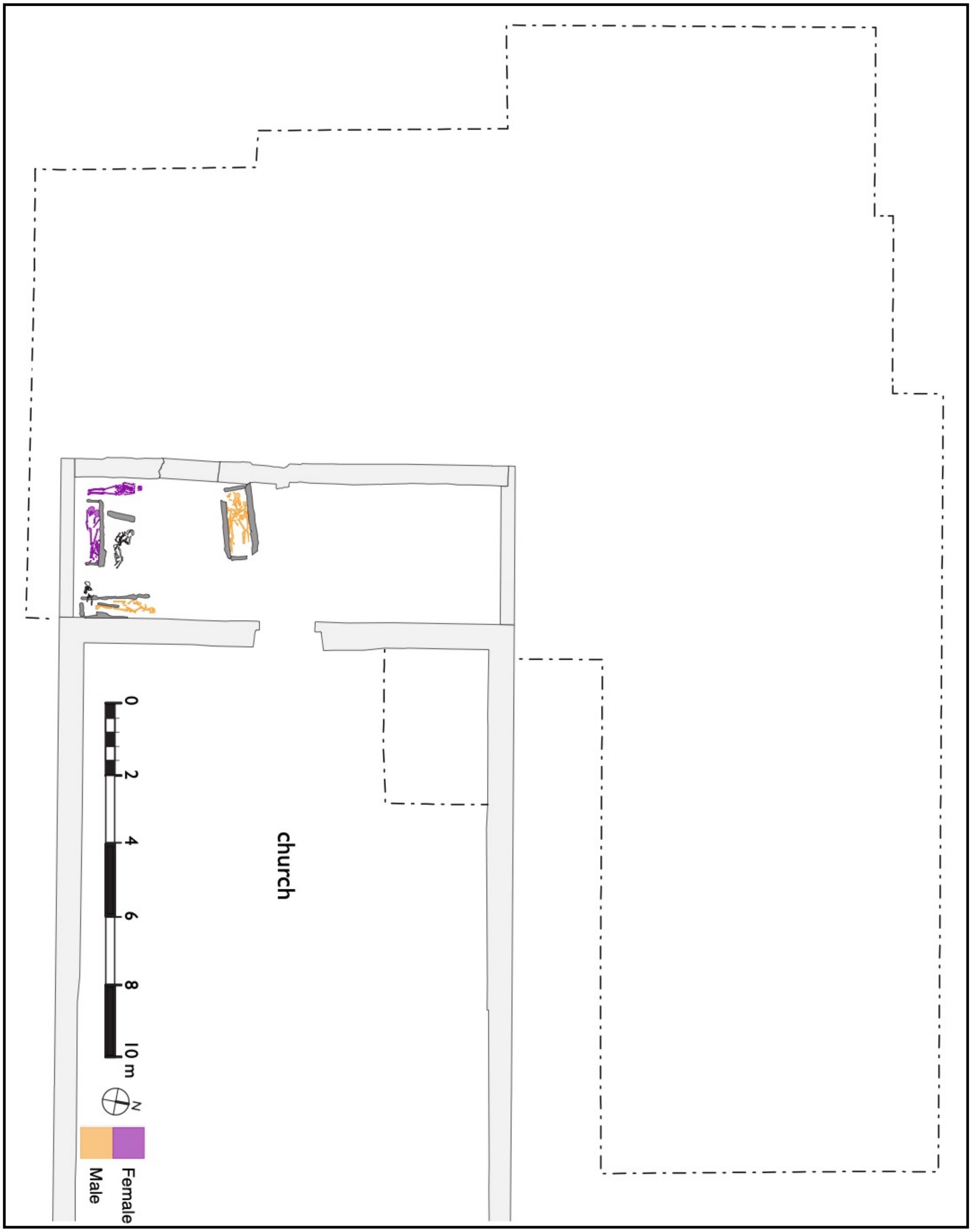


Figure 2.1 – This figure shows the distribution of male (orange) and female (purple) skeletons sampled from the Villamagna site in the Early Medieval period. Skeleton SHP and architecture EPS files provided by Margaret Andrews & Caroline Goodson, adapted by KM Kinkopf.

Figure 2.2 Plan of Central Medieval Cemetery at Villamagna

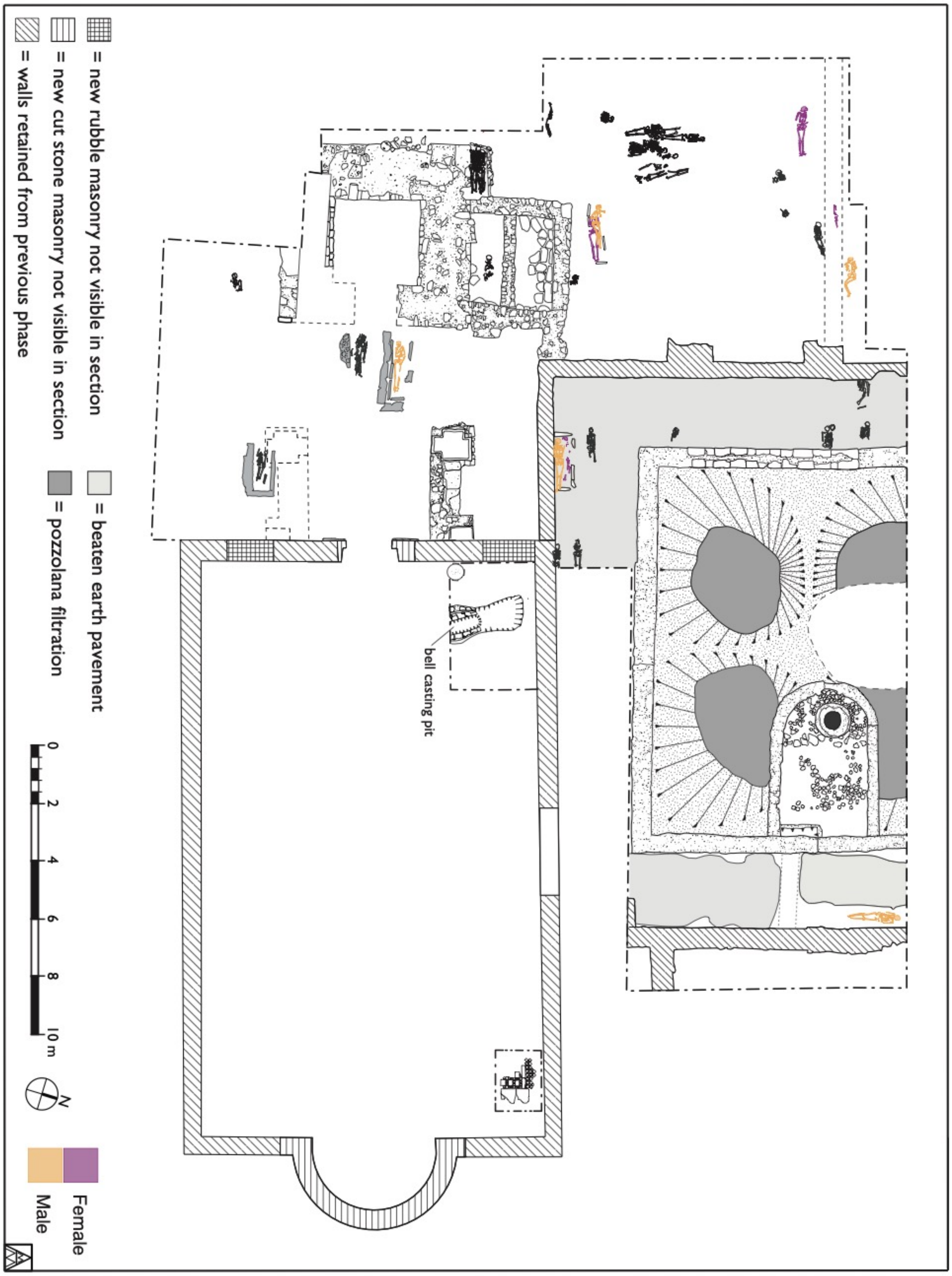


Figure 2.2 – This figure shows the distribution of male (orange) and female (purple) skeletons sampled from the Villamagna site in the Central Medieval period. Skeleton SHP and architecture EPS files provided by Margaret Andrews & Caroline Goodson, adapted by KM Kinkopf.

Figure 2.3 Plan of Late Medieval Cemetery at Villamagna

Figure 2.3 – This figure shows the distribution of male (orange) and female (purple) skeletons sampled from the Villamagna site in the Late Medieval period. Skeleton SHP and architecture EPS files provided by Margaret Andrews & Caroline Goodson, adapted by KM Kinkopf.

Figure 2.4 Plan of Cemetery with Central Medieval Burials at Pava

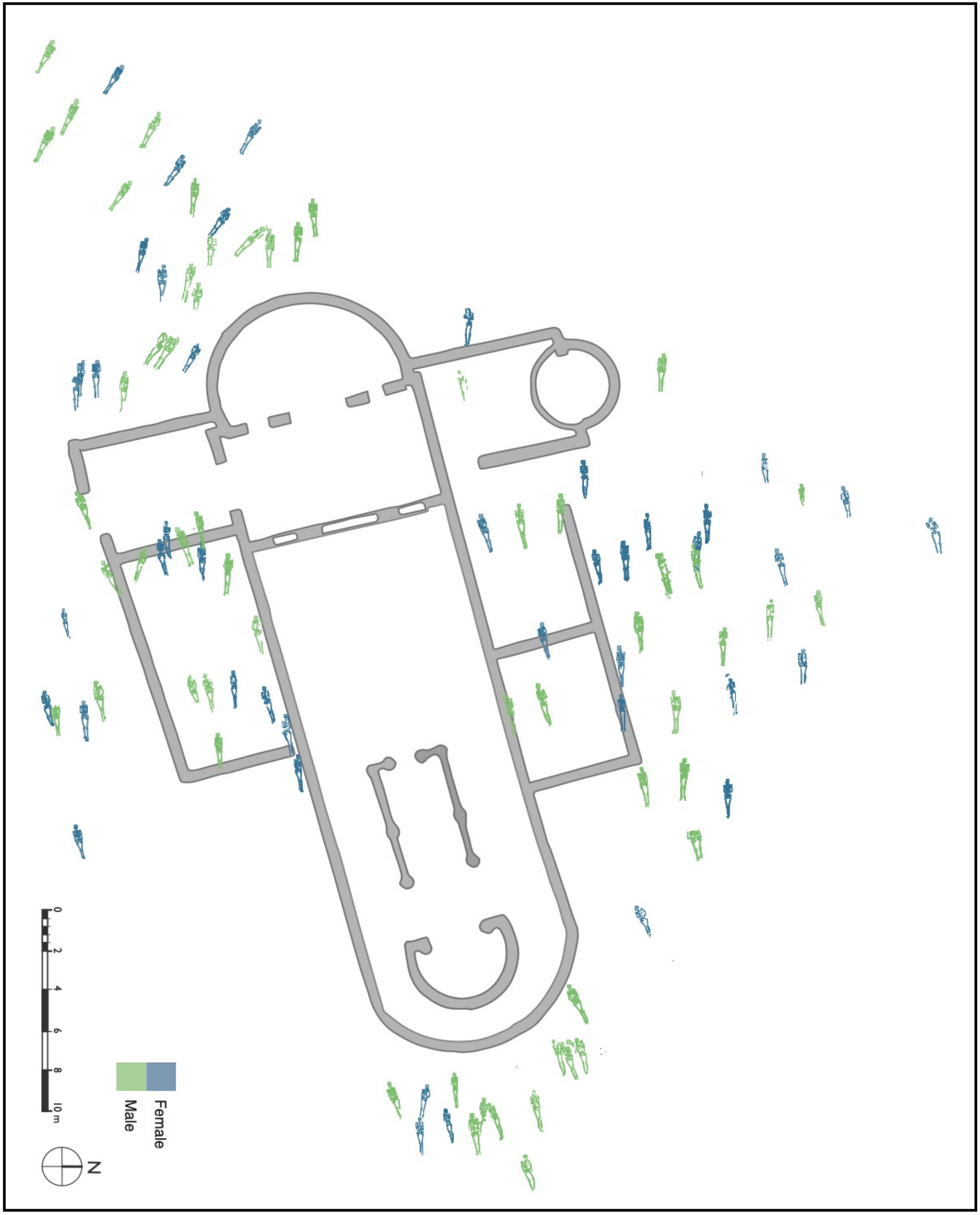


Figure 2.4 – This figure shows the distribution of male and female skeletons sampled from the Pieve di Pava site but does not include unsampled skeletal remains. The sample utilized for this study uses relatively equal numbers of male and female skeletons from all regions of the cemetery. Skeleton SHP file and architectural rendering provided by Cristina Felici and Valentina Giuffra, adapted by KM Kinkopf.

Methods

Method: Estimating Morphological Sex

Morphological sex was estimated based on observation of the *os coxae* and cranial morphology (Ascàdi & Nemeskèri 1970; Brothwell 1981; Buikstra & Ubelaker 1994). Where present, I examined sexually dimorphic morphological differences in the os coxae as the first line(s) of evidence, especially the ventral arc, sub-pubic angle, sub-pubic concavity, and sciatic notch (Ascadi & Nemeskeri 1970, Brothwell 1981, Buikstra & Ubelaker 1994). Second lines of evidence included cranial indicators (Buikstra & Ubelaker 1994) and body size, to refine and ensure accuracy of sex estimation. At Villamagna my assessments of morphological sex were compared with field osteology assessments of the os coxae and cranial morphology, and corroborated by other bioarchaeologists (Agarwal et al. 2015, Beauchesne et al. 2016, Beauchesne et al. 2019, Kinkopf et al. 2019, Trombley et al. 2019). At Pava, my assessments of morphological sex were compared to estimations made by multiple master's students in Paleopathology, and final designations were a consensus between myself and multiple other experienced bioarchaeologists (Drs. Agarwal, Guiffra, Riccomi, Minozzi).

Orientation: Sex & Gender

Bioarchaeologists have written extensively on the issue of binary morphological sex designations and their relationship with gender identities in various historical contexts (e.g., Agarwal 2012, Agarwal & Wesp 2017, Geller 2008, 2009a, 2009b, Hollimon 1997, 2000, 2006, 2017). This body of scholarship has a few focal points, one of these is intensely engaged with actual empirical evidence for discrete sex groups, and another emphases the contextual and historical contingent nature of sex, sexual identity, and gender identity. In *Feminist, Queer, Crip,* Alison Kafer (2013) outlines the fundamental importance of coalition building between and amongst social theorists (and our respective communities) in order to materialize the transformative potential of our scholarly and community-organizing work. This project takes up disability as a politically, socially, and culturally generated phenomenon in an effort to denaturalize the *category* of disability that is pervasive in late liberalism. Fundamental to feminist practice is an explicit reflexivity of the self as scientist-observer (Joyce 2017, Barad 2003, 2007). In bioarchaeology, reflexivity entails activating one's own subjectivity in writing (as it is always already active in the practices of observation and analysis).

This study takes seriously the consequences of reifying a biological sex binary in its design, analysis, and conclusions; although I have hoped to destabilize any one-to-one relationship between identity (sex-gender, age, disability, regional affiliation) and biological condition(s) through an intersectional approach. I use a binary sex variable in my analyses for Chapters 3 and 4. There is ample empirical data (from this study, and elsewhere) to suggest that although Medieval people participated in a larger binary gender system, there were no essential experiences of activity or disease that defined individual experiences based purely along lines of morphological sex (Cadden 1993). In particular, the intersections of gender identity and economic or religious status are well documented in historical documents (Kowaleski 2014, Whittle 2013) and this theme has been widely studied by feminist medieval studies scholars (see the edited volume by Karras and Bennett 2013, Gilchrist 1997, 2000, 2012).

In Chapter 5, I take up some of these issues using an osteobiographical (and multi-scalar) micro-historical framework. Drawing on documents from the medieval archive at Villamagna, and exploring variance within some of the data presented, which tells a more complex story than the population-level data. Although there are statistically significant trends based on broad (generalizing) categories, such as age, sex, and mortuary treatment, the variance within each of these groups is not well characterized by simple statistical methods. Across multiple types of data and through various analyses, it is evident that there is striking amount of variance *within* these groups, indicating that there are confounding effects from latent variables that are shaping experiences of disease and activity across the populations of Pava and Villamagna.

I have no doubt that the population-level results accurately portray some of the inequalities faced at a population-level in medieval society, and overall trends for the population. However, in alignment with my interests in how inequality is embodied at the individual *and* collective levels, I remain committed to examining in the ways in which bodily hierarchies are institutionalized in ways that subsequently constitute an uneven distribution of resources and privilege, as well as pain and disability.

Method: Estimating Skeletal Age-at-Death

Adult age was estimated in adults using multiple standard morphological indicators from the pubic symphysis (Brooks & Suchey 1990) and auricular surface (Lovejoy et al. 1985); these were corroborated by examination of the sternal end of the rib when possible (İşcan et al. 1984; 1985). We categorized individuals using three conservative age groups: 18-29 years (young adult), 30-49 years (middle adult), and 50+ years (older adult) to remedy the issue of precise aging in skeletal assemblages without documentary records of age (Jackes 2000, 2011). Four individuals could not be classed into an age group and were included in some of my analyses (excepting age-contingent analyses) as 18+ years (adult of indeterminate age).

Orientation: Aging

One of the greatest challenges in bioarchaeological analyses is the accurate and precise estimation of age-at-death in older adults. This methodological challenge poses an issue for analyses and interpretations of age-related changes in the skeleton, as well as our narratives of experiences of aging in the past. Bioarchaeological studies of social identity as it relates to age and aging were popularized by scholars from the European tradition of "osteoarchaeology" in the early 2000s (e.g., Gowland 2006, Sofaer 2004, 2006a, 2011). However, substantial research has been dedicated to developing accurate methods for aging the skeleton for many years, drawing on multiple lines of evidence including indicators of degenerative change from non-mobile joints like the pubic symphysis (e.g., Brooks & Suchey 1990, Jackes 1985, 2000, Godde & Hens 2012, 2015) and auricular surface (Buckberry & Chamberlain 2002, Falys et al. 2006, Hens & Belcastro 2012, Hens & Godde 2016), sternal rib end (İşcan et al. 1984, 1985, Yoder et al. 2001) cranial suture closure (Brooks 1955, Hershkovitz et al. 1997, Key et al. 1994, Meindl & Lovejoy 1985), and histological analyses (Dudar et al. 1993, Stout & Paine 1992, Stout et al. 1994, Paine & Brenton 2006, Crowder 2016). As affirmed by Chapter 3, the use of degenerative changes in dynamic and mobile joints such as those of the spine are not suitable for estimating age at death (Snodgrass 2004). The estimation of age is considerably more precise for younger age individuals, because the processes of aging themselves generate instability and variation fundamentally (re)making a body that is difficult to define.

It is widely accepted that aging has a nonlinear relationship with multiple skeletal indicators in the body (e.g., Pessa 1999), and that aging is defined by a constant or linear trend. This phenomenon is what makes estimating adult age at death so difficult for bioarchaeologists. Particularly problematic for bioarchaeologists is the estimation of age for adult individuals in the so-called 50+ age cohort. Anyone who lives in a body witnesses aging and can intuitively question whether the embodied experiences of people between the ages of 50 and 110 are homogeneous, predictable, or uniform. Based on experiential data we would expect that experiences of aging are not only variable based on other axes of identity, but that chronological age (the years since birth according to official documents) does not determine bodily experience for the individual, and that age-related experiences are most certainly not universal (e.g., Agarwal 2016, Gowland 2015). Empirical studies have demonstrated multiple times over that aging is not linear and might even be characterized in terms of variation of experience.

Disability perspectives offer that differences in health, mobility, pain, social position, and daily life are not uniformly distributed across people of any age group, and instead the experiences of disability and chronic disease disrupt these well-formulated boundaries between young, middle, and older age (Wendell 1996, 1999, 2013, Zola 1988). Drawing on the knowledge generated by disabled people's experiences, we can further interrogate the age category of "50+ years" in bioarchaeology. In turn, through this interrogation of age categories, bioarchaeologists can offer examples of aging and life-course experience peripheral and challenging to the normative framework of aging specified by late liberalism.

An introductory concept in bioarchaeology is the difference between skeletal (or physiological, or biological) age, chronological age, and social age (Sofaer 2011, Gowland 2006, see also Agarwal 2012, Molleson 1986, Arber & Ginn 1995, Sofaer 2004, 2006a). Taken together these aspects of age constitute much of the variation of aging and age that is crucial to a monist understanding of this phenomenon. In Chapter 4, I investigate the ways in which the category of "50+ years," or "older-age cohort" create bias in bioarchaeological analyses of age-related trends, and in population trends overall. Using a statistical measure of sample dispersion (coefficient of variation, *CV*), I show that the older-age cohort of individuals in the sample study have higher variance and more diverse experiences. This suggests that older individuals have variance in experience due to differences in age or due to intersectional differences in daily life.

Skeletal Indicators

Degenerative Spine Disease

Spinal degenerative joint diseases (sDJD, DJD, or DSD) broadly affect vertebrate skeletons of multiple species across the globe and since the evolution of vertebrates (Fox 1939, Jurmain 2000, Rothschild et al. 2002, Dawson & Trinkaus 1997). It is one of the most prevalent and frequently observed degenerative conditions among humans and affects a wide proportion of many historic and modern populations ranging from 5-70% prevalence (Bridges 1991, 1992, Ortner & Putschar 1981, Rojas-Sepulveda et al. 2008). Back pain is a leading cause of disability and disability-related leave from work in the U.S. (Murray et al. 2012); and it is estimated that

80% of adults experience low back pain at some point in their lives (Goode et al. 2013, NIH 2015, Rubin 2007). Spine DJD is so commonly seen in archaeological populations that it was considered as a possible age estimation method, however its complex etiology, early onset, and variability in archaeological populations makes it less-than-ideal for precise age estimation (Snodgrass 2004, Klaus et al. 2009).

DJD also provides a unique axis for understanding intersectional identity through a biocultural lens, because of its variable relationship with age, sex-gender, injury and trauma, genetic predisposition, biomechanical stress, and physical activity (Ortner & Putschar 1981, Goodman et al. 1984, Jurmain and Kilgore 1995, Rojas-Sepulveda et al. 2008, Rogers & Waldron 2001, Waldron 1995). For this study, each vertebra in the spine of each individual (typically 24 bones per person) were evaluated for presence and severity of disease on the vertebral body and vertebral articular facets on an ordinal scale (Figure 2.5, see Chapter 3 for further elaboration). These vertebrae were then analyzed at the level of individual bones, regions, and overall for individuals and the effects of site, sex-gender, age, and mortuary treatments were assessed using non-parametric statistical tests and population prevalence.

In Chapter 3, I present the results of my analysis of these data, demonstrating that differential access to economic privilege affects disease outcome at Villamagna and that overall, differences in physical activity along lines of morphological sex (but not exclusively) likely contribute to higher levels of spine disease amongst male individuals. In Chapter 5, I examine individuals who disrupt these trends in gender and economic access, in order to discuss complexity in social life and experience amongst medieval people. I further develop a framework for understanding occupational and physical activities and situated and socially contingent experiences, embedded in a larger landscape of political, cultural, religious, and economic difference.

Figure 2.5 Cervical vertebra inferior view

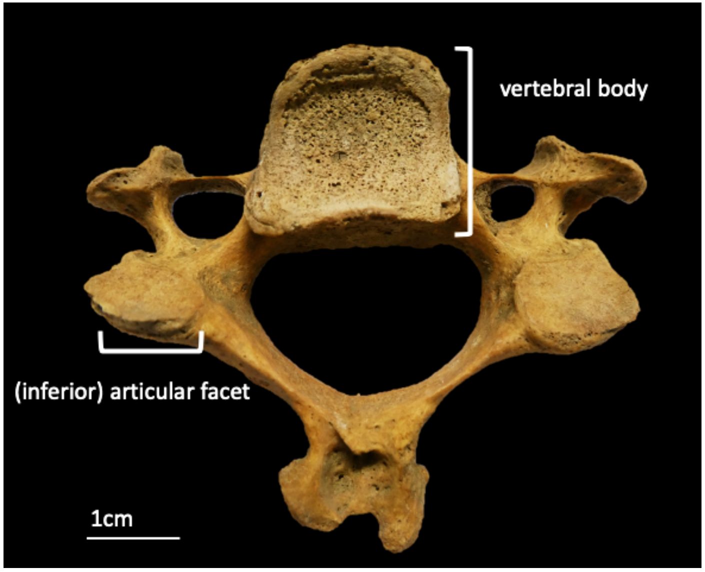


Figure 2.5 – This figure depicts a typical well-preserved cervical vertebra without degenerative changes to the vertebral body or inferior articular facets from the site of Pava (Tuscany). Photograph taken at Università di Pisa.

Femoral Cross-Sectional Geometry

A mosaic of processes influence bone morphology from its developmental origins throughout life, and even after life (in taphonomic changes); these biocultural phenomena include genetic, epigenetic, and environmental constraints and affordances. Bone is a dynamic and plastic tissue, long bones such as the femur are particularly susceptible to the influences of mechanical environment. How bone responds to differential mechanical loading is a central question in biological anthropology, although it is well established that changes in the manner, direction, and repetition of loading in the skeleton affects bone geometry (e.g., Lieberman et al., 2001; Pearson & Leiberman, 2004; Ruff 2008), the extent of biocultural experiences such as sex-gender, age, and disease have not been fully considered as main or confounding effects in most studies of biomechanical use in the past. Femoral cross-sectional geometry analysis provides an accessible and empirical method for examining skeletal robusticity (size and strength), habitual mechanical loading (leg use), and mobility (movement across the landscape). Cross-sectional geometry is an approach that views a broad swath of the population, while maintaining the usefulness for investigating individual variation within, among, and between populations.

The data produced by this methodological approach are continuous measurement variables and are considered less subjective than the ordinal rank data, such as that collected for degenerative joint disease. The primary sampling restriction is taphonomic; individuals who have no femora (left or right) preserved or intact cannot be included for analysis. It is possible that preservation bias might correlate with lower bone mass or reduced bone quality, as those skeletal remains often do not preserve as well as more dense and compact bones.

Foundational studies in femoral cross-sectional geometry focused on over-arching patterns of mobility as they relate to large-scale changes in human behavior and activity (e.g., Bridges 1989, Holt 2003, Ruff & Larsen 2014a, Shaw & Stock 2009); as well as to shifts in subsistence strategy, geographic trends, and climatic change (Ruff et al. 2019, see also, Holt et al. 2018, Macintosh et al. 2017, Stock et al. 2011).

Cortical bone area (bone quantity) reflects axial rigidity and strength (Ruff, 2008; Ruff & Hayes, 1983). Measures of bone quantity, such as cortical area (CA), medullary area (MA), total area (TA), and percent cortical area (%CA) reflect bone remodeling and bone maintenance within the skeleton. Each of these (except %CA) is standardized to account for overall differences in body size. Loss of estrogens or androgens (gonadocorticoids, or steroid class sex hormones) increases the rate of bone remodeling by altering the processes of osteoblastogenesis (bone formation) and osteoclastogenesis (bone resorption), causing an increase in bone resorption (destruction) and a decrease in bone formation (Riggs et al. 2002, Russo et al. 2003, Vanderschueren et al. 2004). Androgens and estrogens have a bi-phasic effect on bone formation, where they can stimulate both growth as well as inhibit bone growth (Vandershueren et al. 2004). Based on clinical studies, it is hypothesized that androgens promote periosteal (radial) bone growth on the outside of the bone, increasing total area (TA); likewise, estrogens are hypothesized to decrease periosteal bone formation and increase endosteal bone-packing (on the interior surface of the bone) (Almeida et al. 2017, Vanderschueren et al. 2004). Clinical research has shown that bone strength can be attributed to this periosteal bone formation and increase in total area (TA), however bioarchaeological research has shown this trend is not straightforward and may be confounded by other biocultural factors (Agarwal & Grynpas 1996, Agarwal & Stout 2003, Agarwal et al. 2004).

Second moments of area (SMAs) reflect bending rigidity in multiple directions in relation to the neutral axis (Figure 2.6, Lieberman et al., 2004; Ruff & Hayes, 1983; Ruff 2008): I_x measures bending rigidity in the anteroposterior plane, and I_y in the mediolateral plane (Ruff, 2008); I_{max} measures maximum bending rigidity, and I_{min} measures the minimum bending rigidity and is calculated perpendicular to I_{max} (Figure Ruff & Hayes, 1983; Ruff, 2008). Polar second moment of area, J is a measure of torsional rigidity and an average of bending rigidity and is calculated as the average of I_{max} and I_{min} (Lieberman et al., 2004; Ruff 2008). Because polar second moments of area reflect the sum of perpendicular second moments of area (I_x, I_y, I_{max}, I_{min}) they provide an estimate of diaphyseal rigidity (Stock and Shaw 2007, Stock et al. 2011).

Figure 2.6 Diaphyseal Shape at 50% of Femur Biomechanical Length

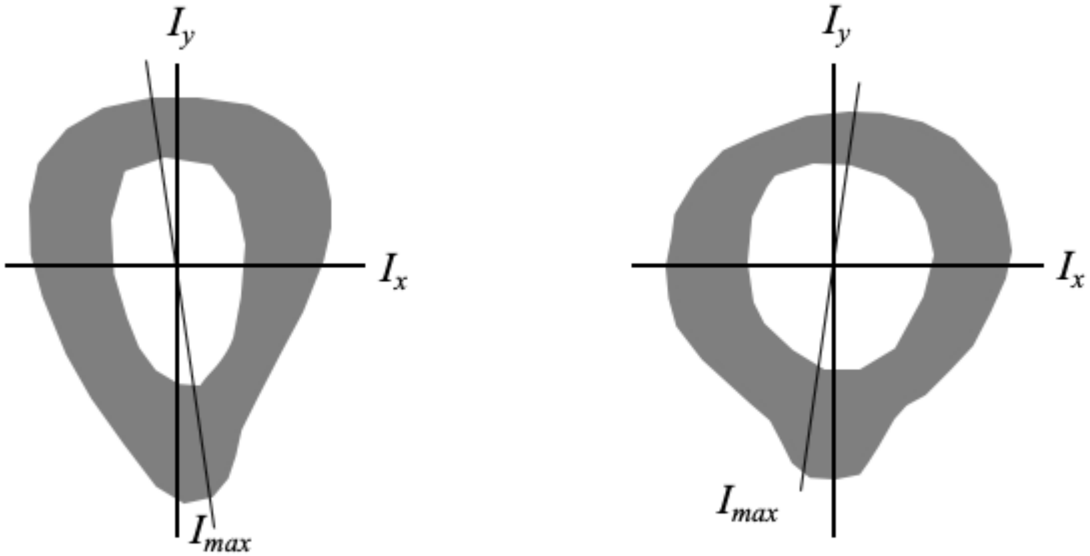


Figure 2.6 – This figure shows the cross sections of two femora at 50% of femur biomechanical length from Villamagna. The neutral axis and second moment of maximum bending (Imax) are shown as an overlay. In the femoral cross section on the left it is easy to see that Imax is very near I_y and that I_x has a smaller distance (indicating high AP loading along the axis of I_y) and for this section there is a high level of concordance between the measurements; in the femoral cross section on the right Ix and Iy have similar values because the slice is relatively more circular than the cross section on the left (equal amounts of AP-ML loading).

The polar second moment of area – *J,* quantifies the resistance of the bone's diaphysis to bending loads. More recently, cross-sectional geometry studies have begun to use the average bending and torsional strength (Z_p) in place of bending rigidity (J) (Ruff et al. 2018). These two measures have high concordance, however the results from both are presented in this dissertation for the purpose of comparing across older and newer studies (e.g., Marchi 2008, Maggiano et al. 2008, Ruff et al. 2018, Holt et al. 2018). Shape indices, I_x/I_y and I_{max}/I_{min}

are calculated as a ratio and are not size standardized; these indices quantify bone shape, where values closer to 1.0 indicates a more circular diaphysis and values diverging from 1.0 reflect increases or decreases in mechanical loadings (Stock et al. 2011). Together diaphyseal shape and robusticity provide evidence for differential locomotor activity levels and patterns within and among groups of humans (Trinkaus and Ruff 1999).

In Chapter 4, I present the results of a population-level study of general trends in mobility and lower limb use at Villamagna and Pava. I find that adults in the older-age cohort have high sample dispersion and high amounts of variation in bone morphology compared to young and middle age cohorts. In addition to the high variation amongst older adults, I find that a lack of access to economic privileges has an effect on female bone quantity, indicating that medieval women without access to economic excess may have also had less access to a nutrient-rich diet needed to maintain bone health (proteins and calcium-rich foods). I also find that regional differences are more important for determining overall population mobility, while sex differences are a crucial predictor for differences in bending strength and rigidity.

In Chapter 5, I examine outliers and extreme values from the analyses completed in Chapter 4. Here I look more closely at trends in spine disease and lower limb use amongst people buried with grave inclusions; examine the experiences and identities of people who had a unusual or “waddle and toddle” type gaits; and follow a case of unusual gait—discussing chronic disease, spine disease, and lived experience.

Chapter 3:

Biocultural influences on spine disease outcomes in two rural Medieval populations from the Italian Peninsula (1000-1350 AD)

Orientation

Our daily lives and our work are intimately tied to multiple aspects of our identity. The physical demands of medieval farming and agricultural techniques, as well as the usual demands of rural and feudal life (building construction, blacksmithing, manufacturing textiles, et cetera) form the foundations of the peasant experience in the medieval period. These experiences mutually shape and are shaped by experiences and ideologies of sex-gender, religious identity and status, access to economic privilege and resources, age and aging, regional and ethnic identities, and disease-status (e.g., lepers/leprosy). The body and skeleton are biocultural entities—with constraints and affordances—that record these social, cultural, and biological experiences into their material structure, surviving in cemeteries, crypts, and mausoleums as an archive of a person's life.

The motivation for this study emerges from my interest in the intersections of inequality with health and disease in rural agricultural areas, where inequality takes many shapes. My orientation to spine disease emerges from personal and familial experiences of back pain and spine disease, but also comes with the explicit goal of claiming disability (i.e., centering, acknowledging, and valuing disability where it emerges, see Linton 1998) and at the same time working to deconstruct the oppressive systems that impose disability (McRuer 2013), differentially debilitate people (Puar 2017), and insist on social marginalization as an ultimate consequence for embodying disability (Siebers 2008, Kafer 2009).In contemporary societies, it is clear that inequality is not uniformly distributed across the population—and the impacts of inequality are more immediate, harsh, and punitive when they are compounded across multiple axes of lived experience and identity (Povinelli 2016, Puar 2017).

My orientation to embodied inequality in the medieval period takes up this premise, of heterogeneous inequality, and utilizes this as a lens for examining trends in spine disease outcomes. In this chapter, I examine the ways in which factors like age, sex-gender, and mortuary treatment (burial practice) intersect with social position to influence degenerative spine disease, and how these might be differentially affecting people based on regional lifestyle and identity. I use a life-course approach to examine the variation in experiences of spine disease across the population. Blending aspects of more traditional paleo-epidemiological (population-level) with paleopathological (individual-level) approaches aids in dismantling the notion of disability as a binary outcome.

Although degenerative spine disease is a leading cause of contemporary disability-related leave from work globally, the historical context, prevalence, and situated position of back-related disability is relatively unquestioned. Back pain and back injury are put forth as universal disabilities due to their ancient origin and presence across multiple extinct and extant species of vertebrates. This has led to an essentialism of these experiences that overlooks important immunological components of arthroses, particularly clinical studies that have implicated socio-economic status (SES) in ultimate health outcomes, vulnerability to disease risk, and disease exposure. In this study I attempt to destabilize normative biologies of the spine and spine disease-related disability, while examining the embodied material consequences of inequality, labor, and social life in medieval Italy. My commitment to centering a complex theory of intersectional embodiment is part of a larger effort by contemporary Disability Studies scholars and community members to cultivate a rich body of scholarship in the line of "Disability Anthropology," as opposed to an "anthropology of disability" (Chapter 1, see also Bloom 2019, Hartblay 2020).

Background

Degenerative Joint Disease

Degenerative Joint Disease (DJD) is a common disease among vertebrates (Fox 1939), and is well documented in New and Old World primates (Jurmain 2000, Rothschild & Woods 1992, Rothschild et al. 2002), *Homo neandertalensis* (Dawson & Trinkaus 1997), and *Homo sapiens* (e.g., Becker & Goldstein 2018, Bridges 1991, Schrader 2012, Walker & Hollimon 1989). Despite its global and temporal ubiquity (Bridges 1991, Jurmain 1977, Jurmain & Kilgore 1995, Plomp 2017, Weiss 2006), the etiology of degenerative joint diseases, specifically in the spine remains unclear (Weiss 2006, Weiss & Jurmain 2007). Progressive degeneration in the many fibro-cartilaginous and synovial joints has a positive relationship with increasing age (Calce et al. 2018, Snodgrass 2004, Weiss 2006, Zampetti et al. 2016), however it is clear that its pathogenesis is non-linear and modulated by multiple factors across the life course (Risbud & Shapiro 2014, Wang et al. 2016).

Epidemiological research suggests that the risk for osteoarthritis (not specific to any particular joint) is correlated social inequality, which is bioculturally entangled with occupation-status in modern populations due to various epigenetic, genetic, and environmental covariates (Brennan-Olsen et al. 2018, Brennan-Olsen et al. 2019, Rubin 2007). Bioarchaeological studies of DJD have examined its expression as a possible marker for activity-related stress with varying conclusions and no overall consensus (e.g., Klaus et al. 2009, Larsen et al. 1995, Novak & Šlaus, 2011, Sofaer Derevenski 2000, Weiss & Jurmain, 2007, Woo & Pak, 2014, Zampetti et al., 2016), likely due to the specific pathophysiology of the disease in different joints across the skeleton. Recent work by Zampetti et al. (2016) found that there was no association between occupation type (i.e., farmer-worker, shopkeeper, soldier, carpenter, plumber; see Zampetti et al. 2016 supplemental tables) and degenerative joint disease expression across the body in a historic Italian sample, suggesting that other interactions (culturally or biologically mediated) produce various disease outcomes. However, it is important to note that the strength of Zampetti et al.'s (2016) findings are reduced because of small sample sizes. The relationship between physical activity and DJD is certainly multifactorial, joint-specific, and contingent on the specific mechanics of a given activity and certainly has a relationship with biocultural experiences that modulate immune function, aging, and bodily biochemistry. This study focuses on degenerative joint diseases of the spine: vertebral osteophytosis and vertebral osteoarthritis.

Vertebral Degenerative Joint Diseases

The distribution of static (weight-bearing) and dynamic (movement) loading across the skeleton plays an important role in the differential expression and pathophysiology of DJD (Bogduk & Mercer 2000, Klaus et al. 2009, Zampetti et al. 2016). The bipedal spine is a unique biomechanical system, in humans it is composed of 25 consecutive amphiarthrodial (fibrocartilaginous) joints between the vertebral bodies, 4 zygapophyseal (synovial) joints between the articular facets of each vertebrae, and a mix of synovial and fibrocartilaginous costovertebral joints in the thoracic region (Figure 3.1, Figure 3.2). In *H. sapiens* loadings in the axial skeleton during bipedal posture and locomotion are passed through the vertebral bodies and discs, zygapophyseal joints and posterior elements, as well as the lateral pedicles (Shapiro 1993, Bogduk & Endres 2005). Disturbances in the metabolic balance of the joint matrices of the intervertebral and zygapophyseal joints due to the compounding effects of aging, mechanical loading, epigenetic, and genetic factors ultimately cause morphological changes and remodeling of vertebral centra and articular facet joint margins and surfaces (Bogduk 2012, Klaus et al. 2009, Risbud & Shapiro 2014, Shen et al. 2012). In contemporary populations the prevalence of degenerative joint disease in the lumbar region of the spine ranges from 40-85% (Goode et al. 2013). Generalized low back pain (LBP) is a common symptom of spinal degenerative joint disease and affects a large proportion of the US American population: 80% of adults in the United States experience at least one episode of LBP in their lifetime (Goode et al. 2013, Rubin 2007).

Vertebral Osteophytosis

The pathophysiology and expression of vertebral osteophytosis (VO) has been well documented in the bioarchaeological and clinical record (e.g., Nathan 1962, Snodgrass 2004, van der Merwe et al. 2006, Wang et al. 2016, Weiss 2006). Vertebral osteophytes are the result of localized and progressive hyperostoses that develop at the attachment sites of the annulus fibrosa at the margins of the amphiarthrodial joints (Figure 3.3, 3.4). Early stages in the pathogenesis of vertebral osteophytosis are marked by horizontally oriented osteophytes on the anterior margin of the vertebral body, which expand to stabilize the compromised disc joint. Severe cases of VO are marked by vertically oriented osteophytes (Figure 3.3, 3.4), which may eventually articulate or fuse to form a bony bridge with adjacent vertebral elements. Intervertebral disc degeneration involves age-related changes in disc composition and biochemistry, as well as accumulated tissue damage due to multiple age progressive stressors, including avascularity resulting in oxidative injury, high magnitude mechanical compression at high frequencies or for prolonged duration, and depleted cellular waste disposal due to acidic, hypertonic, and/or oxidative joint microenvironment (Wang et al. 2016, Risbud & Shapiro 2014). Recent immunological research suggests there is a complex series of cellular mechanisms central to a cycle of phenotypic change in the disc and bony centra, affecting and affected by the amplification of inflammatory pathways and sensitization via neutrophils and other inflammatory mediators (Risbud & Shapiro 2014). The initiation of degenerative changes in the spine likely occurs due to a combination of these stressors and continues in a positive feedback system. Previous research suggests that the pattern of osteophyte expression is also related to the curvature of the spine during load-bearing activities, and that activities that alter the curvature or biomechanical use of the spine result in unusual osteophyte development (Sofaer Derevenski 2000, Merbs 1983). Biomechanical and degenerative changes in the vertebral bodies are hypothesized to impact loading and degeneration in the posterior portion of the vertebrae (Shapiro 1993, Bogduk 2012). Previous bioarchaeological research shows: (a) VO and VOA have different patterning in the spine and sometimes an inverse relationship (Bridges 1994, Knüsel et al. 1997); (b) correlations between known activities and disease

Figure 3.1 Human spine

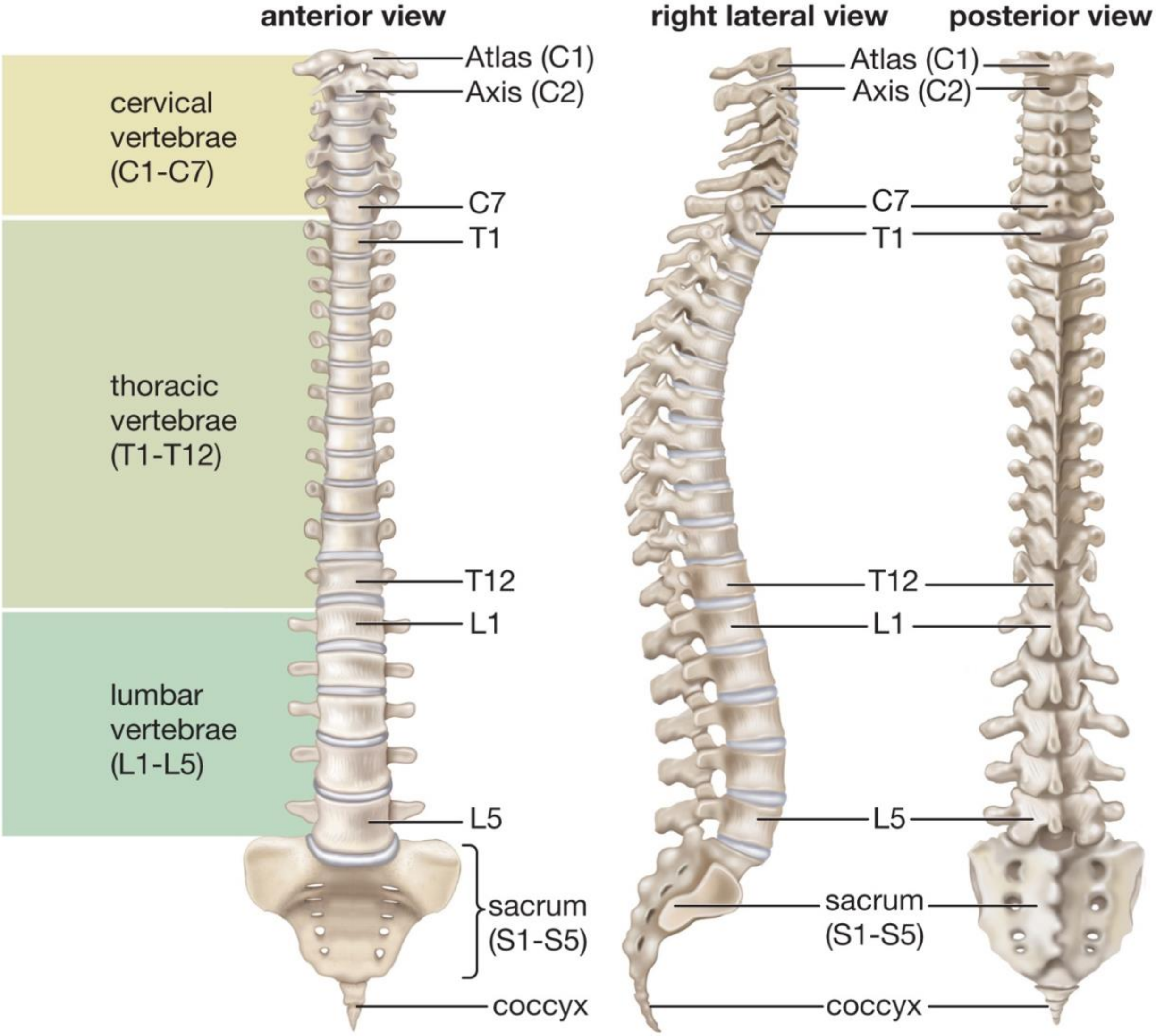


Figure 3.1 – Figure from Encyclopaedia Britannica (vertebral column); spine elements from most superior (C1, articulates with cranium) to most inferior (L5, articulates with sacrum). Between each vertebra is an intervertebral disc that provides shock absorption and cushioning between bones.

Figure 3.2 Cervical vertebra (C3)

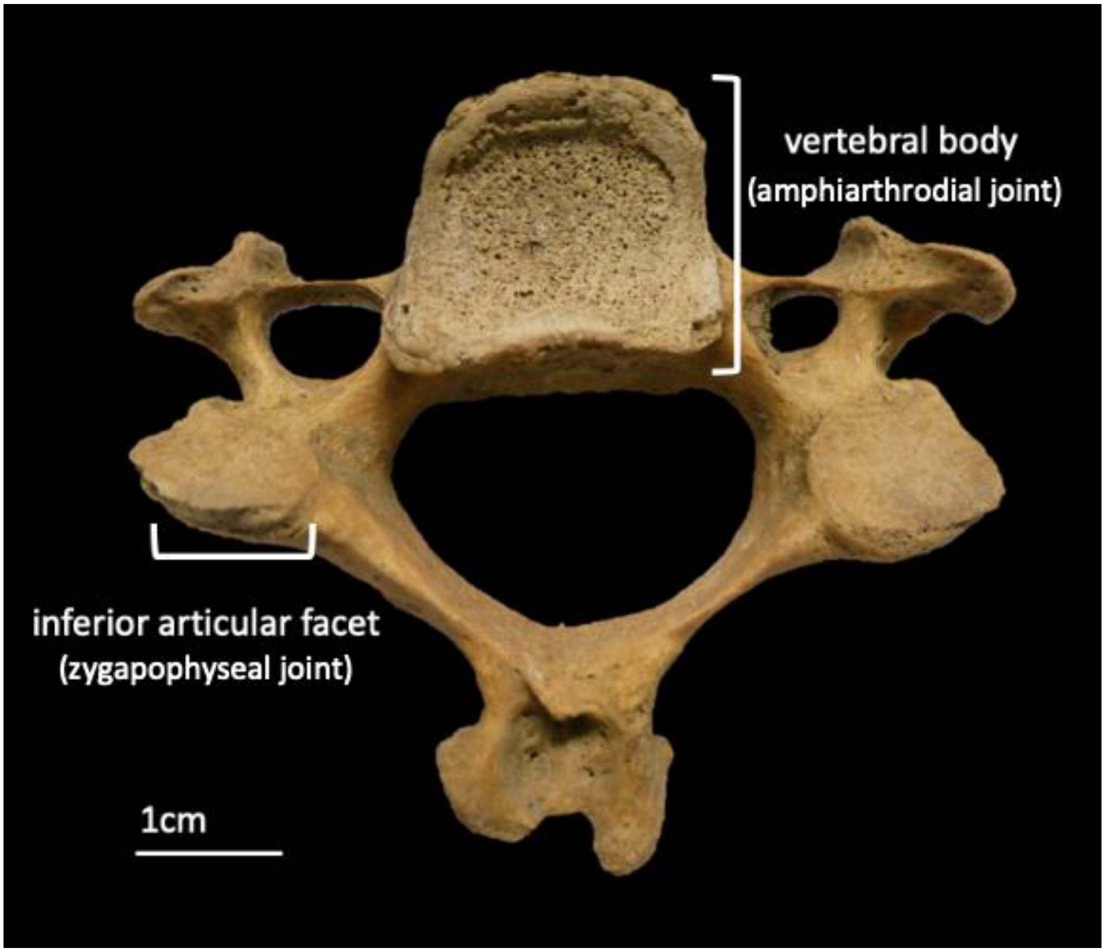


Figure 3.2 – Cervical vertebra (C3) from Villamagna with mild morphological change to the vertebral body and inferior articular facets. Osteophytosis would be scored on the vertebral body (here, score 1) and osteoarthritis would be scored on the inferior articular facts (here, score 2). Photo by KM Kinkopf.

Figure 3.3 Lumbar vertebrae (L2)

Figure 3.3 – Lumbar vertebrae (L2) from Villamagna with mild osteophytosis changes to the superior margin of vertebral body and intervertebral disc area; classified as “low severity” VO. Photo by KM Kinkopf.

Figure 3.4 Thoracic vertebrae (T12)

Figure 3.4 – Thoracic vertebrae (T12) from Villamagna with severe osteophytosis changes to the superior margin of vertebral body and intervertebral disc area; classified as "high severity" VO. Photo by KM Kinkopf.

prevalence (Merbs 1983); and (c) differential distributions of VO based on sex, physical activity, and/or spine region (Dawson & Trinkaus 1997, Lieverse et al. 2007, Lovell 1994, Maat et al. 1995, Sofaer Derevenski 2000).

Vertebral Osteoarthritis

Vertebral Osteoarthritis (VOA) involves the superior and inferior vertebral articular facets, or zygapophyseal joints (Figure 3.2, 3.5, 3.6); these are synovial joints and therefore their degeneration and morphological change are a true arthrosis of the spine (Figure 3.6, Gellhorn et al. 2013). Like VO, VOA is a dynamic process of whole-joint failure, on mechanical, metabolic, and cellular levels, although OA in the facet joints remains one of the most understudied phenotypes of osteoarthritis in the skeleton. VOA is a positive feedback phenomenon, whereby a cycle of degenerative and proliferative bone changes (i.e., narrowing of joint space, subarticular bone erosion, hypertrophy, and osteophyte formation) modulated by pro-inflammatory pathways, meta-inflammation, and toxic internal joint microenvironment lead to disease progression (Gellhorn et al. 2013, Kalichman & Hunter 2008, Risbud & Shapiro 2014, Wang et al. 2015). Previous bioarchaeological studies of VOA have shown a relationship between weight-bearing activities and VOA prevalence (Novak & Šlaus 2011), however the results of bioarchaeological analyses of VOA have largely been inconclusive with regard to physical activity, highlighting the likely confounding effects of epigenetic and environmental factors. Larsen (2002) argues that articular pathology, like VOA is more indicative of general physical injury and stress, rather than particular to specific occupational activities. Prevalence of VOA in the bioarchaeological record is often associated with biomechanical overuse, or injure of the spinal column, and results in differential patterning across regions of the spine (Knüsel et al. 1997, Merbs 1983, Stirland & Waldron 1997).

Schmorl's Nodes

Schmorl's nodes (SN) are lesions on the inferior and superior surfaces of the vertebral body (Figure 3.7, 3.8). They are caused by the vertical herniation with intervertebral disc degeneration and with the aging and dehydration of the nucleus pulposus and annulus fibrosus (Faccia & Williams 2008, Plomb et al. 2012, Wagner et al. 2008). These depressions are widely associated with biomechanical strain associated with high magnitude compressive loadbearing and weight-bearing, especially in the thoracic and lumbar regions of the spine (Cholewiki & McGill 1996, Plomb et al. 2015b). Variation in vertebral morphology is associated with increased risk for spinal stenosis, scoliosis, and spondylolysis (Clark et al. 1986, Watts 2010), and there is some recent research that suggests lumbar vertebral morphology affects the prevalence of Schmorl's nodes (Dar et al. 2009, Wagner et al. 2008). Amongst bioarchaeological studies of degenerative spine diseases, Schmorl's nodes are commonly observed across temporal and spatial contexts, with reported prevalence ranging from 5-76% (Burke 2012, Dar et al. 2009, Faccia & Williams 2008, Klaus et al. 2009, Plomp & Roberts 2012, Plomp et al. 2015a, Sonne-Holm et al. 2013, Üstündag 2009, Williams et al. 2007). Bioarchaeological research suggests that the etiology of Schmorl's Nodes is complex, multifactorial, and does not have a linear relationship with activity itself (Burke 2012, Faccia & Williams 2008, Plomb 2012, Plomp et al. 2015a, 2015b, Williams et al. 2007). Although disc herniation is not frequently correlated with a patient's age in clinical studies, dehydration of the nucleus pulposus and

Figure 3.5 Thoracic vertebrae (T2)

Figure 3.5 – Thoracic vertebrae (T2) from Pava with incipient changes to the superior articular facets; classified as “low severity” VOA. Photo by KM Kinkopf.

Figure 3.6 Thoracic vertebrae (T3)

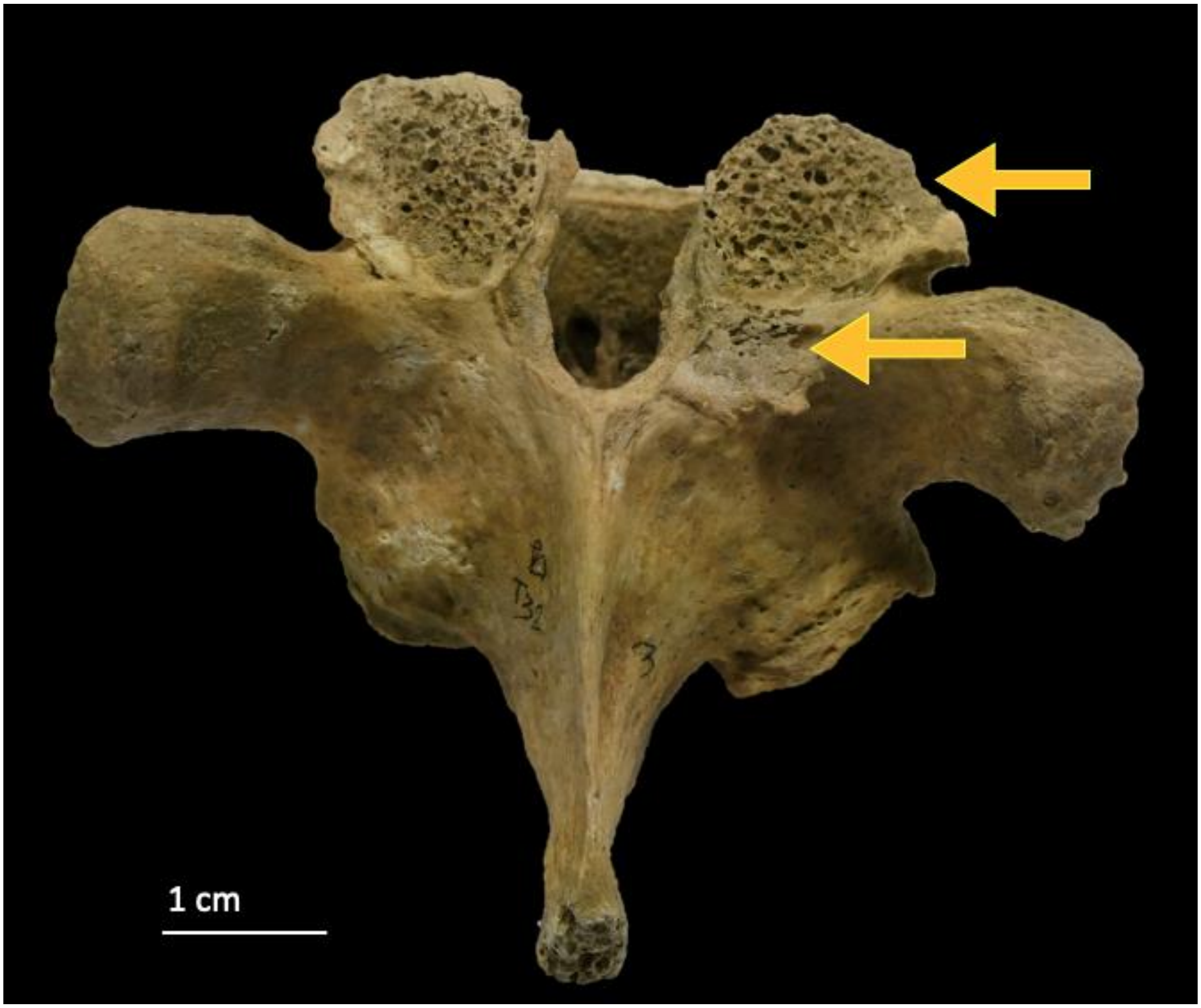


Figure 3.6 Thoracic vertebrae (T3) from Pava with severe changes to the superior articular facets; classified as "high severity" VOA. Yellow arrows point to macroporosity, new bone formation, and eburnation in the right superior articular facet. Photo by KM Kinkopf.

Figure 3.7 Superior surface Schmorl's node

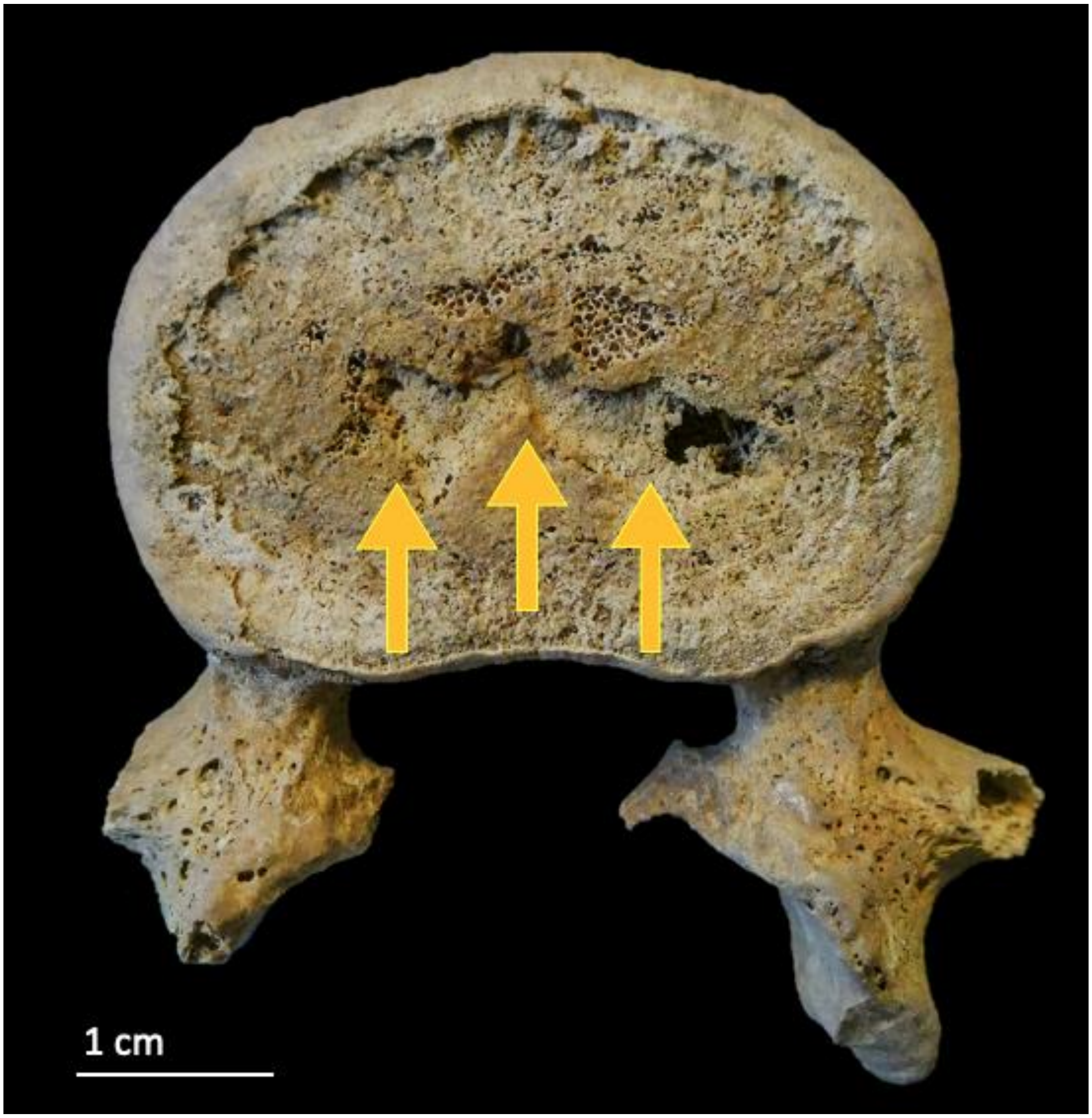


Figure 3.7 – Superior surface Schmorl's node in a lumbar vertebra from Villamagna. Yellow arrows point to one continuous superior surface Schmorl's node that extends approximately half the length of the vertebra in the medio-lateral direction. Photo by KM Kinkopf.

Figure 3.8 Inferior surface Schmorl's node

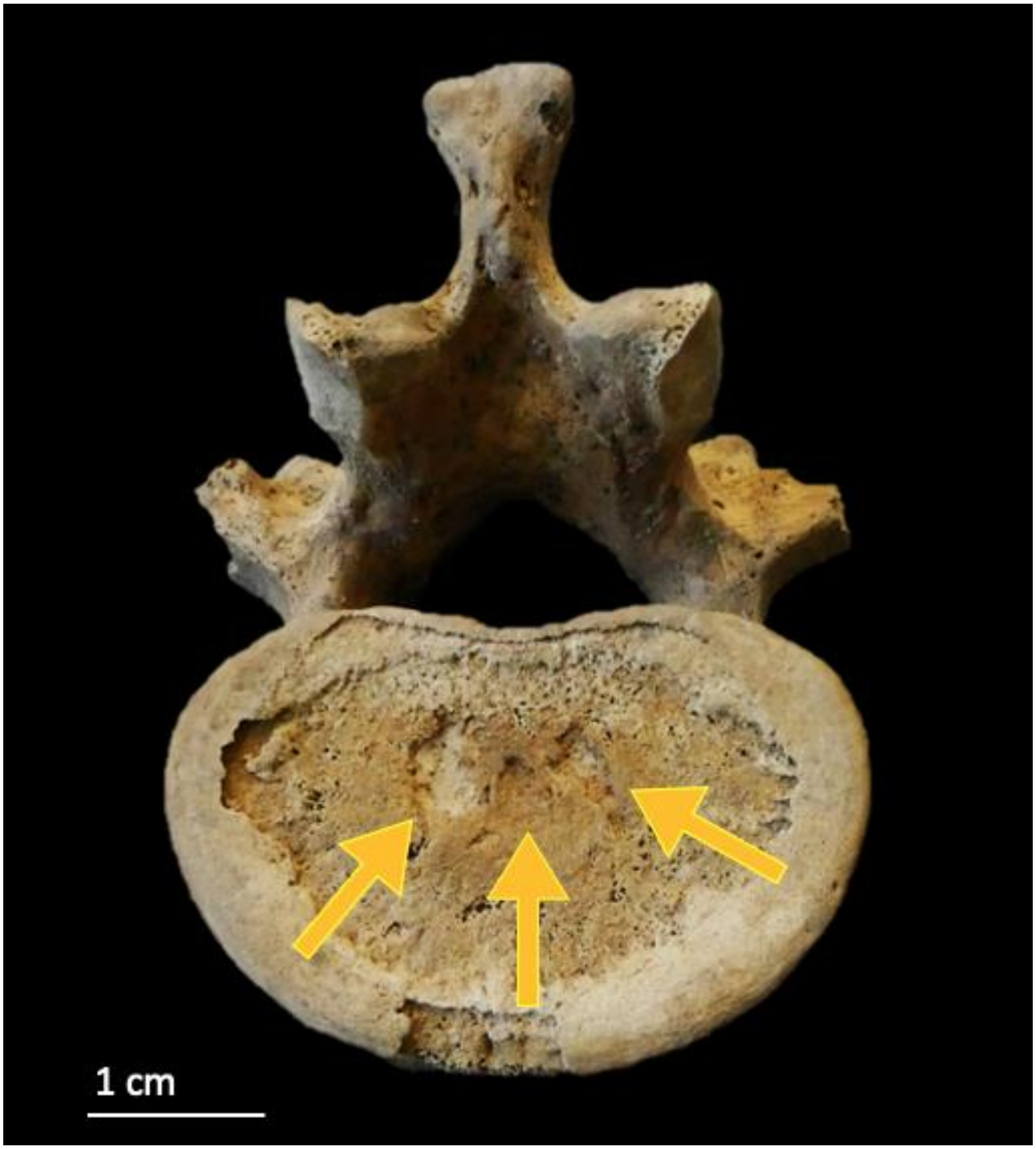


Figure 3.8 – Inferior surface Schmorl's node (outline in pink) in a lumbar vertebra. Yellow arrows point to three distinct and adjacent inferior surface Schmorl's nodes. Photo by KM Kinkopf.

decreases in hydrostatic pressure in the disc are associated with increased risk for herniation and are typical characteristics of the aging spine. I utilize the presence and absence of Schmorl's nodes to complement other lines of evidence for disc and spine health overall, and in order to interrogate the possible roles of compressive weight-bearing activity on experiences of spine disease.

Materials & Methods

Skeletal Sample

Overall 265 individuals from the medieval cemeteries of Villamagna in Lazio (n=128) and Pava in Toscana (n=137) were selected for analysis in this study across all sex groups and age cohorts (Table 3.1, 3.2). Individuals were selected for analysis based on a stratified random sampling strategy at both sites, and all individuals included in this analysis had good preservation of the spine.

Biological Profile

Morphological sex was estimated based on observation of the *os coxae* and cranial morphology (Ascàdi & Nemeskèri 1970, Brothwell 1981, Buikstra & Ubelaker 1994). Where present, I examined sexually dimorphic skeletal indicators in the os coxae as the first line(s) of evidence, especially the ventral arc, sub-pubic angle, sub-pubic concavity, and sciatic notch (Ascadi & Nemeskeri 1970, Brothwell 1981, Buikstra & Ubelaker 1994). Second lines of evidence included cranial indicators (Buikstra & Ubelaker 1994) and body size, to refine and ensure accuracy of sex estimation. My assessments of morphological sex were compared with field osteology assessments of the os coxae and cranial morphology.

Adult age was estimated in adults using multiple standard morphological indicators from the pubic symphysis (Brooks & Suchey 1990) and auricular surface (Lovejoy et al. 1985); these were corroborated by examination of the sternal end of the rib when possible (İşcan et al. 1984, İşcan et al. 1985). We categorized individuals using three conservative age groups: 18-29 years (young adult), 30-49 years (middle adult), and 50+ years (older adult) to remedy the issue of precise aging in skeletal assemblages without documentary records of age (Jackes 2000, 2011). Four individuals could not be classed into an age group and were included in our analyses (excepting age-contingent analyses) as 18+ years (adult of indeterminate age).

Spine Observation

I observed the vertebral body, articular facets, intervertebral disc surfaces of each element of the spine (24 vertebrae) per individual and scored the degree of morphological change to each. Vertebral bodies that were damaged post-mortem were reconstructed and articular facets were refit with their corresponding vertebra, where possible.

Vertebral Osteophytosis (VO) was scored according to standard procedures for recording the presence and severity of osteophytosis on an ordinal scale of 0 to 5 (Table 3.3, adapted from Agarwal 2001, see also Buikstra & Ubelaker 1994, Sofaer Derevenski 2000). Vertically oriented enthesophytes that are associated with spondyloarthropathies (such as ankylosing spondylitis), and diffuse idiopathic skeletal hyperostosis (DISH) were scored as 6.1-6.4 but were not included in our analyses of VO trends.

Table 3.1 Skeletal sample

Table 3.1 – skeletal sample distribution by age and sex at Villamagna and Pava

Site	Sex	Age	N
Villamagna			128
	Male		70
		Young (18-29 years)	16
		Middle (30-49 years)	49
		Old (+50 years)	4
		Adult (indeterminate)	1
	Female		58
		Young (18-29 years)	18
		Middle (30-49 years)	23
		Old (+50 years)	16
		Adult (indeterminate)	1
Pava			137
	Male		78
		Young (18-29 years)	9
		Middle (30-49 years)	39
		Old (+50 years)	30
		Adult (indeterminate)	0
	Female		59
		Young (18-29 years)	21
		Middle (30-49 years)	26
		Old (+50 years)	12
		Adult (indeterminate)	0

Table 3.2 Skeletal sample

Table 3.2 – Skeletal sample distribution by time period at each site

Site	Period	N
Villamagna		
	Early Medieval (8th -9th century AD)	8
	Central Medieval (10th-12th century AD)	14
	Late Medieval (13th-15th century AD)	106
Pava		
	Early Medieval (8th -9th century AD)	10
	Central Medieval (10th-12th century AD)	127
	Late Medieval (13th-15th century AD)	0

Table 3.3 Vertebral osteophytosis (VO) scoring system

Table 3.3 – Vertebral osteophytosis scoring system, an ordinal scale 0-5, the first 3 categories are re-classed as a low-severity outcome and the next 4 categories are re-classes as a high-severity outcome.

Raw Score	Description	Binary Outcome
0.0	No degenerative changes present; smooth body margin	Low
1.0	Initial localized bony deposition on the joint margin; <3 mm discontinuous traction spurs at the superior or inferior margin	
2.0	Osteophytes generally present on less than 50% of the margin with vertical deposition across the joint space <5mm; occasional minor pitting adjacent to the centrum at the base of the traction spurs	
3.0	Pronounced osteophyte deposition on >50% of the margin with marked vertical deposition across the joint space; early claw formation; subperiosteal bone deposition on the antero-lateral aspect of the vertebral body cortex; Mild to moderate expansion and distortion of the centrum	High
3.5	More developed osteophytosis than seen in stage 3, marked by involvement of the articular surface, no eburnation present	
4.0	Severe osteophytosis and claw formation extending across the IVD; osteophytes articulate with adjacent vertebrae; large claw formations give centrum a pinched appearance; severe subperiosteal ossification of the antero-lateral cortex; severe expansion and distortion of the centrum morphology; eburnation on articular surface or on claw(s)	
5.0	All of Grade 4, with ankylosis of claw osteophyte formation	

Vertebral Osteoarthritis (VOA) was scored according to standard procedures for recording presence and severity of zygapophyseal osteoarthritis (Table 3.4, adapted from Agarwal 2001; see also Sofaer Derevenski 2000, Klaus et al. 2009). Additionally, these procedures were refined to account for the varied pathophysiology of degenerative changes in the different regions of the spine (i.e., cervical, thoracic, lumbar). Where possible all four articular facets were observed and scored during data collection.

Data Reduction

For my statistical analyses, vertebral body osteophytosis (VO) and vertebral osteoarthritis (VOA) raw scores were reduced to a binomial outcome variable: low severity or high severity in order increase statistical power and examine the influence of biocultural factors on disease prevalence (Table 3.3, 3.4). For observations of vertebral osteophytosis this was a straightforward process; each vertebral element had a single observation of the vertebral body, and these were reduced based on physiological consequence and disease progression (Table 3.3, Figure 3.3-3.4). For the vertebral articular facets, each of the four facet variables was scored during data collection according to the criteria established in Table 3.4. In order to assess the relationship between these different articular facets, I used a correlogram to assess how consistent facet scores were or were not amongst individual vertebrae. I found that the facet scores had a slightly higher correlation coefficient with their paired articular facet at the superior (ρ=.81) or inferior (ρ=.78) aspect. Due to the ordinal nature of the spine disease observations, these data we reduced based on conditional criteria outlined in Table 3.5.

Pooled Spine Regions

To increase statistical power for most analyses, vertebrae were further pooled by functional region. These regions were assigned by categorizing vertebral number (recorded during data collection), into functional anatomical region: cervical (C2-C7), upper thoracic (T1-T7), lower thoracic (T8-T12), lumbar (L1-L5). The separation of the thoracic segment into upper and lower regions has been shown to be efficacious in differentiating biomechanical and physiological variation in degenerative processes by bioarcheologists and clinicians, and reflects the usual curvature of the spine (Sofaer Derevenski 2000, Klaus et al. 2009, Larsen et al. 1995), as well as the biomechanical difference between the region of the thoracic spine (upper) with less rotational capacity due to the articulation of the spine with the ribs and sternum.

Statistical Analyses

Spearman's Rank correlation rho (ρ), were computed to assess the relationship between vertebral osteophytosis and vertebral osteoarthritis disease outcomes in each region of the spine. To test the relationship between sex, age, and disease outcome in the population, and to understand that relationship across the spine, I utilized Pearson's chi-squared test of homogeneity, and evaluated their subsequent standardized residuals as a post-hoc test where there were statistically significant differences in the prevalence of disease (Delucchi 1983, Haberman 1973). Pearson's chi-squared tests are useful and widely used in biological anthropology and bioarchaeological studies of arthroses in general to assess the distribution of OA presence/absence, and their relationship to explanatory (biocultural) variables (e.g., Woo & Pak 2014, Becker 2019). One of the significant draw backs of chi-square tests for contingency

Table 3.4 Vertebral osteoarthritis (VOA) scoring system

Table 3.4 – Vertebral osteoarthritis scoring system on an ordinal scale of 0-7.

Raw Score	Description
0.0	Smooth joint margin and surface; no evidence of remodeling or degenerative changes
1.0	Incipient changes and remodeling of the facet margins
2.0	Slight lipping of the facet rim; deposition at the facet margins; articular surface unaffected
3.0	Joint enlargement and lipping; deposition at facet margins
3.5	Pronounced joint enlargement and lipping; deposition at facet margins accompanied by surface pitting ≤10%
4.0	Pronounced lipping and pitting of <25% of the articular surface; enlargement of articular surface
4.5	Pronounced lipping and pitting of >25% of the articular surface; marked joint enlargement; no eburnation
5.0	Involvement of entire joint surface: enlargement, pitting, porosity of most of the surface; eburnation and polishing of the articular facet surface
6.0	Stage 5 with partial segmental immobility
7.0	Complete ankylosis of the joint; complete immobility

Table 3.5 Reduction of vertebral osteoarthritis scores

Table 3.5 – Vertebral osteoarthritis (VOA) scores were reduced to a binary outcome (low or high severity) based on the criteria in this table

Condition	**Binary Outcome**
Where all facets had no score >2	Low
Where one or more facets had a score of ≥3, but no facet had an observed score ≥4	
Where one or more facets had a score ≥4, but no facet with a score ≥5	High
Where one or more facets had a score ≥5	

Table 3.6 Percent data missing by variable

Table 3.6 – Total data observations and the percent missingness for each variable used in analysis

Variable	Number of missing observations	Percent missing observations
Vertebral body (VO) score	1193	18.92 %
Schmorl's Node (superior)	1500	23.86 %
Schmorl's Node (inferior)	1292	20.55 %
Left superior articular facet (a)	1871	29.67 %
Right superior articular facet (b)	3367	53.66 %
Left inferior articular facet (c)	1959	31.10 %
Right inferior articular facet (d)	1965	31.20 %
Combined facets (VOA) score	1283	20.36 %

tables larger than 2x2, is their omnibus nature, which limits our ability to show the *source* of a statistically significant result (Delucchi 1983). Although subjective inspection of the data and their frequencies can prove useful for examining the source of the statistical significance in variable distribution, the standardized residual output from a chi-square test can be used as an objective post-hoc test. The standardized residual (*r*) can be calculated as the difference between the observed and expected counts, divided by the square root of the expected counts (Haberman 1973, Delucchi 1983).

$$standardized\ residual\ (r)\ =\ \frac{observed\ count - expected\ count}{\sqrt[2]{expected\ count}}$$

Assuming the null hypothesis is true, the values of the standardized residuals belong to a normally distributed sampling distribution with a mean of 0.0 and a standard deviation of 1.0, using a standard t-table we can therefore calculate the critical values (+/- 1.96) for a 95% confidence interval (α = 0.05) when there are less than 15 degrees of freedom (Haberman 1973, MacDonald & Gardner 2000).

Data were prepared for analysis according to tidyr protocols in RStudio Cloud (Wickham & Wickham 2016). All statistical analyses were completed in R-Studio Cloud v.1.2; statistical tests and relative risk ratios were computed using the mosaic package (Pruim et al. 2017).

Data Screening

Missingness in the dataset was evaluated using the *MissMech* and *VIM* packages in R (Jamshidian et al. 2014, Kowarik & Templ 2016). Overall, all individuals in my analysis had at least 60% of their spine intact. I determined that 20.3% of vertebral facets, and 18.8% of vertebral bodies were missing during analysis (Table 3.6). The first cervical vertebra (C1) was excluded from analyses of vertebral osteophytosis because it does not have a vertebral body that can be affected by disc degeneration.

To test for latent trends in missingness, missing observations were re-coded as dummy variables and it was determined that almost all of these data[1] were missing at random using the VIM package to visualize the missing data, and through Multiple Correspondence Analysis (MCA) to test for clustering with presence or absence of data and other biocultural and skeletal data points. Entries with missing observations were removed from the dataset using pairwise or list-wise deletion methods based on the type of analysis.

Results

Vertebral Osteophytosis (VO) Results

There is a significant difference in the distribution of severe VO outcomes across age cohorts at both sites in all time periods (Table 3.7). At Pava and at Villamagna, there is a linear trend between increased age and VO prevalence (Figure 3.9); where the young cohort has between 0.0% and 2.2% prevalence, where individuals in the middle cohort have between 7.8%

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[1] The only clustering of missingness that co-occurred with a biocultural indicator was with individuals where age could not successfully be estimated. Indeterminate age individuals (n=2) were excluded from my subsequent analyses due to lack of observable data.

and 22.6% crude prevalence (Table 3.7). At Pava there were significant differences in the distribution of severe VO outcomes for male and female individuals in every region of the spine (Table 3.8). Whereas at Villamagna, there was a significant difference in the distribution of severe VO outcomes only in the cervical region of the spine (Table 3.8).

At Pava, males in the older age cohort had 42.1% prevalence of VO, where older age females have 23.1% prevalence in the cervical neck region (Table 3.9). There was a significant sex difference in severe VO prevalence in the upper thoracic region for individuals in the middle age cohort, and in the lower thoracic region for the older age cohort at Pava (Table 3.9). In the lumbar region there was a significant difference in prevalence based on sex in the middle and older age cohorts at Pava (Table 3.9).

In contrast, at Villamagna there was a sex difference in the prevalence of severe VO only for individuals in the middle age cohort, and only in the cervical region of the spine, where female individuals had a 19.0% prevalence of severe VO and males had a 7.1% prevalence (Table 3.9). Villamagna males, in all age groups have less VO than Villamagna females in all regions of the spine (Table 3.9).

Vertebral Osteoarthritis (VOA) Results

There are significant differences in the distribution of severe VOA outcomes between young, middle, and older age cohorts at Pava and Villamagna. The relationship between older age and prevalence of severe VOA is linear between young and middle age, but individuals in the older age cohort do not have a significant difference in prevalence of VOA compared to the middle age cohort (Table 3.12, Figure 3.10).

There were significant differences between young males and females at Pava in the upper thoracic region (females have a higher prevalence), and between older age males and females in the lower thoracic region (males have a higher prevalence, Table 3.12). At Villamagna there are only significant differences between older age males and females in the cervical region (males have a higher prevalence, Table 3.12) Females in the older-age cohort at Villamagna have significantly less VOA in the cervical region compared to older-age males at Villamagna (Table 3.12). Older-age male individuals at Villamagna have 0.0% prevalence of VOA in the lower thoracic region of their spines, however the significant difference between the distribution of severe VOA outcomes in the lower thoracic region might be artificially true, given the small sample size for older-age males at Villamagna (Table 3.12).

Schmorl's nodes Results

Schmorl's nodes were observed on the superior and inferior surfaces of the vertebral body's endplates (Figure 3.9, 3.10). The results here include each aspect of the vertebral body, where Schmorl's nodes on the inferior surface of the vertebra indicate an upward vertical herniation of the disc and superior surface Schmorl's nodes indicate a downward vertical herniation of the disc.

There were significant age-related differences in the prevalence of Schmorl's nodes at both sites in all time periods (Table 3.9, 3.10). Generally, each site and period showed an increase in superior surface Schmorl's nodes in middle and older-age cohorts. Overall, there were significant sex differences in the lower thoracic region at each site, where males had significantly higher prevalence than female individuals. At Villamagna there were significant differences in the lower thoracic and lumbar regions of the spine, where males have an increased prevalence of Schmorl's nodes compared to females (Table 3.9, 3.10).

Investigating these trends further, there is a significant difference at Pava between males and females in the middle age cohort, where males have 40.8% prevalence in the superior surface and 52.2% prevalence in the inferior surface in the lower thoracic region (Table 3.17, 3.18). Similarly, in the lumbar region, Pava males in the middle age cohort have higher prevalence of Schmorl's nodes (Table 3.9, 3.10), however amongst individuals in the young age cohort females have a significantly higher prevalence of superior surface Schmorl's nodes (25.3% prevalence for females, 6.5% prevalence for males, see Table 3.9)

At Villamagna, middle-age males have significantly increased prevalence of Schmorl's nodes in the lower thoracic and lumbar regions (superior and inferior surface Schmorl's nodes, see Table 3.17, 3.18). Young age males have significantly increased prevalence of superior surface Schmorl's nodes in the lower thoracic region of the spine only (Table 3.17).

The inferior surface Schmorl's nodes show significant differences amongst individuals in the young and middle age cohorts. In the young age cohort, males at Pava have higher prevalence of Schmorl's nodes in the upper thoracic region (20.8%, r=3.01, see Table 3.15), and males at Villamagna have an higher prevalence of Schmorl's nodes in the lumbar region (28.2%, r=1.98, see Table 3.15). In the middle age cohort, males at Villamagna have fewer Schmorl's nodes than expected in the cervical region (3.4%, r=-2.14, Table 3.15). In the upper thoracic region, Pava males have more Schmorl's nodes than expected (20.4% prevalence, r=2.70, Table 3.15). In the lower thoracic region, Villamagna females had fewer than expected Schmorl's nodes (18.3% prevalence, r=-3.89), and Villamagna males had more than expected (55.5% prevalence, r=2.11, see Table 3.15)

Inter-site comparisons and economic access

Males at Pava exhibited higher prevalence compared to other groups for all measures of spine disease. Pava males had higher than expected prevalence of VO in the cervical, upper thoracic, and lower thoracic regions of the spine compared to all other groups (Table 3.15, Figure 3.13). Pava males also had higher than expected prevalence of superior Schmorl's nodes in the upper and lower thoracic regions compared to all other groups (Table 3.15, Figure 3.15). Males at Villamagna with less economic access had greater than expected prevalence in VOA in the cervical and lower thoracic regions, and Pava males had greater than expected prevalence of VOA in the cervical region (Table 3.12, 3.15, Figure 3.14). Overall, females at Pava and Villamagna has similar crude prevalence rates, although Villamagna females with more economic access had 0% prevalence of VO in all regions of the spine, and reduced prevalence of VOA in all regions of the spine. Generally, individuals with more economic access had a reduced prevalence of VO and VOA; however, across all economic distinctions and at both sites, males had higher prevalence of Schmorl's Nodes (Table 3.15, Figure 3.13-3.16).

Discussion

Vertebral Osteophytosis

At Pava there is a higher prevalence of severe VO with increasing age (Figure 3.7), with an amplified effect for males in the cervical, lower thoracic, and lumbar regions of the spine (Table 3.7). Age has a reduced effect in females at Pava, and at Villamagna more broadly (Table

Table 3.7 Comparison of sex-differences in VO by spine region and age

Table 3.7 – This table presents the cross tabulation of VO by age (for each site) to compare sex differences in prevalence of severe VO. There are significant sex differences in the cervical, lower thoracic and lumbar regions in old age at Pava, and significant differences in the upper thoracic and lumbar regions in middle age at Pava. There are sex differences at Villamagna only in the cervical region in middle age. Statistically significant p*-values are in **bold**.*

	Female			Male			χ^2*(df =1)*	*p*
	VO	total	% high	VO	total	% high		
Pava (Central Medieval)								
Cervical (C2-C7)								
Young (18-29 years)	5	108	4.6%	0	46	0.0%	-	.323
Middle (30-49 years)	25	120	20.8%	49	195	25.1%	0.54	.462
Old (50+ years)	16	68	23.5%	45	107	42.1%	5.50	**.019** *
Upper Thoracic (T1-T7)								
Young (18-29 years)	0	121	0.0%	0	51	0.0%	-	.999
Middle (30-49 years)	3	141	2.1%	21	241	8.7%	5.48	**.019** *
Old (50+ years)	6	83	7.2%	12	132	9.1%	0.05	.820
Lower Thoracic (T8-T12)								
Young (18-29 years)	1	88	1.1%	0	35	0.0%	-	.999
Middle (30-49 years)	11	100	11.0%	36	178	20.2%	3.25	.071
Old (50+ years)	1	58	1.7%	39	96	40.6%	26.47	**<.001** ***
Lumbar (L1-L5)								
Young (18-29 years)	3	91	3.3%	0	35	0.0%	0.19	.664
Middle (30-49 years)	19	101	18.8%	55	177	31.1%	4.34	**.037** *
Old (50+ years)	18	59	30.5%	57	100	57.0%	9.41	**.002** **
Villamagna (Late Medieval)								
Cervical (C2-C7)								
Young (18-29 years)	0	52	0.0%	1	58	1.7%	-	.999
Middle (30-49 years)	16	84	19.0%	13	183	7.1%	7.29	**.007** **
Old (50+ years)	11	63	17.5%	2	16	12.5%	-	.920
Upper Thoracic (T1-T7)								
Young (18-29 years)	0	57	0.0%	2	57	3.5%	-	.476
Middle (30-49 years)	2	82	2.4%	0	192	0.0%	-	.162
Old (50+ years)	5	76	6.6%	0	14	0.0%	-	.724
Lower Thoracic (T8-T12)								
Young (18-29 years)	0	57	0.0%	0	56	0.0%	-	.999
Middle (30-49 years)	8	91	8.8%	20	196	10.2%	0.03	.872
Old (50+ years)	2	70	2.9%	1	14	7.1%	-	.426
Lumbar (L1-L5)								
Young (18-29 years)	1	49	2.0%	0	39	0.0%	-	.999
Middle (30-49 years)	9	72	12.5%	15	166	9.0%	0.34	.561
Old (50+ years)	7	57	12.3%	3	10	30.0%	0.94	.332

* significant at .05, ** significant at .01, *** significant at .001, α = .05
Pearson's chi-squared test with Yates continuity correction
(-) Fisher's Exact test, where counts were less than 5

Figure 3.9 Vertebral osteophytosis prevalence

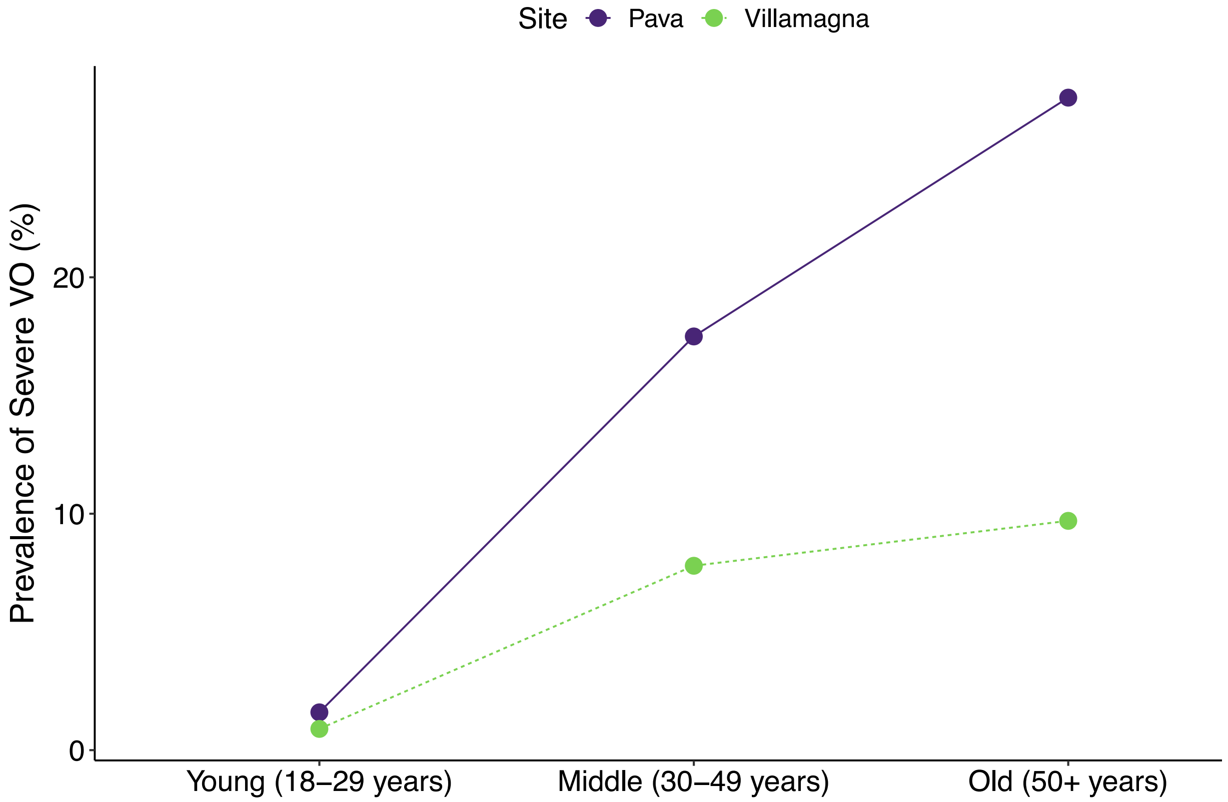

Figure 3.9 – Vertebral osteophytosis (VO) prevalence in each age cohort by site, prevalence is lowest in the young age cohort and highest in the old age cohort for individuals at both sites. Age differences in prevalence are significant at Pava but not at Villamagna (p<.05), so there are also significant differences between sites in the middle and old age cohorts (p<.05).

Table 3.8 Comparison of sex-differences in VOA by spine region and age

Table 3.8 – This table presents the cross tabulation of VOA by age (for each site) to compare sex differences in prevalence of severe VOA. There are significant sex differences in the upper thoracic region in the young age group at Pava, and in the lower thoracic in the older age group at Pava. At Villamagna there is a significant sex difference in the cervical region of the spine in old age. Statistically significant p-*values are in* ***bold****.*

	Female			**Male**			χ^2 *(df =1)*	*p*
	VOA	total	% high	VOA	total	% high		
Pava (Central Medieval)								
Cervical (C2-C7)								
Young (18-29 years)	7	119	5.9%	3	52	5.8%	0.00	.999
Middle (30-49 years)	6	133	4.5%	24	217	11.1%	3.72	.054
Old (50+ years)	13	76	17.1%	31	122	25.4%	1.42	.234
Upper Thoracic (T1-T7)								
Young (18-29 years)	20	107	18.7%	2	51	3.9%	5.11	**.023 ***
Middle (30-49 years)	31	134	23.1%	52	237	21.9%	0.02	.892
Old (50+ years)	19	77	24.7%	45	123	36.6%	2.56	.109
Lower Thoracic (T8-T12)								
Young (18-29 years)	11	80	13.8%	2	35	5.7%	0.87	.351
Middle (30-49 years)	18	96	18.8%	33	171	19.3%	0.00	.999
Old (50+ years)	7	56	12.5%	26	93	28.0%	3.99	**.046 ***
Lumbar (L1-L5)								
Young (18-29 years)	8	96	8.3%	3	40	7.5%	0.08	.778
Middle (30-49 years)	20	99	20.2%	35	180	19.4%	0.00	.999
Old (50+ years)	10	58	17.2%	22	96	22.9%	0.40	.525
Villamagna (Late Medieval)								
Cervical (C2-C7)								
Young (18-29 years)	1	60	1.7%	1	67	1.5%	0.00	.999
Middle (30-49 years)	12	91	13.2%	23	202	11.4%	0.06	.806
Old (50+ years)	8	70	11.4%	4	14	28.6%	-	**<.001 *****
Upper Thoracic (T1-T7)								
Young (18-29 years)	3	46	6.5%	8	48	16.7%	1.46	.227
Middle (30-49 years)	18	77	23.4%	44	177	24.9%	0.01	.925
Old (50+ years)	16	57	28.1%	4	11	36.4%	0.04	.848
Lower Thoracic (T8-T12)								
Young (18-29 years)	7	47	14.9%	8	44	18.2%	0.02	.889
Middle (30-49 years)	9	65	13.8%	40	180	22.2%	1.60	.205
Old (50+ years)	9	54	16.7%	0	8	0.0%	0.51	.477
Lumbar (L1-L5)								
Young (18-29 years)	5	44	11.4%	4	40	10.0%	0.00	.999
Middle (30-49 years)	15	71	21.1%	19	156	12.2%	2.40	.121
Old (50+ years)	14	51	27.5%	3	9	33.3%	-	.704

* significant at .05, ** significant at .01, *** significant at .001, α = .05

Pearson's chi-squared test with Yates continuity correction

(-) Fisher's Exact test, where counts were less than 5

Figure 3.10 Vertebral osteoarthritis (VOA) prevalence

Figure 3.10 – Vertebral osteoarthritis (VOA) prevalence in each age cohort by site, prevalence is lowest in the young age cohort and highest in the old age cohort for individuals at both sites. Age differences in prevalence are significant between young and old age (p<.05).

Table 3.9 Comparison of sex-differences in superior Schmorl's Nodes by spine region and age

Table 3.9 – This table presents the cross tabulation of SNS by age (for each site) to compare sex differences in prevalence of severe SNS. There are significant sex differences in the lower thoracic and lumbar regions in middle age at Pava, and in the lumbar region in the young age group at Pava. At Villamagna there are statistically significant sex differences in the lower thoracic and lumbar regions in middle age, and in the lower thoracic region in the young age group. Statistically significant p*-values are in* ***bold****.*

	Female			**Male**			χ^2 *(df =1)*	*p*
	SNS	total	% high	SNS	total	% high		
Pava (Central Medieval)								
Upper Thoracic (T1-T7)								
Young (18-29 years)	3	118	2.5%	3	45	6.7%	0.62	.433
Middle (30-49 years)	11	144	7.6%	22	231	9.5%	0.19	.661
Old (50+ years)	10	79	12.7%	15	133	11.3%	0.01	.935
Lower Thoracic (T8-T12)								
Young (18-29 years)	24	87	27.6%	10	34	29.4%	0.00	.999
Middle (30-49 years)	24	98	24.5%	73	179	40.8%	6.69	**.009 ****
Old (50+ years)	21	58	36.2%	42	96	43.8%	0.57	.451
Lumbar (L1-L5)								
Young (18-29 years)	23	91	25.3%	2	31	6.5%	3.94	**.047 ***
Middle (30-49 years)	18	101	17.8%	63	173	36.4%	9.71	**.002 ****
Old (50+ years)	20	58	34.5%	31	94	33.0%	0.00	.989
Villamagna (Late Medieval)								
Upper Thoracic (T1-T7)								
Young (18-29 years)	2	55	3.6%	3	57	5.3%	-	.999
Middle (30-49 years)	0	82	0.0%	5	189	2.6%	-	.327
Old (50+ years)	4	66	6.1%	0	12	0.0%	-	.999
Lower Thoracic (T8-T12)								
Young (18-29 years)	3	57	5.3%	20	57	35.1%	13.94	**<.001 *****
Middle (30-49 years)	12	91	13.2%	70	201	34.8%	13.47	**<.001 *****
Old (50+ years)	21	65	32.3%	3	15	20.0%	0.39	.532
Lumbar (L1-L5)								
Young (18-29 years)	9	49	18.4%	12	40	30.0%	1.07	.301
Middle (30-49 years)	9	72	12.5%	43	160	26.9%	5.10	**.024 ***
Old (50+ years)	14	55	25.5%	4	9	44.4%	-	.111

* significant at .05, ** significant at .01, *** significant at .001, α = .05

Pearson's chi-squared test with Yates continuity correction

(-) Fisher's Exact test, where counts were less than 5

Figure 3.11 Superior Schmorl's nodes (SNS) prevalence

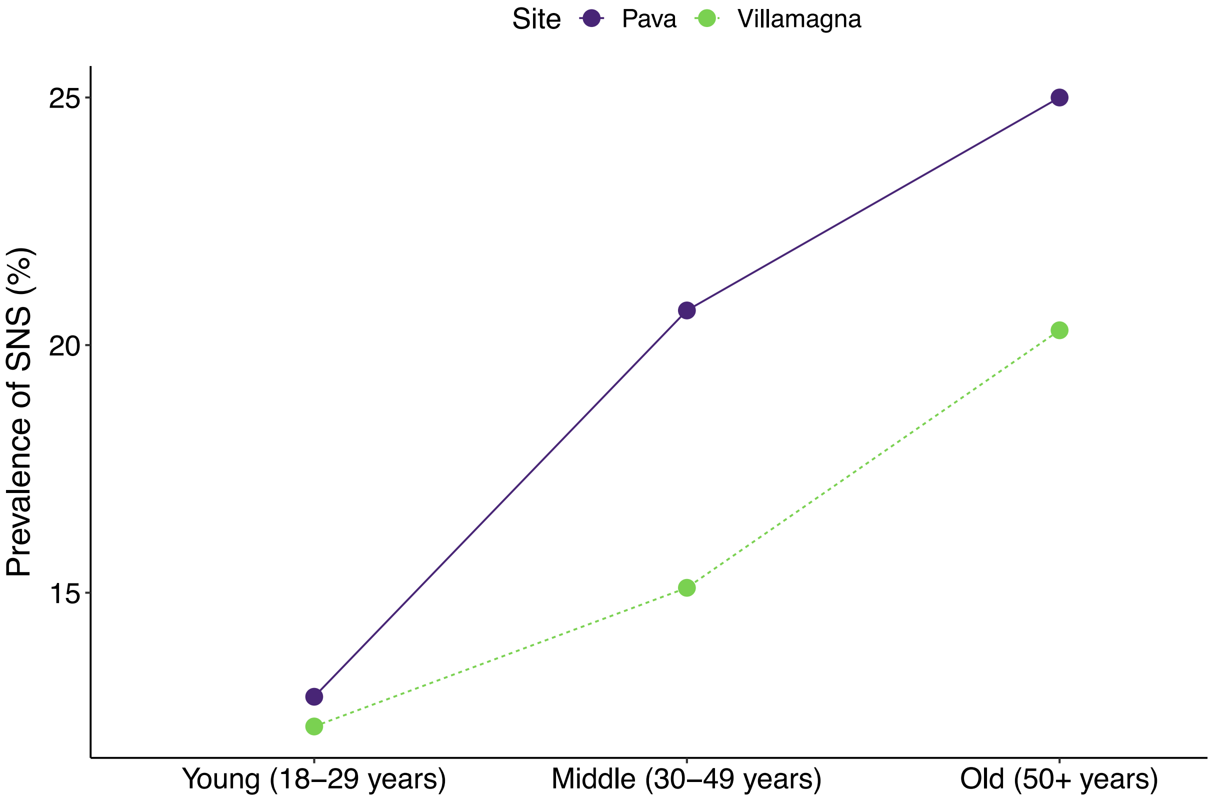

Figure 3.11 – Superior Schmorl's nodes (SNS) prevalence in each age cohort by site, prevalence is lowest in the young age cohort and highest in the old age cohort for individuals at both sites.

Table 3.10 Comparison of sex-differences in inferior Schmorl's Nodes by spine region and age

Table 3.10 – This table presents the cross tabulation of SNI by age (for each site) to compare sex differences in prevalence of severe SNI. There are significant sex differences in the lower thoracic region in middle age at Pava, and in the lower thoracic and lumbar regions in middle age at Villamagna.
Statistically significant p*-values are in* ***bold****.*

	Female			**Male**			χ^2 *(df =1)*	*p*
	SNI	total	% high	SNI	total	% high		
Pava (Central Medieval)								
Upper Thoracic (T1-T7)								
Young (18-29 years)	10	117	8.5%	10	48	20.8%	3.74	.053
Middle (30-49 years)	19	145	13.1%	48	235	20.4%	2.83	.093
Old (50+ years)	22	82	26.8%	24	134	17.9%	1.91	.167
Lower Thoracic (T8-T12)								
Young (18-29 years)	34	89	38.2%	14	36	38.9%	0.00	.999
Middle (30-49 years)	38	99	38.4%	94	180	52.2%	4.37	**.040 ***
Old (50+ years)	30	60	50.0%	59	97	60.8%	1.36	.244
Lumbar (L1-L5)								
Young (18-29 years)	8	91	8.8%	7	32	21.9%	2.66	.103
Middle (30-49 years)	16	100	16.0%	35	174	20.1%	0.46	.496
Old (50+ years)	17	57	29.8%	20	95	21.1%	1.05	.306
Villamagna (Late Medieval)								
Upper Thoracic (T1-T7)								
Young (18-29 years)	2	56	3.6%	1	56	1.8%	-	.999
Middle (30-49 years)	3	82	3.7%	21	194	10.8%	2.88	.090
Old (50+ years)	11	67	16.4%	2	14	14.3%	-	.999
Lower Thoracic (T8-T12)								
Young (18-29 years)	14	56	25.0%	24	56	42.9%	3.23	.072
Middle (30-49 years)	17	93	18.3%	111	200	55.5%	34.25	**<.001 *****
Old (50+ years)	31	65	47.7%	8	15	53.3%	0.01	.914
Lumbar (L1-L5)								
Young (18-29 years)	7	49	14.3%	11	39	28.2%	1.80	.180
Middle (30-49 years)	7	69	10.1%	37	159	23.3%	4.51	**.033 ***
Old (50+ years)	8	53	15.1%	2	9	22.2%	0.00	.962

* significant at .05, ** significant at .01, *** significant at .001, α = .05
Pearson's chi-squared test with Yates continuity correction
(-) Fisher's Exact test, where counts were less than 5

Figure 3.12 Inferior Schmorl's nodes (SNI) prevalence

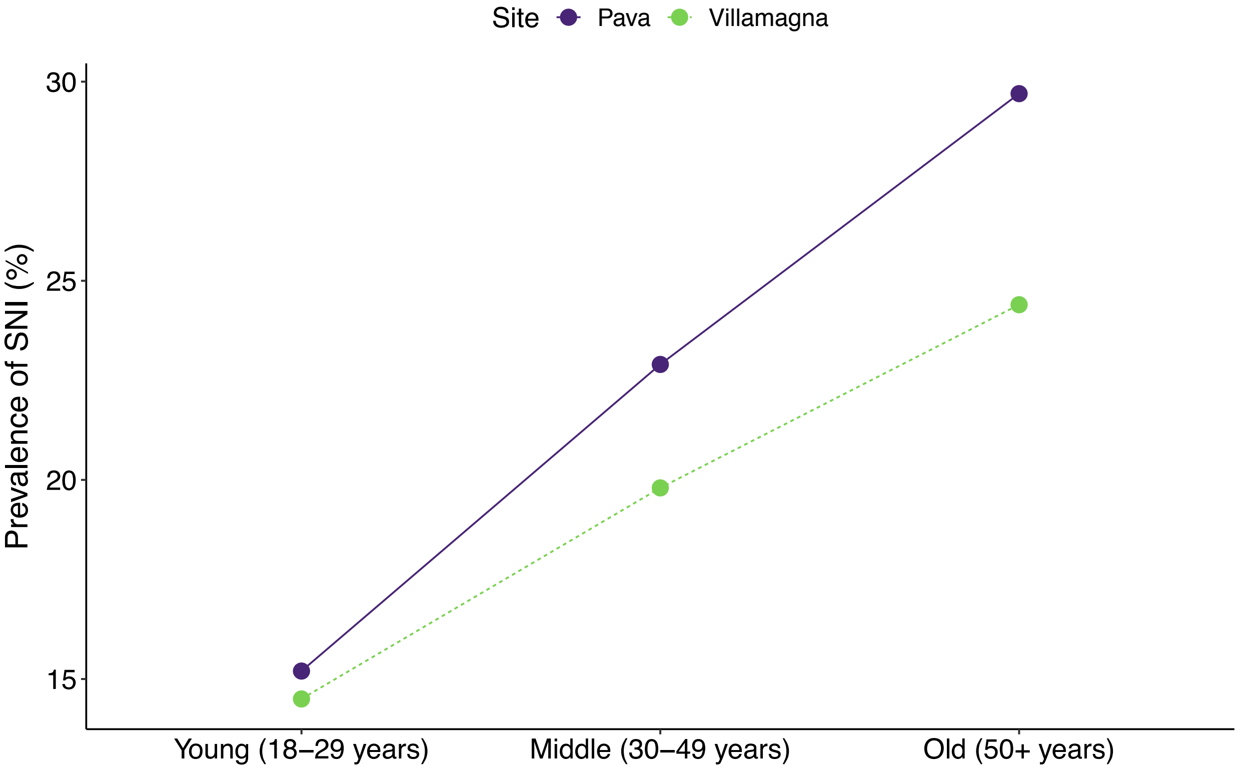

Figure 3.11 – Inferior Schmorl's nodes (SNI) prevalence in each age cohort by site, prevalence is lowest in the young age cohort and highest in the old age cohort for individuals at both sites.

Table 3.11 Vertebral osteophytosis comparison by site

Table 3.11 – There are significant differences in the distribution of VO in all regions in the middle age group, and in the cervical, lower thoracic, and lumbar regions of the spine. In middle age, Pava males have the most cervical VO, then Pava females. Pava males, Pava females, and VM females have similarly high levels of VO in the cervical region – an indication that they share a particular risk or activity, such as carrying heavy weights on the head or shoulders (e.g., grape harvesting). Overall, Pava males have significantly more VO than other groups. There is almost no VO in young age, which is expected given the pathophysiology of VO.

	Pava						**Villamagna**							
	Female			**Male**			**Female**			**Male**			$\chi^2(df=3)$	p
	VO	total	% high	VO	total	% high	VO	total	% high	VO	total	% high		
Young (18-29 years)														
Cervical	5	108	4.6%	0	46	0.0%	0	52	0.0%	1	58	1.7%	5.06	.168
Upper thoracic	0	121	0.0%	0	51	0.0%	0	57	0.0%	2	57	3.5%	-	.110
Lower thoracic	1	88	1.1%	0	35	0.0%	0	57	0.0%	0	56	0.0%	-	.999
Lumbar	3	91	3.3%	0	35	0.0%	1	49	2.0%	0	39	0.0%	-	.754
Middle (30-49 years)														
Cervical	25	120	20.8%	49	195	25.1%	16	84	19.0%	13	183	7.1%	22.41	**<.001 *****
Upper thoracic	3	141	2.1%	21	241	8.7%	2	82	2.4%	0	192	0.0%	23.96	**<.001 *****
Lower thoracic	11	100	11.0%	36	178	20.2%	8	91	8.8%	20	196	10.2%	11.11	**.011 ***
Lumbar	19	101	18.8%	55	177	31.1%	9	72	12.5%	15	166	9.0%	29.46	**<.001 *****
Old (+50 years)														
Cervical	16	68	23.5%	45	107	42.1%	11	63	17.5%	2	16	12.5%	15.99	**.001 ****
Upper thoracic	6	83	7.2%	12	132	9.1%	5	76	6.6%	0	14	0.0%	1.71	.635
Lower thoracic	1	58	1.7%	39	96	40.6%	2	70	2.9%	1	14	7.1%	55.53	**<.001 *****
Lumbar	18	59	30.5%	57	100	57.0%	7	57	12.3%	3	10	30.0%	33.12	**<.001 *****

* significant at .05, ** significant at .01, *** significant at .001, α = .05

Pearson's chi-squared test with Yates continuity correction

(-) Fisher's Exact test, where counts were less than 5

Table 3.12 Comparison of sex and site differences in severe VOA between Pava and Villamagna

Table 3.12 – There are significant differences in the distribution of severe VOA amongst individuals in the older age group in the cervical and lower thoracic regions of the spine. Older age Villamagna females have less than expected cervical VOA; older age Villamagna males have less than expected VOA in the lower thoracic region. The difference in VOA in older age Villamagna males may be due to the small sample size for this group.

	Pava						**Villamagna**							
	Female			**Male**			**Female**			**Male**				
	VOA	total	% high	VOA	total	% high	VOA	total	% high	VOA	total	% high	χ^2 (*df* =3)	*p*
Young (18-29 years)														
Cervical	7	119	5.9%	3	52	5.8%	1	60	1.7%	1	67	1.5%	-	.370
Upper thoracic	20	107	18.7%	2	51	3.9%	3	46	6.5%	8	48	16.7%	9.00	.029
Lower thoracic	11	80	13.8%	2	35	5.7%	7	47	14.9%	8	44	18.2%	2.71	.439
Lumbar	8	96	8.3%	2	39	5.1%	5	44	11.4%	4	40	10.0%	1.12	.771
Middle (30-49 years)														
Cervical	6	133	4.5%	24	217	11.1%	12	91	13.2%	23	202	11.4%	6.11	.106
Upper thoracic	31	134	23.1%	52	237	21.9%	18	77	23.4%	44	177	24.9%	0.49	.922
Lower thoracic	18	96	18.8%	33	171	19.3%	9	65	13.8%	40	180	22.2%	2.21	.530
Lumbar	20	99	20.2%	35	180	19.4%	15	71	21.1%	19	156	12.2%	4.66	.199
Old (+50 years)														
Cervical	13	76	17.1%	31	122	25.4%	8	70	11.4%	4	14	28.6%	26.39	**<.001** ***
Upper thoracic	19	77	24.7%	45	123	36.6%	16	57	28.1%	4	11	36.4%	3.57	.311
Lower thoracic	7	56	12.5%	26	93	28.0%	9	54	16.7%	0	8	0.0%	-	**.054** *
Lumbar	10	58	17.2%	22	96	22.9%	14	51	27.5%	3	9	33.3%	-	.501

* significant at .05, ** significant at .01, *** significant at .001, α = .05

Pearson's chi-squared test with Yates continuity correction

(-) Fisher's Exact test, where counts were less than 5

Table 3.13 Comparison of sex and site differences in superior surface Schmorl's Nodes between Pava and Villamagna

Table 3.13 – There are significant differences in the distribution of superior surface Schmorl's Nodes (SNS) in the lower thoracic region for the young age group, and in the middle age group in the upper thoracic, lower thoracic, and lumbar regions of the spine. Villamagna females have less than expected lower thoracic SNS in young and middle age, and less than expected SNS in the lumbar region, also in middle age. Middle age Pava males have more than expected SNS in the upper thoracic region. There are no significant differences amongst the older age groups.

	Pava						Villamagna							
	Female			Male			Female			Male				
	SNS	total	% high	SNS	total	% high	SNS	total	% high	SNS	total	% high	$\chi^2 (df = 3)$	*p*
Young (18-29 years)														
Upper thoracic	3	118	2.5%	3	45	6.7%	2	55	3.6%	3	57	5.3%	-	.561
Lower thoracic	24	87	27.6%	10	34	29.4%	3	57	5.3%	20	57	35.1%	15.85	**.001 ****
Lumbar	23	91	25.3%	2	31	6.5%	9	49	18.4%	12	40	30.0%	6.84	.077
Middle (30-49 years)														
Upper thoracic	11	144	7.6%	22	231	9.5%	0	82	0.0%	5	189	2.6%	-	**<.001 *****
Lower thoracic	24	98	24.5%	73	179	40.8%	12	91	13.2%	70	201	34.8%	24.57	**<.001 *****
Lumbar	18	101	17.8%	63	173	36.4%	9	72	12.5%	43	160	26.9%	19.99	**<.001 *****
Old (+50 years)														
Upper thoracic	10	79	12.7%	15	133	11.3%	4	66	6.1%	0	12	0.0%	-	.418
Lower thoracic	21	58	36.2%	42	96	43.8%	21	65	32.3%	3	15	20.0%	4.35	.226
Lumbar	20	58	34.5%	31	94	33.0%	14	55	25.5%	5	9	55.6%	3.54	.315

* significant at .05, ** significant at .01, *** significant at .001, α = .05

Pearson's chi-squared test with Yates continuity correction

(-) Fisher's Exact test, where counts were less than 5

Table 3.14 Comparison of sex and site differences in inferior surface Schmorl's Nodes between Pava and Villamagna

Table 3.14 – There are significant differences in inferior surface Schmorl's Nodes (SNI) amongst young and middle age. Amongst young age groups there are significant differences in the upper thoracic and lumbar regions. Young age Pava males have more than expected SNI in the upper thoracic region, and Pava and Villamagna females have less than expected SNI in the lumbar region. Amongst the middle age groups there are significant differences in the upper thoracic and lower thoracic regions. Middle age Villamagna females have less than expected prevalence of SNI in the upper and lower thoracic regions of the spine.

	Pava						**Villamagna**							
	Female			**Male**			**Female**			**Male**			$\chi^2(df=3)$	*p*
	SNI	total	% high	SNI	total	% high	SNI	total	% high	SNI	total	% high		
Young (18-29 years)														
Upper thoracic	10	117	8.5%	10	48	20.8%	2	56	3.6%	1	56	1.8%	-	**.004** **
Lower thoracic	34	89	38.2%	14	36	38.9%	14	56	25.0%	24	56	42.9%	4.38	.223
Lumbar	8	91	8.8%	7	32	21.9%	7	49	14.3%	11	39	28.2%	8.91	**.030** *
Middle (30-49 years)														
Upper thoracic	19	145	13.1%	48	235	20.4%	3	82	3.7%	21	194	10.8%	17.19	**<.001** ***
Lower thoracic	38	99	38.4%	94	180	52.2%	17	93	18.3%	111	200	55.5%	41.16	**<.001** ***
Lumbar	16	100	16.0%	35	174	20.1%	7	69	10.1%	37	159	23.3%	6.14	.105
Old (+50 years)														
Upper thoracic	22	82	26.8%	24	134	17.9%	11	67	16.4%	2	14	14.3%	-	.340
Lower thoracic	30	60	50.0%	59	97	60.8%	31	65	47.7%	8	15	53.3%	3.25	.355
Lumbar	17	57	29.8%	20	95	21.1%	8	53	15.1%	2	9	22.2%	3.56	.313

* significant at .05, ** significant at .01, *** significant at .001, $\alpha = .05$

(-) Fisher's Exact test, where counts were less than 5

Table 3.15 Comparison differences in spine disease crude prevalence at Pava and Villamagna

Table 3.15 – Prevalence rates with significant positive standardized residuals (greater than expected disease) are in purple, prevalence rates with negative standardized residuals (less than expected disease) are in green. Overall Pava males have more than expected spine disease (especially VO, and Schmorl's Nodes); Females with grave goods (+) have less than expected spine disease.

	Pava		Villamagna					
	Female	**Male**	**Female -**	**Female +**	**Male -**	**Male +**		
	% high	% high	% high	% high	% high	% high	χ^2 *(df =5)*	*p*
VO								
Cervical	15.5%	27.0%	17.8%	0.0%	4.0%	10.8%	58.76	<.001 ***
Upper thoracic	2.6%	7.8%	4.2%	0.0%	1.1%	0.0%	26.34	<.001 ***
Lower thoracic	5.3%	24.3%	5.8%	0.0%	9.1%	5.6%	74.66	<.001 ***
Lumbar	15.9%	35.9%	12.2%	0.0%	11.0%	2.9%	88.29	<.001 ***
VOA								
Cervical	7.9%	14.8%	12.5%	0.0%	16.4%	2.3%	27.68	<.001 ***
Upper thoracic	22.0%	24.1%	25.4%	2.6%	28.8%	13.8%	16.72	.005 **
Lower thoracic	15.5%	20.4%	16.3%	10.8%	26.9%	7.9%	17.09	.004 **
Lumbar	15.0%	18.7%	22.9%	11.4%	15.9%	6.0%	11.36	.045 *
SNS								
Upper thoracic	7.0%	9.8%	3.2%	2.2%	3.4%	2.4%	-	.005 **
Lower thoracic	28.4%	40.5%	15.1%	23.4%	31.5%	39.1%	37.45	<.001 ***
Lumbar	24.4%	32.2%	17.5%	20.5%	29.7%	26.6%	12.62	.027 *
SNI								
Upper thoracic	14.8%	19.7%	8.9%	4.3%	8.3%	10.7%	23.94	<.001 ***
Lower thoracic	41.1%	53.4%	26.9%	36.2%	49.2%	60.0%	43.16	<.001 ***
Lumbar	16.5%	20.6%	10.6%	20.5%	22.2%	28.6%	12.36	.030 *

* significant at .05, ** significant at .01, *** significant at .001, α = .05

(-) Fisher's Exact test, where counts were less than 5

Prevalence rates are purple to indicate that the standardized residual (*r*) is greater than 1.96 (significantly more than expected observations) and prevalence rates are green to indicate that the standardized residual (*r*) is less than -1.96 (significantly less than expected observations)

Individuals at Villamagna without grave inclusions (Male/Female -), with grave inclusions (Male/Female +)

Figure 3.13 Vertebral Osteophytosis (VO)

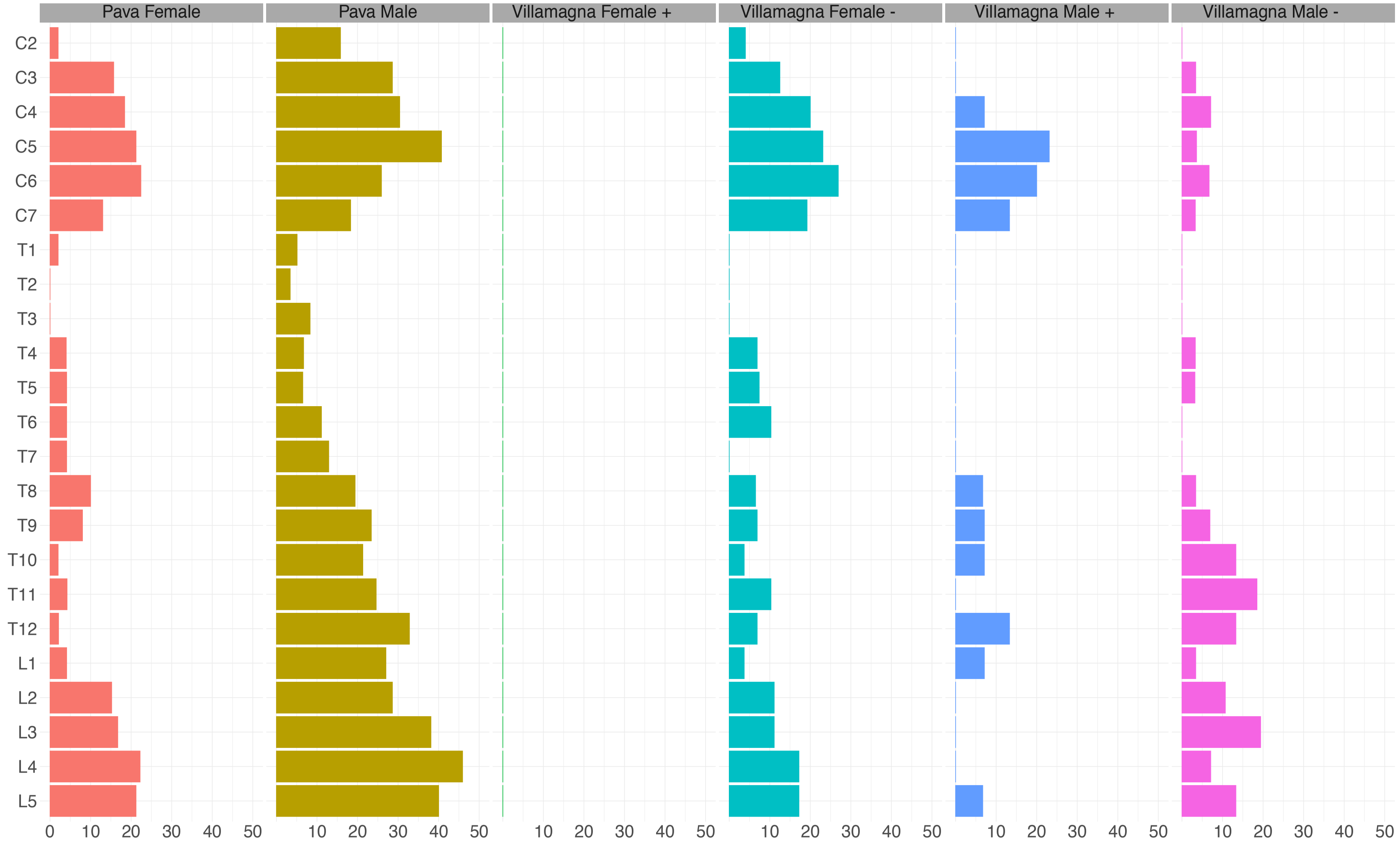

Figure 3.13 – Prevalence (%) of severe vertebral osteophytosis (VO) by spine element (y-axis), grouped by site and sex, and grave good inclusion at Villamagna; the y-axis is the vertebral element from the superior-most portion of the spine (C2) to the inferior-most portion of the spine (L5); the x-axis measures the prevalence of disease across the population in that vertebral bone

Figure 3.14 Vertebral Osteoarthritis (VOA)

Figure 3.14 – Prevalence (%) of severe vertebral osteoarthritis (VOA) by spine element (y-axis), grouped by site and sex, and grave good inclusion at Villamagna; The y-axis is the vertebral element from the superior-most portion of the spine (C2) to the inferior-most portion of the spine (L5); the x-axis measures the prevalence of disease across the population in that vertebral bone

Figure 3.15 Superior Schmorl's nodes (SNS)

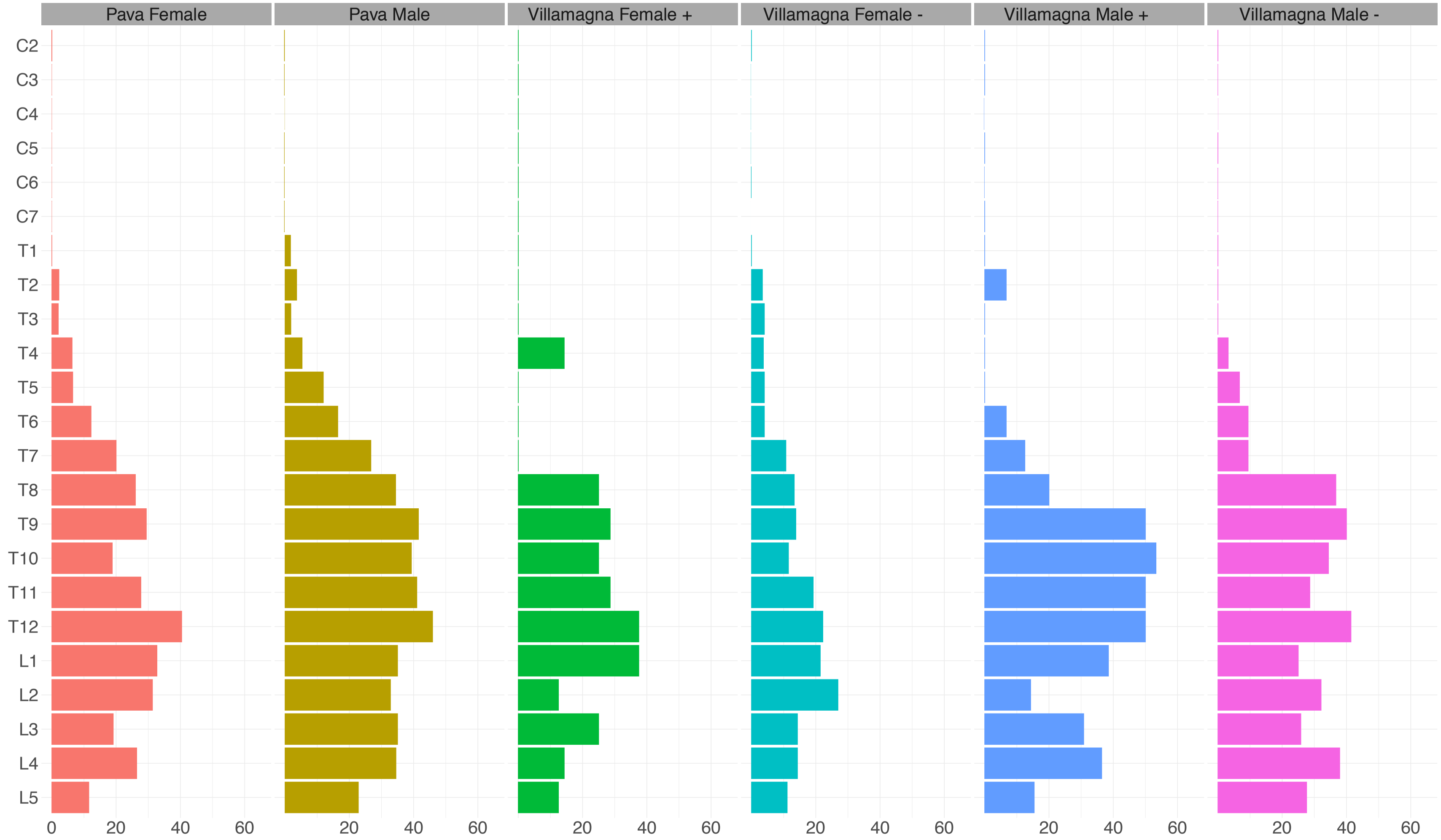

Figure 3.15 – Prevalence (%) of superior-surface Schmorl's nodes (SNS) by spine element (y-axis), grouped by site and sex, and grave good inclusion at Villamagna; the y-axis is the vertebral element from the superior-most portion of the spine (C2) to the inferior-most portion of the spine (L5); the x-axis measures the prevalence of disease across the population in that vertebral bone

Figure 3.16 Inferior Schmorl's nodes

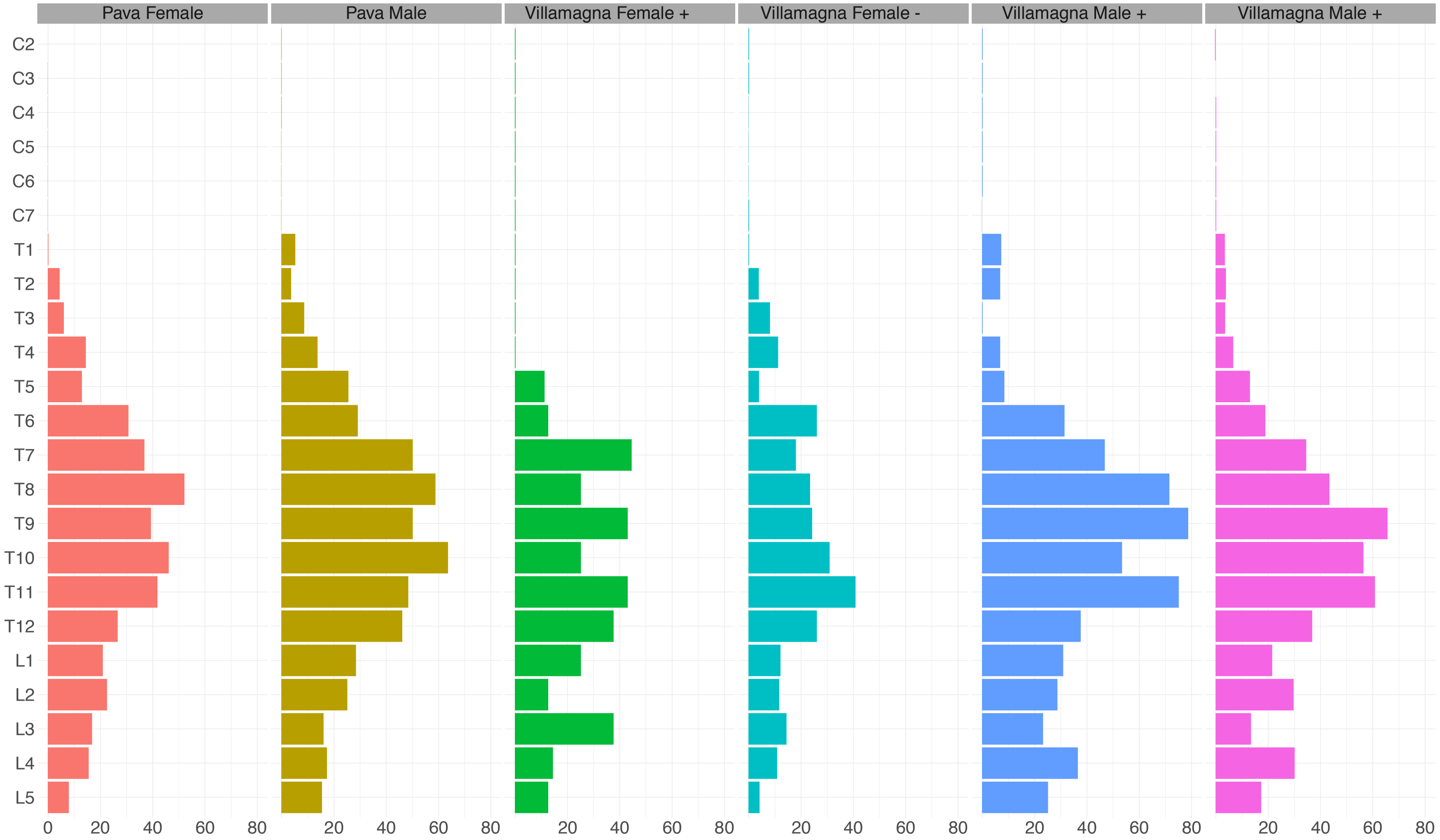

Figure 3.15 – Prevalence (%) of inferior-surface Schmorl's nodes (SNI) by spine element (y-axis), grouped by site and sex, and grave good inclusion at Villamagna; the y-axis is the vertebral element from the superior-most portion of the spine (C2) to the inferior-most portion of the spine (L5); the x-axis measures the prevalence of disease across the population in that vertebral bone

3.7). Overall, sex differences in VO emerge in the middle age cohort, likely due to the normative integrity of the intervertebral disc over the life course. Due to the morphology, physiology, and biochemistry of the cervical and lumbar segments of the spine, these regions are particularly sensitive to age-related changes in the biochemical and structural changes to the joint environment. The intervertebral disc functions to transmit, absorb, and diffuse mechanical loads/strains in the spine (Risbud & Shapiro 2014), and the degeneration of disc with senescence is responsible for loss of joint stability, stenosis, and reduction of movement in the spine, usually resulting from a combination of morphological changes to the bone and inflammatory internal joint microenvironment. The cervical disc lacks a concentric anulus fibrosus, and therefore the anulus functions more akin to an interosseous ligament (Bogduk 2012, Mercer & Bogduk 1999, Oda et al. 1988); additionally, the nucleus pulposus only persists for approximately 20 years, when it disappears and leaves a fibrocartilaginous plate in its stead (Bland & Boushey 1990, Bogduk 2012). In contrast, the lumbar disc has a robust concentric anulus fibrosus, supporting its robust weight-bearing capabilities, and degenerative changes to the disc are related to the dehydration of the nucleus and changes in the concentration and nature of proteoglycans, which shift dramatically across the life course, especially in older age (Oda et al. 1988, Risbud & Shapiro 2014, Shen et al. 2012, Taylor & Twomey 1986). The increased in VO prevalence in the cervical and lumbar spine between the young and middle age cohorts likely reflects this accumulation of injury and the life course trajectories of the intervertebral disc. Differences observed between individuals in the middle age cohort and older age cohort are likely a reflection of normative biological changes to the disc and vertebrae, being exacerbated by the cumulative effects of aging or of working-while-aging.

Compressive load-bearing in the thoracic spine ranges from 9%-47% of body mass between T1-T12 (White 1969), and overall the stability of the thoracic spine benefits from the structure of the ribcage and accompanying fascia and ligaments which reduce rotational mobility in the upper thoracic region of the spine (Edmondston & Singer 1997). Low prevalence of VO in the upper thoracic regions of the spine at both sites, for all sex and age groups, is likely due to this phenomenon (Table 3.7). Higher prevalence of severe VO in the lower thoracic regions in middle age for males and females may be a consequence of load-bearing physical labor resulting in mechanical strain and injury to that region (Jurmain 2013, Klaus et al. 2009). Pava males have a significantly higher prevalence of VO in the lower thoracic region compared to other groups, nearly a 200% higher prevalence compared to their female counterparts, and a more than 200% higher prevalence compared to people at Villamagna (Table 3.7).

When comparing prevalence across sites and with regard for the presence or absence of grave goods, I found that females buried with grave goods at Villamagna had no incidence of VO in *any* region of the spine (Table 3.15, Figure 3.13) and that males buried with grave goods had a slightly higher prevalence of VO in the cervical region (10.8%), but overall had lower prevalence of VO in all other regions. At the population-level the possible causes of economic-based differences in disease outcome may be attributed to the complex environmental (i.e., activity-related) and epigenetic consequences of inequality (e.g., Brennan-Olsen et al. 2019, Dressler et al. 2005).

Vertebral Osteoarthritis

Similar to VO, there is a positive relationship between age and severe VOA prevalence at Pava and Villamagna (Figure 3.8, Table 3.12). Significant age differences in severe VOA prevalence are expected due to the pathophysiology of VOA, where severe disease results from an accumulation of changes to joint biochemistry and biomechanics. Age-related increases in the cervical region likely reflect the aging and continued use of the neck for weight-bearing activities, as the articular facets of the cervical spine face superior-posteriorly and therefore share in the axial and compression loading and weight bearing function of the cervical centra (Bland & Boushey 1990, Bogduk & Mercer 2000). In contrast, thoracic articular facets have limited flexion and anterior translation due to the configuration of their lamellae, and primarily provide rotation in the upper back (White, 1969). We expect then, that differences in thoracic region VOA are related also to occupational-labor stress, and degenerative changes are exacerbated by these activities, if not a direct consequence. In two medieval British samples, Sofaer Derevenski (2000) found that the highest prevalence of facet remodeling and change was in the upper thoracic region. At Ensay and Wharram Percy, Sofaer Derevenski (2000) attributes these plastic changes in the upper thoracic region to overall skeletal stress paired with a complex positive feedback system in the upper thoracic region. The upper thoracic region is particularly vulnerable to weight-bearing due to the curvature of the spine in the C7-T2 region, therefore axial rotation with any load bearing activities in the upper body might exacerbate or cause degenerative changes such as remodeling, pitting, or eburnation in that region of the spine (Sofaer Derevenski 2000).

Villamagna females have higher prevalence of VOA in the lumbar region compared to males (Table 3.8, 3.12), however when controlling for age, only individuals in the older age cohort show a sex difference in prevalence (Table 3.8). Overall, differences in VOA were considerably more constrained than differences in VO, although the trend of lower prevalence among individuals buried with grave goods is maintained (Table 3.12, 3.15, Figure 3.14). Individuals buried with grave goods at Villamagna had significantly lower than expected prevalence in the cervical and upper thoracic regions for females, and in the cervical, lower thoracic, and lumbar regions for males—and lower prevalence in all regions generally. These differences may be due in part to different modes of weight-bearing and movement, differential divisions of labor, and/or gendered activities. Increased prevalence, as seen in males across both sites indicates that they were either more vulnerable to severe VOA or were differentially affected by or participating in weight-bearing physical activities in daily life.

Documentary sources from the medieval period in Italy suggest that non-elite women were likely involved in a range of general activities of the home, farm, and village, and overall occupational experiences were more homogenous, therefore we expect less differentiation amongst females. Villamagna females without grave goods and Pava females have nearly identical prevalence of VO and VOA in each region of the spine, however there is a deviation from this trend for females buried with grave goods at Villamagna (Figure 3.11, 3.12). This suggests that economic privileges reflected by the presence of grave goods may have been advantageous for long-term disease outcomes. These privileges may have had direct consequences in terms of access, such as type of employment, avoiding work when injured; or broader consequences, such as access to quality nutrition, health management, and access to spiritual and physical care.

Villamagna males without grave goods have similar prevalence and distribution of VOA compared to all Pava males (Figure 3.15). Males at Pava and Villamagna have a relatively uniform distribution of severe VOA (Figure 3.12). Males have divergent trends between VO and VOA, which I explore further below. We know from historical documents (Carocci 2016, Goodson 2016) that the annual grape harvest and regular agricultural work at Villamagna were a foundation to everyday life at Villamagna and are possible causes of severe cervical VOA. Therefore, it is possible that grape and agricultural harvesting contributed to the elevated levels of cervical VOA in middle age adults in all sex groups. Lovell (1994) and Bridges (1994) have suggested that higher prevalence of VOA in the cervical spine region may reflect activity-related stresses, such as carrying heavy loads on top of the head, or the use of tumplines.

Although it is expected that activity and labor differences influenced the expression and severity of spine disease in the population (Bridges 1994, Kiorpe 2014, Rojas-Sepúlveda et al. 2008, Sofaer Derevenski 2000, Zhang et al. 2017), there were possibly other epigenetic and environmental factors that contributed to the differential prevalence of disease severity amongst lower and higher status individuals, as the primacy of biochemical components of VO and VOA has been established in recent years (Gellhorn et al. 2013, Kalichman et al. 2008, Risbud & Shapiro 2014, Wang et al. 2016) and further research has demonstrated the role of epigenetic modifications in the pathogenesis of VO and VOA in clinical populations (e.g., Barter, Bui, & Young 2012, Shen et al. 2017). Individuals with less access to economic privilege may have increased risk for VO and VOA because of epigenetic and environmental risk factors, such as high pathogen load, nutrition quality, infection/adaptive immune response, mechanical stress and trauma, toxin exposure, and maternal stress, which may be differentially incorporated into the skeletal system across the life course (e.g., Thayer & Kuzawa 2011, Gowland 2015), and may lead to increased vulnerability to chronic disease. McDade et al., (2019) suggest that socio-economic status plays a role in the enrichment of genes related to the regulation of T-cell mediated cytotoxicity, which has been hypothesized by Risbud & Shapiro (2014) to play a role in the proinflammatory response and resulting phenotypic changes in disc degeneration associated with VO especially. The role of epigenetic modifications in so-called non-inflammatory arthroses, such as osteoarthritis, is well established (Barter et al. 2012, Barter & Young 2013, Shen et al. 201), although the role of socio-economic status, or social inequality in these epigenetic modifications remains unstudied. Future studies on the epigenetic regulators of osteoarthritis and osteophytosis are needed to better understand the role of immune function in osteoarthritis, as well as the role of biocultural factors in degenerative joint disease pathogenesis.

Due to the particular biochemistry of the disc, as compared with the cartilage of the facet joints, it is expected that the effect of epigenetic modifications would be amplified for VO, whereas VOA would be more affected by environmental and behavioral components of everyday life. Differences in VO and VOA prevalence might be explained by these differences in exposure to risk, which modulate downstream vulnerability to severe disease outcomes. Although it has been hypothesized that VO and VOA are strongly correlated, and have a purely functional relationship, I found that VO or VOA were not strong predictors for each other. Future bioarchaeological work could further test my new hypothesis through paleo-epigenomic analyses and would consider the patterning and prevalence of severe VOA and VO alongside other skeletal indicators of generalized physiological stress and diet, although these are also often entangled with biocultural and developmental processes.

Schmorl's Nodes

The distribution of Schmorl's nodes is skewed towards the lower thoracic and lumbar regions of the spine (Figure 3.9, 3.10). At Villamagna the maximum prevalence of superior and inferior Schmorl's nodes is 60%; and at Pava the maximum prevalence is 53.4% (Table 3.9, 3.10). Other archaeological sites have reported prevalence rates between 4% and 62.9% and contemporary populations have a similar reported prevalence (Üstündag 2009, Novak & Šlaus 2011, Šlaus 2000, Klaus et al. 2009, Plomb 2017). There are significant sex differences in the prevalence of Schmorl's nodes in the lower thoracic region amongst people in the middle age cohort in both samples (Table 3.19, 3.10).

Pava males have higher than expected prevalence of Schmorl's nodes (superior and inferior) in the upper and lower thoracic regions of the spine compared to all other groups (Table 3.21), which might reflect differential experiences of labor. Schmorl's nodes have been widely used as indicators of activity in bioarchaeological studies (Novak & Šlaus 2011, Klaus et al. 2009, Merbs 1983, Robb 1994, Üstündag 2009), although their etiology and symptomology remains disputed in the bioarchaeological and clinical literature (Plomb 2012, 2015). Although Schmorl's nodes may only have a correlative relationship with labor and activity (and not in all cases), it is clear from clinical studies that Schmorl's nodes often cause debilitating pain and impact ability to work and quality of life (Mattei & Rehman 2014, Sonne-Holm et al. 2013, Williams et al. 2007), with a nerve block being one of the primary treatments for pain induced through the Schmorl's node phenomenon (Mattei & Rehman 2014). Faccia and Williams (2008) found that Schmorl's nodes often cause debilitating pain, where 92% of their study participants reported limits to their daily life activities. Clinical research links torsional loading, flexion, and extension of the spine with Schmorl's node incidence.

Schmorl's nodes alone are not necessarily robust indicators of activity, therefore my purpose in examining these trends is to contextualize degenerative spine disease in terms of biocultural *experiences* of labor and the ways in which these experiences are embedded into larger landscapes of inequality. The relationship between vertebral osteophytosis and disc degeneration and mechanical or oxidative (chemical) injury is clear from the clinical literature, however many of these studies are not concerned with the timing and severity of morphological changes in bone. I argue that the comorbidity of VO and Schmorl's nodes is indicative of a compounding and cumulative effect of aging, labor, and inequality in the spine. Repeated and sustained biomechanical loading in an injured spine increases likelihood for severe disease outcome in VO and is therefore an embodiment of sociopolitical inequality and an issue of economic privilege. As such, males at Pava have higher prevalence of disease across the spine, and across multiple indicators; strikingly they also have increased prevalence of Schmorl's nodes in the low back region an indication that they likely worked more with existing injuries and experienced more nerve pain as a result.

Conclusions

Socioeconomic status (SES) is an important determinant of health and disease outcomes in modern human populations. Bioarcheologists offer unique insights into pre-industrial, pre-globalization populations, with varying implementations and configurations of status differentiation, which allow us to test hypotheses not possible due to medical intervention, post-industrialization. Bioarchaeological approaches have considered the complex relationship between occupation, physical activity, and disease outcome, but few studies consider the downstream effects of status on the molecular and cellular systems that regulate disease pathogenesis and physiology. Future bioarchaeological research might implement immunoassays, or assess other biochemical, microbiome, isotopic, or genomic data into studies of social inequality and health disparities in past societies; one difficulty remains the variable taphonomic preservation of skeletal remains at various sites.

Anthropological research has highlighted the consequences of social inequality in producing human health disparities for decades (Gravlee 2009, Nguyen & Peschard 2003, McDade 2008), and the development of a biocultural approach to disease ecology and health disparities in the past and present has demonstrated the complexity of intra-actions between social life, health, and disease in multiple contexts (e.g., Buikstra & Beck 2006, Cohen & Armelagos 1984, Klaus 2014). Socio-economic status, synonymous with social inequality and difference in many studies, is a key predictor of health and disease outcomes in our contemporary world, and typically access to economic resources and privileges are encompassed in SES.

The relationship between health outcomes, physical and occupational activities, and access to economic resources is multifactorial and intersectional. If we understand occupational activities as situated and socially contextual experiences, we begin to see that occupation or “activity” is not straightforward as a singular variable for analysis. Neither is activity merely what we do in our everyday lives. Occupational activities and various types of manual labor are situated in broader political and cultural landscapes of inequality, commonly conceptualized in the bio/archaeological literature as gendered labor practices. Occupational activity, as a variable of analysis, is confounded by the interaction effects of systemic institutional inequality and hierarchical social structures (i.e., access to quality nutrition, intergenerational wealth, physical or biochemical trauma, exposure to chemicals or pesticides, access to economic resources). Where physiological stress, social status, and labor occupation are typically analyzed as discrete effects, I argue for a more intersectional view of these influences. Attention to how inequality shapes life history and differentially produces occupational risk and vulnerability to that risk is crucial for understanding the multiple, cofounding, and inter-related effects of social inequalities on disease outcomes.

From my perspective, which foregrounds the body and embodied experience at individual and collective levels, it is clear that economic and political inequalities it is clear that there is are differences in disease outcomes and in comorbidities based on regional and intra-class differences at these two sites. Although there is evidence at both sites for labor-related degenerative changes in the spine, there is also evidence that males at Pava had VO degeneration comorbid with increased prevalence of Schmorl’s nodes. There is an underlying assumption in many bioarchaeological interpretations of labor and work, that occupational activity ends with injury, largely based on contemporary notions of economic mobility and freedom. The results of this study suggest that more subtle differences in economic experience, an order of magnitude smaller than the traditional "socio-economic status" scale may influence and affect disease outcomes and lived experiences of those diseases and should be considered as possible confounding factors for understanding epidemiological, or population-wide trends. In this context, I hypothesize that subtle "intra-class" differences in lifestyle including occupational hazards, pathogen-load, access to clean water/foods, nutrition quality and variation due to cultural or practical mores, biological ancestry, and/or environmental exposure to toxins (there was a medieval lime kiln and bell casting pit excavated at the site) may affect the differential vulnerability to and effects of regulatory and biochemical mechanisms that influence degenerative spine disease pathogenesis and pathophysiology and hope to test this hypothesis in future research.

Tuscany is often highlighted in economic historiography because of its early adoption of sharecropping in the central to late medieval period (Emigh 1997, Herlihy & Klapisch-Zuber 1985, Jones 1968). Tuscan sharecropping was embedded in the larger economics of the region, which centered, at least in historical thought, in Florence, Siena, and Arezzo. Rural agricultural areas were part of a *contado*-city relationship (even at hyper-local scales) that connected them with the broader medieval economy, although sharecropper's landlords typically resided in more urban areas (Abulafia 2004, Epstein 2000, Wickham 1984, 2008, 2011). In the rural medieval (feudal) economy, where exploitation and class struggle define the relations of production, it is unlikely that injury precluded continued physical labor. These dynamics further exacerbated class divisions, even within the peasant class. Sharecropping farmers would have been more likely to work while injured, since they had less control of their harvesting work and were beholden to their landlords (Wickham 2008, 2011).

Much anthropological and epidemiological research focuses on the differences *between* economic class groups; however, I suggest that intra-class differences in lived experience, and the ways in which more subtle forms of inequality operate may be meaningful in terms of understanding disease experience and outcome in the archaeological past. This aligns with contemporary theorization of how inequality is unevenly distributed amongst people in the population, of how detrimental effects of systemic, institutional, and ideological inequalities rests more heavily on some parts of society than others, and of how heterogeneity is generated in an intersectional and cumulative manner.

Chapter 4:

Cripping plasticity: understanding variation and sample dispersion in two Medieval populations (1000-1350 AD)

Orientation

Past people with a wide range of "healthy" and "pathological" biomechanical modes are central to our evolutionary history and contemporary health, and yet have remained at the margins of biological anthropology research. This study seeks to address a gap in our understandings of limb use and biomechanics in past populations, where the effects of chronic degenerative spine disease on bone have not been considered. In this study I set the groundwork for investigating *alternative bipedalisms*. Drawing on Kafer's articulation of crip futurity (2009, 2013, see also Chapter 1), I use empirically derived data from 151 adult individuals from the medieval sites of Villamagna, Lazio (n=69) and Pava, Toscana (n=82) to investigate (a) trends in limb use between and across both populations (this Chapter), and (b) to operationalize a serious consideration of alternative bipedalisms and their crip potentiality in the archaeological past (Chapter 5). Kafer's (2013) theorization of crip futurity is the foregrounding theoretical orientation for pursing alternative bipedalism with a sound ethical-political orientation towards disability visibility and crip solidarity. Employing a multi-scalar approach entails the examination of population-level trends (Chapter 4), in addition to examining individual skeletons in comparison to their own communities (Chapter 5).

The notion that evolution has directionally aimed "goals" or thresholds is a widespread misconception of evolutionary mechanisms and processes that stems from the eugenic ideologies of the late 19th and early 20th centuries, surrounding ideas of progress and the enhancement of humans as a species (Groce & Marks 2000, Gould & Gold 1996, Joyce 2005, Marks 1993). Although the processes of evolution often result in directional selection, where allele frequencies shift in favor of one phenotype over another, these processes are not acting towards an *a priori,* predetermined adaptive condition (Oyama 2000, Oyama et al. 2003, West-Eberhard 1989, 2003; see also Ghalambor et al. 2015, Stearns 1989). Adaptive traits are highly contextual by nature—and theoretically any trait that maintains fitness levels can be adaptive. By contextualizing adaptive conditions and considering the ways in which culture shapes the biocultural niches human bodies must adapt to, we can imagine a future where disability is not maladaptive (Davis 2013, c.f., Sinha 2015). This approach does not seek to diminish the importance of minimizing human suffering, nor do I advocate for the neoliberal "smoothing" of disability into a unified experience (Ahmed 2006, Povinelli 2016, Puar 2017, see also Introduction).

Underlying biases against disabled people shape the orientation of the observer and are a legacy of eugenic ideologies (Davis 2013). These biases have helped predetermine expectations of normative bipedalisms and can account for disregard for the ways in which disease shapes mobility, limb use, and biomechanics in past populations (except see Drew 2015, Nystrom & Buikstra 2005). The scientific process requires the elaboration of hypotheses before the collection or analysis of data, often based on results or gaps from previous research, or alternatively based on intuition and observation. It is apparent that biases on the part of the scientist shape not only the interpretations of results but contribute to bias from inception of research design and the development of a research rationale.

The eugenic science of the 19th and 20th centuries has largely been condemned as a bygone aberration by biological anthropologists (Gould & Gold 1996, Marks 1993); and although there has been ample work by historians of science on the eugenics movement in the United States, Germany, and Great Britain (e.g., Shakespeare 1998, Bashford & Levine 2010, Groce & Marks 2000, Marks 1993, Pernick 1996, Trent 1994), the role of eugenic science and its ideologies remains underwhelmingly unaccounted for amongst *practitioners* of human biology or biological anthropology in research itself. It is not uncommon to come across citations in contemporary journal articles that cite eugenic "experimental studies" from the early 20th century (for example, see Schrader 1938). The ongoing citation of eugenic science "experiments" is emblematic of two larger issues in biological anthropology: (1) a continued lack of reflexivity towards the eugenic legacies in the implementation of scientific studies themselves (Ordover 2003, Wolf-Meyer 2019), and (2) a historical lack of movement in the discipline to dismantle settler-colonial, racializing, and ableist prejudices (c.f., Antón et al. 2018, Fuentes et al. 2019, Turner et al. 2018). In order to disrupt the normative (eugenic) approaches applied to these datasets I employ queer-crip theoretical and disability anthropology orientations to movement and mobility.

Drawing on the theoretical orientations outlined in Chapter 1, I investigate mobility and limb use in an assemblage of human femora and skeletal remains from these two Medieval sites: Pava and Villamagna. In this chapter, I take up the issue of variation—both the statistical sense, as well as variation in bodily experience. Many studies of cross-sectional geometry focus on long-term trends in bone robusticity and limb use (Holt et al. 2018, Holt 2003, Ruff et al. 1993, Ruff et al. 2018, Stock & Shaw 2007) or in average differences between populations or sub-samples of individuals (e.g., sex-gender divisions of labor; Macintosh et al. 2017, Maggiano et al. 2008, Miller et al. 2018). These studies make broad conclusions about population-level trends without attention to the ways in which certain individuals might have shared configurations within the larger group. Although cross-sectional geometry properties are generally normally distributed (Ruff et al. 2018), they often intersect with each other to form a specific configuration of traits. This is due to the dependent nature of cross-sectional geometry data; measures of diaphyseal (bone) shape are not independent from measures of diaphyseal (bone) loading. Measures of cross-sectional geometric properties reflect a small set of observations on the apparatus of biomechanical limb use (Cowgill et al. 2010), hence why more studies of cross-sectional geometry are moving towards the incorporation of experimental data from living humans (e.g., Cowgill et al. 2010, Nikander et al. 2010, Niinimäki et al. 2019). Rather than reducing data to clean means and averages based on known biocultural variables, such as age and sex-gender, I examine the range of variation within these known categories and look at the ways in which human experience defies neat categorizations.

Introduction

Overview

A mosaic of processes influence bone morphology from ontogenesis through senescence; these biocultural phenomena include genetic, epigenetic, and environmental constraints and affordances. Wolff's Law updated and reconceptualized as *bone functional adaptation* (Ruff et al. 2006, Pearson & Lieberman 2004), establishes that mechanical loading and strains influence bone morphology. Theoretical advancements in Wolff's Law and bone functional adaptation (Cowin 2001, Pearson & Lieberman 2004, Ruff et al. 2006); and mechanisms for bone modeling and remodeling (Frost 1987, 1990, 1994, 2001; Hall 2005; Parfitt 2003) have transformed the ways in which biological anthropologists are oriented to the human skeleton. Although Wolff's Law has been critiqued and dismantled in terms of its mathematical veracity (Cowan 2001, Currey 2002, Pearson & Lieberman 2004, Ruff et al. 2006), many of the conceptual tenants of Wolff's Law remain intact. Contemporary interpretations of Wolff's Law preserve the concept that bone adapts to its mechanical environment through a series of mechanisms, and that changes in bone morphology reflect mechanical loading and unloading history (Ruff et al. 2006). Empirical evidence from experimental animal studies has validated this theory (Lanyon et al. 1982, Lanyon & Rubin 1984, Lieberman et al. 2004), in particular Robling et al. (2002) demonstrated that increased mechanical loading differentially affected second moments of area (SMA). Early experimental studies of healthy bone response to mechanical stimuli were critiqued for their inattention to the effects of inflammation and woven-bone modeling due to acute trauma (surgery) involved in initiating the experiment (Frost 1988), however subsequent studies have attempted to address this critique by controlling for surgery's effects or through less invasive experimental methods (Turner et al. 1994, Robling et al. 2002) and have found commensurate results.

The theory of bone functional adaptation is now widely accepted by human biologists and biological anthropologists, and is based on observational and experimental studies from clinical and archaeological populations for *H. sapiens* (e.g., Cowgill 2010, Lieberman et al. 2001, Stock & Macintosh 2016, Ruff et al. 1993), as well as non-human primates (e.g., Demes et al. 1991, 2001, Ruff et al. 2018, Sarringhaus et al. 2016). The analysis of long bone cross sectional geometry is an accessible and useful tool for investigating skeletal robusticity (Cowgill 2010, Ruff et al. 1993, Stock & Pfeiffer 2001, 2004, Stock & Shaw 2007, Wescott 2006), habitual limb use (Macintosh et al. 2017, Maggiano et al. 2008, Miller et al. 2018, Sparacello & Marchi 2008), populational mobility (Bridges 1989, Holt 2003, Ruff & Larsen 2014, Shaw & Stock 2009), and loadings generated in mature and immature bipedalisms (Cowgill et al. 2010, Ruff 2003, Van Gerven et al. 1985). These foundational studies in bone functional adaptation have been key to understanding normative human biomechanical loadings and bone's plastic responses to them, as well as temporal and geographic trends in mechanical loading and activity in more recent human history (Holt et al. 2018, Macintosh et al. 2017, Stock et al. 2011). And yet, as Cowgill et al. (2010) notes, these models position ontogenetic responses to loading as goal-oriented towards a singular mode of mature bipedalism that is itself characteristic of *H. sapiens* and perhaps the *Homo* lineage*.* Although selective pressures have certainly shaped bipedalism in *H. sapiens*, there is far from one mode of mature bipedalism. Although this is scarcely evident from limited clinical studies (Berger et al. 1984, Forssberg et al. 1984, Waters & Mulroy 1999), there is an abundance of ethnographic and disability life-writing that provides evidence for difference and variation in walking and bodily movement (e.g., Couser 1997, 2004, 2009, Dauncey 2012, Mintz 2007, Robson 2004).

The ontogeny (growth and development) and maintenance of the skeletal system is influenced by a number of intrinsic and extrinsic stimuli, including genetic and epigenetic regulation and their downstream effects, (mal)nutrition, hormonal signals, and physiological and biomechanical stressors (Nelson et al. 2002). It is widely accepted that bone form reflects mechanical loading history (discussion in Ruff et al. 2006), therefore we must deduce mechanical histories from bone morphology. Long bone morphology can be quantified in terms of its geometric properties. These properties, which quantify both the shape and structure of the diaphysis of long bones has been used for nearly 40 years to examine trends in physical activity, habitual limb use, repeated strains, mechanical loading and overloading, and changes in skeletal health (Bridges 1989, Ruff & Hayes 1983a, 1983b, Ruff et al. 1993, Stock & Pfeiffer 2001, 2004, Stock et al. 2011).

Few studies have investigated the role of bone metabolism in relation to bone biomechanics (e.g., Eleazer & Jankauskas 2016), nonetheless the primary mechanism attributed to increases in bone quantity have been load-induced bone formation (Roblin et al. 2002). The systemic robusticity hypothesis has been tested with regard to the effects of climate, growth hormone, and thyroid hormone (Kraemer et al. 1990, Shackelford et al. 2004). And recent research suggests that climate and physical activity may have more limited effects than previously thought on systemic bone remodeling with unknown confounding factors contributing more to variation in cortical bone robusticity (Baab et al. 2018). Recent research suggests systemic bone remodeling may be modulated by epigenetic or biocultural factors, such as diet (Holt et al. 2018). It is well established that bone quality (i.e., turnover, microarchitecture, mineralization) is affected by physical activity (Agarwal & Grynpas 1996, Agarwal et al. 2004, Bailey et al. 1999), and further research shows that metabolic shifts associated with aging and degenerative joint disease may contribute to bone loss and vice versa (e.g., Fujita 1998). Bone quantity is clearly influenced by more than biomechanical factors, as research shows that metacarpal bone quantity, which is theoretically free from the effects of biomechanical use is modulated by lifestyle, diet, sex- and age-related biocultural phenomena (Agarwal 2017, Beauchesne & Agarwal 2014, Beauchesne & Agarwal 2017, Glencross & Agarwal 2011).

Kinematics

The kinematics of bipedalism for nonhuman primates (Demes 2011, Demes et al. 1991, 2001, Demes & O'Neill 2013, Rose 1976, Shapiro & Jungers 1988, Stanford 2005, Watson et al. 2009) and bipedalism's evolution in hominids (Latimer & Lovejoy 1989, Lovejoy 2005, Rodman & McHenry 1980, Steudel 1996) has received a lot of attention in biological anthropology research; however considerably less anthropological research has been directed at intraspecific variation in mature human bipedalism outside of a strictly evolutionary perspective (Bridges 1994, Castillo et al. 2017, Cowgill et al. 2010, Ruff 1994, Gruss 2007). Mature bipedalism (walking and/or running) is characterized by narrow stance width, anti-phase coordination of pelvic and shoulder girdles, arm-swing, and walking velocity (Cowgill et al. 2010, Dedieu & Zanone 2012, Sutherland 1997). Immature bipedalism is characterized in terms of wider stance, smaller step length, slower cadence, and decreased walking velocity compared to mature bipedalism (Cowgill et al. 2010).

Mature gait is characterized by regular and repeating cycles of coordinated step length, step rate, joint activation, pelvic and spine rotation, and balance (Cowgill et al. 2010, West & Scafetta 2003). In-phase girdle coordination is maintained at low-speed walking velocities, and transition to anti-phase coordination is implemented at higher-speed walking velocities (Dedieu & Zanone 2012); this pattern is seen in so-called *pathologic gaits*[1] as well, although the transition to anti-phase coordination occurs infrequently and with much difficulty compared to control subjects in experimental studies (Lamoth et al. 2006). Limited studies of pathologic gait biomechanics suggest that the transition to anti-phase coordination may be delayed, although these studies have focused exclusively on the effects of neurological diseases on gait (e.g., Berger et al. 1984, Forssberg et al. 1984). Unsurprisingly, studies of pathological gait energetics have shown that accommodating physical limb impairment with an upper extremity assistive device (e.g., cane, crutches) increases energy expenditure and loading in the humerus, where non-assistive accommodations decrease cadence but do not affect overall energetic costs (Waters & Mulroy 1999). Subjects with increased overall strength and increased muscle function were able to improve walking efficiency and lower energetic cost (Waters & Mulroy 1999), suggesting that variability between pathologic and normal gait has many downstream consequences for mechanical loading, limb use, and overall physical activity in the upper and lower limbs.

Biomechanics

Adjacent to anthropological studies of bipedalism and its kinematics, are biomechanical studies more broadly focused on trends in primate locomotion (e.g., Ruff et al. 2018, Demes et al. 2001), mobility in early hominids and modern humans (Cowgill 2010, Trinkaus 1976, Ruff et al. 1993, Shaw & Stock 2013); mobility and limb use associated with subsistence transitions (Ruff & Hayes 1983a, 1983b, Ruff et al. 1984, Wescott & Cunningham 2006); as well as intra-populational studies of physical activity (Maggiano et al. 2008, Pomeroy 2013); and individual-level studies of individuals with severe and unique pathology (Hawkey & Merbs 1995).

By applying "beam theory" to the analysis of long bone cross-sectional geometry it is possible to quantify cortical bone area and bone shape, which can be used as measures for inter- and intra-site-specific differences in activity, use, mobility, and robusticity (Ruff 2005). Cortical bone area (bone quantity) reflects axial rigidity and strength (Ruff 2008, Ruff & Hayes 1983), and these measures of bone quantity and (re)modeling help elucidate trends in bone maintenance in past populations. Second moments of area (SMAs) reflect bending rigidity in multiple directions in relation to the neutral axis (Lieberman et al. 2004, Ruff & Hayes 1983a, Ruff 2008): I_x measures bending rigidity in the anteroposterior plane, and I_y in the mediolateral plane (Ruff 2008); I_{max} measures maximum bending rigidity, and I_{min} measures the minimum bending rigidity and are calculated perpendicular to each other (Ruff & Hayes 1983a, Ruff 2008). Polar second moment of area, J is a measure of torsional rigidity and an average of bending rigidity and is calculated as the average of I_{max} and I_{min} (Lieberman et al. 2004, Ruff 2008). Many studies have used these measures in conjunction with skeletal data from the humerus to examine trends within populations, especially regarding gendered divisions of labor (Maggiano et al. 2008, Miller et al. 2018). Most studies consider cross-sectional properties at 50% of the biomechanical length of the femur; although studies have demonstrated the efficacy

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[1] For the sake of consistency, I will use the term "pathologic gait" when I reference clinical literature. All other instances of discussion regarding gait or movement regarded as outside the normative range will be referred to as "alternative gaits" or "unusual gaits"

of considering femur diaphyseal shape and structure in the proximal and distal portions of the femur in order to assess robusticity and fragility, or variation in hip displacement and femoral neck retroversion or anteversion (Ruff & Hayes 1983a, 1983b, Robin et al. 2008).

Background

Biomechanics and Activity in Medieval Europe

Recently there have been an increasing number of studies that have examined Medieval European long bone morphology and robusticity with regard to biomechanical use (Holt et al. 2018, Pomeroy & Zakrzewski 2009, Ruff et al. 2018, Saers et al. 2017). In a recent study of temporal and geographic trends in mobility and limb use, Holt et al. (2018) found that the Medieval populations they examined had unexpected an increased degree of robusticity in upper and lower limb measures compared to the Mesolithic and Neolithic periods. They identify a declining trend in femoral robusticity from the Paleolithic through the early medieval period, and yet there are small and unexpected gains in relative bone strength in both lower and upper limbs during the Late Medieval period. This increase in robusticity is attributed to the demands of physical labor that shift during the latter part of the medieval period, in particular that mechanized tools were not widely available to *all* laborers during these periods (Holt et al. 2018). Similarly, Berner et al. 2018 suggests that with the introduction of more intensive manorial agriculture, intensive woodworking, plowing, and water drainage (Hoffmann 2014), medieval peasants might have had heavier workloads and increased labor expectations in the Medieval Period. Further, when art historical and literary evidence is taken into account (Kowaleski 2014), it is clear that some forms of mechanized labor (ploughs or carts) may have actually increased bending rigidity due to the new ways in which bodies were manipulated and used in relation to these machines (see Figures 1.1-1.13 in Chapter 1 and discussion of rural economy).

It is unclear how mechanized labor may have differentially impacted the sexes, particularly rural women; manuscript illuminations in the Luttrell Psalter depict medieval women threshing wheat and working soil *alongside* men in agricultural fields (Figures 1.1-1.13), however only men are shown ploughing fields, stacking wheat, and hauling it on carts (Figure 1.1-1.13). Berner et al. (2018) notes that there is historical and archival evidence that there were gendered divisions of labor in Medieval households, and that the types of tasks women partook of daily were more likely to be in closer proximity to the home, while men were more likely to be traveling to work in fields, plowing, or traveling to nearby towns. This is a simplification of the complex configurations of labor performed in rural agricultural households, where there was more fluidity in occupation, daily tasks, and seasonal work (Bennett 1996, 2006, Bennett & Karras 2013, Whittle 2013; see also Chapter 1). Likewise, there has been considerable research that suggests that divisions of labor are not simply divided along lines of sex-gender (Grauer 1993, Grauer & Miller 2017, Judd & Roberts 1999, Yaussy & DeWitte 2016); although historical research shows that daily life experiences were certainly gendered (Bennett & Karras 2013, Kowaleski 2014). Therefore, it is expected that males and females will have variable levels of bone strength and bending rigidity, which might reflect differences in labor practices, levels of repetitive activities, and overall limb use.

In comparisons of rural and urban medieval people, Holt et al. (2018) found that rural males and females showed significant increases in percentage of cortical area, perhaps due to calcium- and protein- rich diets, better nutrition, and decreased pathogen load, in rural compared to urban areas. The influence of mechanical loading (increased in rural areas) and its effects on bone strength might contribute to bone maintenance and bone area (Mays 2006a, Mays et al. 1998), as bone area has a mathematical relationship with bone strength (Ruff et al. 2006).

Increases in bone strength during the medieval period relative to the Bronze and Iron/Roman periods suggests that despite declines in mobility across the landscape, overall workload and mechanical loadings related to physical activity did not decline during this period (Holt et al. 2018, Ruff et al. 2018). Holt et al. (2018) note significant differences in AP bending strength due primarily to the influence of terrain on mobility signatures in bone, although they admit that all cross-sectional geometry measures have multifactorial influences. Diaphyseal bone shape (I_x/I_y, I_{max}/I_{min}) is a better indicator of mobility than overall bone robusticity (J_{std} or $Z_{p\text{-}std}$), however body shape also has a significant influence on mobility and movement (Holt et al. 2018, Ruff et al. 2006, Shaw & Stock 2011).

Hypotheses

(1) Previous research suggests that terrain and local geography have an important influence on long bone geometry (Holt et al. 2018), results from a recent comprehensive study (Ruff et al. 2018) demonstrate that AP loading (increases in I_x/I_y ratios) occur in populations living in more mountainous or hilly regions. Therefore, I expect that there will be regional differences in diaphyseal shape (I_x/I_y) between the two study samples Pava and Villamagna due to the differences in topography and general geography of southern Tuscany and southern Lazio.

(2) Sex and gender differences in occupation, physical activity, and daily life are well documented in Medieval Europe (e.g., Bennett & Karras 2013, Kowaleski 2014, Sofaer Derevenski 2000), therefore I expect there will be differences in bone strength and diaphyseal shape based on skeletal sex at both sites.

(3) Previous research at Villamagna (Fentress et al. 2016) demonstrates that there are variable levels of economic on access to economic privileges (grave inclusions), therefore I expect that there will be a difference in cross-sectional properties related to physical activity, limb use, and bone quantity based on economic access at Villamagna.

Materials

Study Sites

The study sites for this project are two rural medieval sites, radiocarbon dated to 1100-1450 AD (Fentress & Maiuro 2011, Fentress et al. 2016, Giuffra et al. 2019, Riccomi 2020, Mongelli et al. 2011, Stewart 2017). Extensive documentary records and historical evidence for activity and behavior make the medieval period ideal for examining intra-populational variation in bone morphology due to activity and lifestyle (Carrocci 2016, Fentress et al. 2016, Flascassovitti 1994). Elaborate social complexity and marked inequality produce distinct social hierarchies in the medieval period (e.g., DeWitte 2015, Reitsema & Vercellotti 2012, Walter & DeWitte 2017), where I would expect to find differences in daily life at the individual-level, as well as shared experiences of peasant farming at the population-level. Stewart & Vercellotti (2017) found that differences in socio-economic status, inferred from geospatial arrangements of skeletons at Trino Vercellese (Italy), were correlated with osteometric measurements of bone length. Other medieval sites outside of Italy have shown that there are marked sex and status differences in teeth (Watts 2015, Trombley et al. 2019), stature (Vercellotti et al. 2011), and diet (Alexander et al. 2015, Nitsch 2016, Nitsch et al. 2011, Reitsema & Vercellotti 2012).

The medieval study sample (n=151) for this study was composed of 115 individuals from Villamagna in Lazio (Central Italy) and 120 individuals from Pieve di Pava in Toscana (North-Central Italy). Adult individuals with complete and intact femora were selected for analysis: 64 individuals had both left and right femora intact and were scanned for analysis; all other individuals had either the left or right femur scanned (Table 4.1).

Biological Profile

In order to examine population trends, I control for age at three levels: young-age adult (18-29 years), middle-age adult (30-49 years), and older-age adult (50+ years); and skeletal sex: female, male (see Chapter 2 for further elaboration on age and sex). Adult age was estimated in adults using multiple standard morphological indicators from the pubic symphysis (Brooks & Suchey 1990) and auricular surface (Lovejoy et al. 1985); these were corroborated by examination of the sternal end of the rib when possible (İşcan et al. 1984; 1985). I group individuals into three conservative age cohorts: 18-29 years (young adult), 30-49 years (middle adult), and 50+ years (older adult) to remedy the issue of precise aging in skeletal assemblages without documentary records of age (Jackes 2000). Morphological sex was estimated based on observation of the *os coxae* and cranial morphology (Ascàdi & Nemeskèri 1970, Brothwell 1981, Buikstra & Ubelaker 1994). Where present, I examined sexually dimorphic skeletal indicators in the os coxae as the first line(s) of evidence, especially the ventral arc, sub-pubic angle, sub-pubic concavity, and sciatic notch (Ascadi & Nemeskèri 1970, Brothwell 1981, Buikstra & Ubelaker 1994). Second lines of evidence included cranial indicators (Buikstra & Ubelaker 1994) and body size, to refine and ensure accuracy of sex estimation. My assessments of morphological sex were compared with field osteology assessments of the os coxae and cranial morphology.

Methods

CT Scanning Procedure

Non-invasive sectioning of femora was completed using Computed tomography (CT) scanning in the Radiology Department at the Ospendale Cisanello in Pisa, and at Ars Medica medical facility in Roma. CT scans of the femur were completed according to standard procedures outlined in (Ruff 2008): a series of standard morphometric measurements were observed using sliding and spreading calipers and an osteometric; and bones were scanned at 20, 35, 50, 65, and 80 percent of the total femur biomechanical length, unless taphonomic changes to the bone prevented accurate measurement. Obtaining sections at 15% intervals along the diaphysis is sufficient for fully describing morphological variation, however studies of

Table 4.1 Sample distribution of femora

Table 4.1 – The number of femora observed per side and site, paired and unpaired number.

	Paired (n)	Right (n)	Left (n)	Unpaired (n)
Villamagna	17	63	69	115
Pava	47	84	82	119
total	64	147	151	234

Table 4.2 Sample distribution

Table 4.2 – The demographic distribution of individuals represented by the femora observed in this analysis.

	Villamagna	**Pava**	**Total**
Female	50	54	104
Young (18-29 years)	15	19	34
Middle (30-49 years)	19	25	44
Old (50+ years)	16	10	26
Male	64	65	129
Young (18-29 years)	16	5	21
Middle (30-49 years)	43	35	78
Old (50+ years)	5	25	30
Pooled sex	**114**	**119**	**233**

the femoral cross sectional geometry typically examine trends at the 50% section (Ruff & Hayes 1983a, Ruff 2002, 2008). In this study, we examine only the 50% sections of the femur. Using GE Discovery CT750 HD (Pisa) and GE Optima CT660 (Roma) machines, .625 mm slices were made with 10.0cm display field of view (DFOV) for single bones, and 20.0cm of DFOV for paired bones. The scan time was set to 1s at 120 kV/175 mAS. Dicom files of slices were then used for analysis in ImageJ using the MacroMoment macro plugin according to well-established digital analysis procedures (Ruff 2008, Ruff & Hayes 1983a, Stock et al. 2011).

Body size standardization

Body mass estimation is a crucial step in reconstructing behavioral differences through cross-sectional geometry analyses, as body size has a significant effect on mobility, movement, and limb use (Niskanen & Ruff 2018, Ruff et al. 1993, Ruff et al. 2017). There are two general approaches to body mass estimation: mechanical or theoretical and morphometric (Ruff et al. 2012). Mechanical estimations rely on a theoretical relationship between body mass and skeletal element size, and most often extrapolate body mass from femoral head breadth (Grine et al. 1995, Ruff et al. 1997, 2006, 2012, Stock & Pfeiffer 2001). Morphometric estimations are calculated from biiliac breadth (maximum pelvis breadth), avoiding allometric effects on femoral head size (Auerbach & Ruff 2004, Kurki et al. 2010, Ruff et al. 2012). One of the primary drawbacks for all morphometric methods of estimating body mass (or stature) is that they require the preservation of a complete pelvis (Arsuaga et al. 1999, Kurki et al al. 2010, Rosenberg et al. 2006, Ruff 1994, Ruff et al. 2006, 2012). The data in this study were standardized based on mechanical body mass equations for European skeletal remains from Ruff et al. 2012 (see also Ruff 2018). These standardizations are calculated using a combination of body mass and bone length: bone area measures (TA, CA, MA) are standardized by dividing the values by body mass times 10^2 (Table 4.3, Ruff, 2008); and SMAs are standardized by body mass times bone length squared then multipled by 10^3 (Table 4.3, see Stock & Shaw, 2007; Ruff & Larsen, 2014). Ratios or percent calculations do not need to be size standardized (Table 4.3, Ruff, 2008).

Asymmetry and Sex Difference

Asymmetry has been observed across multiple populations (Shaw et al., 2012), and the presence of asymmetries reveals much about the habitual activities and beahvioral variations in limb use (Churchill & Formicola 1997, Miller et al. 2018, Maggiano et al. 2008, Ruff et al., 2017, Sládek et al. 2006, Trinkaus et al. 1994). While we can provide robust, evidence-based speculations on the types of activities that would produce these asymmetrical differences, the lack of empirical data highlights the need for experimental and clinical studies on contemporary people. With new experimental studies, we can better understand the mechanical loadings and strains produced by various activities and build more accurate narratives and powerful predictive models. Hominins are relatively unique among primates for their increased magnitudes of directional asymmetry in lower and upper limbs (McGrew and Marchant 1997; Latimer and Lowrance 1965). The law of bone functional adaptation plays an important role in the (re)modeling and ontogeny of morphological asymmetry in the limbs (Auerbach & Ruff 2004, Ruff 2006); and studies of asymmetrical limb use in athletes and other people with mechanically unique limb use only further supports this hypothesis (e.g, Churchill & Formicola

Table 4.3 Cross-sectional geometry properties

Table 4.3 – Cross sectional geometry properties measured and analyzed in this study, with their respective standardization equations for body mass and length. BM = body mass, FBL = femoral biomechanical length

	Cross-Sectional Property	*Description*	*Size Standardization Equation*
TA	Total (Subperiosteal) Area	Measurement of the area within the subperiosteal surface (mm^2) including medullary and cortical bone areas; estimates the overall size of the diaphysis (Ruff 2008; Ruff et al. 2012, 2017)	$*TA = (TA/BM)*10^2$
CA	Cortical Area	Measurement of the compact bone area (mm^2); used as an estimate of a bone's diaphysis' compressive and tensile rigidity and strength (Ruff 2008; Ruff et al. 2012, 2017)	$*CA = (CA/BM)*10^2$
MA	Medullary Area	Measurement of the area within the medullary cavity (mm^2) (Ruff 2008; Ruff et al. 2017)	$MA = TA - CA$ $*MA = (MA/BM)*10^2$
%CA	Percent Cortical Area	Proportion of diaphysis that is cortical bone; estimates bone's compressive and tensile rigidity and strength (Ruff 2008)	$\%CA = (CA/TA) *10^2$
I_x	Second Moment of Area M-L plane	A-P bending rigidity (mm^4) (Maggiano et al. 2008; Ruff et al. 2012)	$*I_x = I_x/(BM*FBL^2)*10^3$
I_y	Second Moment of Area A-P plane	M-L bending rigidity (mm^4) (Maggiano et al. 2008; Ruff et al. 2012)	$*I_y = I_y/(BM*FBL^2)*10^3$
I_x/I_y	Ratio of AP to ML bending rigidity	Ratio of AP to ML bending rigidity; measure of circularity (1.0) in the diaphysis (Ruff 2008; Ruff et al. 2012); values greater than 1.0 indicate greater AP bending rigidity, and values less than 1.0 indicate greater ML bending rigidity (Ruff 2008)	I_x/I_y
I_{min}	Minimum Second Moment of Area	Minimum bending rigidity (mm^4)	$*I_{min} = I_{min}/(BM*FBL^2)*10^3$
I_{max}	Maximum Second Moment of Area	Minimum bending rigidity (mm^4)	$*I_{max} = I_{max}/(BM*FBL^2) *10^3$
I_{max}/I_{min}	Ratio of maximum to minimum bending rigidity	Expresses diaphyseal shape; closer the ratio is to 1 the rounder the diaphysis	I_{max}/I_{min}
J	Polar Second Moment of Area	Torsional and twice average bending rigidity (mm^4) (Maggiano et al. 2008; Ruff 1995, 2000)	$*J = (J/(BM*FBL^2))*10^3$
Z_p	Polar Section Moduli	Torsional and twice average bending strength of the diaphysis; an expression of the diaphysis' overall strength (mm^3)	$*Z_p = (Z_p/(BM*FBL))*10^4$

Z_x	Section Moduli about M-L plane	Torsional and average AP bending strength of the diaphysis (mm^3)	*Z_x = (Z_x/(BM*FBL))*10^4
Z_y	Section Moduli about A-P plane	Torsional and average ML bending strength of the diaphysis (mm^3)	*Z_y = (Z_y/(BM*FBL))*10^4
BM	Body mass	Mechanical body mass estimation, based on femoral head breath; quantifies body mass for body size standardization of bone properties (Ruff et al. 2017)	Body mass (kg) Male = 2.80*FHB-66.70 Female = 2.18*FHB-35.81

Table 4.4 Asymmetry and sexual dimorphism

Table 4.4 – Descriptions and equations for calculating and assessing asymmetry and sexual dimorphism or difference according to standard cross-sectional geometry analysis procedures. Calculations are done per individual, for individuals with paired bones only.

	Index	*Description*	*Calculation*
%MaxA	Percent Maximum Asymmetry	Expresses the overall amount of asymmetry (Ruff et al. 2017); value of zero "0" indicates bilateral symmetry. Sometimes referred to as %AA, or percent absolute asymmetry	%MaxA = [(max-min/max+min)/2)]*100
%DirA	Percent Directional Asymmetry	Percent asymmetry between the right and left sides; right-sided asymmetry is indicated by a positive value, left-sided asymmetry is indicated by a negative value; values near zeo "0" indicate no asymmetry (Ruff et al. 2017)	%DirA = ((R – L)/ R + L) *100
SexD	Sexual dimorphism	Differences in asymmetry between male and female observations	SexD = $\%A_{male}$ - $\%A_{female}$

1997, Biewener & Bertram 1993, Mays 1999, Stirland 1993, Trinkaus et al. 1994). Numerous studies have addressed the level of phenotypic plasticity in long bone length and cross-sectional geometry dimensions, finding that morphology is more plastic than bone length (e.g., Churchill & Formicola 1997, Ruff & Jones 1981). However, these studies unilaterally fail to account for the ways in which developmental impairments or other changes to the body might produce asymmetry, as they do not include a representative sample of the population as a whole (only of a normate sub-population).

Data Screening

All data screening and analyses for this study were completed using R.Studio-Cloud v.3.6. During data screening, response variables were screened for normality, distribution, homoscedasticity, and multicollinearity. All response variables followed a normal distribution, with 5 statistical outliers identified. Two statistical outliers were identified for bone area, each of these individuals were males from Pava, with 47% and 64% cortical area respectively. Three statistical outliers were identified for bone shape (I_x/I_y or I_{max}/I_{min}), each of these individuals was from Villamagna and were identified as middle age (30-49 years) cohort males. These outliers were removed from statistical analyses in this chapter, however the observational data made with their skeletal remains, mortuary treatment, and interpretations of their experience are presented in Chapter 5.

Statistical Methods

For the population-level analysis, I relied on a combination of simple descriptive statistics, parametric statistical tests (e.g., MANOVA, ANOVA, post-hoc *t*-test), nonparametric tests (Kruskal-Wallis test, Wilcoxon signed-ranks test, Mann-Whitney *U*-test) to test my hypotheses about the influence and interaction effects of regional differences, sex, age, and economic access. Non-parametric tests were used to evaluate non-normally distributed data, specifically percent Directional Asymmetry (%DirA) and sexual dimorphism (SexD), and other percent-type data (Auerbach & Ruff 2004). Parametric tests were used to evaluate all cross-sectional geometry properties since they met the necessary criteria (normal distribution, relatively homoscedastic).

To quantify sample dispersion in mean cross-sectional geometric properties due age-, sex-, and status- related variation in lived experience, I computed the coefficient of variation (CV) for each sample mean. The coefficient of variation, or relative standard deviation, is a simple and robust standardized measure of sample dispersion that quantifies the precision of a mean and is not contingent on comparability of units of measure (Reed et al. 2002). Recently, this statistical technique was employed by Holt et al. (2018) to quantify heterogeneity in limb robusticity between Neolithic, Bronze Age, and Iron Age archaeological samples.

Asymmetry

Results for Sex-Related Differences in Asymmetry

Mean directional asymmetries and “sexual dimorphism” values were calculated for all individuals with paired bones from Villamagna and Pava (n=64, Table 4.2), these results are presented in Table 4.5. In measures of femoral robusticity, only Villamagna means were

Table 4.5 Directional asymmetry at Pava

Table 4.5 – Means with standard deviations and calculated % directional asymmetry and sexual dimorphism (difference) for each cross-section geometry property at Pava. ***Bold*** *values were statistically significant* p*<.05; Mann-Whitney* U*-test for SexD, Wilcoxon signed-ranks* test *for %DirA.*

			Right		Left			SexD	
	Site	*n*	mean	SD	mean	SD	*%DirA*	R	L
TA_{std}	Female	20	844.86	53.63	851.70	58.56	0.0%		
	Male	27	831.10	86.52	846.08	119.41	-0.5%	-1.6%	-0.7%
CA_{std}	Female	20	610.65	64.12	611.03	72.52	-0.8%		
	Male	27	604.59	62.99	610.62	85.67	-1.3%	-1.0%	-0.1%
MA_{std}	Female	20	234.21	59.37	240.67	61.67	-2.3%		
	Male	27	226.50	95.32	235.46	80.40	-6.3%	-3.3%	-2.2%
%CA	Female	20	72.33	6.67	71.76	7.01	0.8%		
	Male	27	73.31	8.86	72.50	6.83	0.8%	1.4%	1.0%
I_x/I_y	Female	20	1.06	0.16	1.05	0.13	0.6%		
	Male	27	1.10	0.19	1.05	0.15	**4.1%**	3.7%	-0.1%
I_{max}/I_{min}	Female	20	1.18	0.10	1.16	0.08	2.1%		
	Male	27	1.30	0.16	1.26	0.16	3.4%	**9.7%**	**8.4%**
J_{std}	Female	20	395.54	49.63	386.51	43.09	2.1%		
	Male	27	416.84	60.99	423.41	88.13	-0.4%	5.4%	9.5%
$Z_{p\text{-}std}$	Female	20	1071.77	109.77	1072.43	95.26	-0.2%		
	Male	27	1059.52	121.83	1081.22	173.95	-1.4%	-1.1%	0.8%

Table 4.6 Directional asymmetry at Villamagna

Table 4.6 – Means with standard deviations and calculated % directional asymmetry and sexual dimorphism (difference) for each cross-section geometry property at Villamagna. ***Bold*** *values were statistically significant* p*<.05; Mann-Whitney* U*-test for SexD, Wilcoxon signed-ranks* test *for %DirA.*

		Right			Left			SexD	
	Site	*n*	mean	SD	mean	SD	*%DirA*	R	L
TA_{std}	Female	7	850.11	56.11	895.42	65.86	**-5.7%**		
	Male	10	790.94	103.77	855.11	124.93	**-9.6%**	-7.0%	-4.5%
CA_{std}	Female	7	589.85	89.75	623.64	89.18	**-5.1%**		
	Male	10	576.48	85.65	634.18	83.50	**-7.8%**	-2.3%	1.7%
MA_{std}	Female	7	260.26	114.76	271.78	118.27	-4.0%		
	Male	10	214.46	67.15	220.92	65.72	-3.9%	**-17.6%**	**-18.7%**
%CA	Female	7	69.76	11.72	70.04	11.25	-0.6%		
	Male	10	73.09	7.84	74.45	5.13	-2.2%	4.8%	6.3%
I_x/I_y	Female	7	1.00	0.12	1.03	0.07	-3.5%		
	Male	10	1.22	0.22	1.12	0.16	**7.9%**	**22.2%**	8.9%
I_{max}/I_{min}	Female	7	1.28	0.21	1.25	0.18	2.3%		
	Male	10	1.31	0.28	1.27	0.08	1.8%	2.5%	2.1%
J_{std}	Female	7	445.11	62.20	482.33	74.12	**-7.9%**		
	Male	10	407.39	86.36	468.96	108.59	**-13.4%**	-8.5%	-2.8%
$Z_{p\text{-}std}$	Female	7	1104.60	118.10	1183.07	139.47	**-6.8%**		
	Male	10	1010.06	168.58	1140.28	195.31	**-11.8%**	-8.6%	-3.6%

Table 4.7 Comparison of paired and unpaired femora

Table 4.7 – Comparison of means from paired and unpaired femora. Asterisks indicate that there are statistically significant differences between the means computed from paired bones only, and the means computed from all bones (one laterality per HRU). Statistically significant results suggest that side differences might effect the sample means, the mechanism for this could be preservation or sampling bias might effect the

Comparison means from Paired vs. Unpaired

	Villamagna		**Pava**	
	Female	Male	Female	Male
TA std	**			
CA std				
MAstd				
J std	**			
Zp-std	**			
Ix/Iy	*			
Imax/Imin			**	

Significance levels, * p<.05, ** p<.01, *** p<.001

Figure 4.1 Comparison of Total Area (TA_{std})

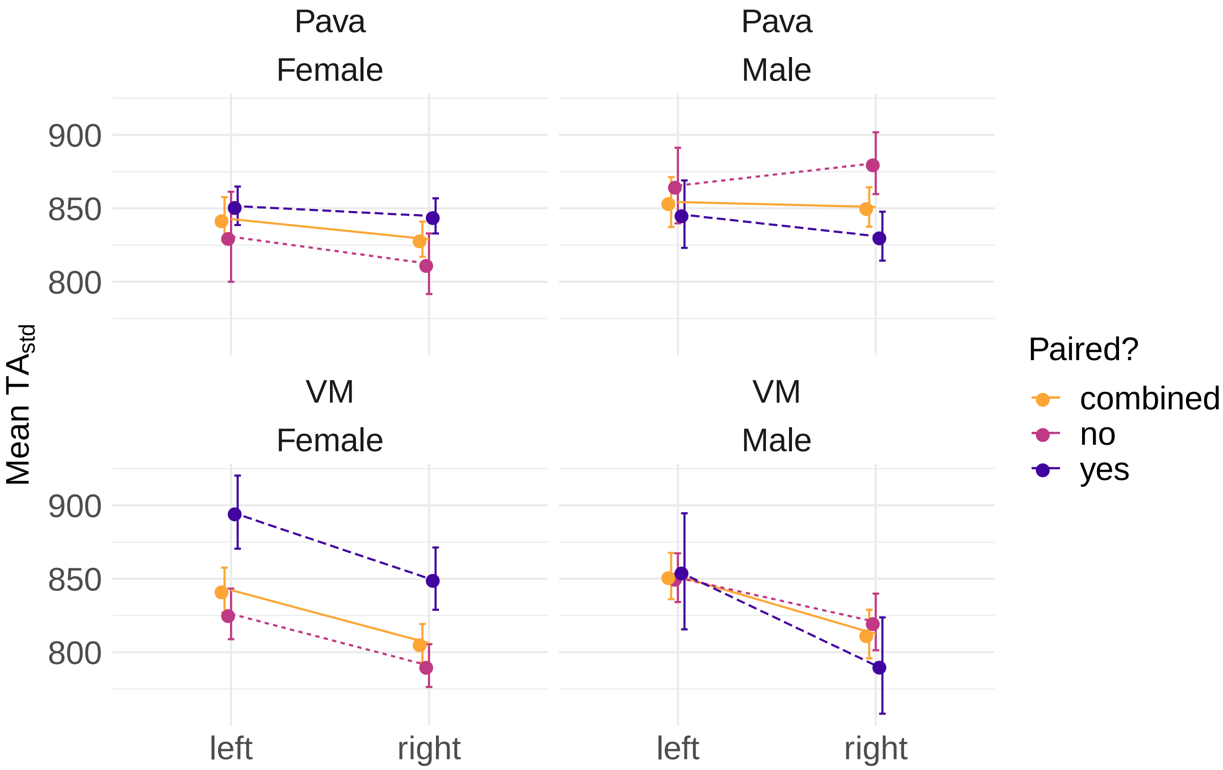

Figure 4.1 – In this figure, mean values for total area (TA) are shown for paired bones (purple), unpaired bones (pink), and all bones combined (orange). Left side femora are shown on the left side of each chart, right femora on the right side. Observations from Pava are shown on the top and observations from Villamagna (VM) on the bottom. Clustered means indicate that there is high concordance between combined, paired, and unpaired bones and means that are more dispersed indicate that there sample size might influence the results for that group.

Figure 4.2 Comparison of Medullary Area (MA_{std})

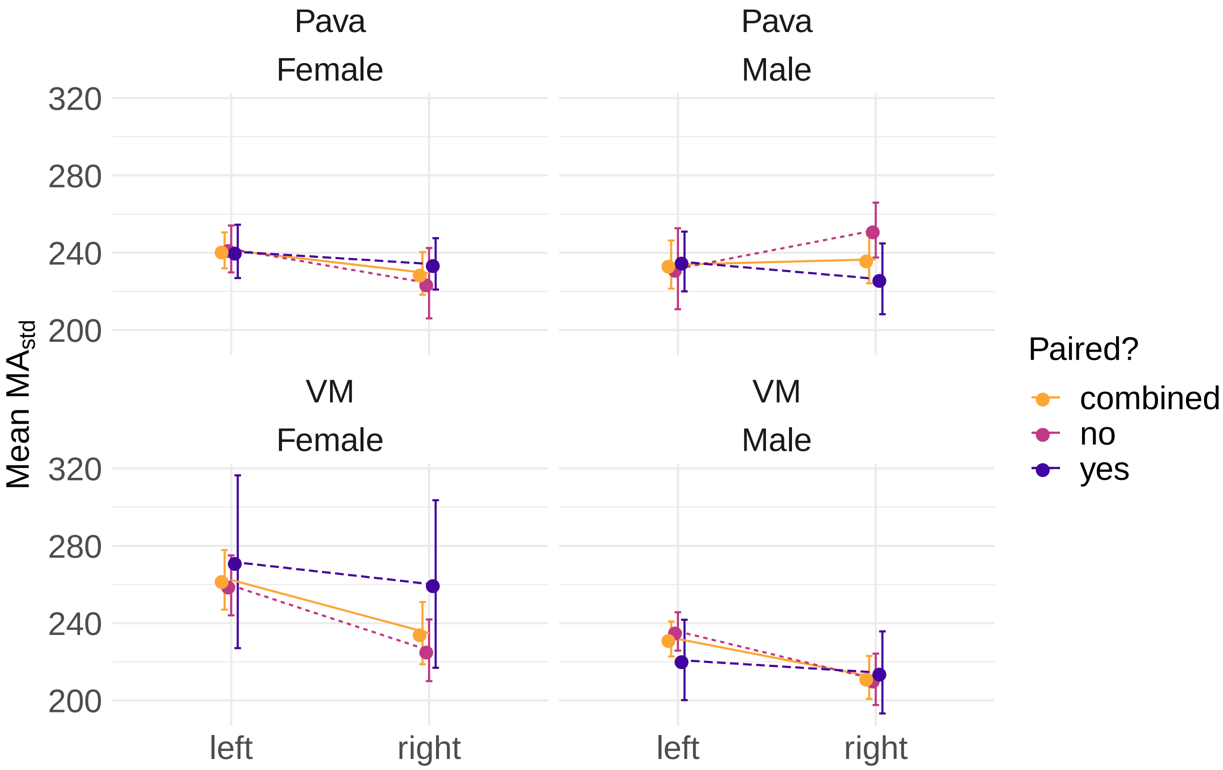

Figure 4.2 – In this figure, mean values for medullary area (MA) are shown for paired bones (purple), unpaired bones (pink), and all bones combined (orange). Left side femora are shown on the left side of each chart, right femora on the right side. Observations from Pava are shown on the top and observations from Villamagna (VM) on the bottom. Clustered means indicate that there is high concordance between combined, paired, and unpaired bones and means that are more dispersed indicate that there sample size might influence the results for that group.

Figure 4.3 Comparison of Cortical Area (CA_{std})

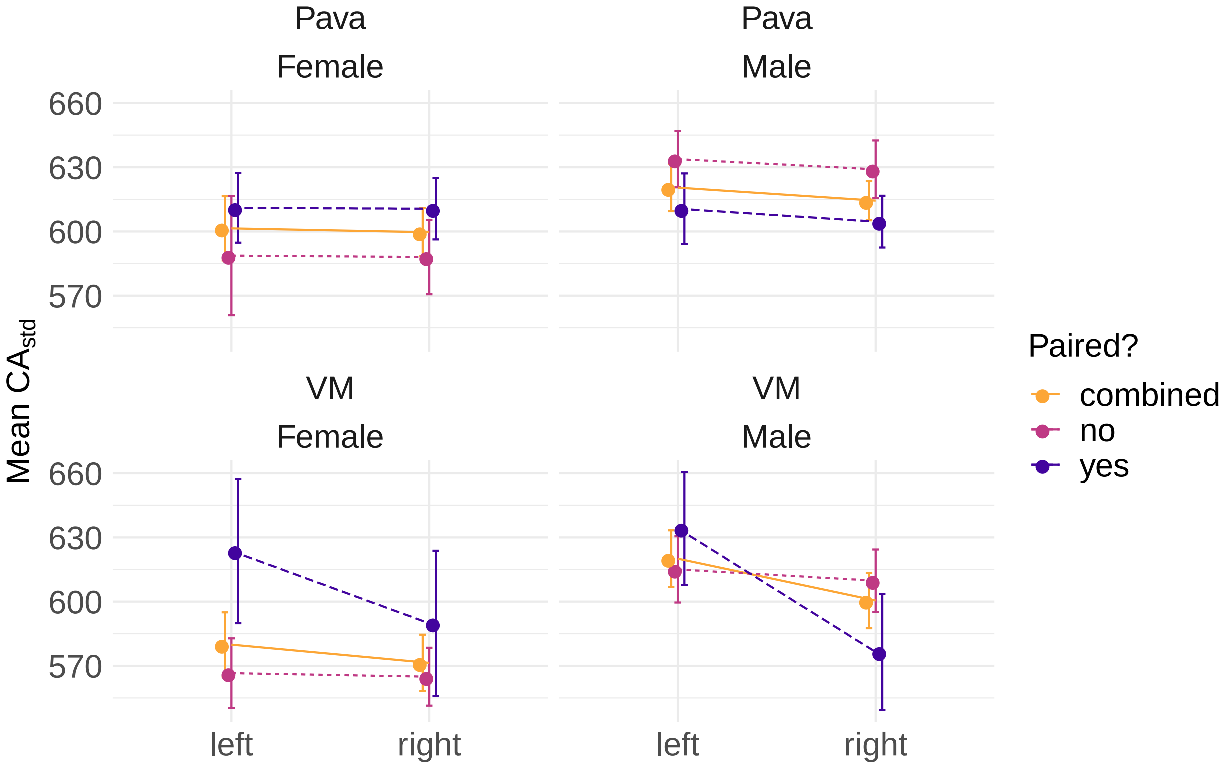

Figure 4.3 – In this figure, mean values for cortical area (CA) are shown for paired bones (purple), unpaired bones (pink), and all bones combined (orange). Left side femora are shown on the left side of each chart, right femora on the right side. Observations from Pava are shown on the top and observations from Villamagna (VM) on the bottom. Clustered means indicate that there is high concordance between combined, paired, and unpaired bones and means that are more dispersed indicate that there sample size might influence the results for that group.

Figure 4.4 Comparison of Percent Cortical Area (%CA)

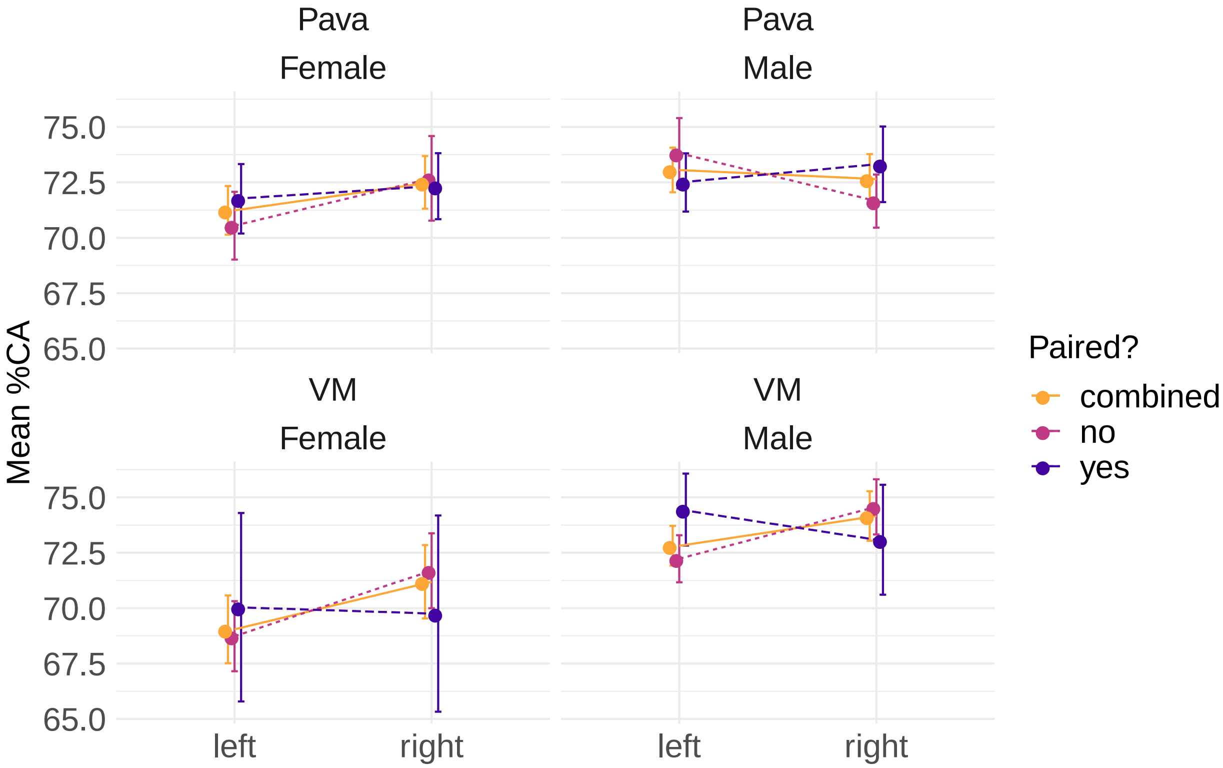

Figure 4.4 – In this figure, mean values for percent cortical area (%CA) are shown for paired bones (purple), unpaired bones (pink), and all bones combined (orange). Left side femora are shown on the left side of each chart, right femora on the right side. Observations from Pava are shown on the top and observations from Villamagna (VM) on the bottom. Clustered means indicate that there is high concordance between combined, paired, and unpaired bones and means that are more dispersed indicate that there sample size might influence the results for that group.

Figure 4.5 Comparison of Femoral Robusticity (J_{std})

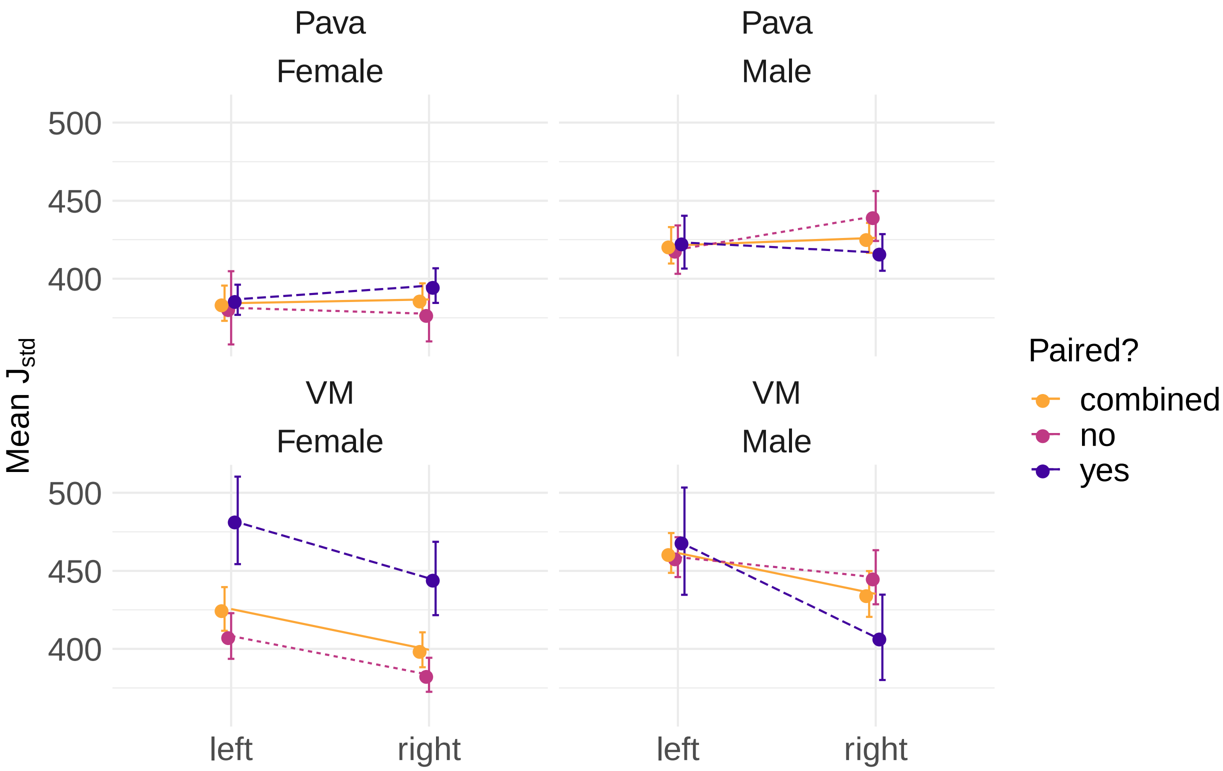

Figure 4.5 – In this figure, mean values for bending rigidity (J) are shown for paired bones (purple), unpaired bones (pink), and all bones combined (orange). Left side femora are shown on the left side of each chart, right femora on the right side. Observations from Pava are shown on the top and observations from Villamagna (VM) on the bottom. Clustered means indicate that there is high concordance between combined, paired, and unpaired bones and means that are more dispersed indicate that there sample size might influence the results for that group.

Figure 4.6 Comparison of Femoral Robusticity ($Z_{p\text{-std}}$)

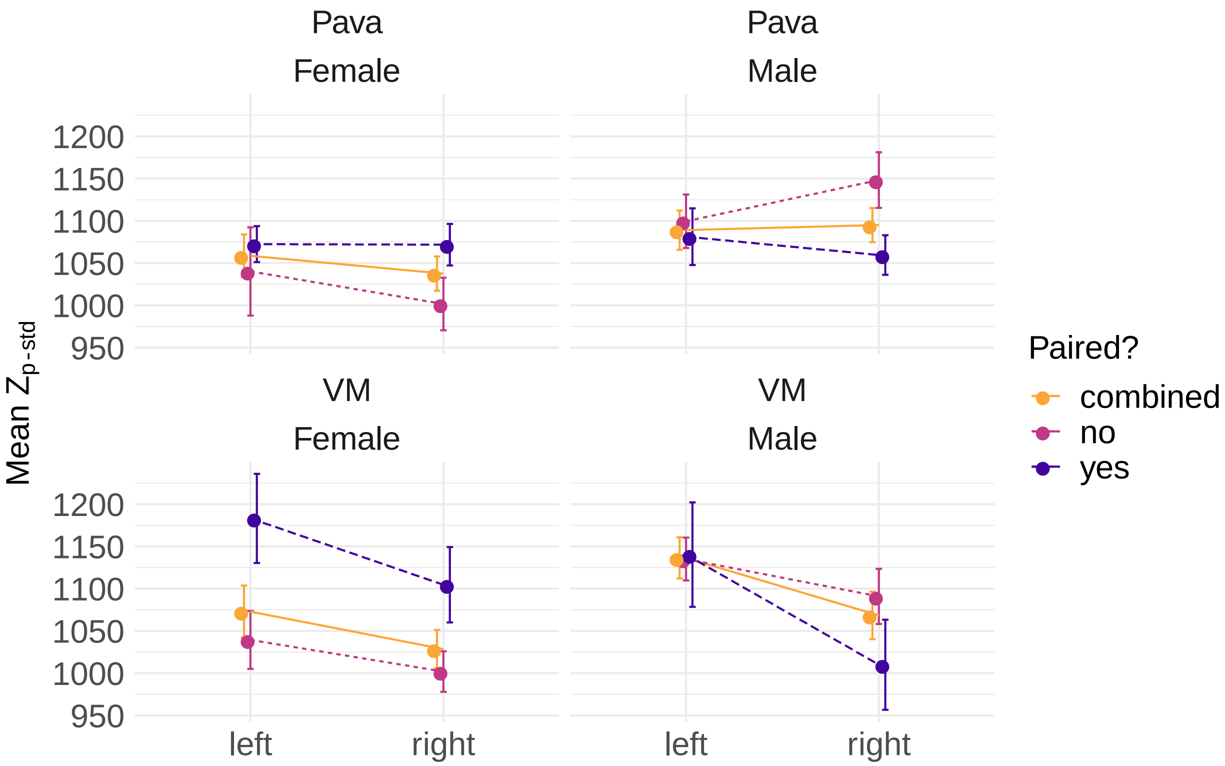

Figure 4.6 – In this figure, mean values for bending strength (Z_p) are shown for paired bones (purple), unpaired bones (pink), and all bones combined (orange). Left side femora are shown on the left side of each chart, right femora on the right side. Observations from Pava are shown on the top and observations from Villamagna (VM) on the bottom. Clustered means indicate that there is high concordance between combined, paired, and unpaired bones and means that are more dispersed indicate that there sample size might influence the results for that group.

Figure 4.7 Comparison of Diaphyseal Shape (I_x/I_y)

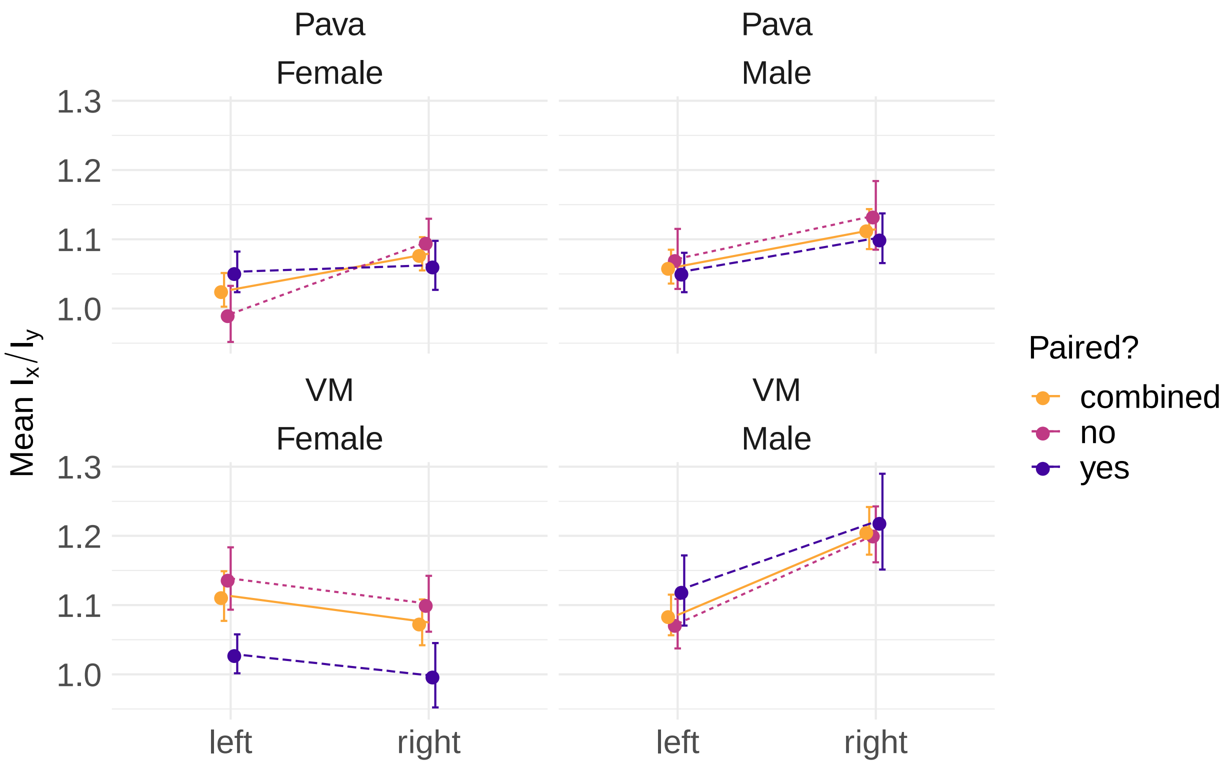

Figure 4.7 – In this figure, mean values for diaphyseal shape (I_x/I_y) are shown for paired bones (purple), unpaired bones (pink), and all bones combined (orange). Left side femora are shown on the left side of each chart, right femora on the right side. Observations from Pava are shown on the top and observations from Villamagna (VM) on the bottom. Clustered means indicate that there is high concordance between combined, paired, and unpaired bones and means that are more dispersed indicate that there sample size might influence the results for that group.

Figure 4.8 Comparison of Diaphyseal Shape (I_{max}/I_{min})

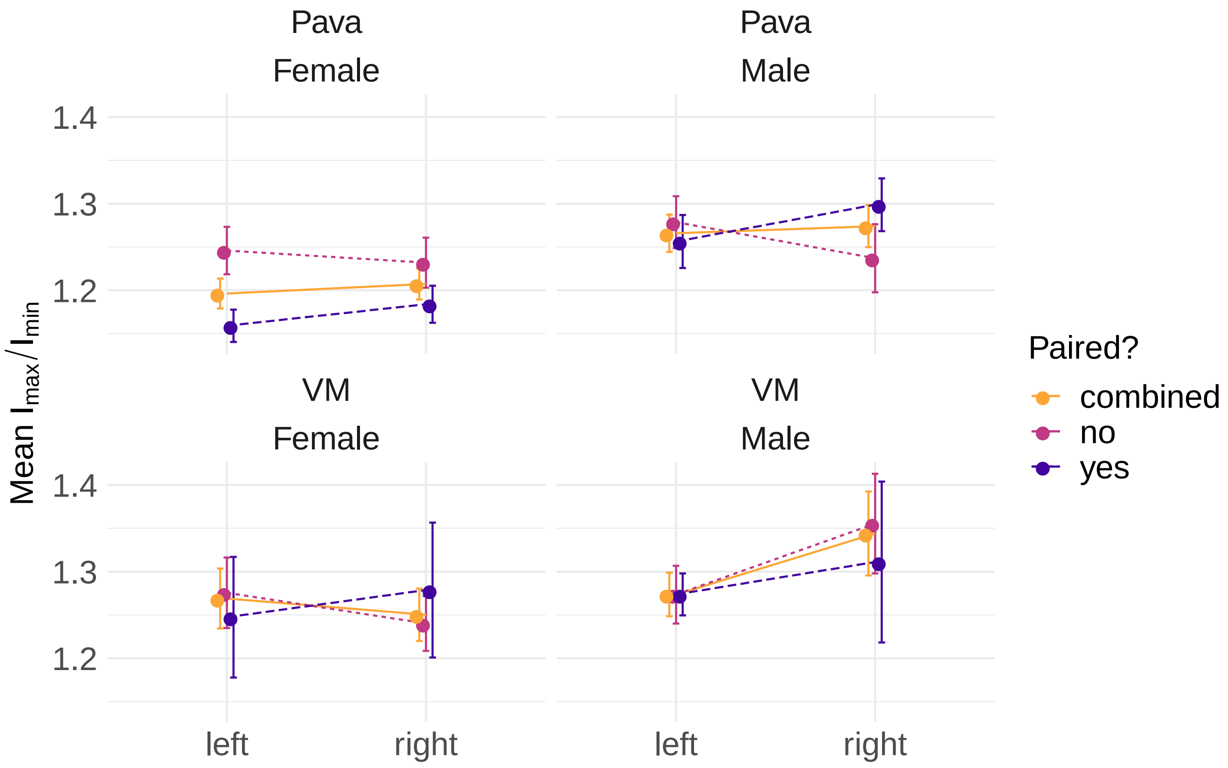

Figure 4.8 – In this figure, mean values for diaphyseal shape (I_{max}/I_{min}) are shown for paired bones (purple), unpaired bones (pink), and all bones combined (orange). Left side femora are shown on the left side of each chart, right femora on the right side. Observations from Pava are shown on the top and observations from Villamagna (VM) on the bottom. Clustered means indicate that there is high concordance between combined, paired, and unpaired bones and means that are more dispersed indicate that there sample size might influence the results for that group.

significantly different between the right and left sides (Wilcoxon signed-ranks test) in TA_{std}, CA_{std}, J_{std}, and $Z_{p\text{-}std}$ (Table 4.6). In measures of femoral diaphyseal shape, Villamagna males had significant differences between the right and left side for I_x/I_y, and Pava males had significant differences between the right and left side for I_x/I_y and I_{max}/I_{min} (Table 4.5). Overall, Villamagna females had increased measures of femoral robusticity in the left femur, while males had significant differences in diaphyseal shape in the right femur. Right-side femora at Villamagna exhibited significant sex differences for I_x/I_y values (Table 4.6); and both sides at Pava exhibited significant sex-based differences in I_{max}/I_{min} (Table 4.5).

Means from the paired bones were significantly only for Villamagna females where the unpaired means for TA_{std}, J_{std}, $Z_{p\text{-}std}$, and I_x/I_y were significantly different from the paired bone means (Table 4.7, Figures 4.1, 4.5, 4.6, 4.7), and for Pava females where the unpaired mean of I_{max}/I_{min} was significantly different for the paired means (Table 4.7, Figure 4.8). These data statistically support the trend observed from the paired bones alone, as the differences between paired and unpaired bones provide empirical evidence for a greater directional asymmetry, rather than a reduced effect. Therefore, in order to control for confounding effects of directional asymmetries, analyses were performed for each laterality (right, left) separately, or side was included as an explanatory variable in the statistical tests or models.

Discussion of Sex-related differences in Asymmetry

Overall, there was significant sex difference in measures of diaphyseal shape (Ix/Iy, Imax/Imin) at both Pava and Villamagna. These significant differences likely reflect a gendered difference mobility in the Medieval Period and are consistent with findings from other Medieval sites in Europe (Ruff et al. 2018, Holt et al. 2018, Berner et al. 2018). Historical documents from Villamagna indicate that male individuals likely traveled between Villamagna and neighboring towns (e.g., Sgurgola) for business, as well as to tend to their allotted land for agricultural reasons, while there is no clear evidence that females regularly traveled widely. Within the medieval period more broadly, there is evidence that medieval men traveled farther and more often than their female counterparts to participate in the rural medieval economy (Whittle 2013).

Females at Villamagna have expected age-related differences in MA_{std}, especially between older and younger individuals. This is an expected trend based on previous evidence that suggests that decreases in estrogens have a pleiotropic effect and are associated with increases in endosteal bone resorption (Almeida et al. 2017, Duan et al. 2001, Gosman et al. 2011, Khosla et al. 2012, Manolagas et al. 2013). Therefore, increases in medullary area are expected in older age. However, as I discuss below, the highest variation in MA_{std} occurs in older age (Table 4.11). This indicates that there is not a homogeneous or tightly controlled outcome for MA_{std}, but rather a range of outcomes that might be related to other risk factors accumulated during development and life.

Overall Population

Cross Sectional Geometry Trends

Table 4.8 Results from Two-Way Factorial ANOVA Tests

Table 4.8 – Results from a two-way factorial ANOVA. Main effects in parentheses were not assessed with post-hoc tests, as they were included in post-hoc tests for interaction effects.

ANOVA equation	*Main Effects*	*Interaction Effects*
TA_{std} ~ side * site * sex * age* grave goods	side, *p = .048 **	site:sex:age, *p = .023**
CA_{std} ~ side * site * sex * age* grave goods	(sex, *p = .005 ***)	site:age, *p = .048 *** sex:grave goods, *p = .049 **
MA_{std} ~ side * site * sex * age* grave goods	(age, *p < .001 ****) grave goods, *p = .025 **	site:sex:age, *p = .039 **
%CA ~ side * site * sex * age* grave goods	sex, *p = .013 *** (age, *p = .002 ***) grave goods, *p = .023 **	site:age, *p = .021 **
I_x/I_y ~ side * site * sex * age* grave goods		side:site:sex, *p = .043 **
I_{max}/I_{min} ~ side * site * sex * age* grave goods	site, *p = .018 *** sex, *p = .003 ***	
$Z_{p\text{-}std}$ ~ side * site * sex * age* grave goods	(sex, *p = .006 ***)	sex:age:grave goods, *p = .036 **
J_{std} ~ side * site * sex * age* grave goods	site, *p = .002 **** (sex, *p < .001 ****) (age, *p = .029 **)	sex:age:grave goods, *p = .023 **

α=.05, significance levels, * p<.05, ** p<.01, *** p<.001

Table 4.8 presents the significant main effects and interaction effects from two-way factorial ANOVA tests, which were performed for each of the response variables of interest. The results from these ANOVA tests suggests that the presence or absence of grave goods has an interaction effect with both sex and age in J_{std}, $Z_{p\text{-}std}$; an interaction effect with sex on CA_{std}, and has a main effect on MA_{std} and on %CA. Main and interaction effects in these factorial ANOVA tests were assessed using independent two-way *t*-tests as post-hoc tests of significance.

Bone Area Results

At Pava there was only one significant difference in bone area: young females from Pava had significantly larger mean medullary area (mean MA_{std} = 257.17, $p < .05$) compared to young males (MA_{std} mean = 180.84). Young females at Pava had the largest mean medullary area for any age-sex group in the left femur (Table 4.9, Figure 4.9). Percent cortical area at Pava had relatively high levels of sample dispersion in older age for males in the right femur (CV = 16.61, Table 4.11), but not in the left femur where the sample dispersion was 50% less than the right femur (CV = 8.30). Pava females had less sample dispersion overall for all bone area indicators, but the highest levels were seen in the young age group (right CV=11.65, left CV = 11.41; Table 4.11, 4.12).

At Villamagna, middle age males had significantly higher mean cortical area than females in the left femur (Table 4.10, Figure 4.10). Older females at Villamagna had significantly larger medullary area than older males at Villamagna in the left femur (Figure 4.11); however, trends amongst older age individuals could not be assessed for the right femur due to sample size (Table 4.10). In the right femur percent cortical area at Villamagna had relatively high levels of sample dispersion in older age females compared to other age groups (female CV = 15.02, Table 4.11).

Comparatively, there are more age and sex differences on bone area at Villamagna than there are at Pava, and all differences in bone area are significant only in the left femur. There are no sex or age differences in bone area properties for any age-sex group in the right femur. Sample dispersion is higher in the right femur compared to the left for %CA (Table 4.11, 4.12); and older females at Villamagna and older males at Pava have the highest levels of sample dispersion in percent cortical area in the right femur (VM female CV = 15.02, Pava male CV = 16.61, Table 4.11).

Mechanical Loading & Mobility Results

Ratios of diaphyseal shape give a measurement of circularity and mechanical loading. I_x/I_y ratios close to 1.0 indicate a circular shape, whereas values greater than 1.0 indicate deviation from circularity in the antero-posterior direction and values less than 1.0 indicate deviation from circularity in the medio-lateral direction. The I_{max}/I_{min} ratio gives a general sense of circularity and shape but does not measure these deviations from circularity in any particular directions. I_{max}/I_{min} is a less specific, but more robust indicator of shape because it is less sensitive to interobserver error and variation in bone placement during scanning (Figure 4.15, Stock & Shaw 2007).

There are no sex differences at Pava in mean I_x/I_y, where the mean is between 1.06 and 1.20 (Table 4.9). Older individuals (all sexes) at Pava have more AP (antero-posterior) loading than younger individuals in the right femur, but the effect is not significant (Table 4.9). In the left femur, there is an inverse relationship between age and mean I_x/I_y, where the mean value for I_x/I_y in older age females at Pava is 0.99 (Table 4.9). This illustrates a significance in mean asymmetry amongst older age females at Pava in mechanical loading ($p<.05$), which may be due in part to the small sample size for older age females at Pava.

At Pava there are relatively high levels of sample dispersion in measures of mechanical loading and mobility in the right femur (CV = 11.83-19.27) across the population, with the highest variation amongst males in older age (I_x/I_y CV=19.27), and the highest variation amongst Pava females in middle age (I_x/I_y CV=15.46, Table 4.11). Sample dispersion is relatively lower for I_{max}/I_{min}, suggesting that there is more variation in direction of mechanical loadings rather than magnitude of mechanical loadings (Table 4.11). At Pava there is a significant sex difference in older age for mean I_{max}/I_{min} in the right and left femurs (Table 4.9, Figure 4.15). Older age males at Pava have relatively higher sample dispersion compared to all other groups at Pava, suggesting they have variation in magnitude of mechanical loadings as well as direction of mechanical loadings.

There are no significant sex differences in mean I_x/I_y at Villamagna, where the mean is between 1.03 and 1.18 (Table 4.10). Older individuals have less AP loading than individuals in the middle and young age groups (not statistically significant). There are relatively high levels of sample dispersion in I_x/I_y at Villamagna: in the right femur the highest levels are amongst middle age females (CV=20.86) and middle age males (CV=18.51, Table 4.11); and in the left femur middle age females have the highest sample dispersion (CV=22.62) then young males (CV=21.17, Table 4.12). This demonstrates that there is a high level of variance between individuals in these groups with regard to mobility and mechanical loadings.

At Villamagna there are significant sex differences in the mean I_{max}/I_{min} in young age in the right femur only (Table 4.10); and there are no significant differences in mean I_{max}/I_{min} by age. Males have higher mean I_{max}/I_{min} (male mean = 1.32, Table 4.10) compared to females at Villamagna (female mean = 1.19, Table 4.10).

There is relatively higher sample dispersion for I_{max}/I_{min} at Villamagna than at Pava; greater variance in the Villamagna sample likely reflects a wider range directions and magnitudes of mechanical loadings. Overall each age group has moderately high variance, excepting older age males who have lower amounts of variance as well as a small sample size (left femur only, Table 4.12). Overall, there are relatively higher antero-posterior (AP) mechanical loadings at Villamagna compared to Pava (see also *Comparison with Italian Peninsula* below).

Bone Rigidity and Strength Results

It is expected that measures of bending strength $Z_{p\text{-}std}$ are generally correlated with bending rigidity J_{std}, although in these samples there are a few instances where their trends diverge. At Pava there are no significant sex differences in bending strength ($Z_{p\text{-}std}$), and no significant differences between age groups (Table 4.9). There is a significant sex difference in bending rigidity (J_{std}) at Pava, where middle age males have significantly higher mean J_{std} than middle age females in the right femur (Table 4.9, Figure 4.18). Middle age females at Pava also have significantly higher J_{std} than young females at Pava in the right femur (Table 4.9, Figure 4.18). Within Pava males there is a significant difference between young and middle age groups in the left femur (young mean = 343.54, middle mean = 433.20, $p<.05$, Table 4.9).

Table 4.9 Summary statistics for Pava

*Table 4.9 – **Bold** values indicate statistically significant sex differences (calculated for left and right sides) at α=.05, based on two-tailed independent t-test. There are significant sex differences in the young age groups in MA (left femur), significant sex differences in both femurs in the older age group for I_{max}/I_{min}, and significant sex differences in the right femur for J_{std}.*

	Left femur						**Right femur**					
	Male (n=40)			Female (n=34)			Male (n=45)			Female (n=37)		
	N	**mean**	**SD**	***N***	**mean**	**SD**	***N***	**mean**	**SD**	***N***	**mean**	**SD**
Total Area (TA_{std})												
Young (18-29 years)	2	761.21	83.14	11	857.74	103.10	2	845.46	184.56	15	791.60	78.62
Middle (30-49 years)	21	862.15	132.64	17	840.40	89.29	24	857.81	86.17	17	859.08	51.16
Older (50+ years)	17	868.82	89.28	6	828.67	72.93	12	827.87	101.28	5	848.78	99.13
Cortical Area (CA_{std})												
Young (18-29 years)	2	565.72	87.55	11	600.56	118.09	2	623.02	113.39	15	580.41	79.91
Middle (30-49 years)	21	629.99	81.46	17	595.00	79.02	24	629.60	55.22	17	616.68	53.72
Older (50+ years)	17	625.07	50.85	6	611.45	67.85	12	576.14	58.42	5	595.99	81.60
Medullary Area (MA_{std})												
Young (18-29 years)	2	**195.49**	4.40	11	**257.17**	55.12	2	222.44	71.17	15	211.19	75.58
Middle (30-49 years)	21	232.15	88.37	17	245.4	53.47	24	228.21	57.54	17	242.39	62.89
Older (50+ years)	17	243.75	70.85	6	217.22	44.86	12	251.73	129.48	5	252.80	74.02
%CA												
Young (18-29 years)	2	74.13	3.40	11	69.52	7.93	2	73.99	2.74	15	73.49	8.56
Middle (30-49 years)	21	73.51	6.58	17	70.78	5.45	24	73.63	4.91	17	71.92	6.60
Older (50+ years)	17	72.32	6.01	6	73.80	5.04	12	70.70	11.74	5	70.36	7.63
I_x/I_y												
Young (18-29 years)	2	1.00	0.20	11	1.08	0.14	2	1.10	0.19	15	1.06	0.15
Middle (30-49 years)	21	1.04	0.15	17	1.02	0.15	24	1.08	0.14	17	1.08	0.17
Older (50+ years)	17	1.05	0.21	6	0.99	0.09	12	1.20	0.27	5	1.14	0.12
I_{max}/I_{min}												
Young (18-29 years)	2	1.23	0.03	11	1.21	0.13	2	1.20	0.04	15	1.18	0.10
Middle (30-49 years)	21	1.24	0.12	17	1.20	0.08	24	1.23	0.12	17	1.23	0.12
Older (50+ years)	17	**1.30**	0.18	6	**1.16**	0.12	12	**1.39**	0.23	5	**1.21**	0.12
Z_{pstd}												
Young (18-29 years)	2	979.01	155.55	11	1060.83	189.63	2	1074.36	206.08	15	999.47	145.35

Middle (30-49 years)	21	1111.91	190.20	17	1049.51	137.92	24	1126.41	141.77	17	1067.86	91.93
Older (50+ years)	17	1107.59	104.88	6	1083.89	129.68	12	1021.77	92.12	5	1063.97	175.01
J_{std}												
Young (18-29 years)	2	343.54	46.72	11	379.86	87.32	2	386.16	85.14	15	362.81	64.44
Middle (30-49 years)	21	433.20	95.08	17	382.91	60.04	24	**434.78**	72.14	17	**400.30**	46.06
Older (50+ years)	17	425.70	52.81	6	402.32	52.57	12	414.24	50.87	5	421.06	107.20

Table 4.10 Summary statistics for Villamagna

*Table 4.10 – **Bold** values indicate statistically significant sex differences (calculated for left and right sides) at α=.05, based on two-tailed independent* t-test*. There are significant differences in cortical area for the middle age group (left femur), and in medullary area for the older age group (left femur). In the right femur there is a significant sex difference in the young age group.*

	Left femur						**Right femur**					
	Male (n=38)			Female (n=30)			Male (n=36)			Female (n=21)		
	N	**mean**	**SD**	***N***	**mean**	**SD**	***N***	**mean**	**SD**	***N***	**mean**	**SD**
Total Area (TA_{std})												
Young (18-29 years)	7	882.61	76.21	8	835.55	72.49	10	817.59	80.75	6	773.56	71.85
Middle (30-49 years)	22	848.66	75.94	9	803.45	84.06	19	831.88	100.56	8	817.07	63.65
Older (50+ years)	5	817.68	120.82	8	872.44	88.27	0			7	802.30	72.66
Cortical Area (CA_{std})												
Young (18-29 years)	7	674.31	37.06	8	629.24	86.65	10	630.32	57.52	6	577.51	56.19
Middle (30-49 years)	22	**612.16**	68.31	9	**556.32**	62.94	19	607.77	72.20	8	596.63	53.63
Older (50+ years)	5	574.60	126.43	8	546.59	87.26	0			7	555.25	85.69
Medullary Area (MA_{std})												
Young (18-29 years)	7	208.30	65.03	8	206.31	43.41	10	187.28	52.82	6	196.05	58.21
Middle (30-49 years)	22	236.50	49.83	9	247.12	55.47	19	224.12	72.85	8	220.43	55.41
Older (50+ years)	5	**243.08**	49.08	8	**325.85**	71.85	0			7	247.05	96.75
%CA												
Young (18-29 years)	7	76.70	5.31	8	75.12	5.68	10	77.30	5.19	6	74.87	6.06
Middle (30-49 years)	22	72.16	4.94	9	69.39	5.46	19	73.41	6.62	8	73.17	5.86
Older (50+ years)	5	69.73	7.55	8	62.64	7.19	0			7	69.49	10.43
I_x/I_y												
Young (18-29 years)	7	1.16	0.25	8	1.16	0.18	10	1.18	0.16	6	1.08	0.13
Middle (30-49 years)	22	1.08	0.18	9	1.18	0.27	19	1.23	0.20	8	1.13	0.24
Older (50+ years)	5	1.08	0.10	8	1.05	0.17	0			7	1.03	0.14
I_{max}/I_{min}												
Young (18-29 years)	7	1.30	0.17	8	1.26	0.16	10	**1.32**	0.14	6	**1.19**	0.10
Middle (30-49 years)	22	1.29	0.16	9	1.36	0.23	19	1.34	0.35	8	1.34	0.14
Older (50+ years)	5	1.16	0.12	8	1.19	0.13	0			7	1.19	0.11
Z_{pstd}												
Young (18-29 years)	7	1196.18	113.19	8	1096.03	164.64	10	1092.47	164.83	6	1008.86	130.00

Middle (30-49 years)	22	1127.29	104.57	9	1012.41	173.22	19	1088.46	155.14	8	1052.32	105.46
Older (50+ years)	5	1063.95	209.50	8	1101.68	203.46	0			7	1030.87	163.03
J_{std}												
Young (18-29 years)	7	490.36	56.47	8	420.61	54.51	10	427.19	84.82	6	389.82	56.06
Middle (30-49 years)	22	456.85	57.79	9	408.48	78.52	19	455.10	84.45	8	404.17	54.19
Older (50+ years)	5	426.11	90.14	8	441.48	107.13	0			7	405.53	79.44

Table 4.11 Coefficients of variation for the right femur

Table 4.11 – Coefficients of variation are a measure of sample dispersion or relative standard deviation. These values quantify the amount of variation relative to the mean for each of these cross-sectional geometry properties. High levels of sample dispersion indicate more heterogeneity within observations for that variable.

	%CA	I_x/I_y	I_{max}/I_{min}	$Z_{p\text{-}std}$	J_{std}
Pava					
Female					
Young (18-29 years)	11.65	13.70	9.24	16.07	19.95
Middle (30-49 years)	9.17	15.46	8.59	10.94	13.64
Older (50+ years)	10.84	11.83	9.17	12.49	18.11
Male					
Young (18-29 years)	3.70	15.37	6.56	17.86	20.92
Middle (30-49 years)	6.67	14.03	9.61	14.62	18.82
Older (50+ years)	16.61	19.27	14.21	9.82	11.77
Villamagna					
Female					
Young (18-29 years)	8.10	13.59	11.04	13.44	13.39
Middle (30-49 years)	8.01	20.86	14.45	13.21	15.68
Older (50+ years)	15.02	13.75	14.21	15.10	19.21
Male					
Young (18-29 years)	6.72	17.05	10.96	16.83	22.18
Middle (30-49 years)	9.01	18.51	19.47	13.58	17.30
Older (50+ years)					

*Coefficients of variation = SD/mean x 100, following Holt et al. 2019

Table 4.12 Coefficients of variation for the left femur

Table 4.12 – Coefficients of variation are a measure of sample dispersion or relative standard deviation. These values quantify the amount of variation relative to the mean for each of these cross-sectional geometry properties. High levels of sample dispersion indicate more heterogeneity within observations for that variable.

	%CA	I_x/I_y	I_{max}/I_{min}	$Z_{p\text{-}std}$	J_{std}
Pava					
Female					
Young (18-29 years)	11.41	13.25	10.48	17.87	22.99
Middle (30-49 years)	7.71	15.21	6.93	13.14	15.68
Older (50+ years)	6.83	8.72	10.50	11.96	13.07
Male					
Young (18-29 years)	4.59	19.43	6.56	15.89	13.60
Middle (30-49 years)	8.96	13.94	9.92	17.11	21.95
Older (50+ years)	8.30	19.46	14.21	9.47	12.41
Villamagna					
Female					
Young (18-29 years)	7.55	15.14	12.44	15.02	12.96
Middle (30-49 years)	7.88	22.62	17.04	17.11	19.22
Older (50+ years)	11.48	15.83	10.72	18.47	24.27
Male					
Young (18-29 years)	6.93	21.17	13.43	9.46	11.52
Middle (30-49 years)	6.85	16.90	12.68	9.27	12.65
Older (50+ years)	10.83	9.73	10.04	19.69	21.15

*Coefficients of variation = SD/mean x 100, following Holt et al. 2019

Figure 4.9 Comparison of mean medullary area at Pava (left femur)

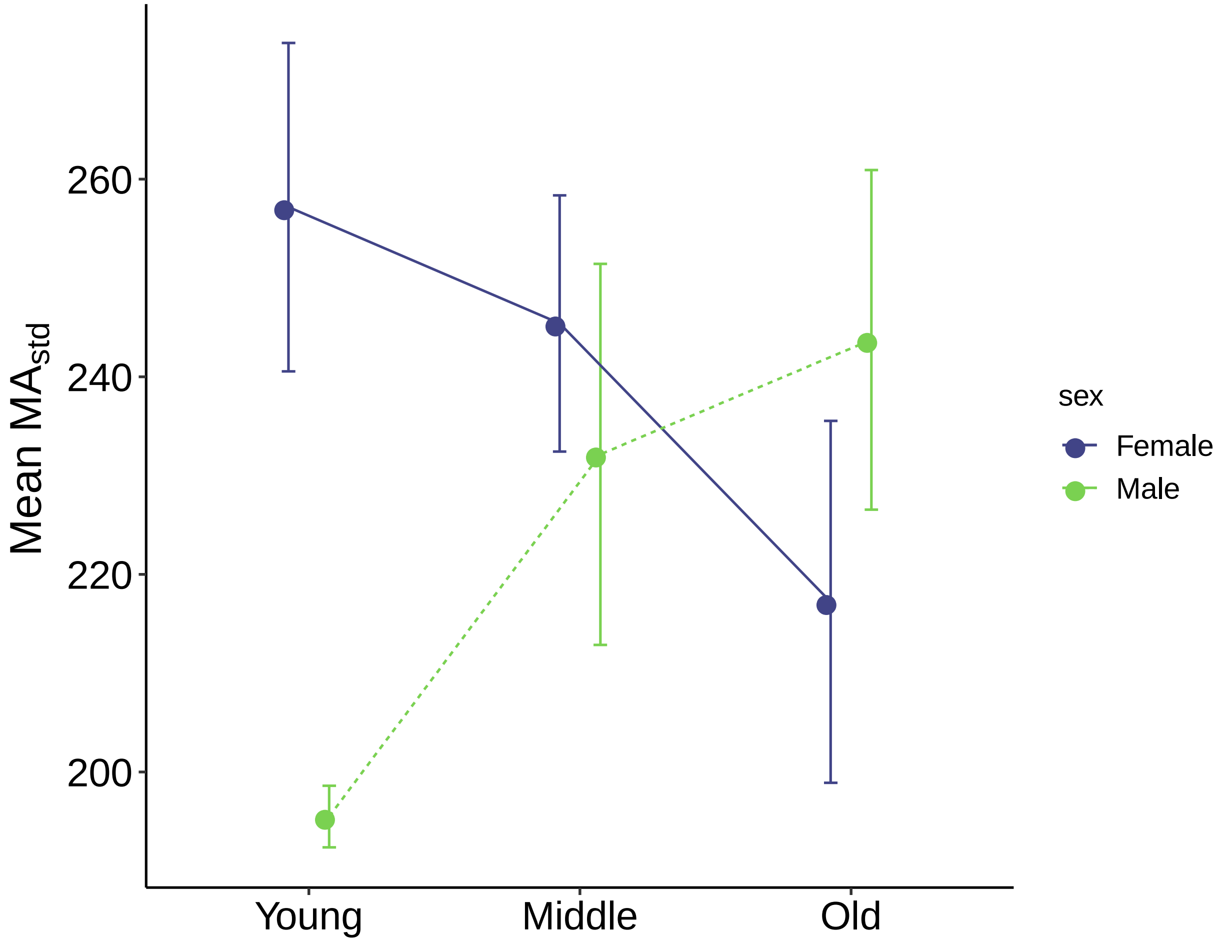

Figure 4.9 – Mean medullary area (MA) is on the y-axis, age groups are on the x-axis. Females are shown in purple while males are shown in green. Mean medullary area (y-axis) at Pava is highest in young females (x-axis, purple), where it is significantly higher than the mean for young males (the lowest mean MA for any group). Mean medullary area is highest in the old age group for males.

Figure 4.10 Comparison of cortical area at Villamagna (left femur)

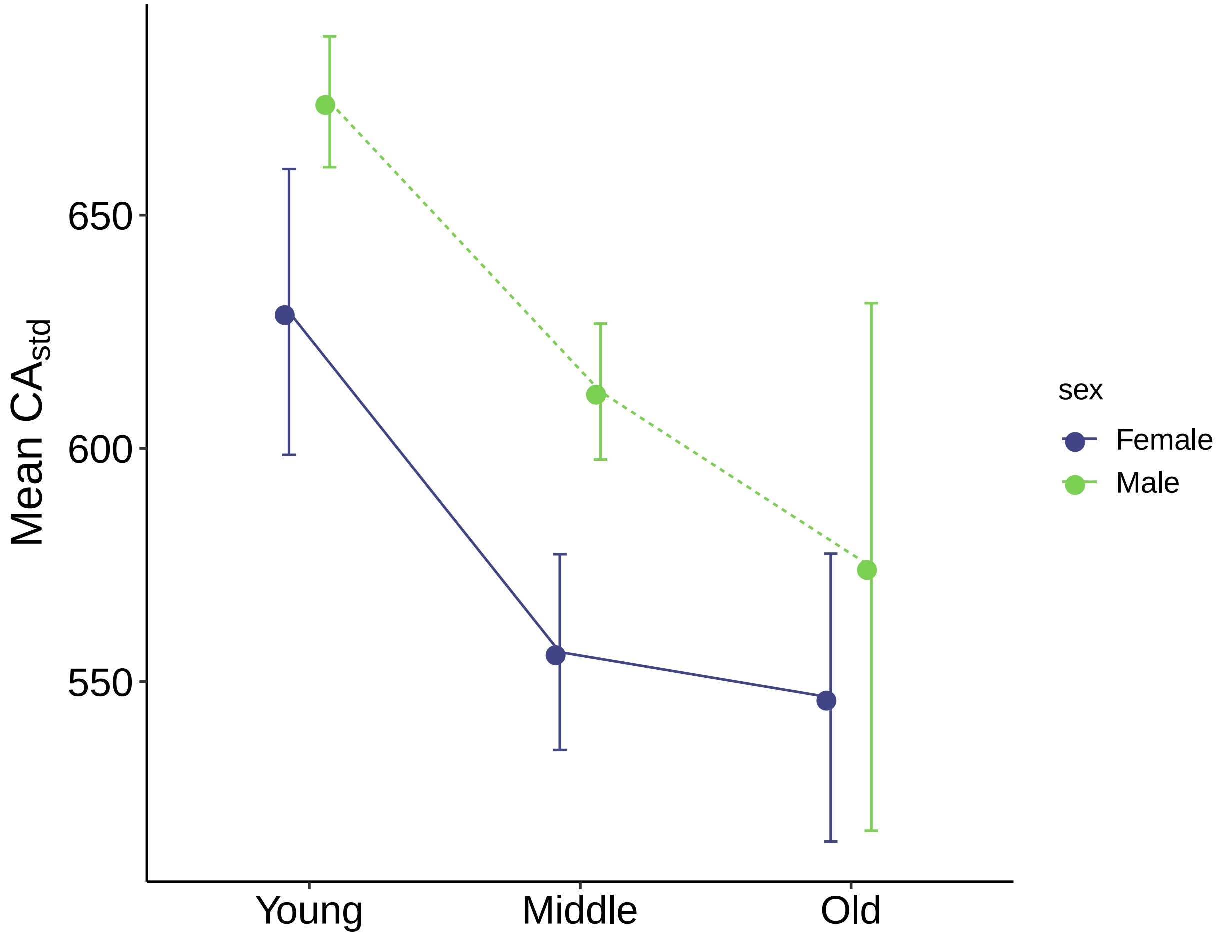

Figure 4.10 – Mean cortical area (CA) is on the y-axis, age groups are on the x-axis. Females are shown in purple while males are shown in green. Males have higher mean CA than females in the young and middle age groups. Overall mean CA is highest in young age and lowest in older age.

Figure 4.11 Comparison of medullary area at Villamagna (left femur)

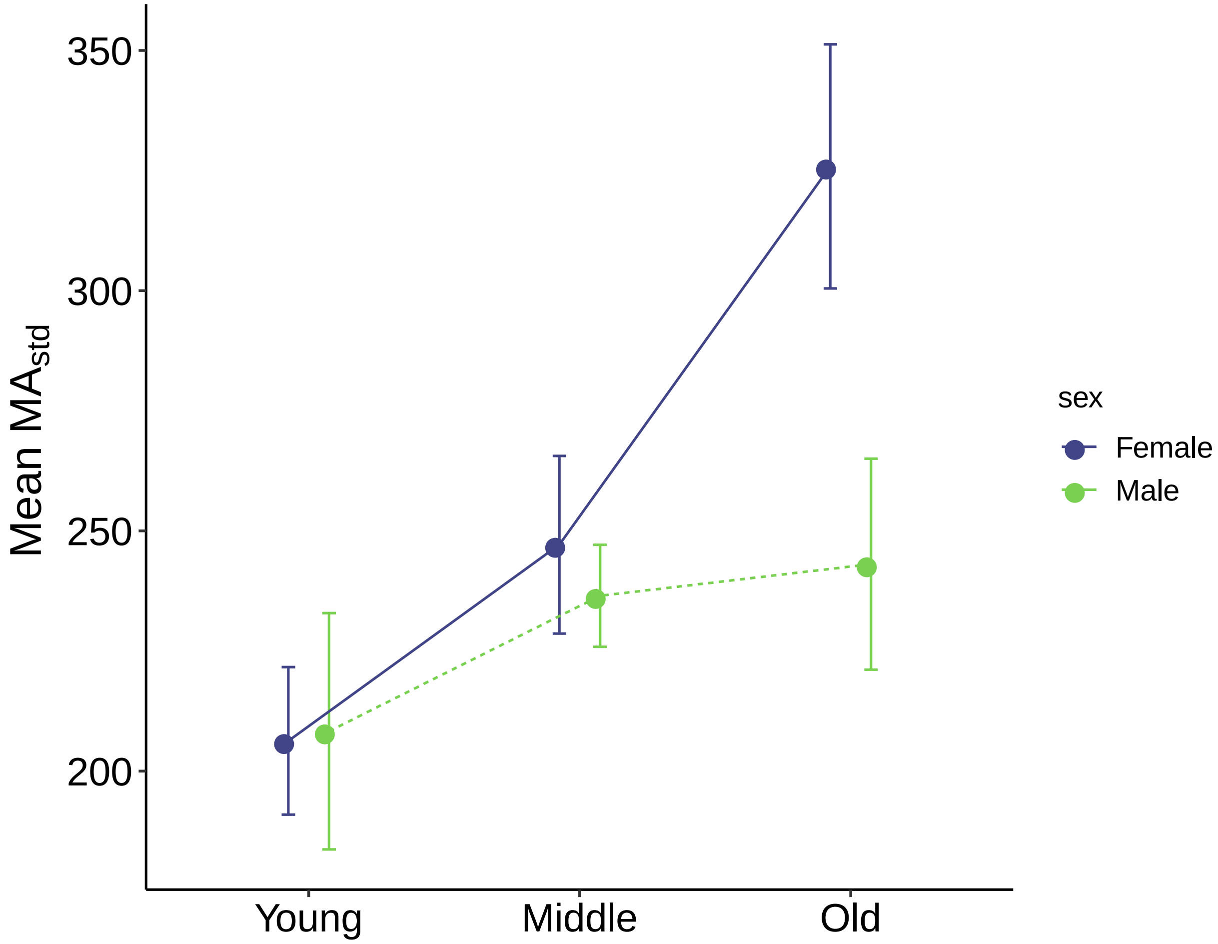

Figure 4.10 – Mean medullary area (MA) is on the y-axis, age groups are on the x-axis. Females are shown in purple while males are shown in green. Old age females have the highest mean MA, significantly higher than middle and young age females and significantly higher than old age males.

Figure 4.12 Sample dispersion in measures of bone area at Pava

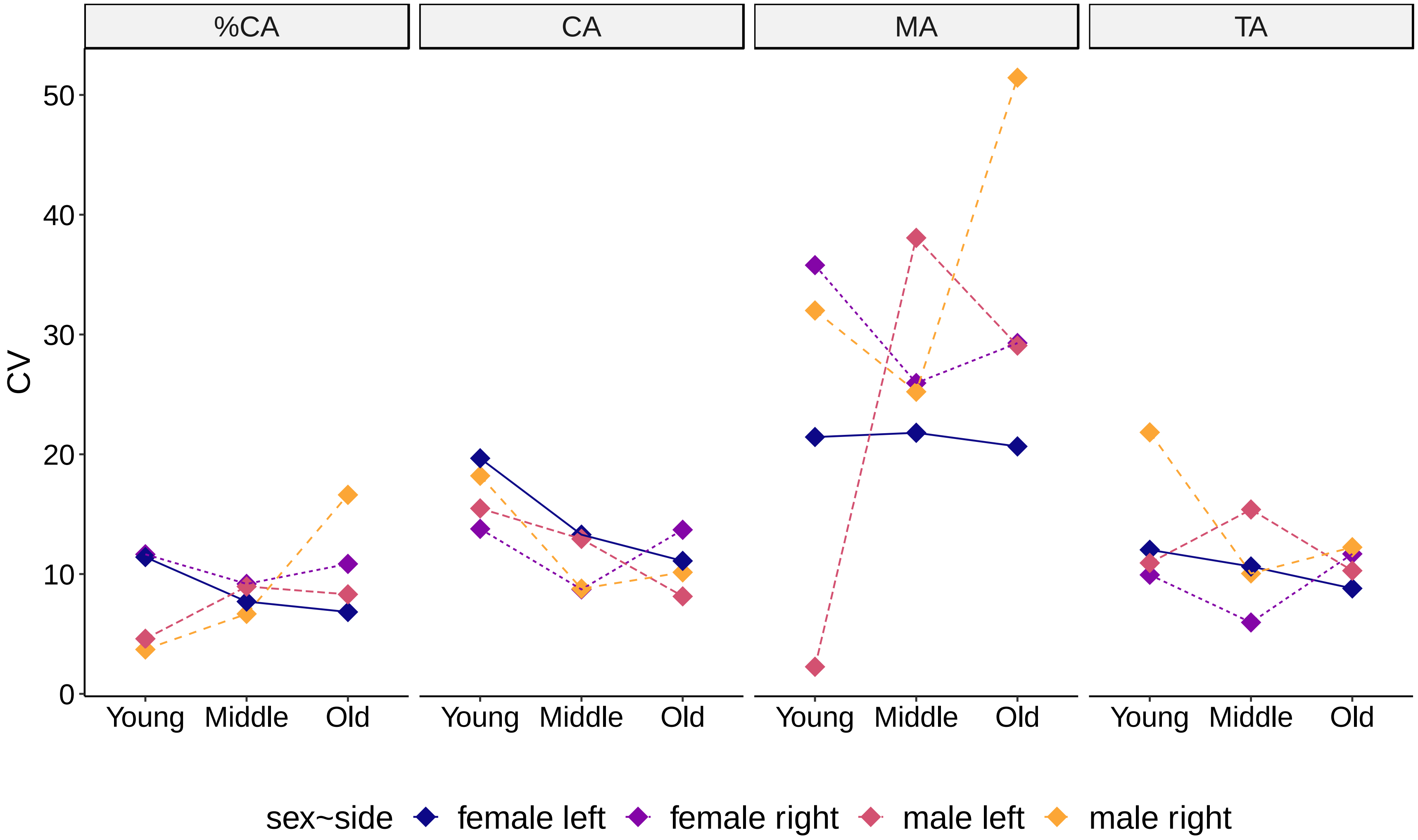

Figure 4.12 – Shows relative measures of sample dispersion (CV) for each bone area measurement for Pava. The highest sample dispersion is in medullary area, for males and females. Higher sample dispersion indicates that individual observations deviate strongly from the mean.

Figure 4.13 Sample dispersion in measures of bone area at Villamagna

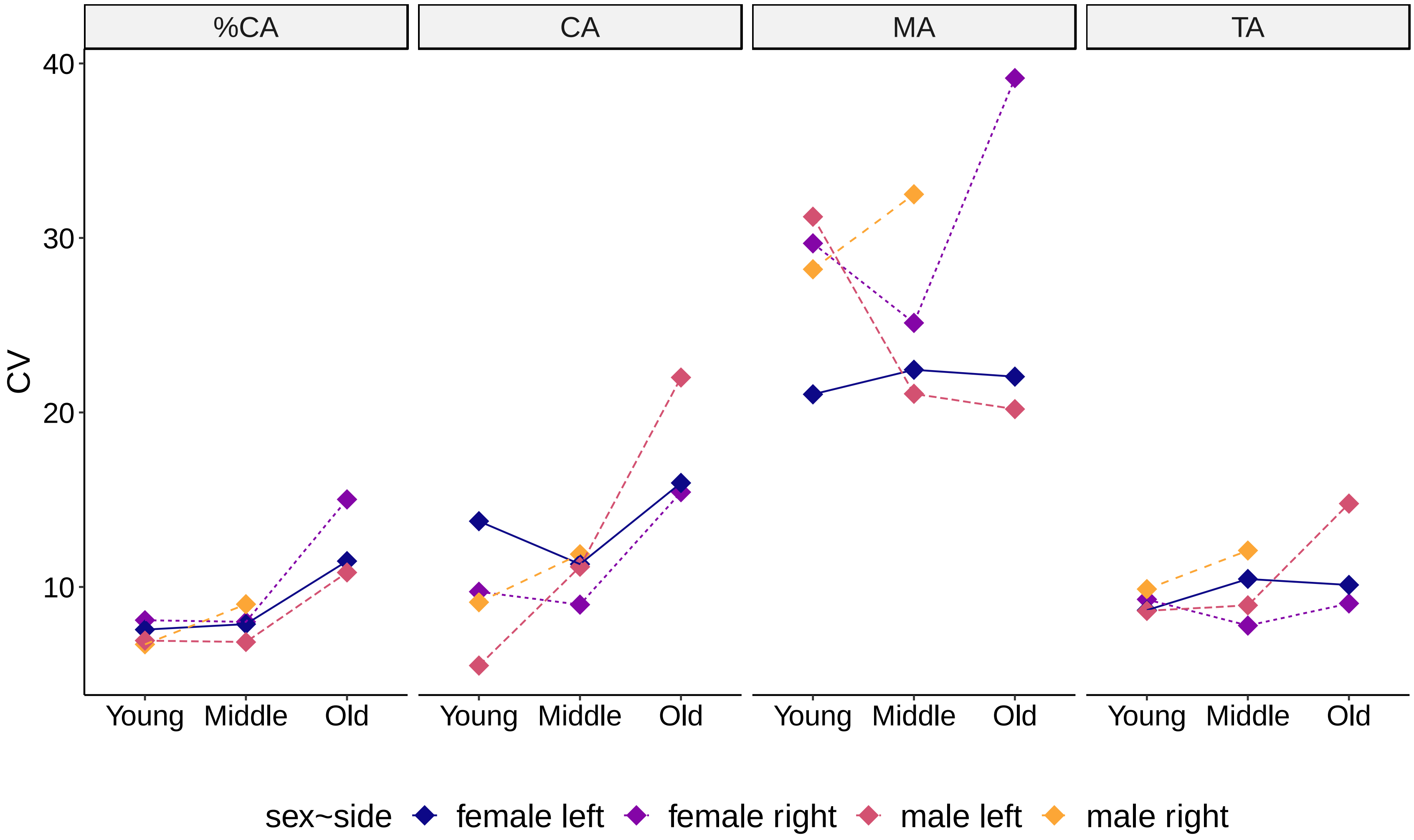

Figure 4.13 –Shows relative measures of sample dispersion (CV) for each bone area measurement for Villamagna. The highest sample dispersion is in medullary area, for males and females. Cortical area observations particularly in the left femur also have relatively high dispersion. Higher sample dispersion indicates that individual observations deviate strongly from the mean.

Figure 4.14 Diaphyseal shape properties (I_x, I_y, I_{max})

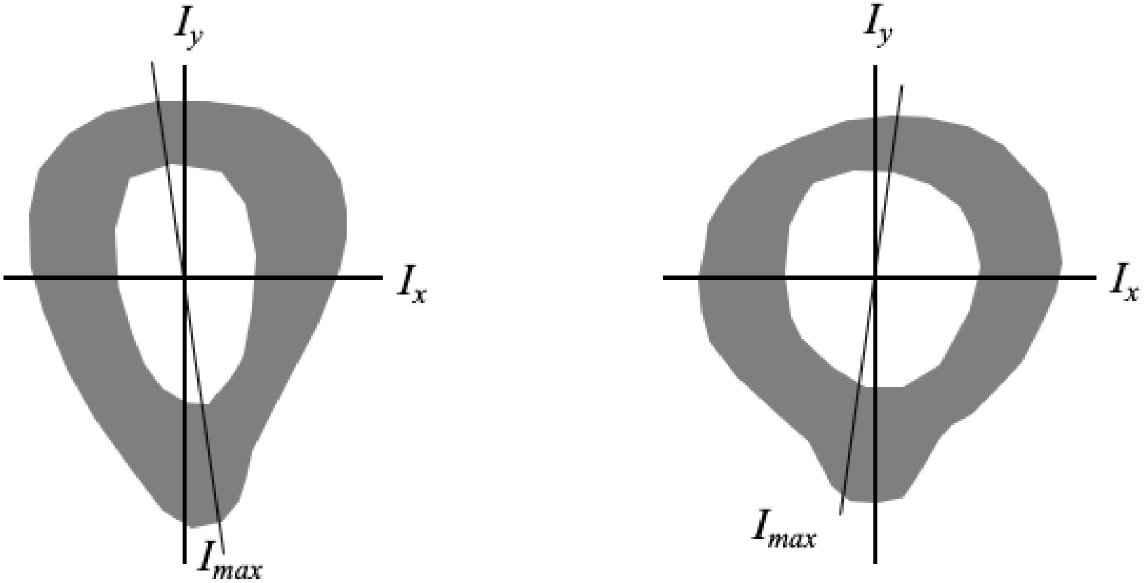

Figure 4.14 – Diaphyseal shape properties are calculated as Ix, Iy, Imax, and Imin. Ix and Iy are measured on a neutral axis that is the same for all individuals – these planes are calculated relative the the CT scan field of view; Imax is calculated based on the furthest distance from the centroid (0,0) and Imin is calculated at a 90-degree angle from Imax. In this example, these two individuals have Imax values slightly offset from the neutral axis.

Figure 4.15 Mean maximum mechanical loading (I_{max}/I_{min}) at Pava

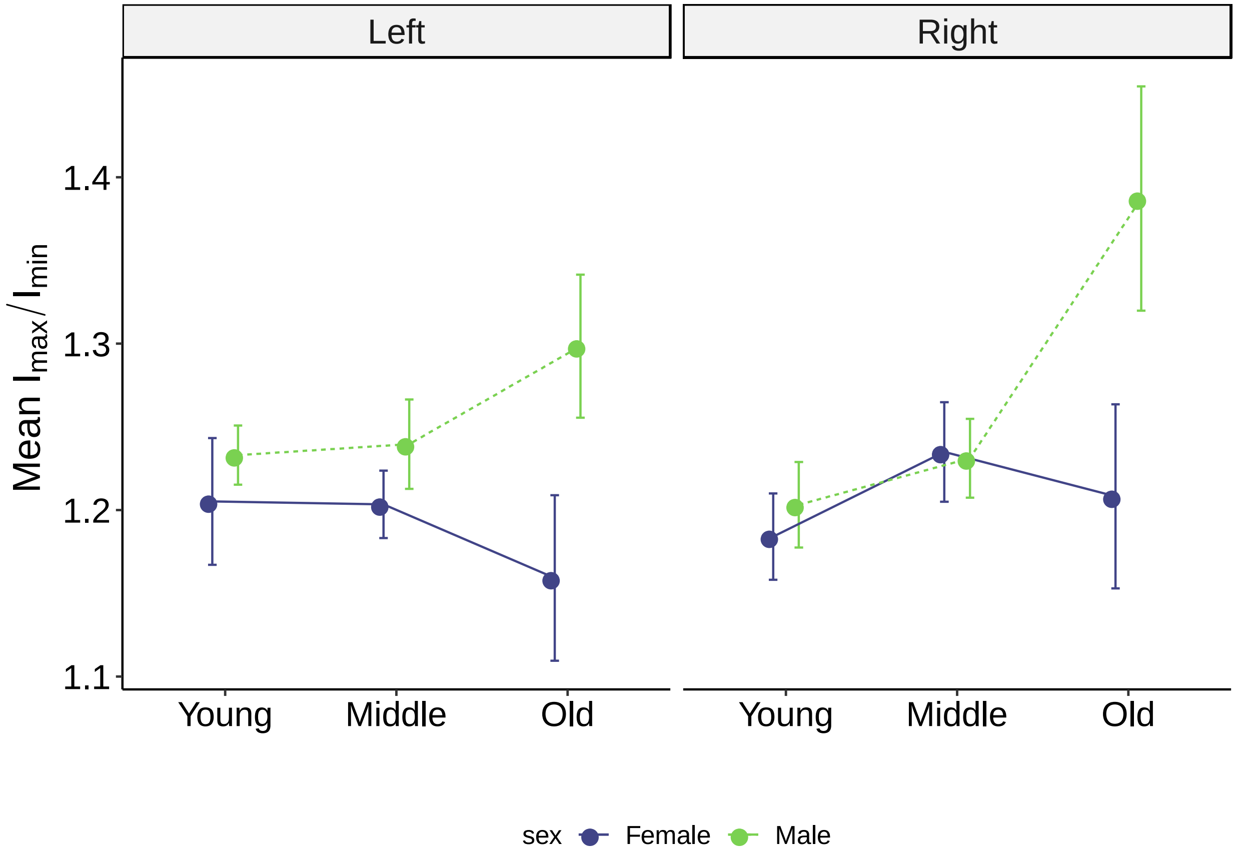

Figure 4.15 – Mean mechanical loading (Imax/Imin) is on the y-axis, age groups are on the x-axis; graph faceting groups the left femur observations on the left and right femur observations on the right. Pava females are shown in purple while Pava males are shown in green. Old age males at Pava have the highest mean mechanical loading, significantly higher than old age females and significantly higher than old age males. There are no differences in mean mechanical loading by sex in young or middle age in the left or right femur.

Figure 4.16 Sample dispersion in measures of diaphyseal shape at Pava

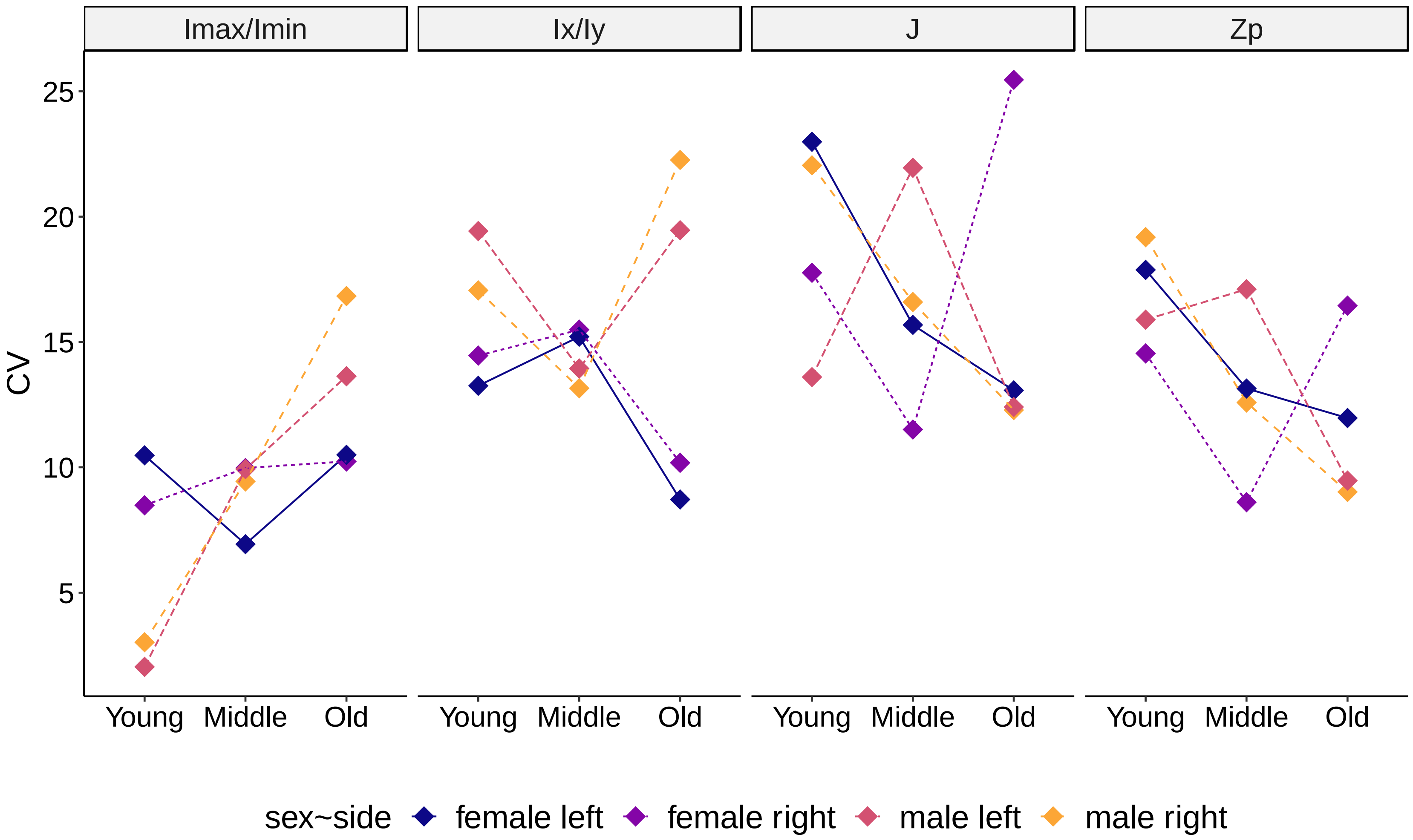

Figure 4.16 – Shows relative measures of sample dispersion (CV) for each bone diaphyseal shape measurement for Pava. Observations in the older age groups have higher relative sample dispersion for many of the bone diaphyseal shape properties here. Higher sample dispersion indicates that individual observations deviate strongly from the mean.

Figure 4.17 Sample dispersion in measures of diaphyseal shape at Villamagna

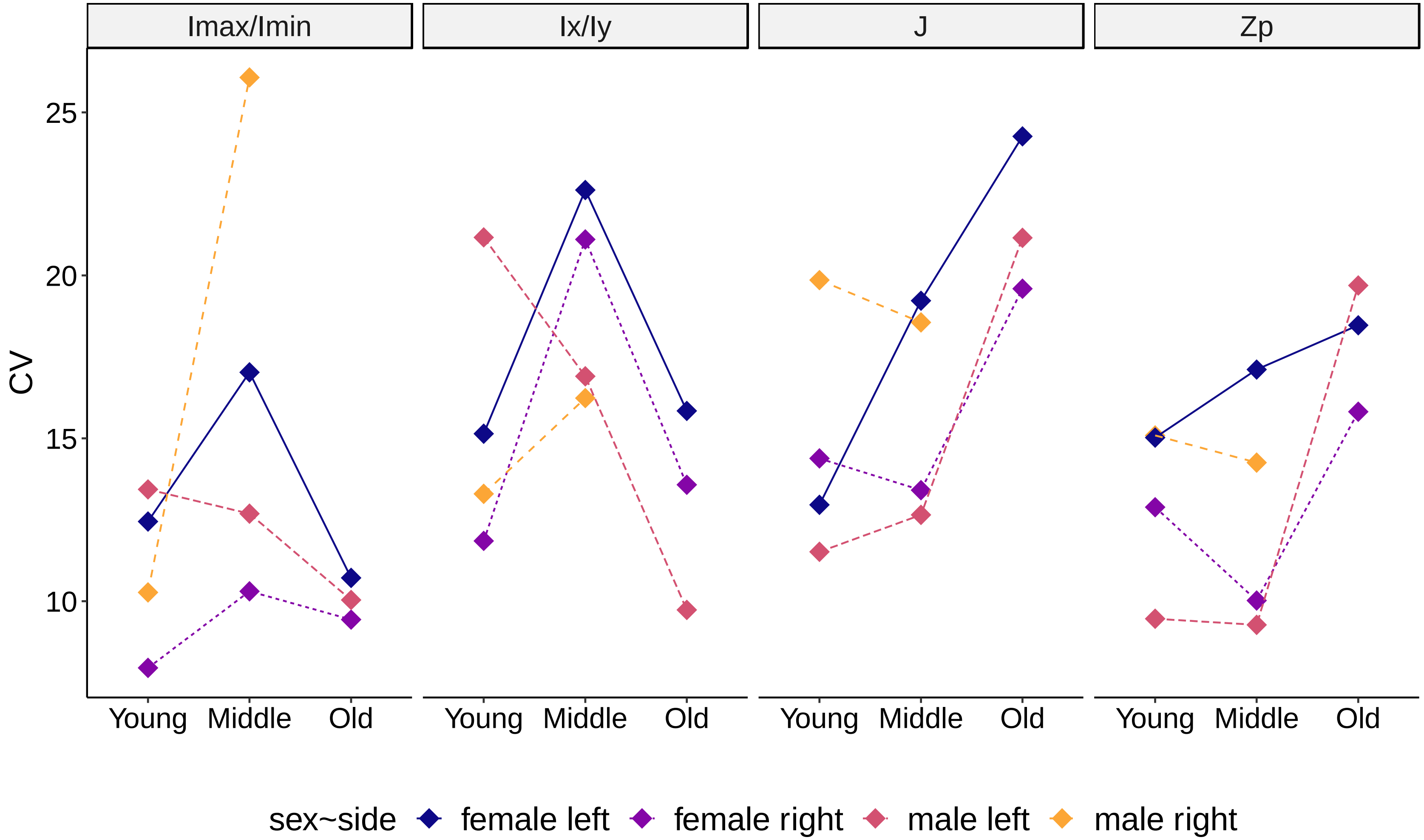

Figure 4.17 – Shows relative measures of sample dispersion (CV) for each bone diaphyseal shape measurement for Villamagna. Observations in the older age groups have higher relative sample dispersion for many of the bone diaphyseal shape properties here. Higher sample dispersion indicates that individual observations deviate strongly from the mean.

Figure 4.18 Mean bending rigidity (J_{std}) at Pava (right femur)

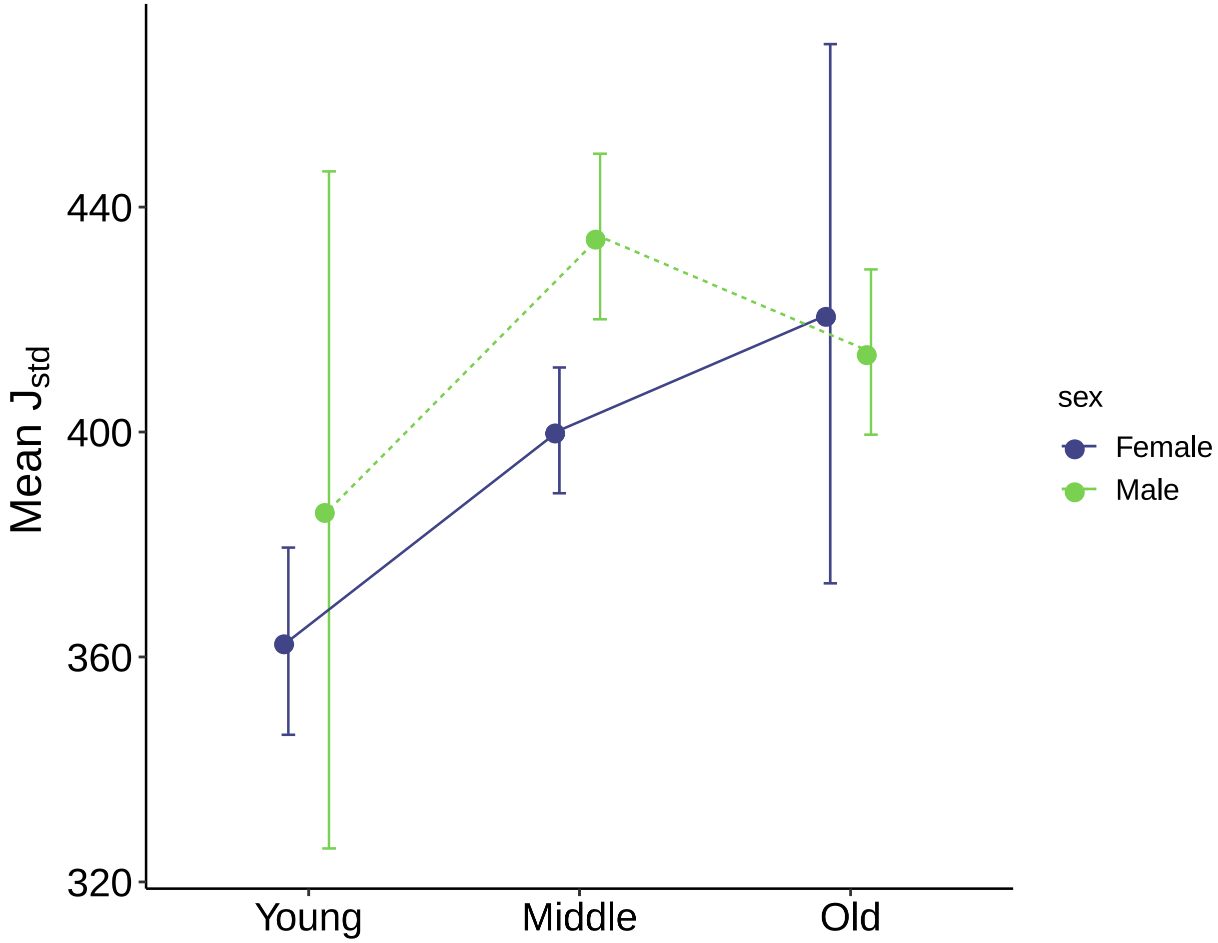

Figure 4.18 – Mean mechanical loading (Imax/Imin) is on the y-axis, age groups are on the x-axis. Pava females are shown in purple while Pava males are shown in green. There is a significant difference between mean J for males and females in the middle age group, where males have significantly higher mean J than females.

There are no sex differences in any age group at Villamagna for bending strength ($Z_{p\text{-}std}$) or for bending rigidity (J_{std}). Villamagna males have no significant difference in mean J_{std} by age group, however they have consistently high mean J_{std} (male J_{std} range = 426.11-490.36), with a relatively high variance in the older age cohort left femur (CV = 21.15, Table 4.12, Figure 4.17). Variance in mean $Z_{p\text{-}std}$ in the left femur is even higher for older age males at Villamagna, compared to J_{std} ($Z_{p\text{-}std}$ CV = 19.69, Table 4.12, Figure 4.17). At Villamagna, the older age group (males and females) have relatively high sample dispersion for J_{std} and for $Z_{p\text{-}std}$ (left CV = 18.47-24.27, right CV = 15.10-19.21, Table 4.11, 4.12). Overall, Villamagna males and females have significantly higher mean J_{std} and $Z_{p\text{-}std}$ than Pava males and females ($p<.05$), but also higher variance (Table 4.11, 4.12).

Discussion of Cross-Sectional Geometry Trends

Males have greater mean bone robusticity than females, and Villamagna males have greater bone robusticity than Pava males. There is significantly higher variance in %CA in older age at Villamagna, compared to Pava and to other age groups. Similarly, there is high variance in the older age cohort for measures of bone strength and rigidity ($Z_{p\text{-}std}$ and J_{std}) in the older age cohort (Table 4.12). This suggests that there are diverse late-life outcomes, possibly due to differences in development or life experience, or that the sample of older individuals is not representative of the population overall. These data suggest that there is not a singular "older age" experience of bone quantity for two possible reasons: (a) the older age category itself lumps individuals from across a 50 year time span into a single age group (50-100 years old), and/or (b) that the embodiment of aging becomes more heterogeneous in older age due to an accumulation of lived experiences, risks, and exposures. Further work is needed to fully explore this trend, both at these particular sites and in general. Future research might include an analysis of stress indicators, intra-skeletal markers of bone maintenance, and histological examination of bone microstructure to further investigate the multifactorial effects of aging and development on bone maintenance across the life course.

Results for bending strength ($Z_{p\text{-}std}$) and bending rigidity (J_{std}) suggest that individuals at Villamagna had higher mean bending strength and rigidity in the femur, compared to individuals at Pava. Sex differences in bending rigidity (J_{std}) are more distinctive in the young and middle age cohorts, while the older age cohort has similar mean values across all sites and sexes. J_{std} is typically considered a robust and meaningful estimation of bone strength (Stock & Shaw 2007), although more recent biomechanical research on historic European populations suggests that $Z_{p\text{-}std}$ may be a more accurate and useful measure of bending strength (Ruff et al. 2018). The results presented above suggest that individuals at VM had increased bone strength compared to Pava in young and middle age, but that in the older age cohort there are not differences by sex or age in overall bone strength.

Diaphyseal shape, analyzed here as the ratio of one plane to another: I_x/I_y is a ratio based on the distance from the centroid in the x and y planes; whereas I_{max}/I_{min} is a ratio based on maximum and minimum distances from the centroid (Figure 4.14). Overall, there is not a sex difference at Pava in the young and middle age cohorts with regard to mean I_x/I_y. In the older age cohort Pava males have significantly higher mean I_{max}/I_{min} than Pava females who have mean I_x/I_y value comparable to the middle and young age female cohorts. The area surrounding

Pava in southeastern Tuscany is “Flat” to “Hilly” based on Ruff et al.’s (2018) criteria, therefore it is expected that Pava would have less AP mechanical loading (I_x/I_y ratio closer to 1.0). Lower mean I_x/I_y values, paired with higher I_{max}/I_{min} values indicate that although people at Pava did not have a high magnitude of AP direction mechanical loading, they still had high levels of mechanical loading in various (non-AP) directions. This finding is further supported by the higher J_{std} and $Z_{p\text{-}std}$ means from Pava groups.

Older age Pava males have relatively high variance in I_x/I_y values; 17 males in the older age group at Pava have I_x/I_y values higher than 1.20, while 19 males in the older group at Pava have I_x/I_y values below 0.90. This high variance in older age males at Pava, in particular, suggests that medieval men at Pava differentially participated in various types of labor and that there was likely a contingency of older male individuals who had more AP loading than others—possibly due to traveling farther distances to participate in the rural Tuscan economy. This wide variance may also be due to the large age range encompassed by the older age cohort; as aging is not a linear experience or process. The age categories used in this analysis (and more widely across bioarchaeological studies), encompass a large range of ages (see Chapter 2). It is possible that due to the large sample of older age males at Pava, this study captures more variation in older age or that there a wider range of males live to older age at Pava.

Similar to Pava, Villamagna also does not have a significant sex difference in any age cohort for mean I_x/I_y, however in the young and middle age cohorts there is higher mean I_x/I_y at Villamagna compared to Pava. Although Villamagna males and females have higher values than Pava males and females. Site differences between Pava and VM are likely due to differences in terrain and mobility, where Villamagna is in an area that is quantifiably more “Mountainous” than Pava (see *Comparison with Italian Peninsula* below).

In theory there should be good concordance between I_x/I_y values and I_{max}/I_{min} values; however, within the Pava and Villamagna samples there is a subset of individuals with significant differences in I_x/I_y and I_{max}/I_{min}. These individuals (n=8) are the individuals with the lowest I_x/I_y values (mean = 0.71), who also have significantly higher I_{max}/I_{min} values (mean = 1.51). Based on results from this study is appears that individuals for some individuals, with extreme deviations from circularity in the ML direction, the I_y distance does not accurately represent loadings in a general ML direction. The range of θ values for these individuals with deviations between I_x/I_y and I_{max}/I_{min} range from θ= -16.82 to θ= 19.93. Indicating that I_{max} is more mediolaterally oriented (with approximately +/- 20 degrees of the x-axis). Cowgill et al., (2010) finds similar trends between I_{max}/I_{min} in toddlers who are learning to walk, or “waddling”. Based on previous research it is possible that a subset of individuals from Pava and VM have a waddling-type gait (see Chapter 5), however this trend has not been examined in clinical or experimental models, so it is difficult to make definitive conclusions.

Effects of Economic Access at Villamagna

Results

Based on results from Chapter 3, it was hypothesized that there would be a difference in bone robusticity or in diaphyseal shape based on the presence of grave goods, which give an indication about differential levels of economic access at Villamagna. Individuals at Pava were not buried with grave goods, and spatial analyses of cross-sectional and spine data have not shown clear results or trends, therefore only the Villamagna subset of data were included in these particular analyses. For this analysis I included right and left femora, with one bone per distinct individual.

Villamagna females *with* grave goods had significantly smaller mean MA_{std} than females without grave inclusions (*p*=.021, Table 4.13, Figure 4.19). Villamagna females with grave goods also had higher mean percent cortical area than females buried without grave goods (*p*=.018). Males buried without grave goods had higher mean total area (*p*=.023) and higher mean bending strength ($Z_{p\text{-}std}$) than males buried with grave goods (*p*=.047, Table 4.13).

Within Villamagna people buried with grave goods there was not a significant sex differences in mean MA_{std}, but both groups had significantly smaller mean MA_{std} than individuals without grave goods (Figure 4.19). Females with grave goods had more relative cortical area (%CA, Table 4.13); mean %CA for females buried without grave goods was 68.4% (SD=8.55, n=43), compared to 75.2% (SD=5.98, n=14) in females with grave goods (Table 4.13). Males did not follow this trend (no difference in %CA for males with and without grave goods), which may be to periosteal expansion in males without grave goods (TA_{std} mean males without grave goods = 853.39, males with grave goods mean = 800.88, Table 4.13).

Older age males buried with grave inclusions had significant lower mean J_{std} and $Z_{p\text{-}std}$, than older age males buried with grave inclusions (Table 4.13, Figures 4.21, 4.22). Middle age males buried without grave inclusions also had significantly higher mean J_{std} than those buried with grave goods, a trend also seen in $Z_{p\text{-}std}$ although the trend is not statistically significant in $Z_{p\text{-}std}$. Older age females *with* grave inclusions had significantly higher mean J_{std} and $Z_{p\text{-}std}$ than those buried without grave inclusions (Table 4.13, Figure 4.21, 4.22). This trend did not follow our expectations; however, it mirrors the trend in severe spine disease for older age females buried with grave goods (i.e., greater than expected prevalence of spine disease in older age females with grave goods).

Discussion

In both cases of medullary area and percent cortical area, it appears that the effect of more economic access, represented by the inclusion of grave goods, has an effect on female bone area measures (Figure 4.20-23). Holt et al. (2018) suggest that increases in %CA are likely due to overall better health and nutrition, especially calcium and protein rich diets. Functionally, a protein and calcium rich diet is necessary to maintain bone health and calcium deficiency has been linked to endosteal bone resorption (Crowder & Stout 2011, Gosman & Stout 2010, Gosman et al. 2011, Sissons et al. 1984, Stauffer et al. 1973); therefore, it’s possible that females without access to a nutrient dense diet may be at increased risk for endosteal bone loss (Agarwal 2016, Gosman et al. 2011, Miszkiewicz et al. 2019). It has also been suggested that increased pathogen loads lead to immune activation, which can affect bone remodeling and overall retention of bone mass (Holt et al. 2018, Brenner et al. 2018, Miszkiewicz et al. 2019). Using data from Chapter 3, I argue that increased risk for spine disease in individuals buried without grave inclusions may be a result of immune activation in synergy with dietary differences and differences in physical activity (Kinkopf et al. *in prep*). Results from this cross-sectional geometry study support and enhance the arguments made based on spine disease data alone: increased medullary area and decreased percent cortical bone suggest that individuals buried without grave inclusions may have had worse health conditions and lower

Table 4.13 Summary statistics for Villamagna by economic access

Table 4.13 – Independent sample t-*tests were performed to evaluate differences between presence and absence of grave goods (e.g., TA~grave-goods) for males and females. Statistically significant differences* (α=.05) *are indicated by **bold** means in this table. Males without grave goods had significantly higher mean total area (p=.023); males with grave goods had higher mean Zpstd (p=.047). Females with grave goods had significantly higher mean %CA (p=.018), significantly lower mean medullary area (p=.021); this suggests than females without grave goods were at increased risk for endosteal bone loss.*

	Grave Goods Absent						**Grave Goods Present**					
	Female			**Male**			**Female**			**Male**		
	N	mean	SD	N	mean	SD	N	mean	SD	N	mean	SD
TA_{std}	31	818.65	78.61	41	**853.39**	95.14	11	802.01	78.51	16	**800.88**	65.65
MA_{std}	31	**257.63**	77.21	41	229.45	65.18	11	**203.96**	55.87	16	207.73	49.63
CA_{std}	31	561.01	72.93	41	623.93	80.29	11	598.05	68.1	16	593.15	50.82
%CA	31	**68.75**	7.82	41	73.24	6.41	11	**74.69**	6.21	16	74.2	5.26
I_x/I_y	31	1.11	0.20	41	1.14	0.19	11	1.13	0.22	16	1.17	0.22
I_{max}/I_{min}	31	1.25	0.18	41	1.31	0.27	11	1.32	0.13	16	1.29	0.16
J_{std}	31	403.1	61.27	41	458.32	80.72	11	412.27	82.68	16	435.81	61.90
$Z_{p\text{-}std}$	31	1031.77	143.66	41	**1132.78**	154.93	11	1052.14	171.32	16	**1058.90**	107.19

Figure 4.19 Economic Access has an Effect on Medullary Area (MA_{std}) at Villamagna

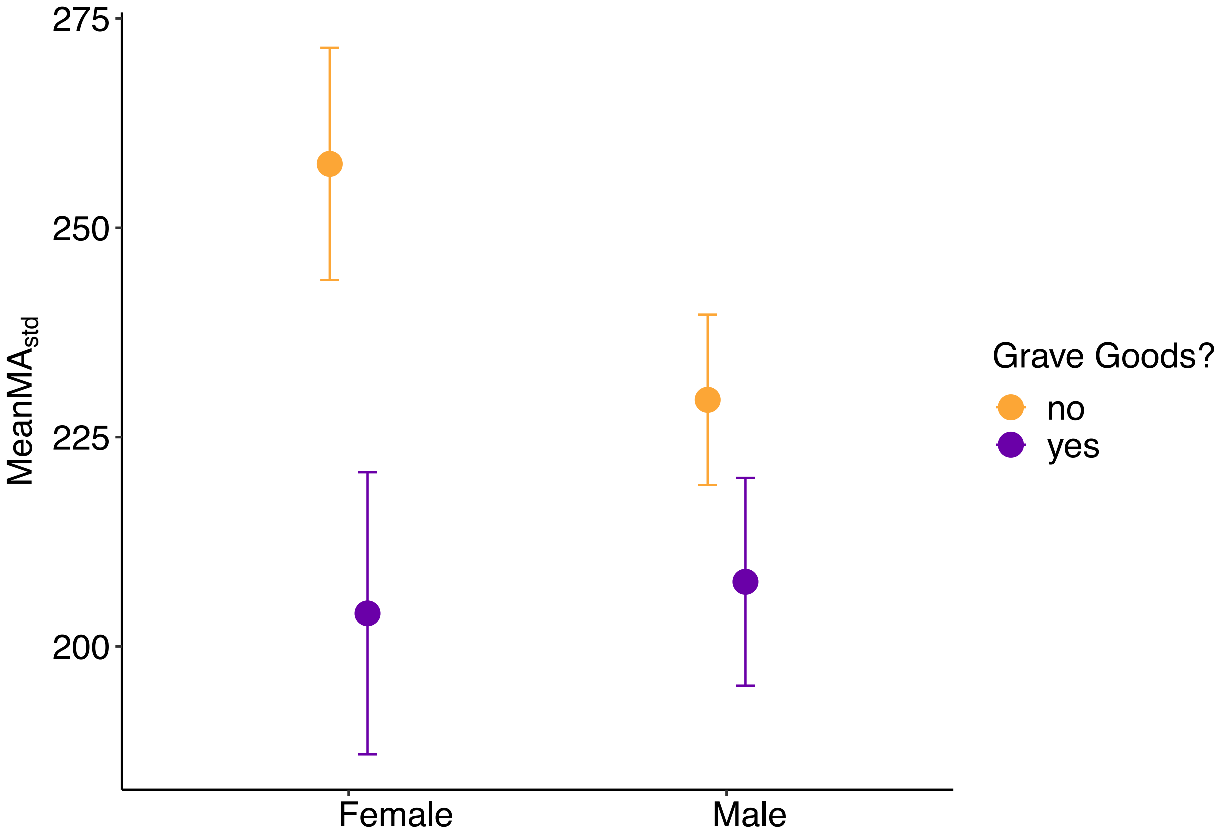

Figure 4.19 – Mean medullary area (MA) is on the y-axis, sex groups are on the x-axis. Femora from individuals buried with grave goods are shown in purple, femora from individuals buried without grave goods are shown in orange. Females buried without grave goods have significantly higher mean MA than females buried with grave goods. Absence of grave goods does not have a significant effect on mean MA for males at Villamagna.

Figure 4.20 Economic Access has an Effect on Percent Cortical Area (%CA) at Villamagna

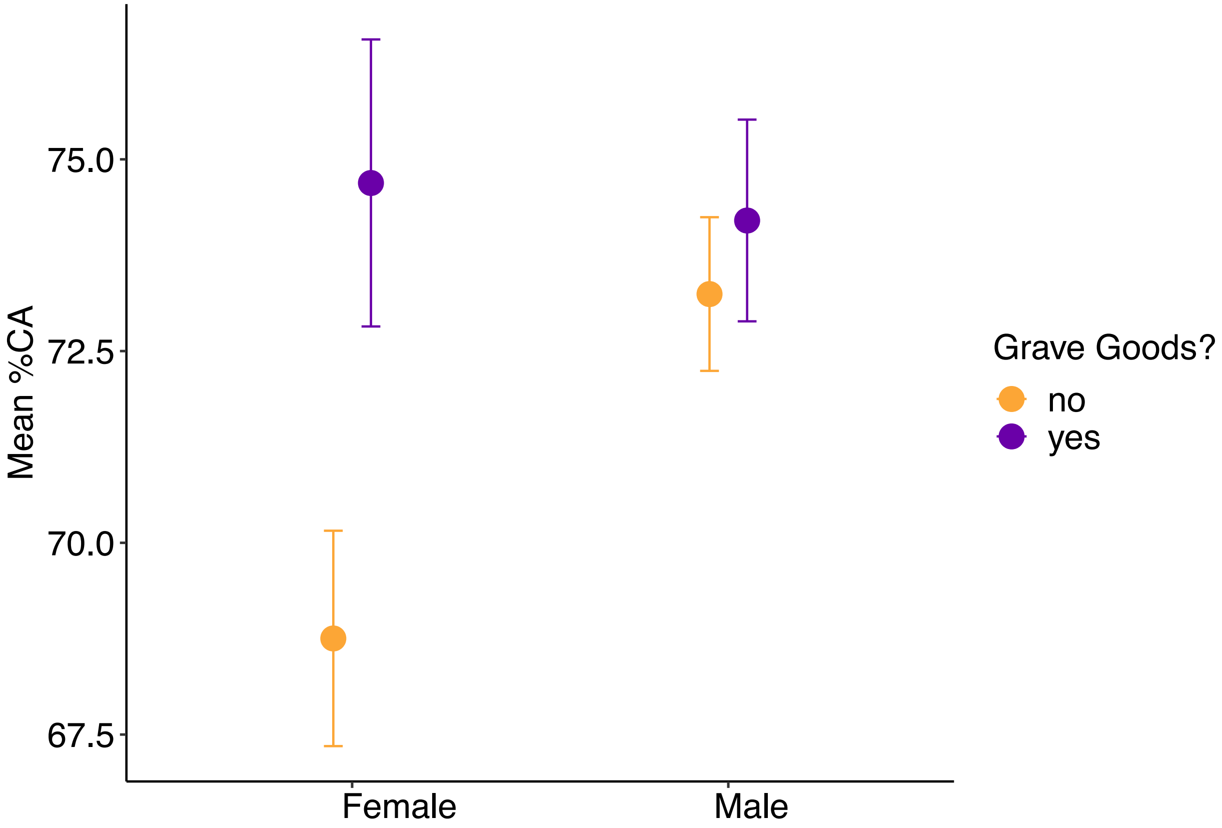

Figure 4.20 – Mean relative cortical area (%CA) is on the y-axis, sex groups are on the x-axis. Femora from individuals buried with grave goods are shown in purple, femora from individuals buried without grave goods are shown in orange. Females buried without grave goods have significantly lower mean %CA than females buried with grave goods.

Figure 4.21 Economic Access has an Effect on Mean Bending Rigidity (J_{std}) at Villamagna

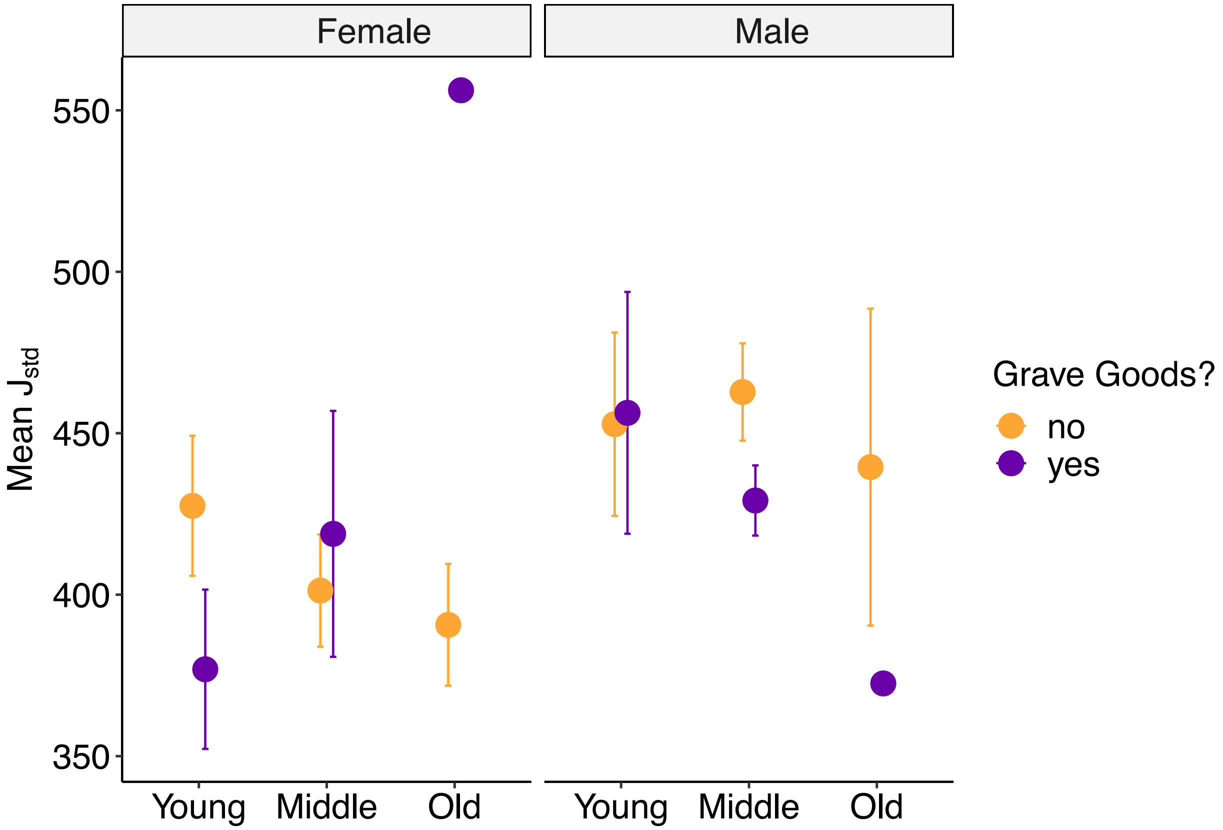

Figure 4.21 – Mean bending rigidity (J_{std}) is on the y-axis, age groups are on the x-axis; chart is faceted by sex, females on the left, males on the right. Femora from individuals buried with grave goods are shown in purple, femora from individuals buried without grave goods are shown in orange. Females buried without grave goods have lower mean J in young age than females buried with grave goods in young age. Females in old age have significantly higher mean J than females without grave goods however the same size is small. Males without grave goods have higher mean J than males buried with grave goods in the middle and old age groups.

Figure 4.22 Economic Access has an Effect on Mean Bending Strength ($Z_{p\text{-}std}$) at Villamagna

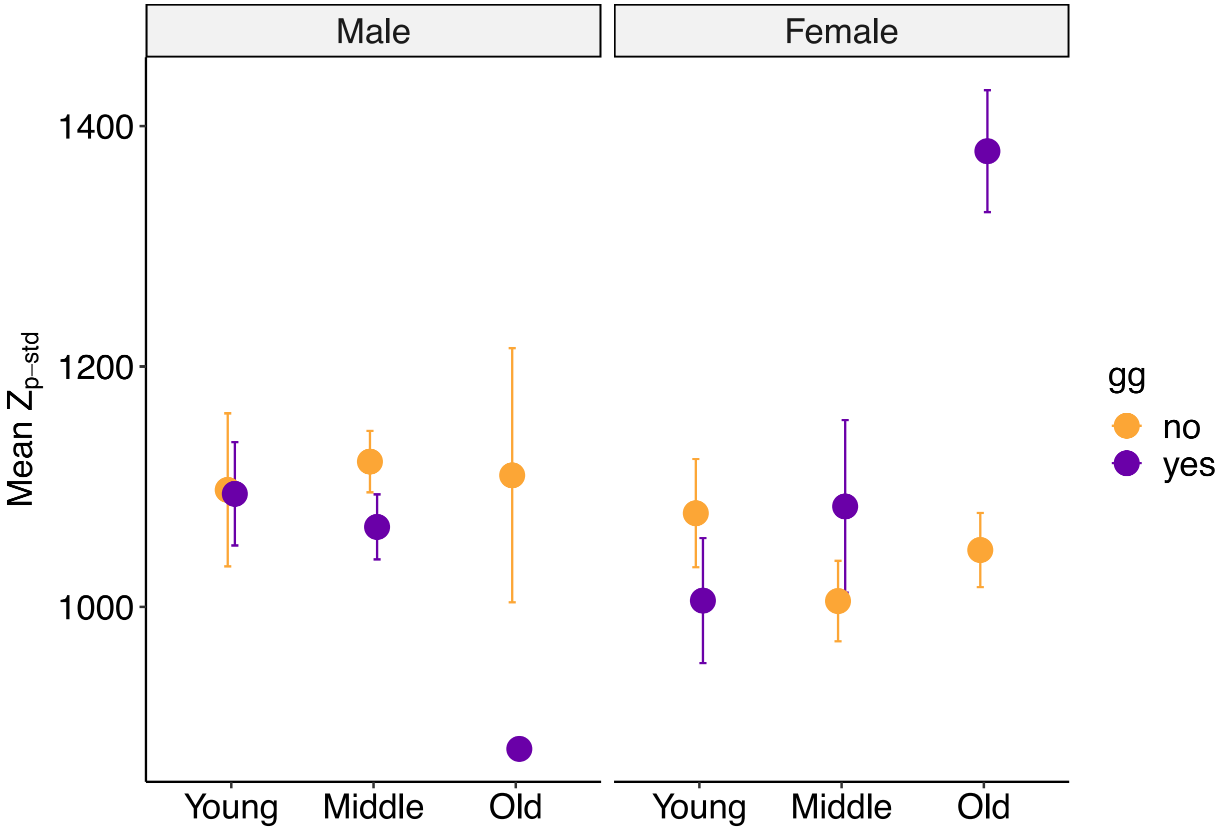

Figure 4.22 – Mean bending rigidity ($Z_{p\text{-}std}$) is on the y-axis, age groups are on the x-axis; the chart is faceted by sex with females on the left and males on the right. Femora from individuals buried with grave goods are shown in purple, femora from individuals buried without grave goods are shown in orange. Males without grave goods have higher mean $Z_{p\text{-}std}$ than males buried with grave goods in the old age group. Females buried with grave goods have significantly higher mean $Z_{p\text{-}std}$ than females buried without grave goods in the old age group.

access to quality nutrition. However, significant increases in mean J_{std} and Z_{pstd} amongst VM females buried with grave goods suggest that differences in economic access might not have extended to completely changing the ways in which mechanical loadings from labor and activity were incorporated into the body. However, it also shows that while economic access might not have modulated work or daily life activities for women, there were certainly long-term health consequences with regard to bone maintenance and quantity. Complementarily, it may also affirm that the positive relationship between bone mass and bone strength that has been hypothesized elsewhere (e.g., Mays 2006a).

Comparison with Italian Peninsula

Raw data published by Ruff et al. (2018) was aggregated and standardized according the procedure outlined above, in order to compare the Villamagna and Pava data with other sites in the Italian peninsula (ranging from 30,000 years BP to 1950) (Figures 4.23, 4.24). With regard to %CA, the mean values computed from the Pava and Villamagna samples were not significantly different from Ruff et al.'s (2018) Medieval, Early Modern, or Very Recent samples (Figure 4.23). All medieval samples had significantly lower mean %CA values compared with the Bronze age, Late Upper Paleolithic (LUP) and Early Upper Paleolithic (EUP) samples (Figure 4.23). This trend is expected based on extensive previous research on long-term changes in human adaptation to climatic and geographic variation since the Paleolithic that shows increasing gracility amongst modern *H. sapiens* globally (Baab et al. 2010, Ruff et al. 1993, Holt et al. 2018, Shaw & Stock 2013, Stock 2006).

Villamagna and Pava (all periods) had increased AP loading compared to other Italian medieval samples, with mean I_x/I_y values more similar to the Mesolithic samples from Italy, but considerably more gracile with less AP loading than the EUP and LUP (Figure 4.24). This may be due in part to relatively higher variance in I_x/I_y means in middle and older age individuals from Pava and Villamagna (Table 4.11, 4.12). Mean I_{max}/I_{min} values from Late Medieval Villamagna, and from the aggregated Late Medieval sites across the Italian peninsula share a high level of variance (Figure 4.25, Table 4.12, Figure 4.16, 4.17).

One of the primary metrics used to interpret trends in AP loading and bending rigidity (I_x, I_x/I_y) is the terrain within 10 km of the site where individuals were presumed to have lived (Ruff et al. 2018); and differences in I_x/I_y and I_{max}/I_{min} ratios are often interpreted as differences in overall mobility. It is likely that the relatively high values of I_x/I_y at Villamagna, compared to other medieval sites, reflects the mountainous to hilly local terrain. Following Ruff's (2018) procedure for classifying terrain and the method for this calculation they outline, I found the average slope of the area directly surrounding Villamagna to be 14.4%, with maximum slope 24.4%. Ruff et al. (2018) classify any area with an average slope above 8% to be mountainous, given there are maximum slopes within the area that range from 22% grade to 44% grade. Therefore, it is expected that individuals at Villamagna might have more AP loading than other medieval people, particularly from the other medieval sites included in Ruff et al.'s (2018) study. Lower I_x/I_y values for people from the central medieval period at VM, indicating less antero-posterior mechanical loading in the femur, may support this notion that the central medieval monastery was particularly compact and that the people buried at VM during that period were not consistently traveling far in the rugged topography surrounding the monastic

Figure 4.23 Comparison of %CA in Italian Peninsula populations from 30kyBP to 1950

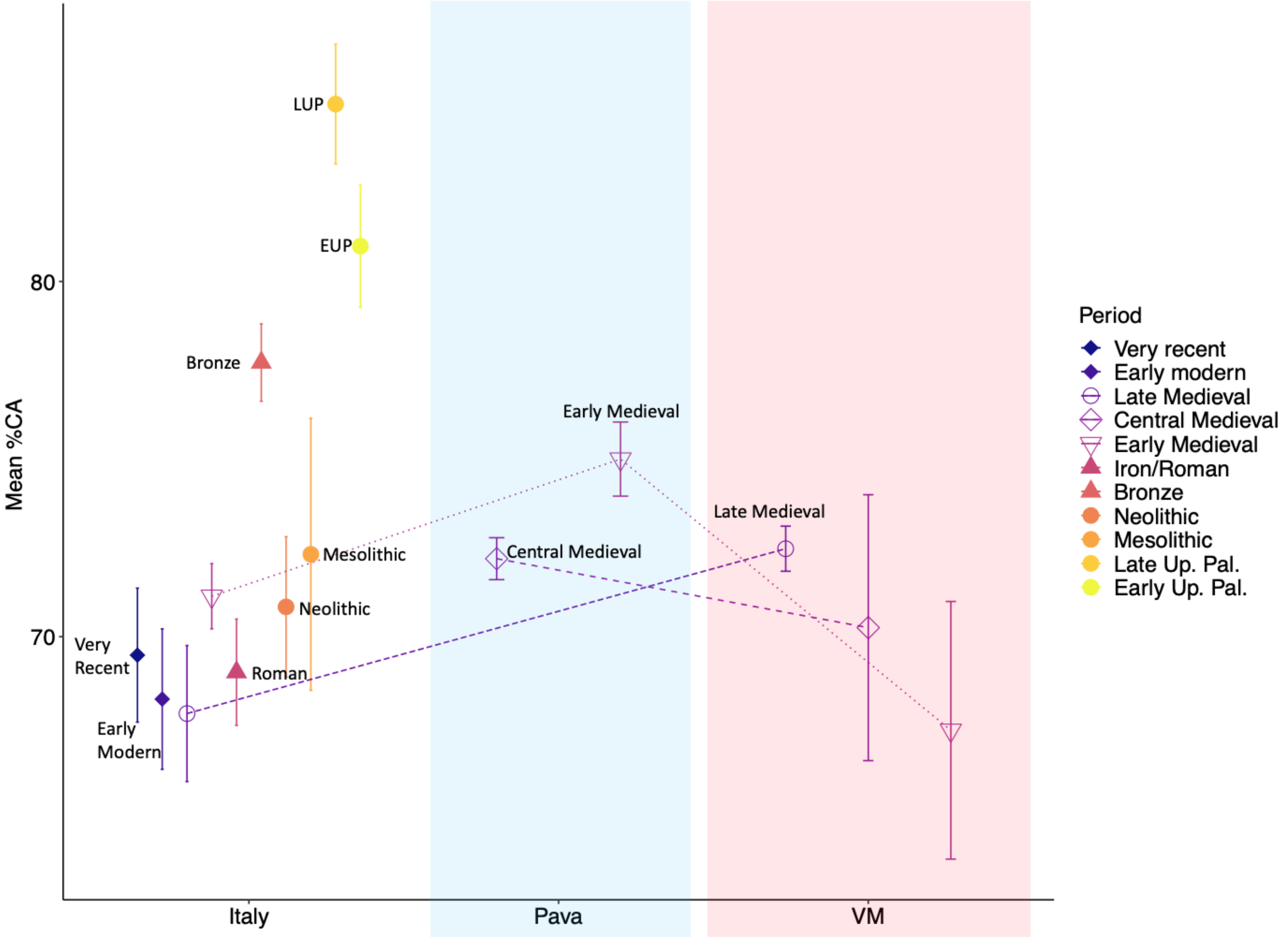

Figure 4.23 – Mean cortical area is measured on the y-axis and location measured on the x-axis; Means from Pava are in the blue box and means from Villamagna are in the red box. Lines connect observations from the same time periods but different sites (i.e., Early Medieval Italy, Pava, and Villamagna). Mean relative cortical area (%CA) is higher for the Central period at Pava and Late period at VM compared to pooled Late Medieval Italian peninsula sites.

Figure 4.24 Comparison of I_x/I_y in Italian Peninsula populations from 30kyBP to 1950

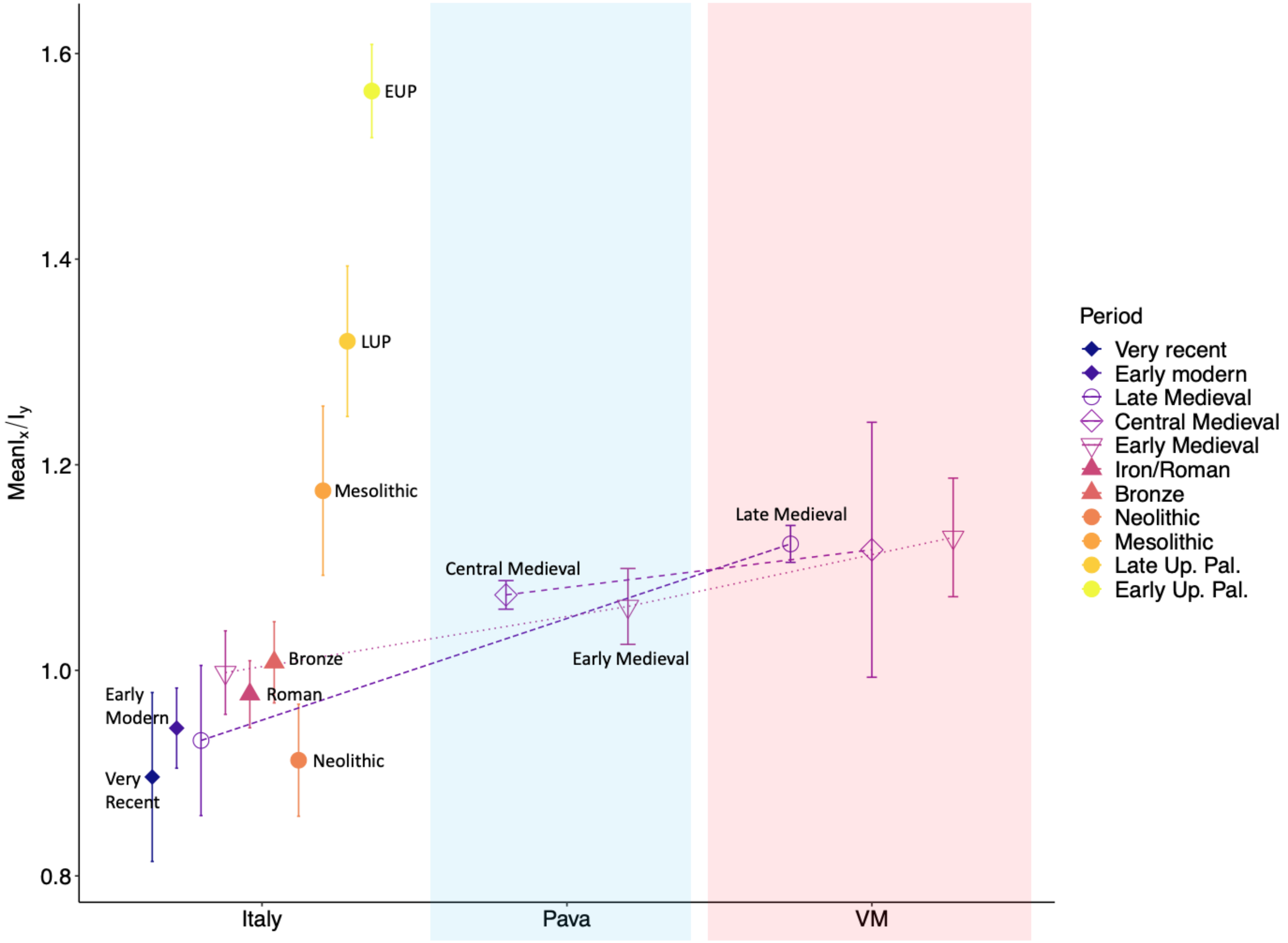

Figure 4.24 – Mean cortical area is measured on the y-axis and location measured on the x-axis; Means from Pava are in the blue box and means from Villamagna are in the red box. Lines connect observations from the same time periods but different sites (i.e., Early Medieval Italy, Pava, and Villamagna). I_x/I_y means significantly higher at Pava and VM compared to other pooled Italian peninsula sites from the same periods.

Figure 4.25 Comparison of I_{max}/I_{min} in Italian Peninsula populations from 30kyBP to 1950

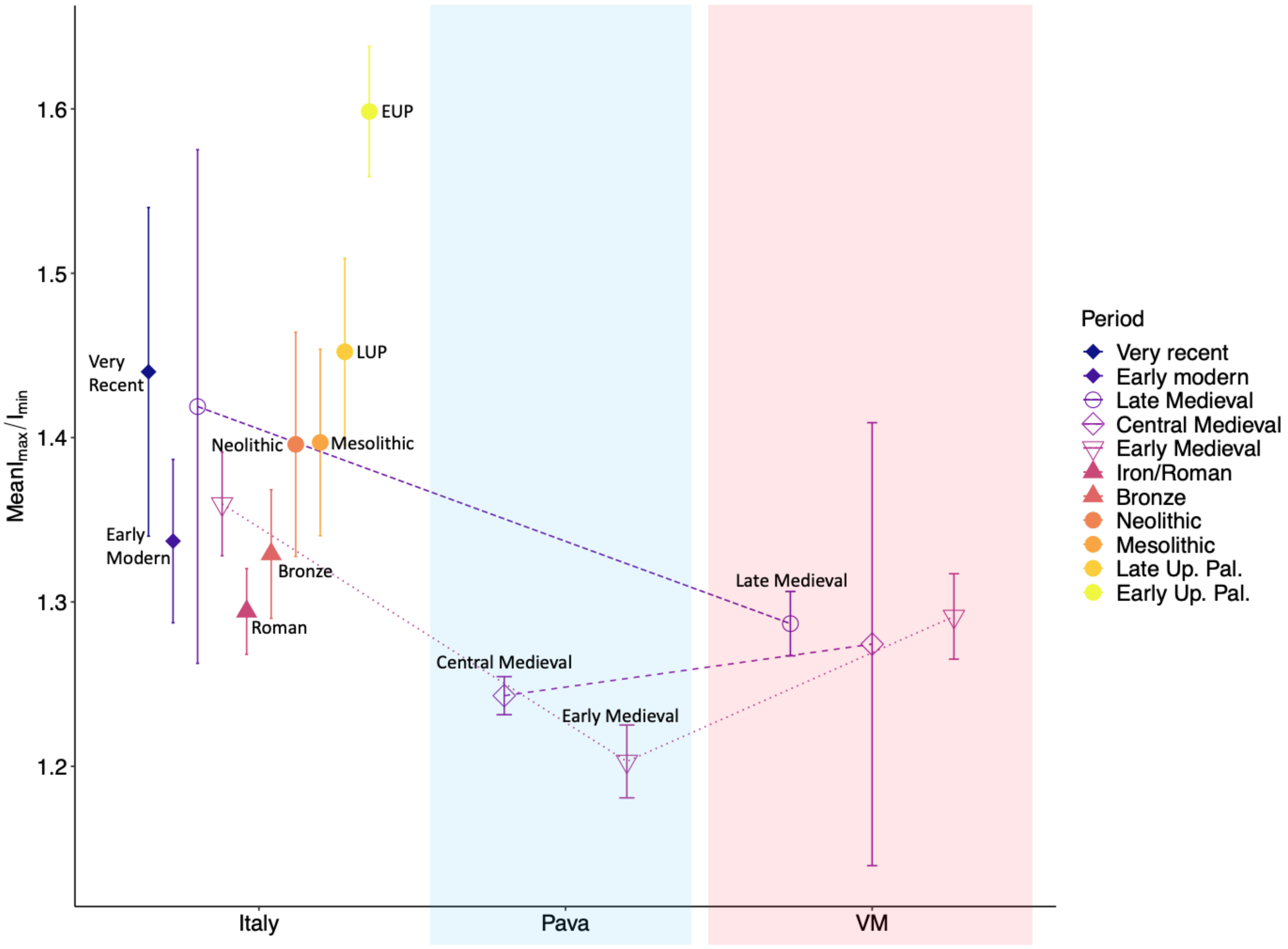

Figure 4.25 – Mean cortical area is measured on the y-axis and location measured on the x-axis; Means from Pava are in the blue box and means from Villamagna are in the red box. Lines connect observations from the same time periods but different sites (i.e., Early Medieval Italy, Pava, and Villamagna). I_{max}/I_{min} are significantly lower at Pava and Late Medieval VM compared to the pooled Italian peninsula samples from the same periods.

estate (Carocci 2016). Expected heterogeneity in medieval life, due to inequality, social complexity, and differential access to opportunity and privilege likely causes the higher amounts of variance in diaphyseal shape. Variation in mechanical loadings (due to a diversity of lived experiences and occupations), within an individual's lifetime as well as between individuals is a probable cause of the higher variance in mean I_x/I_y and I_{max}/I_{min} ratios (Table 4.11, 4.12).

Conclusions

Bone is a dynamic and biocultural tissue fundamental to our understanding of human evolution and archaeological reconstructions of human lifeways. How bone responds to differential mechanical loading is a central question in biological anthropology, although it is well established that changes in the manner, direction, and repetition of loading in the skeleton affects bone geometry (e.g., Lieberman et al. 2001; Pearson & Leiberman 2004; Ruff 2008), the extent of biocultural experiences such as sex-gender, age, and disease have not been fully considered as main or confounding effects in most studies of biomechanical use in the past. It is well established that bone modeling and remodeling are regulated by multiple cellular, physiological, and environmental mechanisms (e.g., diet) across the skeleton during the life cycle (Nelson et al., 2002); and that these mechanisms are impacted by biocultural experiences related to identity in the past. Therefore, it is likely that identity, daily life experiences, and socio-political life impact bone biomechanics.

In this chapter, I have established the baseline trends that shape the Villamagna and Pava populations with attention to the ways in which variation is omnipresent to different extents in the population(s). There are five main conclusions based on the results of this chapter: (1) measures of sample dispersion (CV, or variation) are highest in the older age cohorts at Villamagna, particularly with respect to bending strength ($Z_{p\text{-}std}$), bending rigidity (J_{std}), and percent cortical area (%CA); (2) there are regional differences (between Pava and Villamagna) in mechanical loadings on the AP-ML planes consistent with the expected differences between the site based on their local topography; (3) there are site differences in relative femur bending strength and bending rigidity where Villamagna has increased mean strength and rigidity compared to Pava; (4) there are sex differences in bending strength ($Z_{p\text{-}std}$) and bending rigidity (J_{std}), that are consistent across the two sites and consistent with differences seen at other medieval sites that likely reflect gendered divisions of labor; (5) although medullary area and total area increase with age at Villamagna, J_{std} and $Z_{p\text{-}std}$ are still maintained or even higher amongst older age females indicating that bone loss does not have a linear negative relationship with bone strength.

Regional differences in Medieval Europe were a product both of local environmental differences (e.g., geography, topography, climate, ecology), as well as differences in political, religious, and economic landscapes. Medieval people were embedded in a complex landscape of inequalities and difference, intersecting with regional and local differences in their ecological systems and knowledges, growing seasons, food availabilities, and natural resources. Aside from topographical differences between Pava, in southeastern Toscana, and Villamagna in southern Lazio, are differences in the socio-political histories of these two areas. Pava was located in the abundant hills of southern Tuscany, approximately halfway between two powerful cities: Siena and Arezzo. It is documented that during the earlier part of the medieval period there was unrest and ongoing land disputes between the bishops of Siena and Arezzo regarding the area of Pava and its farmlands. More broadly, Tuscan peasants were part of a primarily sharecropper rural economy, where communities would collectively pay towards the rental costs for feuda that were managed together.

Villamagna, by contrast was located in the heart of the Papal State and was not part of a sharecropping economy. Communities in southern Lazio shared many characteristics with Norman kingdom villages, in particular the organization of the rural monastery and the preservation of a feudum-style institution. It is known that in the Late Medieval period at Villamagna, a majority of individuals traveled from their central residence to the farmlands they cultivated. While there is evidence for peasant subversion of the extractive Tuscan sharecropping system, including a number of revolts and peasant uprisings – the maintenance of class divides between peasants and elites (further divided along axes of proximity to the city and its resources) required the full involvement of the Tuscan peasantry. Villamagna on the other hand, seems to have been left largely to its own devices as the Papacy moved temporarily to Avignon in the 13th century, although Lazio remained part of the papal state. These political histories are part of the larger landscape of inequality, labor, and activity that shapes not only bone morphology at the sites, but also experiences of daily life and physical activity (as seen in Chapter 3).

This study found that sample dispersion, or variance for the older age cohorts was higher than other groups included in the study. The "older age" category is widely used in bioarchaeology, and yet is particularly problematic because it includes individuals presumed to be any age above 50 years old. Based on empirical and anecdotal data, it is abundantly clear that the daily life, experiences, and lifestyles of adults between 50-100 years are variable and distinctive both in terms of biological constraints and affordances, and in terms of cultural position. The intersection of aging with disability is a frequent topic in disability studies and is widely discussed in terms of caregiving (e.g., Stevenson 2014, Hall 2011), the temporalities of the body and identity (e.g., Reynolds 2018, Grenier 2016), and long-term population trends (e.g., Freedman 2018). Although conceptualizations and methodological issues regarding aging for older adults were not the object of this study, it is clear that there is considerable variation in older adults that should be addressed by future research and further studies. Future research looking at variation within the older age cohort is crucial for bioarchaeology to develop a more robust perspective on aging and the life course.

Additionally, results from this study show that economic access to the privileges associated with grave good inclusion may not have improved bone health, but *inaccess* to those privileges certainly had an effect on female bone quantity (increases in %CA, decreased medullary area). Differences in access to economic privilege did not buffer the amount of activity or types of activity performed by people within those groups, as measured through cross-sectional geometry *and* spine disease observations. The average Villamagna female likely did not have access to economic privileges, as the number of females buried with grave goods is quite low (n=11). An in-depth look at *who* the people buried with grave inclusions shows a heterogeneous mix of males and females, of varying age, with diverse and distinctive experiences across the life course (e.g., evidence of joint disease, metabolic difference, stress indicators, fractures).

My disability anthropology orientation to mobility and movement highlights the role of difference in generating the variation seen between and within individuals at Pava and Villamagna. Framing this difference in terms of biopolitical risks (here, with regard to differences in bone quantity) allows for a more complex understanding of the role of variation in individual experience, as well as in the construction of a mean, or average. Medieval economies have long been understood in terms of strict gendered divisions of labor, and generally there were strong gendered expectations and intersectional trends of inequality that shaped medieval culture. Results from this study suggest that gendered divisions of labor and their effects on bone were shared between Tuscany and Lazio, however the ways in which these gendered labor practices were embedded in larger landscapes of inequality was more variable. In this study we found that bone strength and bending rigidity means were higher amongst males overall, however spine evidence suggests that males and females were both participating in strenuous physical activities that produced biomechanical injuries and strain in the spine.

Chapter 5:

Counter-Diagnosis: A case of unusual gait from Medieval Villamagna and the case for crip solidarity with the archaeological past

Orientation

In this chapter I continue my analysis from Chapter 4, focusing on a group of individuals who exhibit signs of unusual gait from one of the study sites: Villamagna. As a group, these individuals are not unified by age, sex, time period, site, economic access, or disease outcome, suggesting that this gait is best understood through the lens of intersectional and particularity of experience—rather than through a generalizing evolutionary or medical lens. I closely examine the skeletal remains of one individual, VM 9, within this sub-population in order to investigate alternative bipedalisms through a crip orientation. I draw on osteological material, published medical research, web-based community support resources, disability assessments, historical archives, and my own embodied knowledge of chronic pain as evidence. Due to the dearth of ethnographic research within and amongst many disability groups, I employ a diffractive reading technique of various modes of writing from clinical and community perspectives (on diffractive reading, see Barad 2007, Geerts & van der Tuin 2016, Trinh Minh-ha 1988, 1997). Diffractive reading, examining the "patterns of difference that make a difference," reveals intensities or gaps in symptomology and situated experience, instead of the typical focus on pathophysiology or disease etiology (Barad 2007:72). In particular I use the Neck Disability Index[1] (NDI, developed by Vernon & Mior 1991), which is widely used by clinicians to assess the effects on daily life of neck disability and used to determine disability status, to diffractively generate a symptomological framework for interpreting the skeletal remains and traces of VM 9.

Osteobiography, the practice of writing biographical narratives based on skeletal remains, is a methodology utilized widely across bioarchaeology (e.g., Hosek 2019, Robb 2002, 2019, Tilley & Oxenham 2011, Hawkey 1998, Stodder & Palkovich 2012). These approaches encompass a spectrum of theoretical-political orientations within bioarchaeology: from speculative fiction at one extreme (e.g., Boutin 2012), to more descriptive and conservative narrative on the other (e.g., Stodder & Palkovich 2012, Saul 1989). Many osteobiographical studies, like clinical case studies, rely on a close examination of a single exemplary individual in order to extrapolate about the population more broadly (e.g., Ellis 2020, Tilley & Oxenham 2011, Robb et al. 2019).

The osteobiography was popularized in the late 1980s from a desire to repopulate the past with individual stories and lives. Feminist interventions in archaeology pushed traditional aggrandizing narratives of power, evolution, politics, and culture, towards more critical, contextual, intersectional, and situated approaches (e.g., Conkey & Gero 1997, Conkey 2003, Joyce 2000, 2005, 2006, Tringham 1994, Wylie 1991, 2002); while feminist interventions in genres tangential to biography, such as life histories (e.g., Behar 1996, 2003), life writing (e.g., Coleman 1997, Lawless 1991, Metta 2010), and autobiography (Perreault 1995) foregrounded

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[1] The NDI is often used and remarked upon in clinical case studies of Klippel-Feil syndrome and other diseases that affect the spine (e.g., degenerative joint disease and whiplash).

discussions of genre and positionality in literature and literary criticism (Kadar 2014). Later, the incorporation of feminist and critical perspectives in bioarchaeology was elaborated in the 2011 edited volume *Social Bioarchaeology* (Agarwal & Glencross 2011), a foundational text that spotlights the role of identity and life history in bioarchaeological research by emphasizing a multi-scalar approach.

Practices of osteobiography in bioarchaeology draw on the materiality of the human skeleton to construct a biography of daily life and lived experience for individual people. The osteobiographical approach examines the particular and the individualistic, as a means of accessing larger cultural dynamics that structure daily experience that have already been observed. The practice of osteobiography falls into the realm of what might be called "scientific biography," which is problematic for its abdication of accountability in the name of fiction and is a largely non-theoretical activity (Monk 2007). Often, the osteobiography tradition has focused especially on people with skeletal indicators of impairment, disease, and physical difference (e.g., Battles 2011, Boutin 2016, Boutin & Callahan 2019, Tilley & Oxenham 2011); and individuals chosen for osteobiographical analysis are always exceptional in some way—much like in political or celebrity biography. Unlike celebrity or political biographies, these subjects are often those who are most vulnerable to misrepresentation and exploitation due to their embodied identities (Couser 2004:15); therefore an osteobiographical rending would require a particularly robust bioethical approach, which is often not achieved (on ethics and activism in osteobiography see Geller 2019, Battles 2011, Boutin & Callahan 2019).

In this dissertation chapter, I see my orientation to vulnerable subjects, or archaeological skeletal remains as tangential to osteobiography as such. As Couser asserts, vulnerable subjects are "persons who are liable to exposure…[and] are unable to represent themselves in writing or to offer meaningful consent to their representation" (2004:xii). The identification of osteological remains as vulnerable subjects, and issues of consent from skeletal remains in bioarchaeology are central to the fomentation of an ethical praxis. Building on feminist and intersectional interventions in life-writing and ethnography (see Visweswaran 1997 for more on the history of feminist ethnography), I approach writing narratives of skeletons as an osteo-ethnographer and disability anthropologist. My practice is influenced and informed by the now-classical writing of feminist ethnographers Ruth Behar (1993), Behar & Gordon (1995), Margery Wolf (1992), and Kamala Visweswaran (1994), and more recent experimental contributions by Berlant and Stewart (2019), Stone (2019), Pandian and McLean (2017), and Joyce (2020). Issues of consent, privacy, and positionality are central in feminist ethnographic writing; therefore, these approaches are particularly suited to developing a more robust ethical orientation in osteo-ethnography. Grounded in materiality, I use a multi-method approach to access embodiments from medieval temporalities—building a narrative that is more ethnographic than biographical in its content and purpose.

Writing is an inherently relational activity, that requires sustained and dynamic reflexivity. This material-discursive (Barad 2007) capacity of writing is particular consequential in research that is community-engaged or community-initiated in nature. I situate my approach to "osteobiographical" writing in terms of my own embodied experiences of disability and chronic pain, which orient my positionality as a researcher and writer. From this position, I align my theoretical engagement more closely with those seen in the genera of disability life-writing (Couser 2009, Dauncey 2012, Kadar 2014, Rimmon-Kenan 2002), disability auto-ethnography

(Bloom 2019, Chang 2016, Kasnitz 2020, Khosravi 2010, 2016, Neville-Jan 2004, Richards 2008), and disability anthropology (Hartblay 2020, Bloom 2019), three practices that find homes in the disciplinarity of Anthropology and Disability Studies (see also Price 2011 on genre). As Miller (2015, 1984:151) writes in her historically transformative paper “Genre as Social Action,” a “sound definition of genre must be centered not on the substance or form of discourse but on the *action* it is used to accomplish” (emphasis my own). In this sense, genre is less taxonomically bound to historic typologies of writing and instead congeals around social actions and the agentive capacity of writings across historically distinct genres. With special attention to the agential capacities of archaeological writing, Joyce (2008:1-5) notes, the situated event of narrativization—an act of “social communication”—is not limited to a certain type of writing within archaeology, as the narrative itself is an emergent and iterative becoming with research practice. Joyce further writes that the, “original narratives of field and lab continue to inhabit written texts as multiple voices,” and also contribute the material consequences of writing. Joyce argues for the expansion of the genre of archaeological writing to include more experimental forms that are united as social communication, rather than historical typologies.

The mode of social communication practiced in this writing speaks to the political aims of disability anthropology—centering “the expertise of the disabled” and exposing “the relationality of the writer” (Kasnitz 2020). The ethics of narrativizing or representing people’s experiences in life-writing, osteobiography, or ethnographic life histories is particularly suspect with subjects who are already disenfranchised (Couser 2004); and therefore, this writing requires a substantive and explicit ethical and political statement of accountability.

My material-discursive intervention attempts to heal the painful erasure of disability and disabled people from the archaeological past. Although much of this erasure is well-meaning and is borne from an attempt to enact the social model of disability (to contextualize and de-naturalize disability as a category of personhood), the denial of bodymind difference functions as an erasure of disabled people’s history and lived experience, no less. In this chapter, I do not attempt to universalize disability nor reify it as a category of existence; instead, I operationalize disability as a political orientation to the body in order to liberate it from eugenic and normalizing ideologies that attempt to limit the temporal and spatial reaches of disability.

Diagnosis and Identification

Bioarchaeological analyses of disease in the past rely on a technique, initially borrowed from medicine and veterinary science known as *differential diagnosis* (e.g., Buikstra & Cook 1980, Lawler 2017, Ortner 2003). In bioarchaeology, the differential diagnosis has been a mainstay of paleopathology, the study of disease in the past. The practice of differential diagnosis begins with gross anatomical observation of traits or features that deviate from the expected macroscopic appearance of bone. An iterative and dialectical process of descriptive writing, photographing, sketching, and active engagement with the skeleton occurs within the skeleton-bioarchaeologist apparatus (Barad 2007). The subfield of paleopathology focuses on how diseases, infections, and differences in life manifest in the skeleton (Buikstra & Cook 1980, Pinhasi & Mays 2006, Ortner 2003, 2011). The skeleton is involved in numerous chronic diseases and infections, including cancers (Klaus 2016, 2018 Lieverse et al. 2014, Melikian

2006), tuberculosis (Klaus et al. 2010, Mays et al. 2001, Roberts 2011, Roberts & Buikstra 2003), syphilis (Erdal 2006, Zuckerman 2016, Zuckerman & Harper 2016), rickets (Brickley et al. 2010, Mays et al. 2006, 2007, Veselka et al. 2015), and rheumatoid arthritis (Fornaciari & Giuffra 2013, Kilgore 1989, Leden et al. 2012, Rothschild et al. 1992) to highlight only a few. Throughout the process of documentation, a list of possible etiologies, or origins for the skeletal involvement are developed. Based on clinical manifestations of disease, as well as previously known examples, the skeletal remains under investigation are examined for features and traits known to be associated with each possible diagnosis. Visualizations of the distribution of lesions across the skeleton is commonly used to help identify infectious diseases, like leprosy, tuberculosis, and treponemal diseases (Roberts & Buikstra 2003).

And yet, the issue of diagnosis remains problematic. Grauer and Miller (2017) points out that many differential diagnoses are made on the basis of skeletal collections like the Hamann-Todd collection (19th century Cleveland, Ohio), which have autopsy reports and clinically known causes of death associated with the skeletal remains. Many of these ostensibly known causes of death are less accurate than previously thought, due to inadequate healthcare or biased diagnoses at the time of death, in the 18th-19th centuries (Grauer & Miller 2017). The process of diagnosis is not ahistorical, and therefore must be carefully applied with attention to how it systematically reproduces historical erasures of disease. Recognizing this limitation, Smith-Guzmán et al. (2016) develop a framework that goes "beyond differential diagnosis" and by incorporating local taxonomies of disease, based on (in their case ancient Near Eastern) texts, population-based diagnostic models of possible diseases for the local area, theoretical models of disease evolution and ecology, modern disease data, skeletal indicators, and spatial trends in disease. Using this approach, they attempt to combat some of the limitations of differential diagnosis in order to make a more holistic claim about the prevalence and incidence of malaria in the ancient Near East.

Diagnosis remains fraught in contemporary medicine: necessary for insurance authorizations, access to care, access to legal protections, and yet also a bin for generalization, otherizing, and exclusion (Price 2009, Rimmon-Kenan 2002). Diagnosis can be a powerful moment of self-recognition and an introduction to the Disability Community (Yergeau 2018); and it can be a demoralizing and slow bureaucratic process or completely socially and economically inaccessible. Diagnosis is an inherently static categorization that seeks to pin down a body that is dynamically unstable. An important intervention for disrupting the hegemonic narratives of diagnosis, is the practice of *counter-diagnosis* (Price 2009). Counter-diagnosis *queers* conventional diagnostic stories through an enactment of complication, confusion, and fragmentation (Price 2009). This subversive refusal to disclose oneself is part of the "shape-shifting" power of counter-diagnosis: "accepting, rejecting, mimicking, and contesting the diagnostic urge" (Price 2009:17). In this work I employ a counter-diagnosis approach to VM 9, whose materiality complicates the practice of traditional differential diagnosis.

Central to contesting diagnosis is the matter of authorization and power. In her book, *Fantasies of Identification* (2014), Ellen Samuels outlines the concept of *biocertification* (Samuels 2014:122), drawing on Foucault's theorization of biopolitical citizenship. Biocertification is a materialization of a person's social identity, apparently with the ideal of authenticating a person's social identity using scientific or biological evidence (Samuels 2014).

This state-recognition of disability is often vital for access to employment, basic needs, and care; and frequently denying embodied experience as evidence, relying instead on medical reporting and documentation.

This process of biocertification is made more discrete with the advent of DNA, and the use of genomic analysis to identify and characterize diseases (see Fausto-Sterling 1992 on feminism critiques, see TallBear 2013 for post-colonial critique). So, although genetic evidence can be used to more discretely define the molecular etiology of a disease, medieval people did not have the technological capability nor epistemological apparatus for genetic identification of diseases. Using a feminist-materialist and disability orientation to these empirical data, I employ a tactic of counter-diagnosis to explore lived experience and bodily difference in the case of VM 9. With this orientation, I use Ginzburg's "method of clues" to improvise a microhistorical approach (Ginzburg 1979, Peltonen 2001, 2014) that encompasses and moves beyond the limits of a diagnosis-centered narrative.

In "Clues" Ginzburg (1979) theorizes "an epistemology based on clues" (283), drawing on the analogous approaches of Giovanni Morelli, Arthur Conan Doyle's Sherlock Holmes, and Freud in order to elaborate this *method of clues*. Particularly salient for my purposes here is that this method of clues, which becomes the basis for the *new microhistory,* is in fact derived from the medical practice of differential diagnosis. Ginzburg (1979) carefully notes that Freud, of course, was a doctor; Giovanni Morelli had a medical degree; and Conan Doyle was a practicing doctor before becoming an author (280). Therefore, the method of clues, as Ginzburg first elaborated it, is a practice of observation and analysis of symptoms, which are not merely semiotic representations of themselves—but clues of something else entirely, albeit on a different scale. It is this particular issue of scale that is characteristic of the microhistorical approach. Clues, or symptoms are the material traces of larger structures and macro-historical phenomena, not merely biographical details.

Ginzburg's method of clues is not a metaphorical attention to symptoms and traces; he insists that this method—derived from his analysis of Morelli, Conan Doyle, and Freud—reveals a "*model of medical semiotics* that makes it possible to diagnose diseases not recognizable through direct observation and is based on superficial symptom sometimes irrelevant to the layman" (Ginzburg 1979: 280). In my approach, I connect Karen Barad's (2014) diffractive technique to Ginzburg's: I emphasize the role of the researcher-writer in the observational process, the dynamism in archaeological temporalities, and "iterative repatterning" (Barad 2014:169). My intervention draws on Ginzburg's theorization of method and scale for historiographical research and articulates it with Barad's diffractive technique in order to examine "thicker" moments of spacetimemattering (2014:169), which are dispersed and diffracted throughout this dissertation and through crip-archaeological time.

Unusual Gait

In Chapter 4, I presented the results of the population-level cross-sectional geometry study from Villamagna and Pava. Over the course of this analysis, I used a series of data-visualization techniques to look at trends in the data and become familiar with the data set. As part of this iterative practice, I made a rudimentary plot of I_x/I_y and I_{max}/I_{min} (Figure 5.1)—two response variables that should be highly correlated for each individual as they both measure directional and overall bone shape related to mechanical loading (Stock & Shaw 2007). A small number of individuals stood out as unusual. These individuals were not outliers but had an unusual configuration of biomechanical indicators; their I_x/I_y values were relatively low and their I_{max}/I_{min} values were relatively high. This unusual combination is similar to results published in Cowgill et al.'s (2010) study of juvenile gaits during growth. Differences in long bone shape have been used to infer differences in terrestrial mobility (Holt 2003, Holt et al. 2018, Larsen 1997, Stock & Pfeiffer 2001, 2004, Ruff et al. 2018) as well as the manner of mechanical loading (Cowgill et al. 2010, Ruff 1995, Ruff et al. 2006). Cowgill et al. (2010) found that young children produce greater ML and lower AP mechanical forces than adults while walking, with greatest peak medial (ML) force at age 1.0-3.9 years and lowest peak medial force in adults. This translates to low I_x/I_y ratios, but relatively high I_{max}/I_{min} ratios. Although this study focuses on mechanical loadings in immature gait, they find a divergent trend between I_x/I_y and I_{max}/I_{min} ratios in very young children, age 1.0-3.9 years, compared to older children (greater than 6.0 years) (Table 2 in Cowgill et al. 2010). Figure 5.1 was made based on adult cross-sectional geometry data from Villamagna and included all individuals who were observed including some individuals with skeletal manifestations of disease (although these were not included in the population-level analyses). It was possible that some of these individuals had different mechanical loadings than other individuals due to disease, although it was not expected for those individuals to have unusual or different biomechanical signatures based on gross anatomical observations during the data collection process. It was also possible that these differences were due to observer error.

All of the Villamagna with this unusual gait signature were further examined for data processing errors or other observation-related reasons for this difference. Due to the independent identification of both lateralities (left and right bones) as different from the population-at-large (they were independently scanned), it is unlikely that the difference between I_x/I_y and I_{max}/I_{min} arises from observer error. Additionally, no abnormalities were observed in the CT scans themselves for these individuals affirming the integrity of the data collected from those CT scans. Only 2 individuals from those observations (in the purple ellipses) in Figure 5.1 had known bodily differences related to disease or trauma. All of these individuals, had an entirely different and unusual gait, compared to other observations at the site—the question I pursue in this chapter is why.

I resist describing the variations in mechanical loading relating to gait in Figure 5.1 "pathologic" or deviations from a "normative" gait because they are not necessarily non-normative. One material-discursive consequence of the rhetorical divide of that otherizes disability is the creation of an artificial boundary between differences in behavior that are perceived as biological and differences in behavior that are perceived as cultural. Disability is often purposefully naturalized as a biological category of personhood, rather than considered a complex biocultural and political identity. Cultural behaviors are rarely linked to biological anthropology studies of gait in past people (c.f., Aldred 2013, Tilley 2012, Tringham 2012), although anthropological studies on the "sociocultural" aspects of walking and movement are abundant, including abstract approaches and more literal approaches (e.g., Bidwell et al. 2013, Doughty 2013, Fuentes 2015, Ingold & Vergunst 2008, Horton et al. 2014, Karasik et al. 2015, Pinder 2011).

Figure 5.1 Plot of diaphyseal shape indices I_x/I_y and I_{max}/I_{min} for all individuals at Villamagna

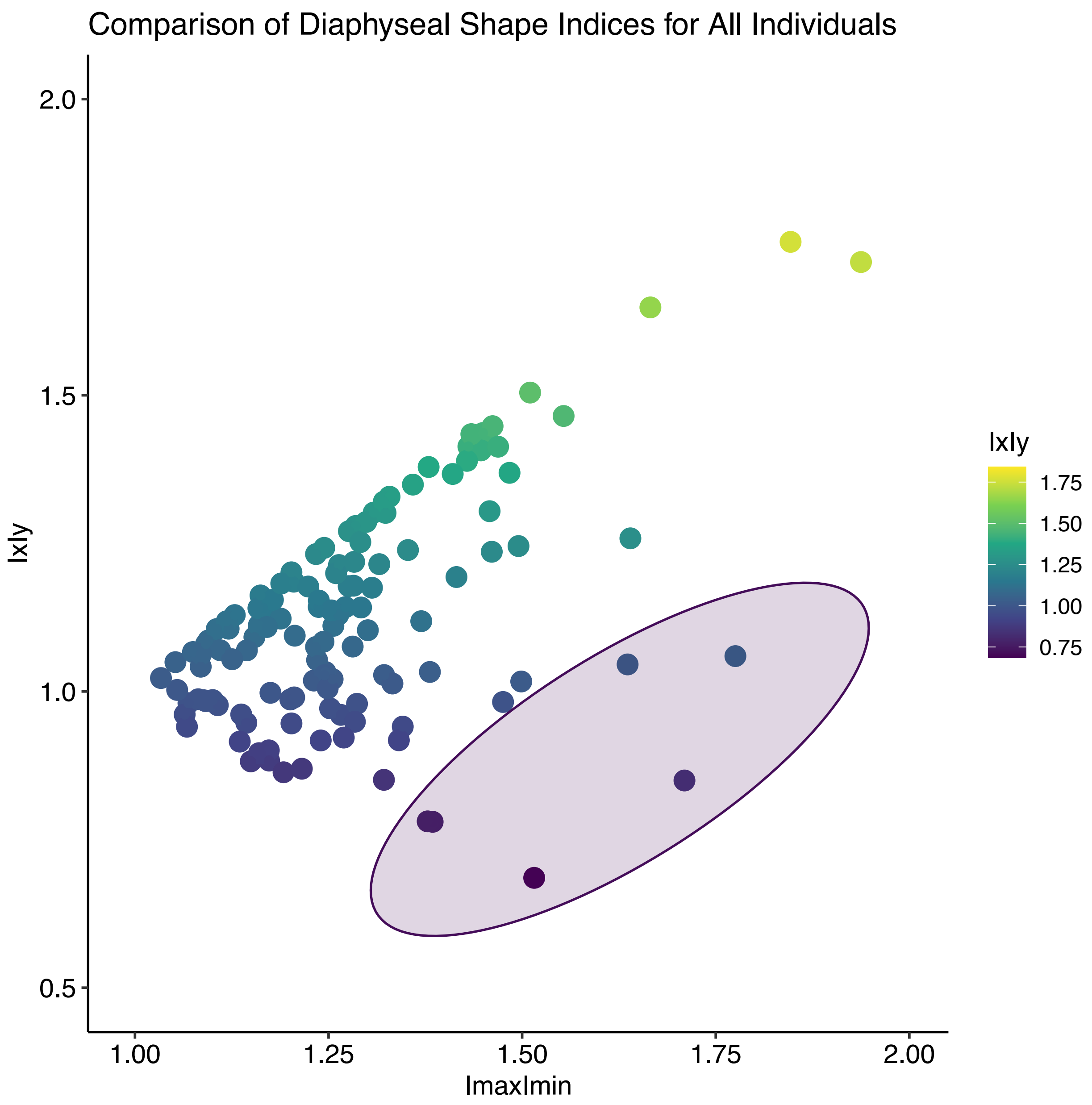


Figure 5.1 – This figure shows I_x/I_y, a ratio of AP to ML loading on the y-axis and I_{max}/I_{min}, a ratio of maximum to minimum loading on the x-axis. Data points represent one femur from the Villmagna study site only. Bones encompassed in the purple ellipses (bottom) have discordant I_x/I_y and I_{max}/I_{min} ratios with greater than 20% difference between to two values.

A Neutral Plane

My first step was to examine the raw data for these individuals (I_x/I_y and I_{max}/I_{min} do not have to be standardized for body size because they are ratios). Table 5.1 presents the raw data for I_x/I_y, I_{max}/I_{min}, and the percent difference (%Diff) in diaphyseal shape for these individuals from Pava and Villamagna:

$$\% \, Diff = \left(\frac{\frac{I_x}{I_y} - \frac{I_{max}}{I_{min}}}{\frac{I_x}{I_y} + \frac{I_{max}}{I_{min}}} \right) \times \, 100$$

Percent difference was calculated for all femora observed, and Table 5.1 was generated to include any individuals who had greater than 20% difference in I_x/I_y and I_{max}/I_{min}. This included all of the individuals in the purple ellipses, as well as two bones that followed the trend but were a frame-shift away from this trend: HRU 8 and HRU 11 had slightly higher I_x/I_y values than others, but their I_{max}/I_{min} value was more than 20% greater than I_x/I_y. Slightly more of the individuals in this subset were male (n=3), compared to females (n=2).

Table 5.1 presents the demographic information for these femur observations with marked differences in I_x/I_y and I_{max}/I_{min}. These people were identified as unusual based on the general population trends at Villamagna for gait and biomechanical limb use. These 5 people had cross-sectional properties that suggest the mechanical loadings from lower limb use were more similar to the gait of very young children (relatively higher ML loadings), who are learning to walk (Cowgill et al. 2010, Schug & Goldman 2014). This side-to-side, mediolaterally reinforced gait is characterized by higher ML loading and consistent AP loading, an unusual gait compared to published literature. This means that these individuals likely shifted their weight from one side to the other, moving their body weight side-to-side rather than front-to-back. These individuals with relatively low I_x/I_y ratios (and high I_y values), and high I_{max}/I_{min} ratios have high maximum mechanical loadings influencing their bone morphology. However, these loadings occurred primarily on an axis other than the neutral axis. This could be due to actual biomechanical differences or due to observer error in bone scanning.

Not all individuals who were identified in this sub-population had extensive osteological material or data to contextualize these findings, and some of this post-hoc analysis is interrupted by access to remains that are currently housed in Italy. Fragmentation is a defining aspect of archaeological data and a valuable component of an archaeological and disability aesthetic (Joyce 2018, Kinkopf 2016). Thus, there are variable levels of resolution for these individuals—and presence of grave goods and disease are confounding factors that influence that amount of information that is known about certain individuals, as these are markers of difference typically legible in any archaeological study and are differentially recognized and recorded. The cemetery at Villamagna was not very orthodox in its adherence to Christian burial rites; for example many of the Late Medieval graves, including HRU 8 and 11, contained inclusions such as bells, rings (Figure 5.3-5.4), rosaries, or clothing notions and many burials are not buried in the traditional west-east direction (Goodson 2016, see Gilchrist 2012b for discussion of medieval burial rites).

Table 5.1 Summary of unusual gait data

Table 5.1 – Individuals with greater than 20% difference between two ratio measures of diaphyseal shape I_x/I_y and I_{max}/I_{min}, all individuals are in Middle or Old age, excepting one young female from Pava

Side	HRU*	Sex	Age	Period	Pathology	I_x/I_y	I_{max}/I_{min}	*%Diff*
Villamagna								
R	8	F	Middle	Late		0.69	1.52	-37.72
R	9	F	Old	Late	KYPHOSIS & TRAUMA	0.85	1.71	-33.59
L	9	F	Old	Late	KYPHOSIS & TRAUMA	1.05	1.64	-22.02
L	10	M	Middle	Late		1.06	1.78	-25.25
L	11	M	Middle	Late		0.78	1.38	-27.93
L	12	M	Middle	Early	TRAUMA	0.78	1.38	-27.68

Figure 5.2 Cross-sections for all individuals with unusual gait

Figure 5.2 – This figure shows the cross-sections of the 5 individuals with unusual gait signatures: lower I_x/I_y *and higher* I_{max}/I_{min}*. Many of the individuals have increased ML loading offset from the neutral axis, although some may have metabolic disturbances that cause these differences (bottom left).*

Figure 5.3 Rings with glass gems from Villamagna

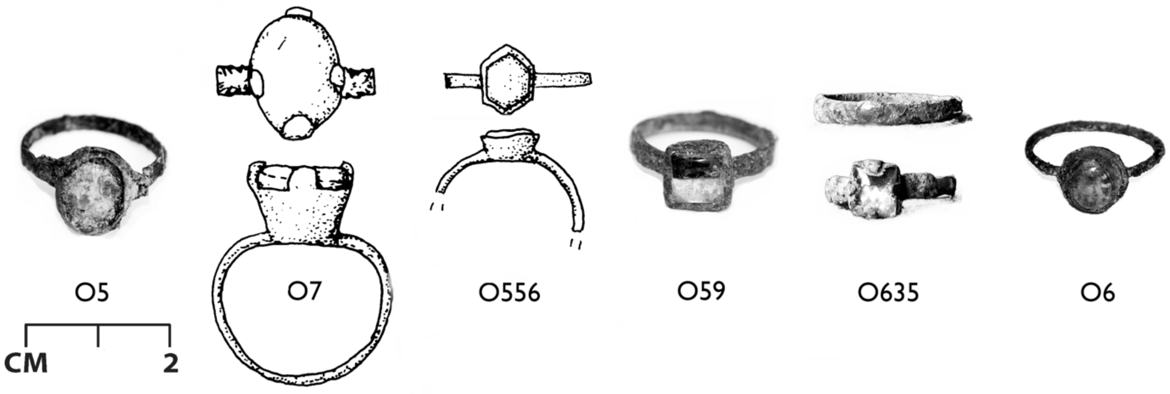


Figure 5.3 – A selection of rings with glass-paste gems, O59 and O635 have almost identical coloring: the gem from O59 is divided in two horizontally (visible above) with dark red (top) and ivory (bottom). O635 has a "zigzag band dividing the two color fields". Based on other evidence from Medieval Italy, it's likely that this decoration relates to a shared family emblem, although it does not match any known emblems (Goodson & Mariani 2016). Figure courtesy of Fentress et al. 2016.

Figure 5.4 Reconstructed ring from the grave of HRU 8

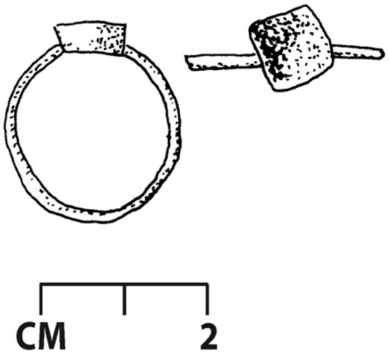


Figure 5.4 – This bronze ring was recovered in the burial of HRU 8, originally a convex glass inlay (blue) was positioned in the central bezel. The glass was positioned to "give a turquoise reflection in a biochrome or trichrome pattern," and the underside of the cap preserved traces of gold leaf, indicating this ring may also have had two color-fields as a family emblem (Mariani 2016, Fentress et al. 2016). Dated to 1200-1300AD, recovered from the burial of HRU 9 in the cemetery from the area of the former monastery.
Figure courtesy of Fentress et al. 2016.

The Case of VM 9

VM 9 is the skeleton of an adult female excavated from the cemetery of San Pietro at Villamagna. The skeletal remains of VM 9 were stratigraphically associated with the Later Medieval Period (13th-14th centuries). The post-cranial remains of this person were mostly complete; however, their cranium was missing during observation. The pelvis was relatively complete, and sex was estimated as female based on the wide-angle of the sciatch notch and sub-pubic angle (Buikstra & Ubelaker 1994); age was estimated as 50+ years based on the auricular surface (Buikstra & Ubelaker 1994) and the pubic symphysis (Brooks & Suchey 1990). VM 9 was chosen for further examination because they fall into this sub-sample of individuals who have extremely low levels of AP (front-to-back) mechanical loading, and yet have very high maximum loading in general (I_{max} R= 307.16, L=323.68). Moreover, this individual had been loaned to UC Berkeley for further osteological analyses based on some anomalies in the spine ("severe kyphosis with some fusion of elements"). This coincidence allowed for this individual to be studied at length, compared to some of the other individuals who remain housed in Italy and were not accessible for further study at this time.

VM 9 was buried in a communal tomb dated to 1250-1350 AD, with at least nine other individuals (Goodson 2015). She was buried in a West-East orientation and was facing North when her remains were recovered during excavations (Fentress et al. 2016, Goodson 2015). This communal tomb was built against the side of the church and contained five articulated adult skeletons buried in a supine position, who were minimally disturbed by the multiple internments (Goodson 2015). These individuals include (a) an older adult (50+ years old) female, (b) a young adult (18-29 years old) male, (c) a middle adult (30-49 years) male, and (d) a very young adult (18-23 years old) male. The tomb also included the very partial and disturbed remains of two young adult females, one child (5-6 years old), and one infant (12-18 months). It's possible that these more disturbed remains were interred prior to the more intact and articulated remains. Furthermore, the evidence for multiple internments over a sustained period of time, a common practice in Medieval Europe, suggests that these individuals did not die together, but were instead intentionally placed together to be reunited in the afterlife (Augenti & Gilchrist 2011, Gilchrist 2008, 2012a, 2012b, Williams 2003).

VM 9 has slight asymmetries in her left and right legs, with the left femur slightly larger overall than the right (total area, L TA_{std} = 922.50, vs. R TA_{std} = 878.45, Figure 5.5). Overall, she has higher %CA and greater bone strength compared to her other older-age female counterparts at Villamagna. VM 9 has a significantly lower I_x/I_y ratio, compared to the older female sample mean (Figure 5.6-7), and a significantly higher I_{max}/I_{min} ratio compared to the older female sample mean (Table 5.2, 5.3).

These differences indicate that, compared to other older females, VM 9 had overall higher bone quantity and robusticity, which are typically indicators of good health and overall skeletal strength. Although it is assumed that older females would be at higher risk for osteoporosis and decreased bone quantity and quality as a result, previous critical feminist biology research has shown that this is an assumption based on contemporary health trends and is not necessarily the case for past populations (Agarwal 2008, 2012, Agarwal et al. 1996, Agarwal et al. 2004). Generally, VM 9 is not an outlier or even an extreme case for any of these measures of bone robusticity, quantity, or biomechanics—aside from measures of diaphyseal shape (I_x/I_y and I_{max}/I_{min}).

Table 5.2 Older female with unusual gait (VM 9)

Table 5.2 – This table presents the values for the right and left femur for cross-sectional geometry properties for VM 9, an older-age cohort female from the Villamagna site. VM 9's total area, percent cortical area, I_{max}/I_{min}, J, and Z_p measures are above the population mean; and her medullary area is smaller than the population mean. There is a 33.6% difference between I_x/I_y and I_{max}/I_{min} values for the right-side femur, and a 22.0% difference between I_x/I_y and I_{max}/I_{min} values for the left-side femur.

VM 9		
	right	left
TA_{std}	878.45	922.50
MA_{std}	232.80	236.69
%CA	73.50	74.34
I_x/I_y	0.85	1.04
I_{max}/I_{min}	1.71	1.64
J_{std}	486.82	521.50
$Z_{p\text{-}std}$	1153.66	1278.01

Table 5.3 Older-age cohort (Villamagna Female) cross-sectional geometry means

Table 5.3 – This table presents the population means with standard deviations for cross-sectional geometry properties for all older-age cohort females from the Villamagna site (n=13).

VM Female (Older-age Cohort)			
	N	mean[a]	SD
TA_{std}	13	828.39	85.51
MA_{std}	13	288.94	97.36
%CA	13	65.50	9.72
I_x/I_y	13	1.05	0.16
I_{max}/I_{min}	13	1.19	0.12
J_{std}	13	403.40	77.57
$Z_{p\text{-}std}$	13	1032.01	159.91

[a]mean calculated from distinct HRUs

Figure 5.5 Left and right femoral cross-sections for VM 9

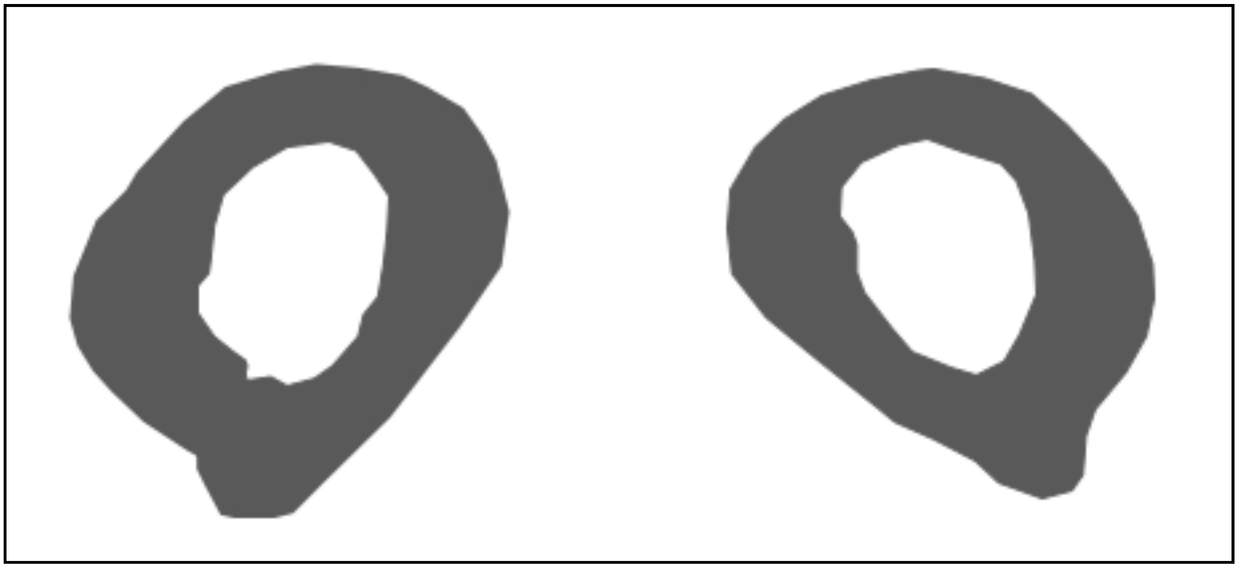


Figure 5.5 – This figure depicts the left (on left) and right (on right) femoral cross sections at 50% of femur length for VM 9 (superior view); the anterior aspect of the bone is towards the top of the image and posterior aspect of the bone is towards the bottom of the image. Overall the right and left side are relatively similar in loading directionality (theta), size, and shape.

Figure 5.6 Left femoral cross-section for VM 9 with equal AP-ML loading (purple)

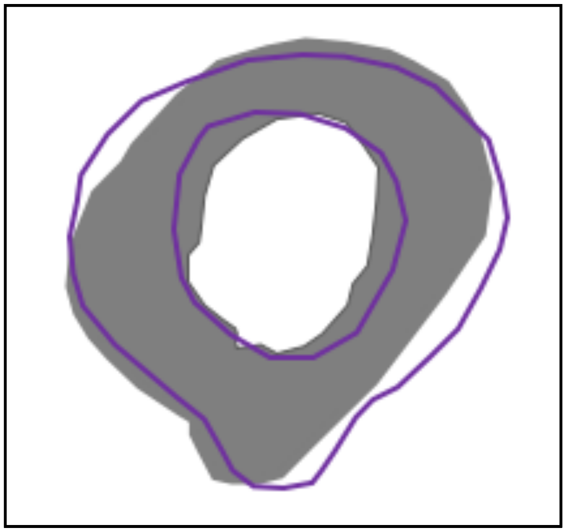


Figure 5.6 – This figure depicts the femoral cross-section from the left femur of VM 9 in gray with a purple outline of the femoral cross-section of a left femur with nearly equal amounts of AP and ML loading ($I_x/I_y = 0.99$). VM 9's femur has more loading (where grey area exceeds purple outline) -47-degrees from the neutral axis.

Figure 5.7 Right femoral cross-section for VM 9 with AP loaded bone (purple)

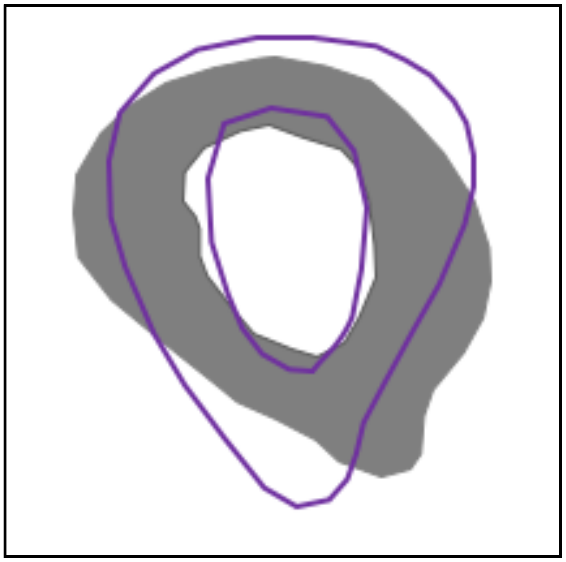


Figure 5.7 – This figure depicts the femoral cross-section from the right femur of VM 9 in gray with a purple outline of the femoral cross-section of a right femur with more AP loading (I_x/I_y = 1.75). VM 9's right femur has more loading (where gray area exceeds the purple outline) 35-degrees from the neutral axis.

The Spine

Based on cross-sectional geometry data, VM 9 is relatively unremarkable aside from the angle and magnitude of the mechanical loadings in her femur (I_x/I_y and I_{max}/I_{min}). These differences suggest higher magnitudes of mediolateral (side-to-side) loading in both femora. Continuing to follow the clues, I draw on another dataset of observations I made between 2015-2016 of VM 9. On July 30, 2015 from 2:44pm to 3:22pm, I examined the spine of VM 9 for the first time. At the time, I was focused on observing spine disease and osteoarthritis more generally at Villamagna. Based on these data, VM 9 clearly had relatively little degenerative spine disease, although there were two anomalies not observed in the rest of the population. VM 9 had fusion of cervical vertebrae (C2-C3), with eburnation (bone-on-bone polishing) on the odontoid process of C2, and the laminae and spinous processes of C4-C6 (Figure 5.8); they also had fusion (ankylosis) of two lumbar vertebrae (L1-L2), and a large claw-like osteophyte on L3 (immediately adjacent to L1-L2). Figure 5.8 is a heatmap of changes to the spine for VM 9.

Closer inspection of these degenerative changes in the spine suggest that the fusion of C2 and C3 in the upper neck region are likely congenital or occurred during development. Congenital vertebral fusion, or block vertebra typically occurs in the cervical or lumbar regions (Ridley et al. 2018). In congenitally fused vertebrae there the intervertebral disc is maintained, although the joint space is narrowed, and fusion occurs at the posterior-lateral aspects of the vertebral body and at the articular facet joint area (Ridley et al. 2018). The fusion of L1 and L2 in the lumbar region is likely not congenital and appears to be the result of a compression fracture, where L2 has collapsed and L1 fused into the body of L2. This also accounts for the osteophyte formation on L3, which is almost certainly a response to the collapse and fusion of L1 and L2.

Figure 5.8 Spine disease heatmap for VM 9

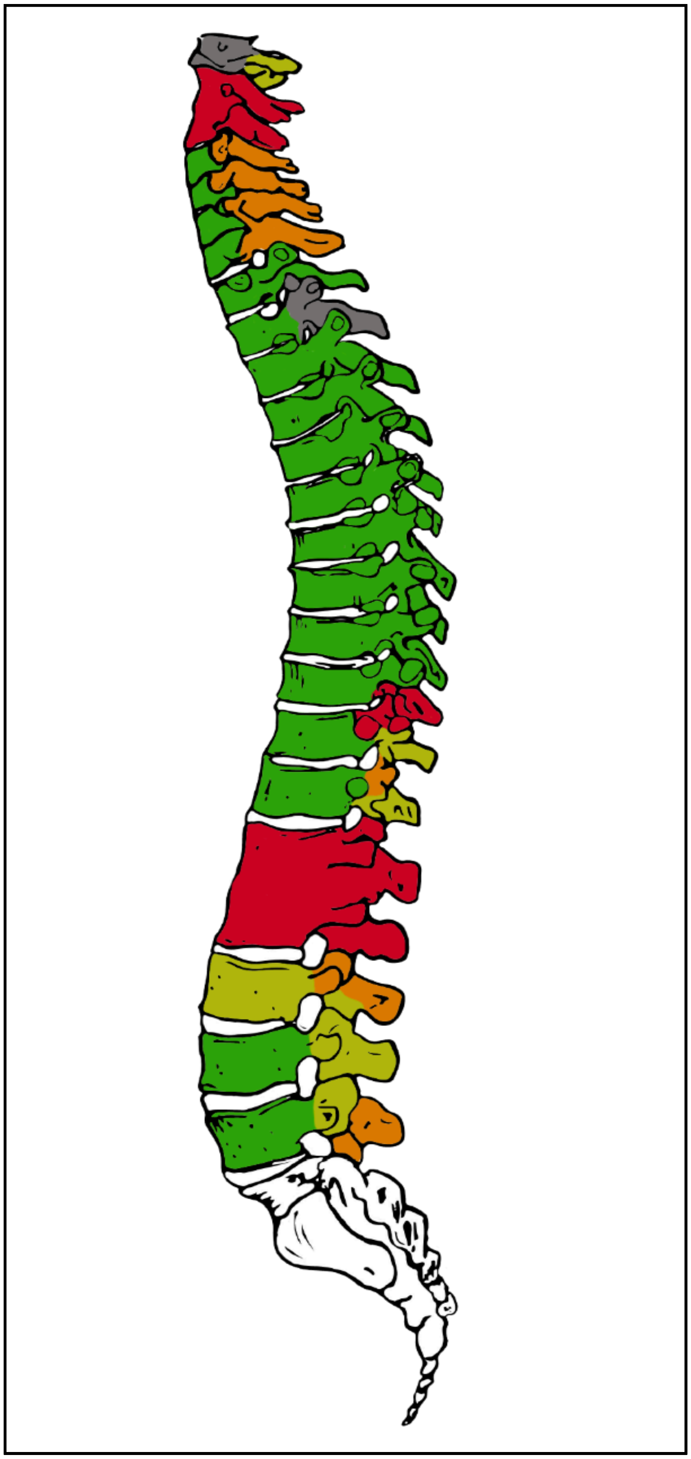


Figure 5.8 – Heatmap of spine disease, as it was recorded on July 30, 2015 at the University of Roma La Sapienza. The second and third cervical vertebra (C2-C3) are fused at the body and laminae, the first and second lumbar vertebrae (L1-L2) are also fused. There is eburnation and degeneration on the laminae (posterior portion) of the fourth through seventh vertebrae (C4-C7) in the neck. There is a claw-osteophyte formation on the third lumbar vertebra (L3), right below the fused L1-L2. Data collection notes also indicate that there is compression and vertebral height-loss in the upper thoracic region (T2-T5). Drawing by KM Kinkopf.

Further Evidence

Prior to the identification of VM 9 for this study, but after the initial spine analysis, the skeletal remains of VM 9 were cursorily examined for skeletal markers of disease and difference at the Skeletal Biology Lab at UC Berkeley, where the remains are currently housed and on loan from the *Ministero dei beni e delle attività culturali e del turismo*, and the *Soprintendenza archaeologia, belle arti e paesaggio per le province di Frosinone, Latina e Rieti.*

During this analysis, I re-identified the congenital fusion of C2-C3 and the healed compression fracture in L1-L2 and noted additional changes or differences across the skeleton of VM 9 (Figure 5.9). The congenital fusion of C2-C3 occurred during development and is therefore primary to the compression fracture in L1-L2. This compression fracture is healed and occurred when VM 9's vertebrae were fully developed. There are oblique displaced fractures on the distal radius and ulna in the left forearm with large ossified calluses that were remodeling at time of death (Figure 5.9). Osteoarthritis was noted in the left elbow of the fractured forearm, and multiple rib fractures with remodeling bony calluses were recorded in the thorax (Figure 5.9). The right scapula had a relatively common occurrence of an os acromiale, or bifurcated acromion process bone (Figure 5.9). The fourth ray (ring finger) of the right hand had two fused phalanges (proximal and intermediate), and there were some morphological changes to the right carpal (wrist) bones; these findings corroborate earlier findings by osteologists from the Villamagna field project (Candilio 2016, Fentress et al. 2016). Based on these findings it is clear that VM 9 has a complex bodily history; she died in older age and lived a relatively long life with multiple fractures that had healed over the course of her life.

In order to better understand the physical lived experiences associated with VM 9's skeletal variation, I first utilized the practices of differential diagnosis. The purpose of diagnosis here is aimed towards solidarity, due to the dearth of ethnographic and critically informed scholarship on vertebral fusion, there is little evidence aside from a radiological identification (Shen et al. 2006, Samartzis et al. 2008) and a few clinical case studies of specific diseases (Hensinger et al. 1974, Stelzer et al. 2018). Although I do not seek to make a definitive diagnosis, the apparatus of differential diagnosis helps arrange and orient VM 9's body in *relation* to other bodies and therefore in relation to other bodies' experiences.

Diffractive Reading, or Counter-Diagnosis

The process of "differential diagnosis" in traditional paleopathology studies involves establishing some baseline observations of the skeletal remains in question. After observing these indicators, a reflexive, iterative, or even diffractive process of research and examination begins. In this section I employ a diagnosis/counter-diagnosis tactic to investigate the lived experience of VM 9, and to build a symptomological landscape based on her skeleton. Due to the complex suite of skeletal features present in the skeletal remains of VM 9, I documented these features using written description and visual documentation (Figure 5.9, Table 5.4).

In the case of VM 9, their skeletal remains are exhibit a few differences that are not commonly observed: fusion of C2-C3, and fusion of L1-L2 (Figure 5.9, purple). Aside from these traits, the fractures, osteoarthritis, and morphological changes in the hands are more commonly observed in skeletal remains (Figure 5.9). Many individuals at Villamagna have a fracture or two, particularly if they have survived to older age. Fractures are often indicative of trauma or injury—the nature of that trauma (accidental, violent, secondary or primary) is a more interpretive step. In the case of VM 9, it is equally possible that these injuries were sustained from a fall due to a violent interpersonal interaction or imbalances and vertigo that are often associated with neural compromise in the cervical spine (Daniilidis et al. 1978, Mayer et al. 1984, Nagashima et al. 2001).

My first step towards (or against) diagnosis was to research the possible causes of congenital C2-C3 fusion. There are two primary causes of C2-C3 fusion, according to a search of "cervical vertebrae fusion" and "C2-C3 fusion" in published clinical literature: an idiopathic anomaly (rare) or Klippel-Feil syndrome (KFS) a genetic disorder that is also rare. Klippel-Feil syndrome is characterized in clinical literature by the congenital malformation or segmentation of the cervical spine (Frikha 2020, Li et al. 2020, Pany & Teschler-Nicola 2007), the extra-spinal manifestations associated with cervical fusion are varied. Li et al. (2020) note that the molecular etiology of Klippel-Feil syndrome remains unknown because of the genetic and phenotypic heterogeneity associated with the condition. Vertebral fusion is caused by the dysregulation of signaling pathways during embryogenesis (Stelzer et al. 2018). The heterogeneity in Klippel-Feil syndrome may lead to under-reporting, as asymptomatic cases are likely not diagnosed and therefore not accounted for in population-level studies (Li et al. 2020). Hensinger et al. (1974) note that the discovery of any lesion relating to Klippel-Feil warrants a careful consideration of the diagnosis, since less than half of the 50 patients in their study exhibited what are erroneously considered "classical triad" of Klippel-Feil: short neck, low posterior hairline, and limitation of lateral neck movements—and instead had a "constellation" of a number of anomalies.

Clinical manifestations of Klippel-Feil syndrome are more commonly associated with Sprengel deformity (a congenital malformation of the scapula), scoliosis, hearing impairments, congenital heart disease, lung defects, and genitourinary malformation (Moore et al. 1975, Hensinger et al. 1974, Saker et al. 2016). Age-biases in clinical and bioarchaeological studies pervade; the mean age in most studies is near 12 years old (e.g., Li et al. 2020, Stelzer et al. 2018, Hensinger et al. 1974). Most clinical case studies focus on Type I or Type III of KFS, which are the more symptomatic types, while Type II is estimated to be symptomatic in only 24.2% of people with the cervical anomaly (Shen et al. 2006).

There are several observations of Klippel-Feil syndrome in bioarchaeological contexts (e.g., Fernandes & Costa 2007, Giuffra et al. 2009, Lewis 2016, Kieffer 2017, Pany & Teschler-Nicola 2007). Paleopathological and bioarchaeological studies note that segmentation failure is characteristic in Klippel-Feil (Scheuer & Black 2000). An important clinical distinction that is also made in most of these cases is the *Type* of Klippel-Feil syndrome diagnosed; Maurice Klippel and Andre Feil first described the anomaly and its three types in 1912 and 1919 (Clarke et al. 1998, Fernandes & Costa 2007). Oxenham et al. (2009) and Tilley & Oxenham (2011), write about the particular case of M9, a young male from Neolithic Vietnam, who likely lived with Klippel-Feil syndrome, Type III. The cases documented by Giuffra et al. (2009) and by Fernandes and Costa (2007) are also of individuals with KFS Type III, which involves modification of the thoracic or lumbar vertebrae. Hemi-vertes, spina bifida, and cleft spinous processes are also common in these cases of KFS Type III, although there is not consensus in more recent clinical literature on how these phenotypic traits might be related to the various genotypic variants of Klippel-Feil syndrome (Clarke et al. 1998, Li et al. 2020, Stelzer et al. 2018).

Figure 5.9 Visual annotation of skeletal indicators for VM 9

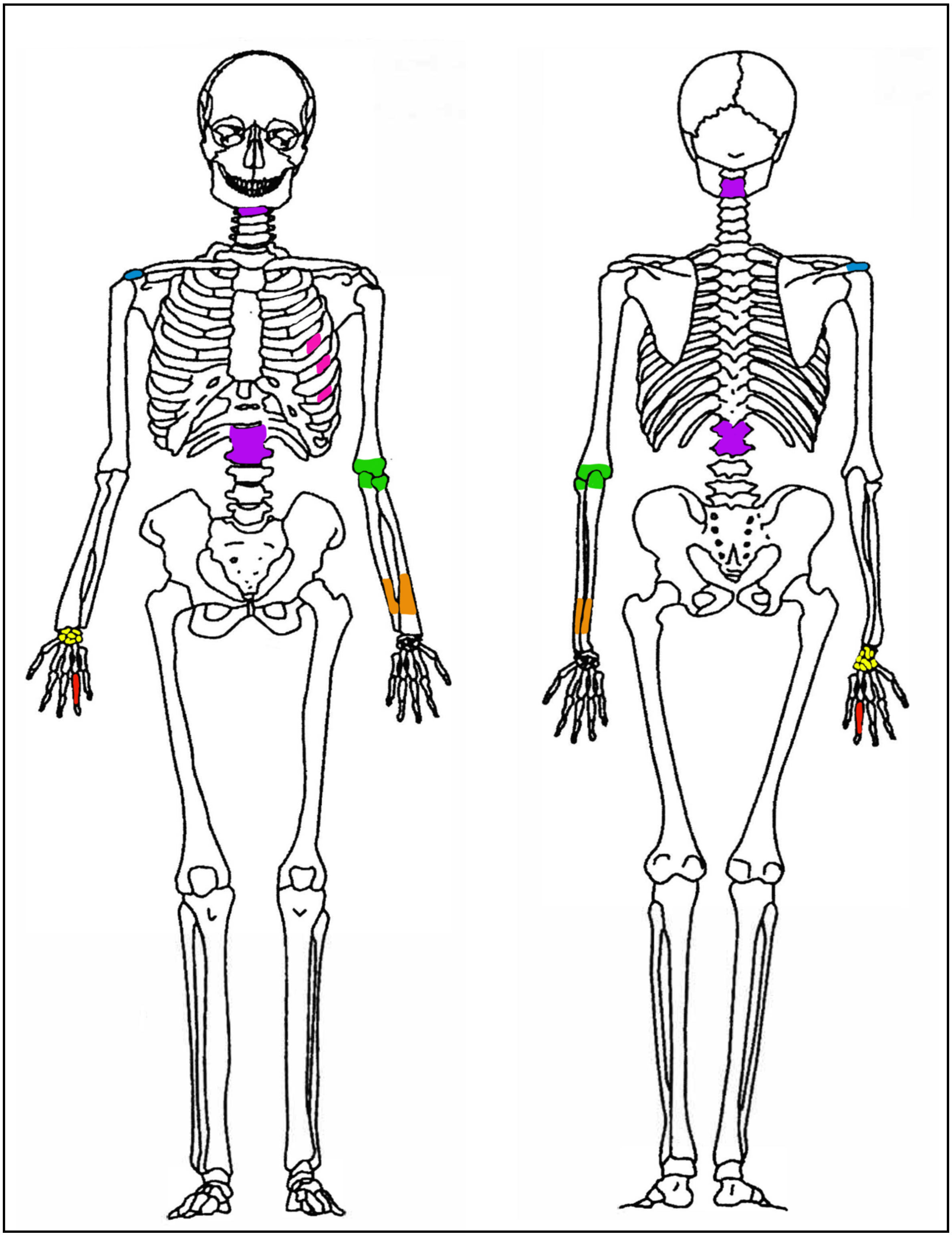


Figure 5.9 – VM 9 had a broken arm with osteoarthritis in the elbow, fusion and morphological changes in the right hand, fusion of C2-C3, and L1-L2 and 3 fractured ribs. It is likely that the broken arm and ribs are secondary to the fusion in the cervical spine (C2-C3). Skeleton figure adapted from Buikstra & Ubelaker 1994.

Table 5.4 Differential diagnosis table for VM 9

Table 5.4 – the various skeletal features expected or observed are listed in the first column; each hypothesized disease is listed subsequently and finally the last column notes which features are present for VM 9. The rows highlighted in gray are features that are present in VM 9. Based on a preponderance of evidence it is possible that VM 9 has Klippel-Feil Syndrome, accompanied by traumatic fractures and secondary osteoarthritis.

Skeletal Feature	**Klippel-Feil Syndrome**	**Trauma**	**Osteogenesis Imperfecta**	**Reactive Arthritis**	**Pott's Disease**	**9**
Block-type congenital fusion in cervical vertebrae (2 or more segments)	***	***		***	**	x
Congenital fusion in thoracic vertebrae	***	***			**	
Congenital fusion in lumbar vertebrae	***	***				x
Scoliosis or Kyphosis	***				***	x
Constriction of medullary canal	*		***			x
Spina bifida	**					
Clefting of neural arches in sacrum	**					
Cervical ribs	*					
External acoustic meati vertically oriented	*					
Cleft lip or palate	**					
High scapula (Sprengel's)	***					x
Bowing of long bones			***			
Multiple fractures		***	*			x
Short stature			***			
Osteoporosis (bone loss)			*			x
Osteophyte formation				***		
Asymmetrical sacroiliitis				***		
Distal interphalangeal joints affected in hands and feet				***		
Changes to the knee joint				**		
Paraplegia		*			**	
C2-C3 fusion	***	**	*	*	*	x
Os acromiale (R scapula)		**				x
Healed fracture (L ulna)		***	*			x
Healed fracture (L radius)		***	*			x
Osteoarthritis (L elbow)		*				x
Fused phalanges (4th ray)		**		*		x
Carpal deformation (R carpals)	***			*		x
Rib fractures (L)		***	**			x
Compression fracture L1-L2		**	*			x

*** = Characteristic, typically used for diagnosis
** = Frequently observed, but not diagnostic
* = Sometimes observed, but not diagnostic
x = feature present

Klippel-Feil syndrome has also commonly been employed as an exemplar of disease experience, in order to make broader claims about societal attitudes towards disability and disabled people. Tilley and Oxenham (2011) make the case for a communal caregiving from M9's community, given that his skeleton shows signs of paralysis and immobility. Using a healthcare model of care (Tilley was originally trained as a nurse), Tilley and Oxenham discuss the basic and advanced care needs of M9 within a reconstructed biocultural context. Alternatively, Lewis (2016) writing about caring for disabled children, argues that Klippel-Feil syndrome is often asymptomatic in childhood and might not be recognized as a physical difference during life.

Many features of Klippel-Feil syndrome that are considered "diagnostic" are traits seen in the most severe cases that result in death at a young or younger age. In the case from Neolithic Vietnam, and also in a case from Austria, the individuals with KFS lived to be young adults; in another case from Portugal the individual lived to middle age (Fernandes & Costa 2007). Taking VM 9's advanced age into consideration, I looked for examples of skeletal manifestation that were associated with middle or older age adults. Like Fernandes and Costa's (2007) case, VM 9 has slight asymmetries throughout the skeleton, which are evident even in the aforementioned cross-sectional geometry data. Unlike their case, VM 9 does not present the butterfly vertebrae, or hemi-vertes; however, these traits are not considered diagnostic by clinicians, who note that the phenotypic expression of Klippel-Feil syndrome is highly variable depending on the genotypic origin (Li et al. 2020; see also Clarke et al. 1998 Hensinger et al. 1974, Stelzer et al. 2018).

Based on previous bioarchaeological research and clinical recommendations for differential diagnosis, and other bioarchaeological studies of congenital cervical vertebrae fusion, I compiled a list of 5 possibilities to differentially consider: Klippel-Feil Syndrome, Osteogenesis Imperfecta, Reactive arthritis, Pott's Disease, and Traumatic Injury. I employ this common differential diagnosis practice in order to position VM 9 in relation to other bodies (archaeological and contemporary) and to illustrate the limitations of differential diagnosis practices in understanding experience. Osteogenesis Imperfecta and Pott's Disease were both suggested by experienced bioarchaeologists as possibilities to rule out, while Reactive Arthritis is a known condition that causes fusion of vertebral elements and was considered in multiple differential diagnoses for Klippel-Feil syndrome. Osteogenesis Imperfecta is a condition that inhibits osteoblastic activity, causing generalized osteoporosis and mineralization defects throughout the skeleton (Cope & Dupras 2011, Ortner 2003, Wells 1965). Reactive arthritis primarily affects men and occurs as a reaction to inflammation cause by infection(s) from bacteria such as *Salmonella*, *Yersinia* (plague), *Shigella*, *Chlamydia*, or *Campylobacter* (Ajene et al. 2013, Carter & Hudson 2010, Honda et al. 2017). Classified as a spondyloarthropathy, reactive arthritis is characterized by proliferative bone deposition and morphological changes to the joints, particularly in the extremities, spine, knees, and ankles (Kumar et al. 2014, Cawley & Paine 2015, Schmitt 2017). Due to the lack of joint involvement in the extremities, reactive arthritis is an unlikely cause of the changes seen in VM 9's skeleton. Finally, Pott's disease is caused by a tuberculosis infection in the spine, and typically affects the thoracic and lumbar vertebrae—resulting in extreme kyphosis (forward bending) of the spine, in addition to proliferative and degenerative changes in the vertebral body itself (Ortner 2003). As all vertebrae were healthy and exhibited no morphological or degenerative signs, aside from the fusion of C2-C3 and the compression fracture of L1-L2, Pott's disease is also unlikely.

For each of these conditions, diagnostic features of each disease were put into a table alongside the specific observations of VM 9. Although these diagnostic criteria implicitly reference experience via symptomology, there is an emphasize on the mineralized aspects of disease (manifesting in the skeleton). Some of the most diagnostic traits for Klippel-Feil Syndrome are morphological differences in the skull, which is missing for this individual—and clinical signs of the alteration in the spine are typically recognized from soft tissue evidence. Other diagnostic traits, such as "Sprengel's deformity" were noted after the initial analysis; for example, the right scapular spine is much higher on the scapula (smaller distance from superior border) than the left scapula.

My orientation to this project, in particular to the issues of representation and narrativizing vulnerable subjects and to diagnosis and counter-diagnosis does not rely on a stable identification of bodies. The fragmentation of VM 9, with the missing skull, demonstrates one of the ways in which fragmentation and taphonomy become a subversive phenomenon, whereby identification is thwarted by incompleteness. VM 9's refusal to be categorized or reduced to a simple diagnosis or identification enacts an agential shift, or a counter-diagnosis (drawing on Price's theorization). This counter-diagnosis foregrounds experience over identification; and it is on the basis of this counter-diagnosis that I move towards a landscape of symptoms and a diffractive reading of these skeletal remains. Typical paleopathology studies would end with no diagnosis, or more extreme and invasive techniques to determine the etiology of these alterations to the skeleton.

In this Chapter, I move beyond this artificial boundary that limits our understanding of human experience in the past. I continue to trace the symptoms and traces of bodily experience embedded in the skeleton of VM 9, mapping these symptoms visually and connecting them with skeletal evidence. Then I discuss the 20th century assessment of neck disability (the Neck Disability Index, NDI) I embrace counter-diagnosis as a subversive technique for writing a more critical, microhistorical, narrative of VM 9.

Tracing Symptoms

The skeletal remains of VM 9 have much to say. In review, she has spine fusion, asymmetrical scapulae, a number of fractures, and morphological differences in their hand (Figure 5.9). What is the relationship between all of these skeletal traces? As a congenital difference, the fusion of C2 and C3 begins during development in utero, when vertebral bones do not fully differentiate (Pany & Teschler-Nicola 2007). This phenomenon causes the vertebrae to develop as one fused "block" of bone. These developmental variations can be caused by a range and combination of genetic alterations and are influenced by the environment (Li et al. 2020). Phenotypic alterations to the spine, like those seen in Klippel-Feil syndrome can cause a range of neurological and muscular symptoms that are directly caused by these morphological differences or can be secondary to them (Mahirogullari et al. 2006). Secondary conditions sometimes also called complications or sequelae, are typically caused by these primary conditions. In the visual representation of VM 9 symptoms, derived from skeletal traces (Figure 5.10) primary conditions are located near the "diagnosis," while secondary conditions are shown at the margins. In Figure 5.10, I show the intermediary experiences that translate into secondary conditions:

(1) C2-C3 fusion leads to hypermobility in the spine, which causes instability and imbalance while doing daily life activities, this imbalance can make individuals more likely to fall and accidentally injure themselves. Likewise, many patients with Klippel-Feil syndrome, neck injuries, or even whiplash report having issues with coordination. The rib fractures and fractured forearm could have happened as a result of this kind of imbalance and subsequent fall.

(2) The relationship between KFS and osteoporosis is unknown, although gonadocorticoids such as androgens and estrogens are known to modulate bone quality and quantity (Nelson et al. 2001) and Klippel-Feil syndrome commonly associated with Mayer-Rokitansky-Küster-Hauser (MRKH) syndrome, which is characterized by an alternative configuration of the uterus and/or vagina and changes in systemic hormones (Rall et al. 2015). It is possible that the L1-L2 compression fracture in VM 9 is the result of osteoporotic vertebrae, which could be influenced by hormones, decreased weight-bearing activity, or other unknown risk factors. These changes could also be caused by a metabolic disorder, where bone quality and quantity are reduced. Overall the vertebral bones of VM 9 are relatively light weight, however there are no signs of osteoporosis in the femur, where cortical area is not significantly different from the sample mean.

(3) Sprengel's deformity, or morphological alterations to the scapula are present in VM 9, although there is some taphonomic damage to the affected scapula therefore it is difficult to establish the extent of these differences. Differences in scapular arrangement and height correspond with enlarged and flared trapezius muscles in the neck and shoulders (Miyamoto et al. 1983). These muscular differences can result in cosmetic variations in the appearance of the neck and are frequently associated with hearing loss and cranial alterations in Klippel Feil syndrome, however slight skeletal asymmetries are not uncommon across populations more generally (Miyamoto et al. 1983).

(4) VM 9 has some alteration to the morphology of the right wrist, accompanied by mild arthritis and a fused 4th finger. These differences could be the result of trauma, or idiosyncratic. However, deformations of the wrist (carpal) bones are sometimes noted in clinical cases of Klippel-Feil syndrome, and typically accompany non-fatal heart defects.

Figure 5.10 Symptom map for VM 9

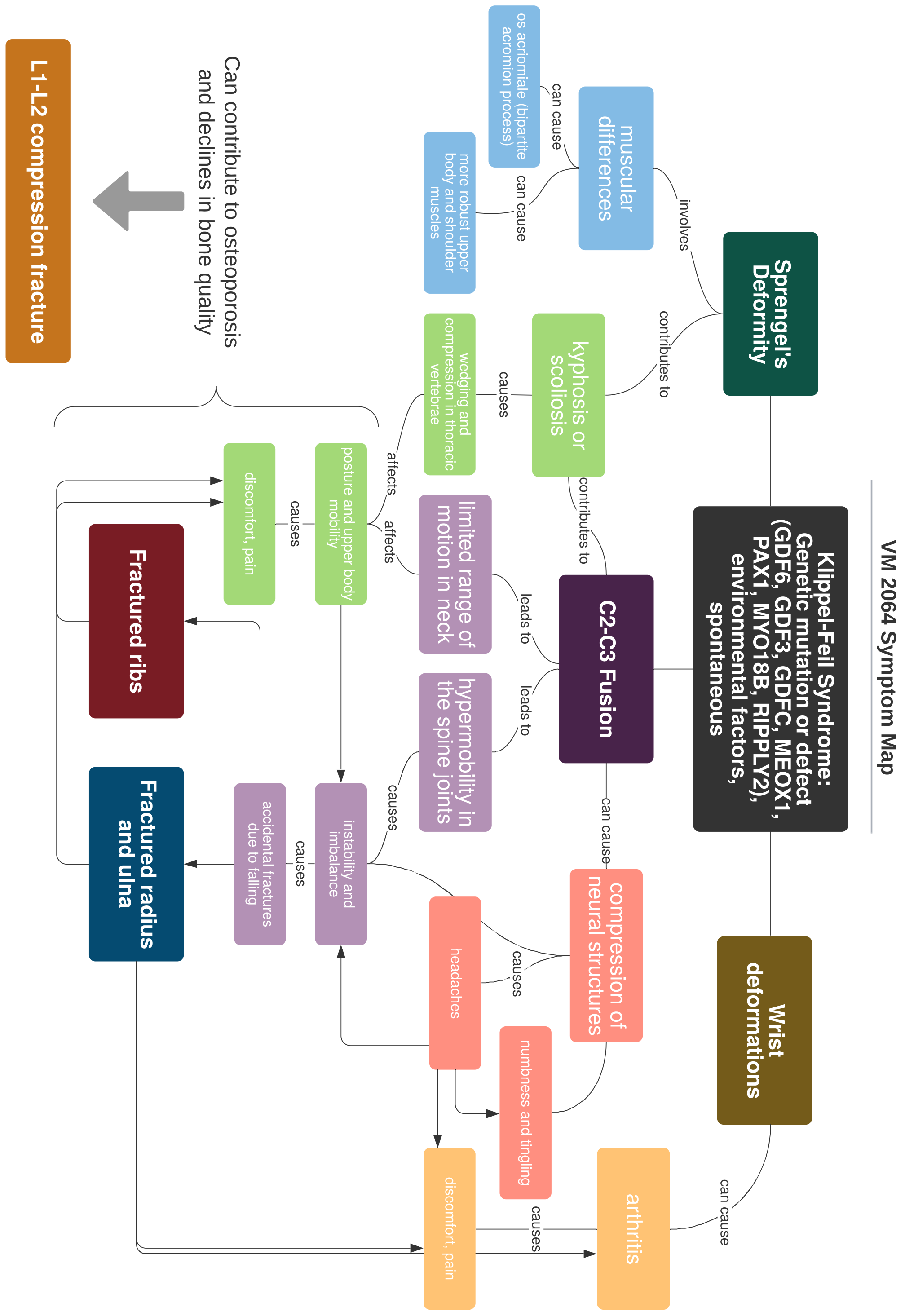
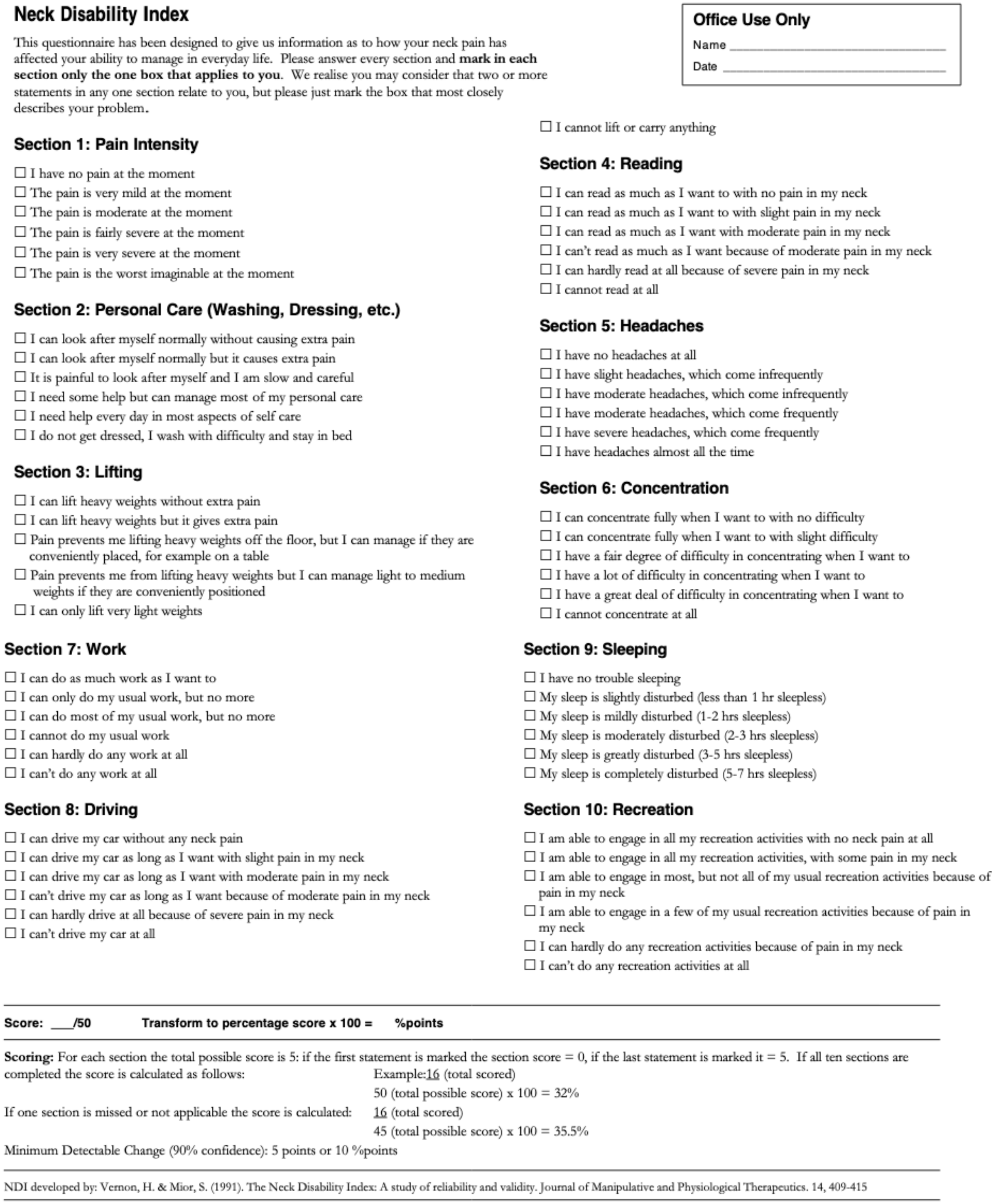


Figure 5.10 – The symptom map for VM 9 presents a visualization of the skeletal findings from VM 9 and associates them with common symptoms or side-effects not visible from the skeleton itself. Through this process, primary and secondary conditions are experientially connected to each other. Pathogenic genes listed in dark gray box are based on findings from Li et al. 2020.

Figure 5.11 Neck Disability Index form



Neck Disability Index

This questionnaire has been designed to give us information as to how your neck pain has affected your ability to manage in everyday life. Please answer every section and **mark in each section only the one box that applies to you**. We realise you may consider that two or more statements in any one section relate to you, but please just mark the box that most closely describes your problem.

Office Use Only

Name ______________________________

Date _______________________________

Section 1: Pain Intensity

☐ I have no pain at the moment
☐ The pain is very mild at the moment
☐ The pain is moderate at the moment
☐ The pain is fairly severe at the moment
☐ The pain is very severe at the moment
☐ The pain is the worst imaginable at the moment

Section 2: Personal Care (Washing, Dressing, etc.)

☐ I can look after myself normally without causing extra pain
☐ I can look after myself normally but it causes extra pain
☐ It is painful to look after myself and I am slow and careful
☐ I need some help but can manage most of my personal care
☐ I need help every day in most aspects of self care
☐ I do not get dressed, I wash with difficulty and stay in bed

Section 3: Lifting

☐ I can lift heavy weights without extra pain
☐ I can lift heavy weights but it gives extra pain
☐ Pain prevents me lifting heavy weights off the floor, but I can manage if they are conveniently placed, for example on a table
☐ Pain prevents me from lifting heavy weights but I can manage light to medium weights if they are conveniently positioned
☐ I can only lift very light weights
☐ I cannot lift or carry anything

Section 4: Reading

☐ I can read as much as I want to with no pain in my neck
☐ I can read as much as I want to with slight pain in my neck
☐ I can read as much as I want with moderate pain in my neck
☐ I can't read as much as I want because of moderate pain in my neck
☐ I can hardly read at all because of severe pain in my neck
☐ I cannot read at all

Section 5: Headaches

☐ I have no headaches at all
☐ I have slight headaches, which come infrequently
☐ I have moderate headaches, which come infrequently
☐ I have moderate headaches, which come frequently
☐ I have severe headaches, which come frequently
☐ I have headaches almost all the time

Section 6: Concentration

☐ I can concentrate fully when I want to with no difficulty
☐ I can concentrate fully when I want to with slight difficulty
☐ I have a fair degree of difficulty in concentrating when I want to
☐ I have a lot of difficulty in concentrating when I want to
☐ I have a great deal of difficulty in concentrating when I want to
☐ I cannot concentrate at all

Section 7: Work

☐ I can do as much work as I want to
☐ I can only do my usual work, but no more
☐ I can do most of my usual work, but no more
☐ I cannot do my usual work
☐ I can hardly do any work at all
☐ I can't do any work at all

Section 8: Driving

☐ I can drive my car without any neck pain
☐ I can drive my car as long as I want with slight pain in my neck
☐ I can drive my car as long as I want with moderate pain in my neck
☐ I can't drive my car as long as I want because of moderate pain in my neck
☐ I can hardly drive at all because of severe pain in my neck
☐ I can't drive my car at all

Section 9: Sleeping

☐ I have no trouble sleeping
☐ My sleep is slightly disturbed (less than 1 hr sleepless)
☐ My sleep is mildly disturbed (1-2 hrs sleepless)
☐ My sleep is moderately disturbed (2-3 hrs sleepless)
☐ My sleep is greatly disturbed (3-5 hrs sleepless)
☐ My sleep is completely disturbed (5-7 hrs sleepless)

Section 10: Recreation

☐ I am able to engage in all my recreation activities with no neck pain at all
☐ I am able to engage in all my recreation activities, with some pain in my neck
☐ I am able to engage in most, but not all of my usual recreation activities because of pain in my neck
☐ I am able to engage in a few of my usual recreation activities because of pain in my neck
☐ I can hardly do any recreation activities because of pain in my neck
☐ I can't do any recreation activities at all

Score: ___/50 Transform to percentage score x 100 = %points

Scoring: For each section the total possible score is 5: if the first statement is marked the section score = 0, if the last statement is marked it = 5. If all ten sections are completed the score is calculated as follows: Example:16 (total scored)
50 (total possible score) x 100 = 32%

If one section is missed or not applicable the score is calculated: 16 (total scored)
45 (total possible score) x 100 = 35.5%

Minimum Detectable Change (90% confidence): 5 points or 10 %points

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NDI developed by: Vernon, H. & Mior, S. (1991). The Neck Disability Index: A study of reliability and validity. Journal of Manipulative and Physiological Therapeutics. 14, 409-415

Figure 5.11 – The NDI form available as a pdf form from the American Academy of Orthopaedic Surgeons (AAOS) website. The AAOS was founded in 1933 at Northwestern University and is self-described as the "world's largest medical association of musculoskeletal specialists" (aaos.org). A recent textbook on the history of the organization lauds the accomplishments of the AAOS in treating polio, Pott's disease, and other orthopedic conditions.

The Neck Disability Index

The Neck Disability Index (Vernon & Mior 1991, updated Vernon 2008) has been cited 3490 times since 1991 (Figure 5.11). It is the most widely used index for neck disability and is endorsed by the American Academy of Orthopaedic Surgeons (AAOS) (Vernon 2008). The assessment is commonly used with patients who self-report neck pain, are diagnosed with neck arthritis, have whiplash from an accident, or who have chronic neck pain. The self-rating type assessment was adapted from the Oswestry Low Back Pain Index (OI) and Roland-Morris Low Back Pain Questionnaire by Howard Vernon, a (DC) chiropractor (Vernon 2008). As a disability index, the assessment takes account for the impact on the activities of daily life rather than on pain location, severity, or duration, which are the focus of the Oswestry Index and Roland-Morris Questionnaire. This feature is shared by many disability indices, which focus on quality of life and the disabling effects of the chronic pain or disease, rather than on the pathophysiology of the disease or pain itself. Vernon and Mior (1991) built the assessment based on a review of descriptive studies of neck pain, informal patient surveys, and discussions with other health practitioners (Table 5.5). Table 5.5 presents the categories of assessment from the NDI, as they were developed. After an initial pilot study, the section on "sex life" was changed to recreation, a change that is suspect because of the historical and continued denial of sexual desire for disabled people (Siebers 2008b).

Table 5.5 Sections of Neck Disability Index (NDI)

Table 5.5 – The NDI is used by clinicians and chiropractors to assess how neck pain affects patient's ability to manage activities of everyday life. Assessments such as these are typically performed in order to assess level of disability using a composite score, which is often reported as part of a disability benefits application or for other policy or care benefits through federal and state governments, employers, or agencies.

Sections based on descriptive patient case studies		
Pain intensity		
Personal care		
Lifting		
Sleep		
Driving		
Sex Life	→	Recreation
Sections based on health practitioner experience		
Headaches		
Concentration		
Reading		
Work		

Each of the 10 sections can be assessed with an ordinal scale of 0-5, like most psychometric or ordinal-ranked assessments the relationship between a score of 0 and 5 is not linear or additive (Figure 5.11). Composite scores, based on patient responses to the various sections of the assessment, are used to provide a clinical recommendation of "recovered, mild disability, moderate/severe disability" (Vernon 2008). Overall the assessment is quite standard and includes prefabricated bins for self-identification.

The assessment sometimes betrays itself with sections such as "reading" where the response of simply "I cannot read at all," is worth 5 points towards the patient's disability

(Figure 5.10). It's unlikely that the designers intended the disabling elitism this materializes, however it's noted in some implementations of the assessment that part of the population being assessed is illiterate and this issue is not addressed (Cook et al. 2006). This betrayal, or misalignment, reveals ideological assumptions underpinning medical determinations of disability, as well as intersectional biases that shape disability as a minority identity and political classification in contemporary Euro-American culture (Siebers 2008a, Samuels 2014).

The inclusion of these sections provides some evidence for the areas of daily life that might be affected by chronic neck pain. However, as someone who is regularly assessed on a (different but similar) disability index, I am particularly sensitive to the reality that these sections are not representative of lived experience or daily life. These categories mainly reflect the requisites for participation in contemporary capitalist society and are infused with the ideologies of late liberalism. And yet these indices are important tools for accessing treatment, care, health insurance, and disability benefits. The historical context of the NDI allows us to see the ways in which chronic neck pain, whatever its origin, is arranged in relation to other embodiments, however in order to better understand these differences in the past it is essential to consider the landscape of contemporary symptoms and question how and if those symptoms are bioculturally modulated both in their physiology and in their cultural context.

Based on this medical tool, it's clear that neck disease and chronic pain in the spine affect a broad array of daily life activities. The inclusion of "headaches" as a section points towards neurological and muscular variations that might be secondary to the neck pain itself. It's likely that VM 9 may have experienced chronic pain from her spine alterations, and certainly from the fractures in her arm and chest. It's also possible that she experienced headaches, vertigo, difficulty concentrating, and reduced mobility in her neck.

Pairing this experiential evidence from chronic neck pain in the 20th and 21st centuries with VM 9's skeletal remains, there is further data to suggest that although VM 9 likely had issues with imbalance and walked with a gait that was more side-to-side, she has no reduction in bone strength—indicating that she actively used her limbs during life. After life, she was buried in a communal, high-status tomb with other adults and children—possibly members of her extended family, a common practice in medieval Europe (Gilchrist 2012). She was not treated differently in death, although it is crucial to attend to the intersection of disease and intergenerational wealth and economic privilege, which shape experiences of disability and disease from the contemporary to historic past (e.g., Blanchett 2010, Erevelles 2014). As demonstrated in Chapter 3 and 4, economic access at Villamagna greatly impacts health outcomes and bone quality and quantity, therefore it's reasonable to contextualize VM 9 in terms of this increased access to economic resources and in the context of medieval material, epistemological, and metaphysical understandings of the body.

Crip Solidarity

Writing osteo-ethnographic narratives (as above) has the potential to bring together seemingly disparate bodies of knowledge and experience. While there is little to no medical research on people's experiences with Klippel-Feil syndrome, and no ethnographic writing about it, there are multiple narratives of Klippel-Feil and degenerative spine diseases in archaeological contexts. The rare disease trope is often used to otherize, rather than to forge alliances through time and space. Bioarchaeology or paleopathology narratives often lack a political or ethical orientation to embodied experience, further otherizing and marginalizing disabled people. Building more ethical and robust histories of disability and understanding the ways in which disability has been constructed and re-constructed historically is at the heart of dismantling ableism in contemporary society. Contemporary justifications for unequal treatment of disabled people relies on a historical foundation and precedence for that treatment; therefore, alternative and complex historical perspectives on disability are urgently necessary for emancipation and liberation.

Without a diagnosis, why write about VM 9? This question applies to (I suspect) hundreds of bioarchaeological cases globally and is a question bioarchaeologists who encounters this chapter will ask themselves. Due to a number of constraints, diagnosis is simply not possible in a variety of cases. This means that some skeletal remains are relegated to the margins, replicating the biases of clinical diagnosis in bioarchaeological case studies. Similar to the medical context, the event of diagnosis becomes the focus of the investigation over the more experiential components. In a clinical context tests are performed, and bodies are examined with the goal of checking boxes (literally). As discussed above, the paleopathology study draws on this approach and implements a similar "box checking" strategy. This process often involves an articulation of acute diseases, conditions, or disorders as distinctive from chronic ones; thereby enacting a binary separation of acute and chronic difference and ignoring the ways in which lived experience across the life course explodes this boundary. The emphasis on diagnosis also separates archaeological bodies from present and future bodies.

In 2011, Mia Mingus a Disability Justice community organizer and writer, published an essay about access intimacy, a radical and transformative concept that is now central to care activism (Mingus 2011, 2017; see also Friedner 2020, Hartblay 2020, Hande 2017). Mingus' elaboration of access intimacy helps us theorize an alternative world where the imagined dichotomy of disabled care-receivers and non-disabled caregivers is de-naturalized, questioned, and queered. Access intimacy describes a manifestation of embodied experiences of difference, and how these might lend themselves to queer arrangements (or orientations) of closeness, friendship, and commiseration (Mingus 2017). Mingus is explicit that access intimacy isn't limited to disabled people or even constrained by a shared diagnosis or embodiment; it's not bounded by temporal constraints that depend on a shared political or social identity. This is not to argue that access intimacy is ahistorical, but rather that the arrangement of the archaeological and contemporary is a nonlinear, or crip temporality. In this chapter, I have proposed a novel approach to thinking with disability in the past, building crip solidarity that extends beyond disability and applies beyond the study of disease. Through the deployment of a counter-diagnosis or the rejection of a diagnosis, I have instead contextualized the experience and skeletal remains of VM 9 in terms of chronic pain and the ways in which disability is assessed or managed. I foreground an ethical obligation to emancipation in this work and ask others to consider more closely how they contribute to conversations about disability, what it means to be disabled, and who decides who is disabled now and in the past.

This is the beginning.

Chapter 6: Conclusions

One of the central goals of this project from its onset was to develop a disability orientation to biological anthropology that went beyond disease. Using a disability framework, disability theory, and/or disability perspectives to better understand disease in the past is fairly straightforward. It takes up disability as an object of study within biological anthropology, rather than as a subject position or onto-epistemological orientation to biological anthropology, writ large. Although the perspectives and experiences of disabled people should be foundational to any study or interpretation of disease or impairment, I demonstrate in this study that disability-orientations lead to more holistic and complex understandings of embodiment, identity, difference, and variation. In this project, difference and variation are centered as valuable loci of inquiry. This is not to say that difference is inherently good or necessary, but rather that the phenomena and apparatuses that produce difference and the difference they generate are worth investigating.

The first parts of this project were fomented in 2013, during a series of conversations I had with the late Tobin Siebers while I was a student at the University of Michigan. Toby had written convincingly in a number of publications that more complex theories of embodiment might draw on disability theory and disability studies to achieve a more robust and ethical orientation. This project thinks with disability to critically understand difference, variation, and daily life—not as a proxy for contemporary disability or to ahistorically implant disability in the past, but rather as a political, ethical, and material orientation to skeletal remains, bodies, and experience.

This dissertation project brings together multiple lines of evidence, including historical, archival, skeletal, archaeological, and visual culture data. Findings from this study point to complexity in the ways in which activity and inequalities are embodied:

- Access to economic privilege, including intergenerational wealth, is an important determiner of health and disease outcomes in contemporary societies, as well as past societies. This study demonstrates that economic access effects both bone quantity in the femur and severe spine disease outcomes (greater prevalence) in groups with less economic access. Results from this dissertation also suggest that this relationship is intersectional, and that gender and age play an important role in how economic access affects lived experience and disease outcomes.

- Activity, especially manual labor, is a situated and embodied experience that is not ahistorical or universal. Like disability, the activities of everyday life are high contextual and the ways in which these activities are embodied is influenced by this context via environmental and epigenetic factors. Activity must be contextualized in terms of its biocultural context in order to fully understand how it is embodied—it's not just how you do something, it's also the accumulation of biopolitical and physiological risk. For example, evidence from this dissertation shows that the accumulation of injuries in vulnerable joints likely leads to increased severity of spine disease: at Pava there is a high prevalence of Schmorl's nodes that are comorbid with vertebral osteophytosis. Interpreted in the context of Tuscan sharecropping, this result points to increased risk for long-term health consequences (severe degenerative spine disease) resulting from mechanical injuries that are often sustained during agricultural activity, as measured by the prevalence of Schmorl's nodes.

- Differences in experience, an order of magnitude smaller than "class" are important for predicting differential health outcomes for medieval peasants. This is often demonstrated in clinical or contemporary health settings (see Chapter 3), however historic examples are frequently discussed in terms of elite vs. non-elite/peasant differences. Results from this dissertation point to a high level of sample dispersion amongst various groups, where experience is not defined at the level of class but rather by intersectional clusters within these groups. These differences are discussed in Chapter 3-4 in terms of "economic access" or "access to economic privilege," which emphasize the fluid and subtle differences in experience that are the result of economic privilege.

- Elevated levels of antero-posterior mechanical loading at Villamagna suggest an increase in terrestrial mobility compared to Pava. Landscape differences within Italy likely influence these differences, due to the differing local topography of Tuscany and Lazio. Differences between age-sex groups suggests that mobility is variable within the population and differently between the sites.

- Relatively high levels of sample dispersion amongst older age individuals affirm that aging experiences are diverse, variable, and nonlinear. Across the life-course there is an accumulation of risk and exposure that differentially shape experiences of older age. Difference is embodied in the skeleton and other tissues from development through adulthood, ultimately leading to diverse health and disease outcomes in older-adult life.

Ultimately, this dissertation draws on multiple lines of evidence to investigate experience in Medieval Italy. In Chapter 5 I draw on data from Chapters 3 and 4 in order to write an experimental counter-diagnosis narrative for one individual from Villamagna. Through this writing I emphasize the ethical capacity of (bio)archaeological research in narrativizing past people's lived experience. Through an explicit articulation of experience and the politics of experience, I argue that pursuing a counter-diagnosis strategy builds crip solidarity with the archaeological past and is a more ethical orientation to past bodies.

Many questions and directions for future research have been illuminated by this dissertation project. Future research might further explore: the ways in which economic access and privilege influence medieval daily life through other skeletal and dental indicators; and more closely examine the influence of degenerative joint disease on mobility and walking itself. I hope to further explore the role of ethnographic writing and experimental approaches to narrativization in bioarchaeological research, in particular by further exploring the experiences of other individuals from Pava and Villamagna using the diffractive counter-diagnosis orientation from Chapter 5. Bioarchaeological investigations of experience benefit from the ethical and political robusticity of disability theory, offering in return visions of crip futures that are beyond the limitations of the contemporary.

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