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Letter From the Editor

As the editor for Volume 12 of the Florida Atlantic Undergraduate Research Journal (FAURJ), it has been a true pleasure witnessing each of the author's research achievements during this year's publication process.

My sincerest gratitude to Florida Atlantic University's Office of Undergraduate Research and Inquiry (OURI) for giving me such an opportunity to be a special part of the publication team. Thank you to all the undergraduate student authors for being receptive and willing to allow me to be a part of your publication preparation. The publication process can be time-consuming, and I am grateful to each of the peer reviewers who took the time to consider each manuscript and assist FAURJ and OURI during this year's publication. Most of all, special thanks goes to the dedicated and passionate Florida Atlantic University faculty research mentors who support the research endeavors of curious undergraduate students committed to academic research. Much success to each author and congratulations on this esteemable achievement!

Respectfully,
Robin Jimenez-Bean

Cover Design Artist Statement

“Reflective Hawk”

This is a photo of a red-shouldered hawk that was taken in the Fakahatchee Strand State Park located within the Everglades. I was hiking a trail looking to take photos of any wildlife I came across, when I heard some splashing next to me on the trail. I looked and saw this hawk kicking its feet in the water with splashing coming from beneath its feet. It must have had a prey item caught because it seemed to be wrestling with something. I have seen many of these birds in this area, but this is the first time I have observed this behavior as they are usually perched on a branch scoping for food, or patrolling the skies.

- Jordan Richman, Undergraduate Student
Florida Atlantic University

Biological Profile & Differential Diagnoses for Teaching Skeleton A-16

Kayla Rae Ahlness and Meredith Ellis, PhD (Faculty Advisor)

Abstract

The examination of the human skeleton can present information about a person, such as age, sex and disease, long after the individual’s death. A paleopathological analysis in the biological profile is instrumental to identifying disease, antemortem and perimortem modifications or postmortem changes and with this information, we can build a biological profile for the individual. This research examines the spinal pathology and vertebral trauma for a skeleton from the Department of Anthropology’s teaching collection (A-16). Further examination of the vertebral profile provides more information in order to create a differential diagnosis. Although a definitive diagnosis is not made in this article, evidence suggests that subject A-16 suffered from a vertebral compression fracture, transverse process fracturing and characteristics of porosity throughout the axial skeleton that are consistent with severe osteoporosis. This research offers insight into the conditions that lead to various vertebral trauma and those insights provide an opportunity to discuss environmental, cultural or lifestyle circumstances of the case study individual.

Introduction

The creation of a differential diagnosis of pathology on skeletal samples can unveil a catalog of information pertaining to the individual’s health, lifestyle, culture and history of trauma. From skeletal remains we can see the potential effects of physical labor (Gerszten et al., 2001) or over-use activity (Foster et al., 1989) and how that can translate in vertebral pathologies

(Lovell, 1994). We can also see osteopathic trauma, including healed and active injuries as well as disease. Disease and trauma of the vertebrae can be particularly influential during skeletal analysis, as the vertebral column displays a series of interesting reactions when faced with distress. The degree of reaction can be as minimal as slight osteophyte formation, which can be defined as bony outgrowth (van der Kraan & van den Berg, 2007), and as severe as complete vertebral fusion, known as Diffuse Idiopathic Skeletal Hyperostosis (DISH). The focus of this research is to conduct an initial visual diagnostic assessment for the subject A-16, catalog all osteological idiosyncrasies, and produce a differential diagnosis, concentrating on the subject's individual vertebrae.

Biological Profile

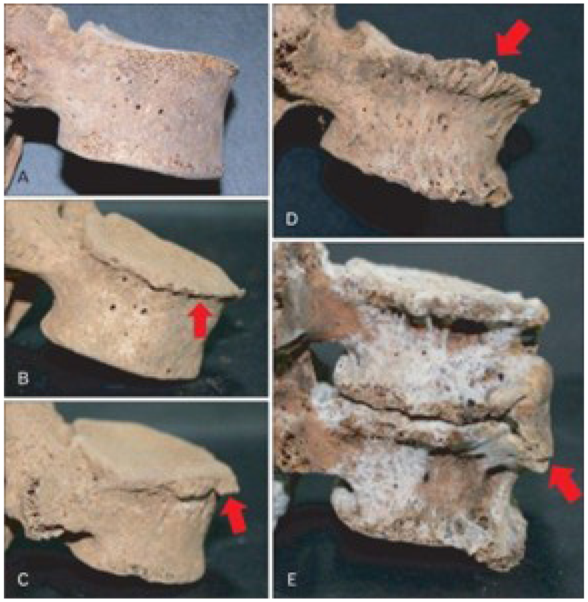
The study subject chosen for this analysis is part of a teaching collection at Florida Atlantic University. During a learning segment, this skeleton was recognized for having specific pathological anomalies that do not exist throughout the complete collection. This study will only provide a differential diagnosis for this specific individual. This subject will be known throughout this research review as A-16, due to the ethical obligation to respect the individual's nomenclature and pronouns used during their life. Efforts are being made to secure accurate information surrounding the acquisition of Florida Atlantic University's teaching skeletons. An ongoing master's thesis (Bunce, personal communication) intends to utilize various bioarchaeological processes, such as dental isotope analysis, to answer biological and ethical inquiries about the origins of these purchased teaching specimens. Because these questions are still being investigated, this research project will use standard methods to present a preliminary assessment for age and sex. The age range at death for subject A-16 is estimated to be 42-45 years using the Suchey-Brooks public symphysis scoring method (1990), and evaluation of the auricular surface of the ilium (Lovejoy et al., 1985a). The sex of A-16 is considered indeterminant based on fluctuating results using methods measuring landmarks of the os coxae, including the ventral arc, subpubic concavity and the ischiopubic ramus ridge (Phenice, 1969) and the greater sciatic notch and preauricular sulcus (Buikstra & Ubelaker, 1994). Additionally, measurements and grading of cranial landmarks, including the nuchal crest, mastoid process, supraorbital sharpness and ridge size and size of mental eminence as recommended in *Standards for Data Collection from Human Skeletal Remains* (Buikstra & Ubelaker, 1994) produced contradictory results. It is relevant to state that A-16 exhibits small skeletal features, inconsistent with the established standards. This type of disparity suggests that the sexual dimorphism of the population from which A-16 originated is inconsistent with the reference populations used to develop the standard techniques utilized in the American bioarchaeological context. Such disparities are suggestive of Asian ancestry (Schmitt, 2004) and while race or national origin is unnecessary to the biological profile, it could be an insight to the possible flaws in the standardized methods.

Diagnostic Data Set

A full skeletal analysis was performed and transcribed into a comprehensive data spreadsheet, with a particular focus on the vertebral column of A-16. The data has been compartmentalized to show bone cell response, state of activity, and condition that is visually displayed, based on a standardized format analysis presented by Owsley et al. (1995). The vast majority of vertebrae exhibited one or multiple osteopathic conditions, including osteophyte formation, as illustrated by Fig. 1.

Figure 1

Visual Example of Osteophyte Formation

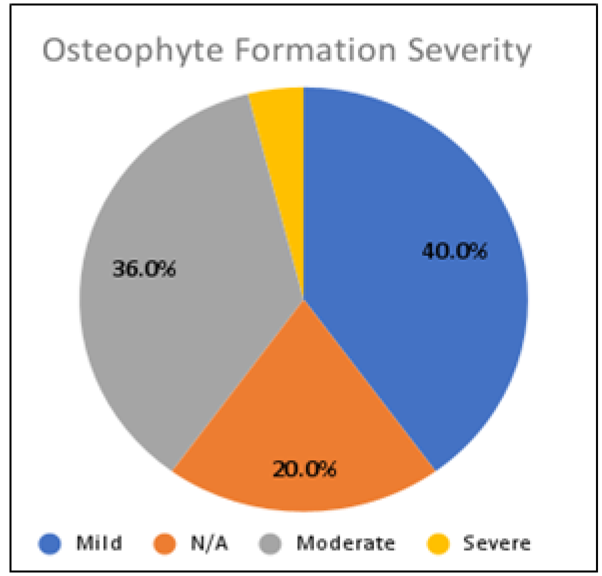


Note. (Kim et al., 2012): A) represents mild to no lipping and osteophyte formation, B) represents moderate formation, C) represents severe formation, D) represents severe formation with lipping and curving, and E) represents fusing of osteophytes of two or more adjacent vertebrae (No cases of D or E are present in subject A-16). This photo is approved to be distributed via Open Access article.

Osteophyte formation was assessed as mild for Cervical vertebrae 1, 2, 6, Thoracic vertebrae 2, 3, 6, 8, 9, 12 and Lumbar vertebra 2, moderate for Cervical vertebra 7, Thoracic vertebrae 1, 4, 5, 7, 11 and Lumbar vertebrae 4, 5, 6 (an additional lumbar) and severe for Lumbar vertebra 3, leaving only five vertebrae without evidence of bone abnormalities (Fig. 2). The osteophytes predominantly concentrated on the centrum with occasional growth on the superior facets of the arch. The centra on Thoracic vertebrae 4, 5, 6, 7, 8 suffer from extreme asymmetry, with the anterior body protruding right. This enigma is only displayed on the mid-late thoracic vertebrae.

Figure 2

Osteophyte Formation Severity of A-16



Note. Mild severity is most occurrent in A-16

Two vertebrae, Lumbar vertebrae 1 and 3, showed evidence of antemortem breaking of the transverse process, both on the right side. Lumbar vertebra 1 exhibited a clear absence of a transverse process with the site presenting as fully healed, indicating that it was broken with enough time to heal and build new cortical bone during the subject's life. Lumbar vertebra 3 exhibited evidence of possible regrowth in the transverse process, with signs of active healing surrounding the distal end of the process. Additionally, Lumbar vertebra 5 is without either transverse process; however, the break likely occurred postmortem; therefore, will not be assessed as pathogenic or traumatic.

In addition to the broken transverse process, Lumbar vertebra 3 suffered a significant compression fracture, whereas the body of the vertebra has collapsed. The centrum indicates active healing surrounding the area with severe osteophyte formation. Thoracic vertebrae 4 and 5 display noticeable active wedging, likely in response to the fracture of Lumbar vertebra 3. The occipital condyles present as asymmetrical and do not align sufficiently with Cervical vertebra 1 with trauma present to the lateral part. This may be the most apparent indication for ongoing spinal distress.

In addition to the vertebral trauma and anomalies, subject A-16 presented a healed fracture on the left rib 12, moderate osteophyte formation on the acromial end of the left clavicle and slight osteophyte formation on the left patella.

Differential Diagnosis

Vertebral Fractures

Before discussing the type of fractures considered for a differential diagnosis, it is imperative to understand possible causes for vertebral trauma. Osteoporosis is a pathological disorder that affects the density and quality of bone and is often the contributing factor for fracturing (Curate et al., 2016). Because the cortical bone becomes thin and porous during the presence of osteoporosis, there is an increased risk of fracture, although the percentage of risk is variable (Ross et al., 1990). A variety of options exist to diagnose osteoporosis including, dual X-ray absorptiometry (DXA), radiogrammetry and ultrasonometry, which provides more qualitative results (Rinaldo et al., 2018). However, with limited access to medical grade technology, a visual assessment was used to determine the level of porosity in subject A-16. During the assessment of subject A-16, osteoporosis is evident throughout the entire vertebral column, concentrated in the thoracic and lumbar region, but not exclusively. Cervical vertebra 6 displays macroporosity, including through the osteophyte formations on the body, an unusual characteristic. Additionally, the weight of long-bones, particularly the tibia and femur, suggest bone density loss throughout the entirety of the body. Subject A-16 was originally hypothesized to be between the age of 42-45 at death and while osteoporosis is classified as a disease that perpetuates with age, the body will eventually reach a peak bone mass (Kralick & Zemel, 2020), creating a plausible notion that A-16 could have experienced onset osteoporosis, even at an early age.

Figure 3

A-16 Crush Fracture

Note. A-16 Lumbar vertebra 3 with evidence of fracturing

Vertebral compression (crush) fractures are the most common in the archaeological record (Kralick & Zemel, 2020), and the most commonly treated throughout the extant human population. The fracture can occur under simple circumstances, such as hauling lightweight objects, or the trauma can occur under extreme duress, such as a fall. In the case of A-16, the sacrum is in near pristine condition with an intact coccyx lacking any visual irregularities. Sacral fractures and fracture of the coccyx would appear apparent, even as indirect trauma, if the individual suffered from a fall (Lovell & Grauer, 2018). If the fracture in Lumbar vertebra 3 of A-16 is a compression fracture, it is unlikely to have been due to an extreme fall landing on the buttocks or pelvis (Fig. 3).

Genant el al. (1993) created a visual and quantitative system to measure compression fractures for both validity and intensity (Fig. 4). The semiquantitative visual valuation provides comparative illustrations to grade wedge, biconcave and crush deformities: Grade 0: Normal, Grade 1: Mild, Grade 2: Moderate, Grade 3: Severe. A-16 is hypothesized to have a crush compression fracture and based on comparison, Grade 2, moderate, would be assigned. In addition, Genant et al. (1993) propose the collection of coordinates in the anterior, posterior and middle portion of the vertebra body. In their study, the coordinates were calculated digitately from X-ray imaging, then the results were plotted on a scatter graph. Due to the inability to capture images for A-16, a similar, crude, measurement system is used in conjunction with the original proposed formula. Measurements obtained for Lumbar vertebra 3 were performed with a standard manual sliding caliper. The threshold to identify a fracture, in this research review, is a 15% difference from the mean value in the general population (Ross et al., 1992; Genant et al., 1993). Results are as follows (Table 1):

Table 1

Calculations of Anterior, Posterior and Middle Portion of Centrum in A-16

Original Formula:
Anterior-posterior ratio (APR) = h_a/h_p
Middle-posterior ratio (MPR) = h_m/h_p

A-16 Lumbar 3 Dimensions:	**Population Mean (n=5):**
a=6.604cm, p=4.826cm, m=2.286cm	a=6.5024cm, p=6.604cm, m=6.4008cm
APR=1.368 MPR=0.47	APR=0.9846 MPR=0.9692

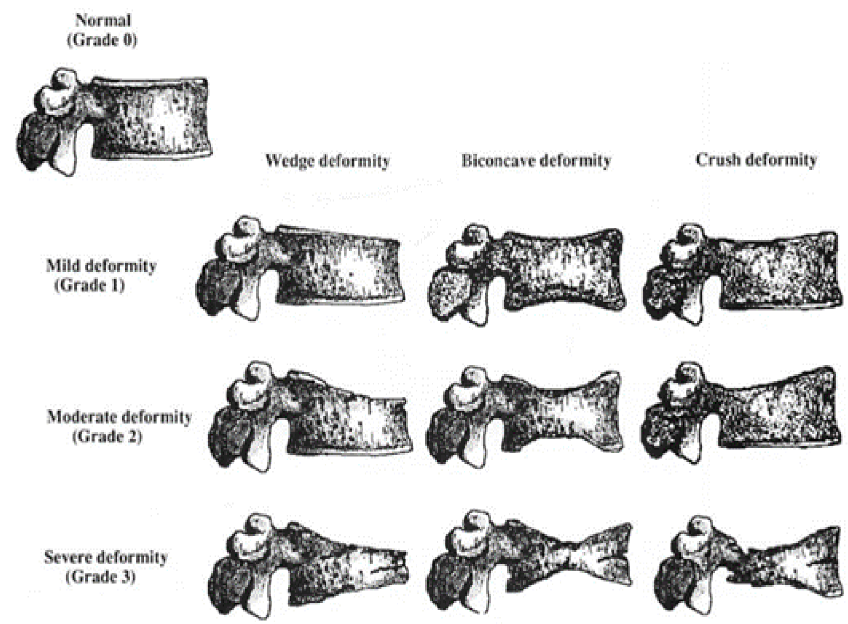
APR Differential Percentage=-39%
MPR Differential Percentage=51%

Note. Adapted from (Genant et al., 1993) in order to measure compression fracture.

Similar to the visual evaluation, Genant et al. (1993) provides a grading system [Grade 0: No reduction, Grade 1: 20-25% reduction, Grade 2: 25-40% reduction, Grade 3: 40%+ reduction]. The anterior measurement for the subject's Lumbar vertebra 3 is statistically a healthy range compared to the population surveyed. The posterior and middle region suffer a great deal of reduction due to the compression fracture. The middle-posterior ratio yields a 51% decrease from the population average (Appendix I), providing strong evidence to categorize the trauma as a severe, grade 3, fracture. An increased margin for error (15%) should be considered, due to the experience level of the observer. The measurable outcome differs from the original assessment and will be considered subsidiary information. Based on the analysis using the Genant et al. (1993) techniques, the fracture in Lumbar vertebra 3 of A-16 can be identified as a grade 2, moderate crush fracture.

Figure 4

(Genant et al., 1993) Semiquantitative Visual Grading of Compression Fracture



Note. Genant et al. (1993) Visual compression fracture guide to assess type of deformity and severity of deformity.

Transverse Process Fractures

Extreme forces are needed in order to fracture the transverse process of the lumbar vertebrae (Krueger et al., 1996). A significant collision, elevated fall, damage to the pelvis or other direct blunt trauma can cause transverse process breakage (Krueger et al., 1996; Miller et al., 2000).

The fracturing of the transverse process is closely connected to the suffering of internal abdominal damage, primarily targeting the liver, kidney and spleen. (Miller et al., 2000). In modern study, athletes who participate in contact sports, such as football, are often missing one or several transverse processes (Brynin & Gardiner, 2001). Subject A-16 displays two incidents of complete elimination of the transverse process, on Lumbar vertebrae 1 and 3. Both sites appear healed with new cortical bone in place. Lumbar vertebra 3 exhibits possible regeneration of the transverse process or indication that the break occurred more laterally, compared to Lumbar vertebra 1. Several case studies show the fracturing of the transverse process as a simple or greenstick fracture, which can be described as a bend on one side rather than a complete break, and the trauma appears to be isolated (Agrawal et al., 2009). A-16 clearly suffered a traumatic injury that caused an absolute removal of the transverse process in multiple areas (Fig. 5).

Figure 5

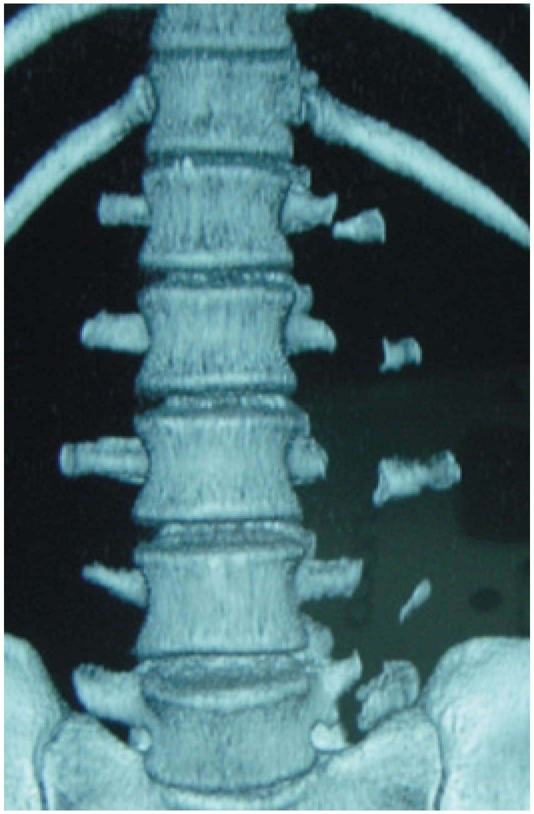
A-16 Missing Transverse Process

Note. A-16 Lumbar vertebra 1 without right transverse process.

A study of multiple level transverse process fractures has identified completed breakage, similar to A-16, in a young, active cricket player (Bali et al., 2011) (Fig. 6). The timescale and ancestry for A-16 is unknown, but A-16 is believed to be a modern individual and the suggestion for athletic participation is plausible. In archaeological record, examples of fractured transverse processes are often accompanied by the hypothesis for domestic or child abuse (Wheeler et al., 2013; Padgett & Jacobi, 2015), due to the increased and sporadic amount of trauma present on the population being studied. The overall trauma present in A-16 is minimal compared to the studies regarding abuse; therefore, it is believed to be incidental and in conjunction with other diagnoses.

Figure 6

Example of Transverse Process Fracturing



Note. (Bali et al., 2011): Anterior view of transverse process fracturing in a twenty-six-year-old cricket player. This photo is approved to be distributed via Open Access article.

Diffuse Idiopathic Skeletal Hyperostosis (DISH)

Diffuse Idiopathic Skeletal Hyperostosis is a condition, usually associated with joint disease, such as osteoporosis, that affects the anterior spinal ligaments and subsequently, the bone making up the vertebral column. If DISH is present, the vertebrae will display a "melting" or "dripping candle wax" appearance (White et al., 2012), due to the ossification of the individual vertebrae. Additionally, DISH most predominantly affects the mid-lower thoracic vertebrae, with little effect on the lumbar region (Rogers & Waldron, 2001). The extra bone formation can be severe, but the condition is recognizable as it does not affect the sacroiliac joints or articular facets (Verlaan et al., 2007), usually associated with other degenerative disorders. Subject A-16 displays no visual indication that DISH could be prevalent in the vertebrae or in the appendicular skeleton. The subject's vertebrae, while exhibiting osteophyte formation, does not appear to be fusing together. Additionally, the osteophyte formation is not solely concentrated toward the anterior portion of the centrum, a key marker for a DISH diagnosis. Finally, the vertebral trauma for A-16 is intensified in the lumbar vertebrae.

Ankylosing Spondylitis

Ankylosing spondylitis is a common rheumatic disease that primarily affects the joints and tendons of the spine (Braun & Sieper, 2007). Low bone density is typically concurrent with Ankylosing Spondylitis, especially in the lumbar region. Similar to the overreaction of the joint trauma found in cases of DISH, ankylosing spondylitis causes the vertebrae to fuse together. Although the reaction and initial appearance is similar to DISH, the sacroiliac joint and articular facets are not preserved in cases of ankylosing spondylitis (Schwartz, 2007). A-16 does not present severe vertebral fusion; therefore, Ankylosing Spondylitis can be dismissed as a reasonable diagnosis.

Schmorl's Node

Schmorl's node is the herniation of the nucleus pulposus, the inner core of the vertebral disc (Schmorl & Junghanns, 1971, as cited in Kyere et al., 2012). The herniation creates a depression in the vertebral body (Schwartz, 2007), visually akin to notches carved from Swiss cheese. Schmorl's nodes are generally common, asymptomatic and have been shown to resolve over time. The pathogenetic reason for the occurrence of herniation is unknown as many researchers theorize everything from degenerative disease to vertebral disc deterioration (Kyere et al., 2012).

Studies of Schmorl's node have found the occurrence to be most common in the lower thoracic region. (Kyere et al., 2012). Hilton et al. (1976) finds distribution of the Schmorl's node in the Dorsolumbar region but primarily in lumbar 1. Upon immediate view of subject A-16, the trauma displayed on Lumbar vertebra 3 could be interpreted as Schmorl's node. However, the indentation produced from a Schmorl's node is distinct and presents as "delicate", unlike the crude permeation from a compression fracture. Additionally, based on previous research studies, the condition is unlikely to be found as low as Lumbar vertebra 3 on the vertebral column.

Metastases

Vertebral trauma can be indicative of a multitude of ongoing ailments, including metastatic disease. Metastases are malignant growths that can occur in the skeletal system when internal organs, such as the breast, lungs or kidneys are affected by cancer. Fracturing of the vertebrae can be a subsequent reaction to the presence of metastases and, unfortunately, can appear identical to "spontaneous compression fractures'' in standard radiographic imaging (Cicale et al., 2013). Magnetic resonance imaging (MRI) technology is helpful to show the difference between benign fracturing and malignant trauma. A differential diagnosis from Cicale et al. (2013) concludes that MRI imaging can show specific characteristics for osteoporotic vertebral compression fractures, such as ordinary bone marrow signaling and the presence of split (retropulsed) fragments. Metastases can affect other areas of the body, including the pelvis and femur (Rybak & Rosenthal, 2001). The ability to determine whether the lumbar compression fracture present in A-16 is caused from metastases rather than an osteoporotic disorder or physical injury is futile without professional imaging, potential biopsy and further examination. Additionally, the os coxae and both femurs do not present visual cause for pathological concern in subject A-16. The potential hypothesis for metastasis will remain as indeterminate.

Tuberculous Spondylitis

Tuberculous of the spine, or Pott's disease, is the distribution and emergence of *Mycobacterium tuberculosis* into the vertebral column. Many times, Pott's disease is not considered in the initial diagnosis for trauma of the vertebrae as it can be difficult to decipher (Morse, 1978 as cited in Schwartz, 2007). The presence of Tuberculous in the spine can cause bone loss and collapse of the vertebra and the process of regeneration will not occur. Because A-16 demonstrates healing in the fractured areas, Tuberculous Spondylitis may be eliminated from possible diagnosis. However, access to MRI imaging would aid in determining the level of bone loss throughout the individual vertebra.

Other Pathology

Asymmetry of the Skull

A-16 presents explicit evidence of irregularity in shape of the skull, of occipital condyles, as well as bone degradation in the lateral part of the occipital region. The superior articular facets of Cervical vertebra 1 do not articulate with the occipital condyles comfortably. This deformity merits further consideration as the cause for the copious traumas to the vertebrae. Little research and few case studies have been presented for abnormal characteristics in the occipital condyles (Das et al., 2006), although the few that are offered indicate the hypothesis for developmental defects. The suggestion of a developmental abnormality certainly aligns with the evidence presented in A-16, specifically concerning the asymmetrical shape of the cranial vault and base. Many major deformities of the skull occur during subadult development and the severity of the asymmetry can denote a possible pathological condition (Russo & Smith, 2011).

Craniosynostosis is a prevalent disorder that causes asymmetry in the skull due to the premature fusion of cranial sutures (Tubbs et al., 2012). The degree of irregularity in the skull of A-16 could indicate mild and non-symptomatic craniosynostosis. Blunt force trauma to the skull could also result in cranial trauma and a possible domino effect along the vertebral column. A-16 lacks evidence of concentric fracturing or internal beveling of the skull, often correlated with blunt force trauma impact (Berryman & Haun, 1996). Because the cervical vertebrae, other than mild osteophyte formation, present as well preserved and without evident trauma, the abnormalities displayed in the occipital condyles and asymmetry of the skull may be a separate issue. There is no clear indication to postulate a conjunction between the idiosyncrasies of the occipital condyles and the trauma in the lumbar vertebrae.

Conclusion

Subject A-16 exhibits significant evidence of trauma, particularly throughout the vertebrae and calvarium. Although osteoporosis and age-based compression fractures are most commonly to blame for vertebral trauma in skeleton collections, a necessary differential diagnosis has been evaluated, as a result of ample and thorough research. I provide the following reasonable diagnosis: The asymmetry of the skull is not likely affiliated with the trauma present in the mid-lower vertebrae. The irregular shape likely comes from a developmental defect of abnormal fusion of the sutures. The occipital condyles may have incurred trauma due to the skull asymmetry as the weight would be unevenly distributed atop Cervical vertebra 1. Lack of evidence for blunt force trauma is indicative of a developmental diagnosis. A-16 has several areas of concern along the vertebral column. Two diagnoses are offered, as the circumstances of fracturing appear isolated. Nearly the entire collection of vertebrae suffers from mild to moderate osteophyte formation and severe osteoporosis. This is consistent with the general state of the rest of the appendicular and axial skeleton. The compression fracture located on lumbar 3 is likely due to the decreased density of the vertebral bones. In cases of noticeable osteoporosis, compression fractures are common and can occur even under low-impact circumstances. The subject was initially assessed to be between the age of 42-45, and although it is not unheard of for that age group to experience osteopathic disease, the level of porosity is concerning. During the original analysis, the cranial suture closures indicated an age of 42-60 based on the *Standards for Data Collection from Human Skeletal Remains* (Buikstra & Ubelaker, 1994). As a result, because A-16 displays heightened porosity, we may want to consider an age range of 42-60, although many factors can influence osteoporosis. Further research into the origin of this individual will allow for biocultural factors to be considered. The transverse process fracturing appears to be a separate pathological outcome from the compression fracture in Lumbar vertebra 3. Although the breakage takes place in the same region, the situation of association is improbable. It takes considerable force to incur a clean break of a transverse process, especially on the lumbar vertebrae. Because A-16 is in relatively healthy condition, with minor trauma in rib 12 and left clavicle, abuse or disenfranchisement as causes are unlikely. A-16 is a modern individual, however, and could be susceptible to an athletic lifestyle. Athletes, particularly participating in contact sport, are seemingly more prone to fracturing of the transverse process. The images provided by Bali et al. (2011) appear most similar to the condition of A-16. Because the processes are in a fully healed state, it may indicate reason to believe that the trauma is more mature, especially compared to the healing condition of the compression fracture. A-16 may have endured sports-related injuries during a young adult stage, providing an adequate timeline for the processes to undergo relatively refined mending. Finally, as mentioned in the review, X-ray and MRI imaging is suggested for the entire vertebral column in order to capture potential disease imperceptible through visual diagnosis. The results presented in this research only cover a fraction of potential pathological conditions affecting A-16. Many factors lead to a diagnosis; however, we can only draw some basic conclusions as there are many things still unknown. This study intends to provide insight into life history information and offer interpretations of pathological anomalies to aid in future academic analysis and understanding. Further biocultural analysis that draws on the social history of A-16 could benefit this case study, strengthening or adjusting the diagnosis.

Appendix I

	Anterior Measurement	Middle Measurement	Posterior Measurement
A-15	6.35cm	6.35cm	6.604cm
A-13	7.112cm	7.112cm	7.112cm
A-11	6.604cm	6.604cm	6.858cm
A-1	5.842cm	5.588cm	6.096cm
A-17	6.604cm	6.35cm	6.35cm

The population measured above includes individuals available to reviewer in an academic setting. The sex, age and ancestry for the above are unknown and may share no commonalities with A-16. The above population was measured for technical practice.

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I would like to thank my project advisor, Dr. Meredith Ellis, for providing unconditional support (and chocolate) throughout this process. Thank you to the FAU Department of Anthropology for allowing me to represent the department and care for the delicate skeletal collection. Thank you, Q and J, for continuously championing me. Last, thank you to the entire FAU Office of Undergraduate Research and Inquiry for facilitating this opportunity.

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Facial Recognition Technology for Identifying *Cercopithecus* Hybrid Monkeys

Connor Cane, Kayla Rae Ahlness, Charlene S. Fournier, Kate M. Detwiler, PhD (Faculty Advisor)

Abstract

Implementing innovative technology has become an invaluable resource for wildlife ecology and conservation studies. Recent studies support the use of facial recognition technology in primate species to assist with data collection. The purpose of this project was to develop a facial recognition software to identify individuals in a habituated population of *Cercopithecus* monkeys, consisting of two species and their hybrids (*Cercopithecus ascanius* and *Cercopithecus mitis*). This research is part of a long-term primate study in Gombe National Park, Tanzania. We developed an identification system by combining machine learning, object detection, and image classification. Using 16,226 images of 61 different monkey individuals, we trained an object detection system to detect the face of each monkey and we combined it with a custom-trained fast.ai Convolutional Neural Network (CNN) learning mode for identification. The sequence of these algorithms resulted in an original machine learning model with a 99.44% accuracy rate in detecting and identifying individuals from this population.

Introduction

The recognition of a single individual is critical to long-term studies of animal behavior and ecology (Crouse et al., 2017). Digital and automated technology are gaining more momentum in the fields of wildlife biology and conservation (Arts et al., 2015). The inclusion of efficient processes is crucial in order to capture accurate data on population trends. The Primatology Lab at FAU is conducting ongoing research on hybridization of *Cercopithecus* monkeys in Gombe National Park, Tanzania (Detwiler, 2019). The goal of the project is to obtain long-term behavioral, ecological, and reproductive data on individual members of the population. The integrity and accuracy of longitudinal research data relies heavily on the ability to identify each individual in the population (Crouse et al., 2017; Clutton-Brock & Sheldon, 2010). Our study population consists of approximately 61 individuals that include blue monkeys (*Cercopithecus mitis*), red-tailed monkeys (*Cercopithecus ascanius*), and their hybrids (Figure 1). Multiple researchers work in the field and in the lab to characterize and identify individuals. Currently, identifications are performed manually by trained field assistants and students; however, misidentifications occur. While these monkeys are phenotypically distinct, the differences can sometimes be too negligible for human researchers to reliably distinguish them visually. Data attributed to the wrong individual can mislead or invalidate outcomes of a study, set back researchers within their plan of study, and potentially impact other projects which rely on these data. Additionally, as field assistants and students join and leave the project, they face a substantial learning curve and need to be intensely trained on how to identify each of the individual monkeys (Loos et al., 2013). We addressed these issues by creating innovative techniques in Artificial Intelligence/Machine Learning (AI/ML) to identify individual monkeys that belong to our long-term study population.

Breakthroughs have emerged on multiple fronts in human facial recognition over the last few years (Coşkun et al., 2017). The underlying models and technologies have evolved along with massive improvements to computing power unlocked by modern graphic cards (Steinkraus et al., 2005). In a pilot study, we tested existing human facial recognition programs on monkey pictures generated from the lab. It resulted in failed identifications, which indicated that existing training models were not appropriate for monkey individuals. New models would need to be trained in order to accommodate the unique facial characteristics of the individuals in our population. An earlier study on chimpanzees had success in identifying specific individuals by using deep learning techniques on facial profiles (Loos et al., 2013). Capturing accurate individual identifications, regardless of the technique, is difficult, yet important, for long-term ecological, behavioral, and life history studies (Guo et al., 2020). The purpose of our research was to (1) design an AI/ML program that can be utilized to automate the identification process of individuals in our study population and (2) provide an efficient and accurate tool to the research team for current and future projects.

Figure 1: *Visual examples of <u>Cercopithecus mitis</u>, <u>Cercopithecus ascanius</u>, and <u>Cercopithecus mitis x ascanius</u> hybrids.*

Note. Top Left: *Cercopithecus mitis* (blue monkey); Bottom Left: *Cercopithecus ascanius* (red-tailed monkey); Top Right: *Cercopithecus* hybrid displaying more blue monkey morphological features; Bottom Right: *Cercopithecus* hybrid displaying more red-tailed monkey morphological features. Photo Credits: Maneno Mpongo and Charlene S. Fournier

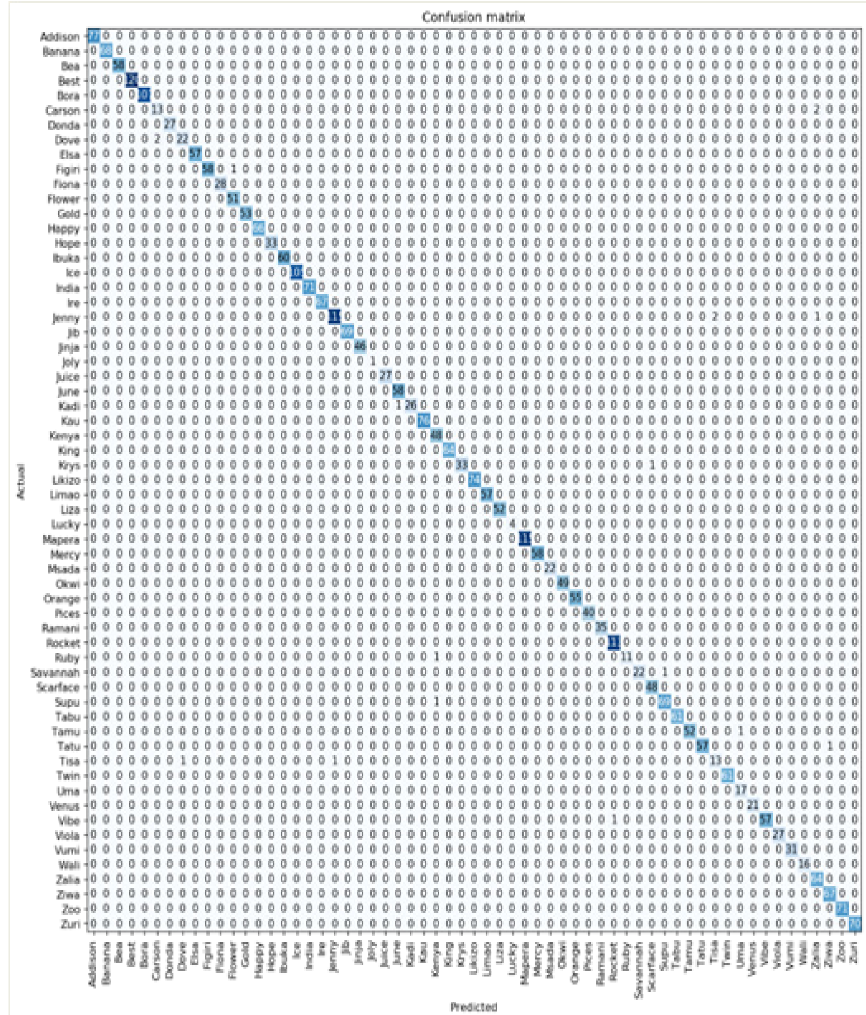
Methods

We created an Artificial Intelligence/Machine Learning (AI/ML) model using thousands of photos and trained it in a high-performance computing environment. To effectively train a unique AI/ML model, a large data set of pre-classified images was required at the outset. In this project, we used a dataset consisting of over 16,226 identified images captured and classified by our research team, which profiled 61 individual monkeys (mean = 261 pictures/monkey). From this dataset, we used 12,800 images to train the model and an additional 3,200 images to validate the procedure. We selected the deep learning and computer vision platform FastAI to develop the AI (https://www.fast.ai/) for its ease of use and powerful machine learning capabilities. Initial attempts at training the facial recognition system resulted in 80% identification accuracy. We hypothesized that incidental information (e.g., trees, backgrounds, sky, etc) in the photos resulted in decreased accuracy. Therefore, we addressed these limiting factors for accurate training of the classifier.

To improve the accuracy score, we created a program that cropped images automatically and only displayed the face of the individual, which eliminated confusion from background noise in the image. Object detection is considered one of the most challenging tasks in the computer vision field (Liu et al., 2019; Fischler & Elschlager, 1973). We used YOLOv3 (You Only Look Once, Version 3), a real-time object detection algorithm to identify specific objects in videos, live feeds, or images. YOLO is a Convolutional Neural Network (CNN) (Redmon & Farhadi, 2018), which uses features learned by a deep convolutional neural network to perform object detection in real-time. CNNs are classifier-based systems that can process input images as structured arrays of data and identify patterns between them. We then trained a YOLOv3 (Redmon & Farhadi, 2018) object detector with over 4,000 iterations to achieve a 95.9% accuracy rate in identifying and extracting monkey faces from photos. For the image label feature, we used HyperLabel to manually label an initial training set of 1,000 images, which allowed for accelerated ML dataset creation for the computer vision model.

We developed a web application that displays the distribution of probabilities as to the unknown or test monkeys' possible identification. The computational platforms needed to train a machine learning model are expensive, high-performance, and specialized; however, once a final model is created, it can be exported and used on common CPU-based systems, including basic web-hosted shared and virtual environments. The final web application we created runs on a single CPU processor and utilizes an Apache web server and Python. Both the YOLO object-detection model and the individual prediction model enable any user with access to the application the ability to upload a photo, have the application detect a monkey face, and display a ranked probability of matching. We designed the model as a web-based application for use in the field and optimized it for a mobile-phone-based browser and camera. We tested multiple CNN training models utilizing Google Compute (AI/ML optimized) clusters including Resnet34 and Resnet50, with the latter yielding better accuracy (Figure 2).

Figure 2: *Confusion matrix for our AI model.*



Note. Confusion matrix showing prediction, actual loss, and probability (n=61 profiles).

Results

We successfully created an AI/ML monkey facial recognition model that can correctly identify an individual from the study population with 99.44% accuracy (Figure 3). The models created were exported and used to create a live website, where researchers can upload photos of the monkeys and get identification in real-time.

Our results were obtained through the program implementation of FastAI, a deep learning program that allowed for the development of facial recognition through the deep learning library. It provided a layered architecture, which expresses common underlying patterns of many deep learning and data processing techniques in terms of decoupled abstractions. These abstractions can be expressed concisely and clearly by leveraging the dynamism of the underlying Python language and the flexibility of the PyTorch library (Practical Deep Learning for Coders, v3. (n.d.). Retrieved from https://course.fast.ai/). The system is productive and provides a user-friendly interface making it ideal for the implementation of our program. A follow-up study that analyzed photos taken in the field between 2015-2022, showed that our AI/ML application was successful at recognizing 94.9% of the individuals, multiple years before and after their initial classification in 2019 (Ahlness, 2022). Additionally, the web application contains a database of categorized and identified monkey photos for manual reference.

Discussion

We successfully created a two-step Artificial Intelligence/ Machine Learning (AI/ML) program that identified a study individual with a 99.44% accuracy rate. Our research program aimed to eliminate costly identification errors to support the ongoing primate research taking place in the Primatology Lab at FAU and our field study site, Gombe National Park, Tanzania.

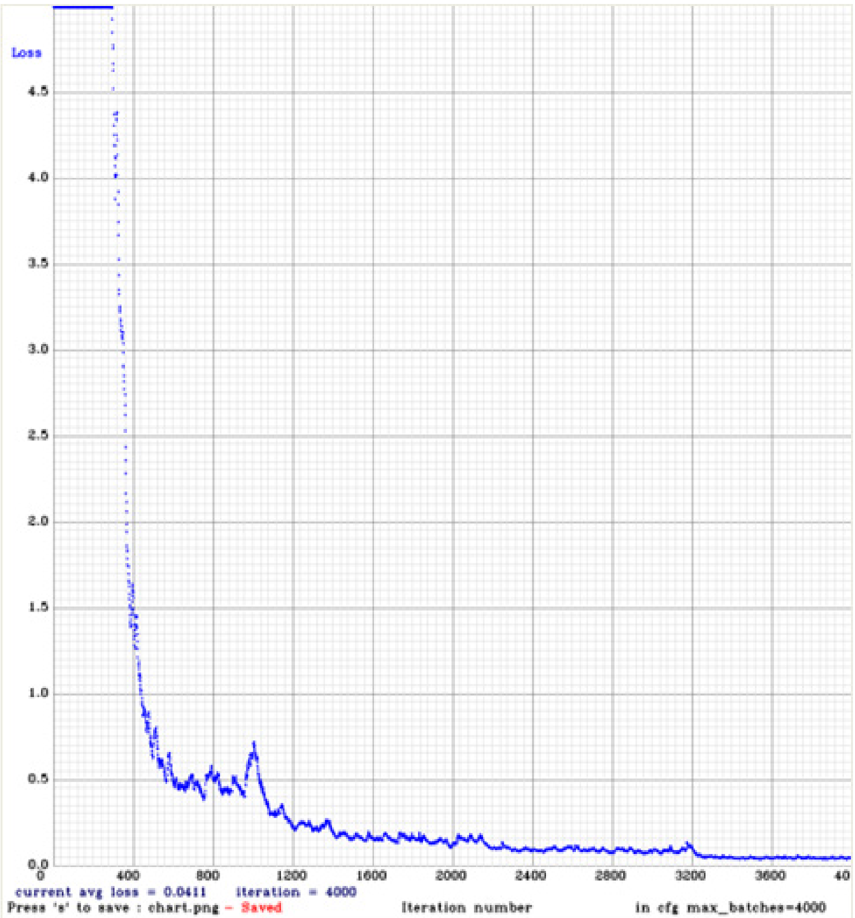
We created a web application which enables end-users to take or upload a photo of a known member of the group. Using medium and high-resolution cameras, including mobile phones, along with a mobile-friendly web application, researchers have the potential to get instant and highly accurate identifications of monkey individuals over a cellular or Wi-Fi connection. The utilization of the FastAI deep learning program allowed the combination of high-level components through a standard deep learning domain and additionally enabled the use of low-level components that could be combined with other systems for the development of our new program (Howard & Gugger, 2020). During the initial training, we experienced varied results with an 80% accuracy rate for identifications. Other researchers have reported difficulties with challenging lighting, various positions which make facial visibility less than complete, as well as potential partial occlusion by tree branches, leaves, or other monkeys (Loos et al., 2013; Clapham et al., 2020). To overcome the obstacles that decrease accuracy, we used YOLO object detection to find and crop faces before passing the information to the fast AI model for a probability distribution for individual monkey identification. YOLO has the advantage of being much faster than other networks while still maintaining accuracy (Redmon & Farhadi, 2018). Additionally, the YOLO platform allows the researchers to provide contextual feedback, enabling future versions of the application to improve accuracy and functionality. Through this project, we illustrated the power of using AI/ML to assist with deficiencies in long-term population tracking.

For the next step of this project, we will test if the program can be trained to recognize and confidently track individuals from birth to adulthood as they mature within the study group. Training with an expansive set of photos throughout multiple time periods may create more margin for error as previously seen in humans (Rashmi et al., 2017). However, future training models may show improvement for non-human primates as the facial characteristics may be less susceptible to vast changes over an individual lifetime. Additionally, improvements to the web application for better use as a data validation tool and the inclusion of more profiles may increase the effectiveness of this program as a research tool. New methods of training AI/ML also become available each year, which could help in creating more accurate predictive models in the future.

Data Availability Statement

The facial recognition model (FastAI Notebook) is available from faculty advisor, Dr. Kate M. Detwiler, upon reasonable request. kdetwile@fau.edu

Figure 3: *Loss rate using YOLOv3 object-detector.*



Note. Loss rate through >4,000 iterations using YOLOv3 object-detector.

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Home Range Analysis of *Cercopithecus* Monkeys in Gombe National Park, Tanzania

Casey Hudspeth, Dr. Diana Mitsova, Dr. Kate Detwiler (Faculty Advisor)

Abstract

Home range analysis provides insight into animal behavior and ecology. We documented the home range of a group of hybrid *Cercopithecus* monkeys in Gombe National Park, Tanzania over 40 months (June 2015-September 2018). We analyzed spatial data of monkey movement using ArcGIS software. We measured home range area from the total aggregate range from all years and between seasons in 2016. We found the total home range to be 61.83 ha and the seasonal ranges to be 39.94 ha and 37.04 ha for wet and dry seasons, respectively. Range size was larger than most study groups of the parental species at different sites. Hot spot analysis revealed seasonal differences in intra-range movement with increased utilization of the southeastern part of the range in the wet season and the northwestern section in the dry season. Factors affecting range size are likely linked to food availability and distribution, and group size.

Introduction

A home range consists of the region holding resources, such as food or mates, in which the animal or animals concentrate (Wartmann et al., 2014). Borders of the range may overlap with other neighboring ranges, with "core" areas that exhibit less overlap and greater defense effort (Wrangham et al., 2007). Home range analysis has been utilized as a tool in ecological studies to provide insight into the behavior, abundance, and habitat of animals with regard to seasonal or environmental changes (McLester et al., 2019; Miller et al., 2012). It is widely used in primatology to examine spatial constraints and habitat preferences related to social and feeding behavior (Cords, 1986; Kaplin, 2001; McLester et al., 2019; Struhsaker, 1980; Wartmann et al., 2014), as well as how spatial constraints relate to morphological and physiological characteristics of primate species (Boinski, 1987; Cords, 1986; Kaplin, 2001; Struhsaker, 1980).

Gombe National Park (GNP) in western Tanzania, alongside the eastern edge of Lake Tanganyika, has been a site of primatology study since the 1960s (Goodall, 1986). Within the park, a rare phenomenon occurs between red-tailed monkeys (*Cercopithecus ascanius schmidti*) and blue monkeys (*Cercopethecus mitis doggetti*). These two *Cercopithecus* species interbreed naturally and produce viable and fertile hybrid offspring (Detwiler, 2002). Documentation of *Cercopithecus* hybridization has been reported for decades, alongside other primate research in GNP (Clutton-Brock, 1975; Detwiler, 2019; Goodall, 1986;). However, further information regarding the ecology and behavior of hybrid monkey social groups is needed (Detwiler, 2019).

In this study, we determined the home range of a habituated hybrid monkey group and investigated patterns of movement between seasons and over multiple years. The study group consisted of *C. ascanius schmidti*, *C. mitis doggetti*, and their hybrids (59 individuals at the end of 2018: 9 *C. mitis*, 37 *C. ascanius*, 13 hybrids). Prior studies have examined the home ranges of the parental species, for example: *C. ascanius* range was documented as 44-65 ha in Ngogo, Kibale National Park, Uganda; 60 ha in Kakamega Forest Reserve, Kenya (Cords, 1986); and 1600 ha in the Issa Valley, western Tanzania (McLester et. al. 2019). *C. mitis* range was documented as 38 ha in Kakamega (Cords, 1986) and 88 ha in Nyungwe National Park, Rwanda (Kaplin, 2001). McLester et al. (2019) found differences in temperature and food availability as factors contributing to variation in the movement of *C. ascanius* groups. However, no previous study has investigated the effect of hybridization on home range and how it may affect range size.

Thus, we established three objectives to build an understanding of GNP's hybrid monkey home range behavior: (1) determine the size of the study group's home range, (2) determine if the study group has seasonal patterns of movement, and (3) determine how the study group's home range size and internal movements compare to those of the parental species from other forests in East Africa (e.g. Cords, 1986; Kaplin, 2001; McLester, 2019).

Methods

Study Site

We conducted the study in Gombe National Park, Tanzania, a forested and hilly region on the eastern edge of Lake Tanganyika. Open and thicket woodlands, including *Brachystegia* woodland, cover the upper and lower slopes with evergreen forests covering valley bottoms (Collins & McGrew, 1988). Grasslands occur at the highest points of the valley ridges (Collins & McGrew, 1988). GNP experiences two major seasons: a dry season from approximately June to October and a wet season from approximately November to May (Goodall, 1986). We defined seasons based on average monthly precipitation. We used spatial data collected from the start of the dry season of 2015 (June) to the end of the dry season in 2018 (September) for a total of 40 months (Table 1).

Data Collection and Formatting

Field assistants collected location data using handheld GPS units which recorded the spatial location of the study group as a GPX file. Each waypoint was documented in a field journal as either "initial contact" with the group, "group scan" every 30 minutes, or "final contact" when the field assistant left the group. Field assistants were typically in contact with the group for approximately 7 hours a day, between 7:00 and 12:00, and then again between 16:00 and 18:00. Due to field assistant schedules and fieldwork conditions, sampling effort varied within hours of the day, days of the month, seasons, and years (Table 1).

In our lab, we transferred the GPX data from the handheld GPS recorder into the DNR GPS program, which transformed the data from GPX files into ArcGIS shapefiles. We set the projection to WGS 1984 UTM Zone 35S. Next, we converted the shapefiles to Excel files (.xlsx), which were consolidated to include only waypoints needed for the study. Once the filtered dataset was created, we imported the information into ArcMap 10.7.1 as XY coordinate data.

Minimum Convex Polygons

We created minimum convex polygons (MCPs) from the XY coordinate datasets for all waypoints and the waypoints from the 2016 wet and dry seasons. We selected 2016 waypoints for seasonal data as it had the most frequent and consistent work effort. In ArcMap, we used the respective XY coordinate data to create a new feature class displaying minimum bounding geometry. We set the geometry type to "Convex hull," resulting in the smallest convex polygon that encompassed the XY data.

Hot spot Analysis

We conducted a hot spot analysis for each dataset using a search radius of 5m and 15m, for the seasonal and total datasets respectively. A hotspot analysis is a spatial analytical technique based on the Getis-Ord Gi* statistic, which facilitates the identification of patterns in the spatial distribution of a dataset. The tool generates p- and z-values, which help the user determine if there is a statistically significant pattern of spatial clustering. We used hot spot analysis to track intra-range movements, thus allowing for a more precise visual of ranging behavior than MCPs. The hot spot analysis accounted for the variation in work effort seen between seasons, as the clusters still indicated areas of frequent use.

Results

Sampling Effort

From the beginning of the dry season in 2015 to the end of the dry season in 2018, we identified 4,155 waypoints from group observational data. Concerning seasonal data, 744 waypoints were from the 2016 wet season (56% of 2016 waypoints), and 573 waypoints were from the 2016 dry season (44% of 2016 waypoints). Over the full course of the study, the average number of waypoints per month was 104 ($\sigma = 43$). We found the average for the 2016 wet season to be 106 waypoints per month ($\sigma = 31$) and 115 waypoints per month for the dry season ($\sigma = 23$).

Minimum Convex Polygons

Using an MCP, the total home range for the group during the study period was 61.84 ha. Seasonally, the MCP for the wet season and dry season were 39.94 ha and 37.04 ha respectively (Figure 2).

Hot spot Analysis

Using hot spot analysis to analyze intra-range movement, we found that the group spread out more in the wet season than in the dry season. We found overall concentration in the wet season to be in the southeast part of their range, whereas in the dry season, the group concentrated in the northwest section (Figure 3).

The overall trend of the full dataset resembled the dry season pattern with a concentration in the northwest section of the range (Figure 4). The results indicate a statistically significant clustering of "hot spots," within the respective radius used in the analysis (orange = $z > 1.65$, $p < 0.1$); red = $z > 1.96$, $p < 0.05$; dark red = $z > 2.58$, $p < 0.01$; Figure 4). The "cold" spots indicate that there is a statistically significant clustering of low values in that area (light blue = $z < -1.65$, $p < 0.1$; blue = $-2.58 < z < -1.96$, $p < 0.05$; Figure 4).

Discussion

The results of our study confirmed the ranging behavior of the hybrid monkey group of *C. ascanius schmidti* and *C. mitis doggetti* to clustering within a defined area. We also were able to locate areas with minimal usage. The cold spots in the range may indicate that the area was lacking in sufficient food sources, covered difficult terrain for the field assistants to traverse, or was in some other way less suitable than the preferred regions. Another factor to consider is areas where home range overlaps between neighboring groups, as such regions are often under-used (Wrangham, 2007).

Seasonal movement was the most obvious trend observed in our study and thus was likely behaviorally motivated. Food availability is cited as a reason for seasonal movement in primates (Cords, 1986; Kaplin, 2001; McLester et al., 2019; Sugiyama, 1976) as seasonal changes in vegetation affect the food sources of primates and consequently lead to the movement of primate groups in a cyclical, temporal manner (Li et al., 2000). Thus, the shift of the study group from the southeast to the northwest may be connected to food resources.

In Nyungwe National Park, *C. mitis* was observed with season-specific behavior, traveling farther in the wet season compared to the dry. At Nyungwe, fruit availability varied with the season, and the monkeys were more prone to travel when the number of fruiting trees diminished, and their diet became more varied (wet season) (Kaplin, 2001). Cords (1986) found the consumption of major diet elements to be seasonally different in Kakamega. Diet likely plays an important role in intra-range movements in our study group as well.

The total aggregate range size of the hybrid monkey group (61.83 ha) was close to the upper end of those previously reported. Our study group had a larger home range than the *C. ascanius* study group in Kakamega, Kenya (Cords, 1986), and all but one of the study groups in Kibale National Park, Uganda (McLester et al., 2019). The hybrid group's range was smaller than the *C. mitis* home range size at Nyungwe National Park, Rwanda, which measured at 87.7 ha (Kaplin, 2001), but *C. mitis* in Kakagmega had a smaller range at 37 ha (Cords, 1986). However, the *C. ascanius* study group's home range size of 1600 ha in Issa Valley in western Tanzania was considerably larger than our study group's home range and the ranges of all other groups reported (McLester et al., 2019).

The longer time scale of the current study resulted in a larger range to encompass all movements from multiple years. As most comparative studies evaluated home range on shorter time scales, the 2016 seasonal range sizes may be more accurate for comparison. Certainly, the seasonal ranges were very similar to the *C. ascanius* range from the Kibale National Park and the *C. mitis* range from Kakamega (Cords, 1986; McLester et al., 2019). A likely factor driving differing range sizes between the hybrid group and parental groups is habitat differences (McLester, 2019). Though all sites include tropical forest (Cords, 1986; Kaplin, 2001; Struhsaker, 1980), GNP's steep valleys allow for diverse terrain shifts from grassland to woodland to forest (Collins & McGrew, 1988).

Additionally, the number of individuals in the reported groups differed, with our hybrid study group having the highest number of individuals compared to the *C. ascanuis* or *C. mitis* groups in the Kibale National Park, Kakamega Forest Reserve, or Nyungwe National Park (Cords, 1986; Kaplin, 2001; McLester et al., 2019). Differences in size between intraspecies groups are common and are likely linked to variances in food availability (McLester et al., 2019). This correlation may indicate that GNP is rich in food resources due to its ability to maintain a group larger than those seen in either parental species without excessive increase in home range size, such as the home range of the Issa Valley group. Hybridization in our study group may also have an impact on range size. Brown (2013) found interspecies interactions a variable in range size due to intergroup conflict. A large group comprised of two species and their hybrids may face less disruption in ranging patterns due to reduced competition, although more research is needed to investigate the impact of hybridization on range size.

Future studies will continue tracking the movement of the hybrid study group and monitoring for shifts in the ranging pattern. Additional data on neighboring groups' ranges would allow for understanding of inter-group relationships, motivations behind range usage and constraints on home range size. One important direction for future work lies in studying the diet of the hybrid study group. Comparing home range data to spatial data on food items would provide information on seasonal patterns of movement. By understanding the distribution and abundance of the foliage and fruits that make up the flora portions of *C. ascanius* and *C. mitis'* diets, we can gain further knowledge on the important factors for home range size, movement, and survival (Boinski, 1987; Wada & Ichiki, 1980).

A technical limitation of our study was that MCPs give an estimate for the maximum home range with a tendency to overestimate total size (Ostro et al., 1999) and thus do not give information regarding core ranges or intra-range movement throughout seasons. We compensated for this by using hot spot analysis which gives a more precise visual of group movement and location. Additionally, it is important to note the periods of the day where most waypoints were recorded (7:00 - 12:00 and 16:00 - 18:00), and the data were not representative of all daylight hours.

Home range studies are important for the evaluation of animal behavior and ecosystem structure, as well as for aid in the conservation of habitats (Li et al., 2000). By studying home range behavior from multiple study groups from different populations, we can understand what factors an animal or group relies on for survival and can monitor for an increase or decrease in the health of their habitat.

Acknowledgments

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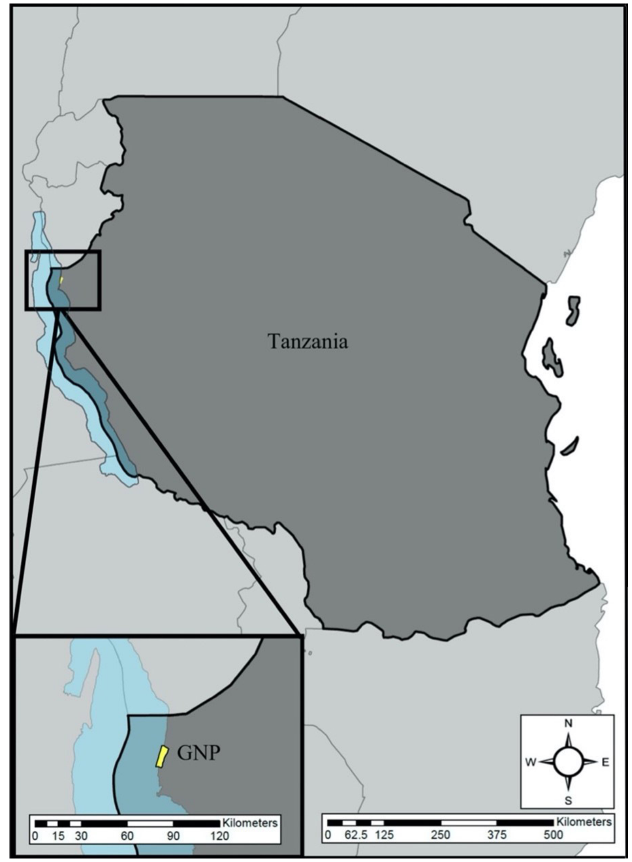
Figure 1

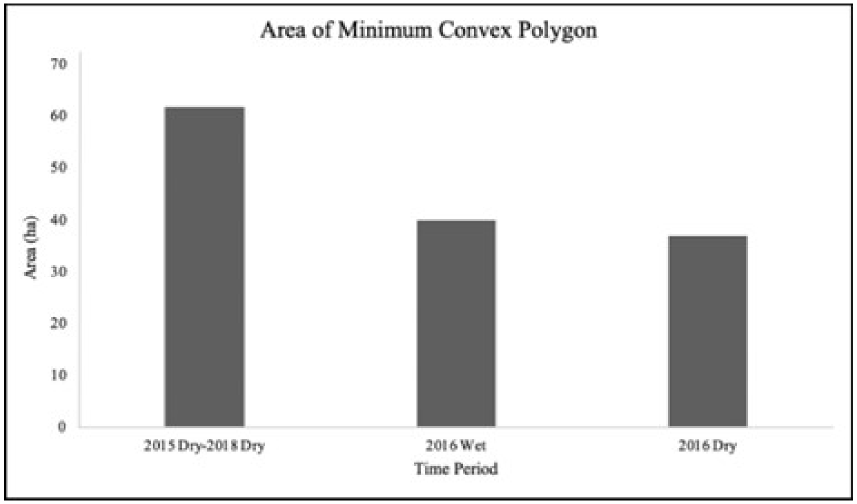
Map of Tanzania



Note. Location of Gombe National Park (GNP) in western Tanzania alongside Lake Tanganyika.

Figure 2

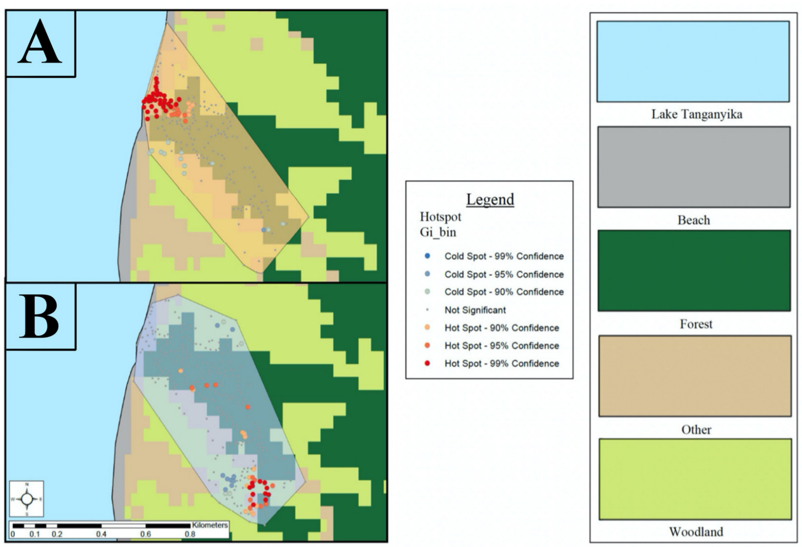
Area of Minimum Convex Polygon



Note. Area of total home range throughout the study (Start of dry season 2015-end of dry season 2018) and range in 2016 wet and dry seasons.

Figure 3

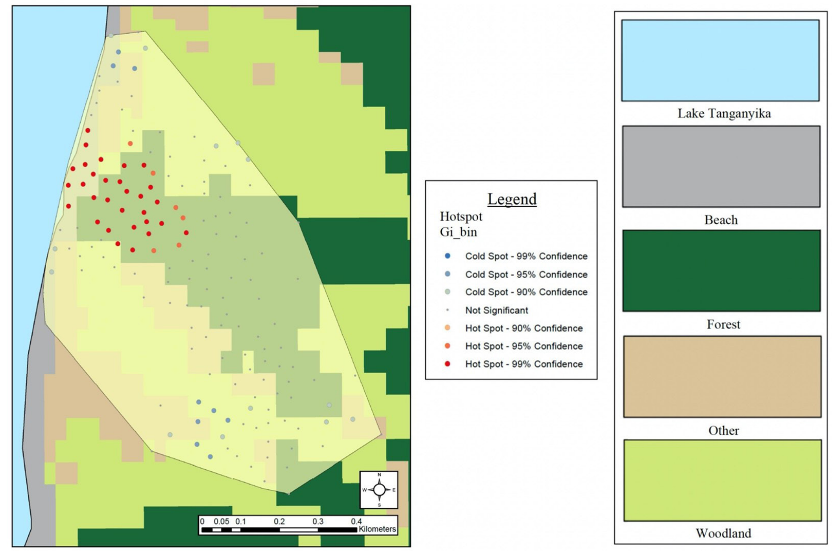
Minimum Convex Polygons of Seasonal Ranges



Note. Minimum Convex Polygons of home range use during 2016 dry (A) and wet (B) seasons combined with results from the hot spot analysis (a cold spot indicates an area that is significantly underused, whereas a hot spot indicates an area that is significantly frequented).

Figure 4

Minimum Convex Polygon of Total Range



Note. Minimum Convex Polygon of total range used throughout the study combined with results from the hot spot analysis (a cold spot indicates an area that is significantly underused, whereas a hot spot indicates an area that is significantly frequented).

Table 1
Total number of waypoints recorded during the study: June 2015-September 2018

Month	2015	2016	2017	2018
Jan		87	92	53
Feb		55	61	26
Mar		155	82	41
Apr		110	136	36
May		124	112	96
Jun	124	109	133	102
Jul	104	106	152	129
Aug	119	156	172	137
Sep	140	98	140	225
Oct	70	104	151	
Nov	46	111	80	
Dec	54	102	25	

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The Structure of Stigma: Developing a New Measure of Mental Health Attitudes and Knowledge

Melanie Sanders, Tristan A. Stinchcomb, Dr. Laura L. Vernon (Faculty Advisor)

Abstract

Although nearly half of all adults in the United States experience issues with mental health, the stigma around it remains a pervasive and stalwart barrier to treatment-seeking. Current research on stigmatization typically focuses on attitudes towards populations experiencing mental illness and receiving mental health treatment, but often lacks items measuring attitudes toward suicidality and mental health knowledge. Therefore, this study aimed to develop a new measure of mental health attitudes and knowledge that includes these aspects. The 27 original items were administered to 145 college students. A principal components analysis was conducted and four factors were identified – Stigma (10 items), Shame (3 items), Resource Knowledge (3 items), and Applied Knowledge (3 items). Items that did not load strongly onto any of these factors or that had significant cross-loadings (n = 8) were dropped, leaving a total of 19 items. We found positive correlations between the Stigma and Shame factors as well as Resource Knowledge and Applied Knowledge factors. Both Knowledge factors were negatively correlated with Shame. Implications for measurement and research of mental health stigma and knowledge are discussed.

Introduction

In most situations, the way an individual copes with a condition or illness depends highly on their conceptions of the condition or illness, as well as the social body of knowledge built around it. Hagger and Orbell (2003) demonstrated in their research that one's subjective representations of a physical health condition have a direct relationship to the responses towards said condition, such as ideas around said condition (like perceived controllability or social identity) or a willingness to seek treatment for it. From a body of related research in psychology, we can see that this relationship can hold true for differing conditions of mental health and mental illnesses. The current study aims to potentially reify the link between mental health stigmatization, perceptions of one's own condition, and treatment-seeking behavior. To this end, we have deigned the best course of action to be formulating a new scale which measures mental health knowledge in addition to mental health stigma.

Societal Misconceptions

People also tend to relate the consequences of their mental health to the subjective ideas they retain regarding it (Chan & Mak, 2016; Fox et al., 2018). Even though we have come to a point where we have started to culturally pay more attention to mental health and the societal stigma surrounding mental illness, there are still many misconceptions regarding the subjective and symptomatic experiences of those living with mental health conditions. In turn, these misconceptions tend to heighten existing stigmatizing attitudes around mental health, on both personal and wider scales. Stigma is generally defined as negative personal beliefs and social expectations that lead to discrimination (Shim et al., 2009), and there are two prominent forms that stigma can take. The kind of stigma that is societally enforced, public stigma, leads to social barriers to equitable housing, vocational/career opportunities, and accessible healthcare (Corrigan et al., 2015). Socially held beliefs that people with mental illnesses are dangerous or incapable leads to the repeated restriction of their opportunities. In turn, individuals with mental health issues may tend to avoid seeking mental health treatment entirely to avoid any stigmatization that comes with trying to access help (Corrigan et al., 2015). In addition, individuals suffering from mental health conditions can also display self-stigma, which is when one internalizes and agrees with negative public attitudes and stereotypes, and then applies those negative beliefs to themselves and their conditions (Corrigan & Rao, 2012). The endorsement of negative stereotypes about the self can lead to low self-esteem, low self-efficacy, self-imposed isolation, decreased treatment-seeking, and an overall poorer quality of life (Corrigan & Rao, 2012).

Despite the fact that nearly half of all adults in the United States will experience and be diagnosed with a mental illness at some point in their lives, information about mental health is obscured heavily by stigma and misconceptions created by the media (Johnson & Riles, 2018; Nairn, 2007). Some people hold stigmatic beliefs that those with mental illnesses are dangerous, or untrustworthy, or that mental illnesses are uncurable (Hirai & Clum, 2000). Studies around this topic revealed that this sort of stereotypic, inaccurate representation can lead to discomfort around those who were identified as having mental health concerns (Johnson & Riles, 2018). Other examinations concerning conceptualizations of mental illness have shown similar stereotypic attributions. Open-ended questions about mental illness have been shown to conjure recurring themes of pity and discomfort in participant responses (Matteo, 2013). Even with the most empathic responses of those surveyed, these themes of pity were associated with the kind of pity reserved for other socially stigmatized out-groups such as disabled communities and elderly people (Matteo, 2013; Fiske et al., 2002).

Other societally held ideas of mental illness may draw upon depictions of mental health from media which are sensationalized and predominantly inaccurate, not only in works of fiction but in factual sources as well (Nairn, 2007). Oftentimes, stereotypical depictions of those living with mental health issues show these individuals as otherized, and the social construction of people living with mental illnesses as "other" has become reified by the media and maintained in our persistent social consciousness (Nairn, 2007). Corrigan et al. (2015) stated that, with regards to mental illness labels, the way that this stigmatization begins is with a delineation between in- and out-groups of those fitting social ideals and those on the margins; or 'us' and 'them.'

Internalization of Misconceptions

As society continues the reinforcement of these stereotypes of people with mental illnesses as being dangerous and unpredictable, the stigma around mental health tends to engender feelings of self-blame, embarrassment, shame, and discourages treatment-seeking in affected individuals (Benbow, 2007). Regarding the current evidence surrounding the relations between stigma and treatment seeking, Britt et al. (2015) found that worries about being stigmatized are associated with fewer inclinations to seek help, and Fung et al. (2007) observed that they were associated with decreased compliance with treatment suggestions and recommendations. Additionally, there have been several studies wherein researchers have reported a significant relationship between stigma and treatment-seeking. Multiple researchers found links between mental illness stigma and a reluctance to seek treatment (Henderson et al., 2013; Hirai et al., 2015), both in terms of self-stigma and perceived public stigma (Lally et al., 2013).

In part due to the nature of stigma, perceived stigmatization may influence whether individuals seek mental healthcare by potentially heightening their own self-stigmatizing views (Cheung et al., 2015). Some literature around this relationship has also revealed that the anticipation of being stigmatized is related to decreased treatment seeking in those experiencing severe symptoms of their condition (Fox et al., 2018). Other work on the relationship of treatment seeking and stigma also includes the concept of resilience. Low resilience has been linked to an increase in mental health stigma, suggesting that when an individual's resilience is compromised, they may be less likely to seek help and recover (Crowe et al., 2016), feeding into a vicious cycle. This may imply that affected individuals who perceive themselves as being in an unsafe environment that would not understand their mental health concerns may be even more loath to seek treatment due to a fear of being othered

by their peers, even with the widely held belief that treatment can be effective in reducing their symptoms (Dobranksy, 2020). Not only might personal and public stigma act as an obstacle towards accessing care for those who need it, but it has been observed that there is a stronger correlation between self-stigma and symptom distress when individuals self-report low levels of social support (Denenny et al., 2015).

Research suggests that increasing mental health awareness and literacy has been a big contributor to decreasing mental health stigma (Milin et al., 2016). Increasing college student knowledge about available mental health resources appears to be a likely contributor to the ability to self-identify issues and self-refer to the proper resources. In addition, those with more mental health knowledge are more likely to be able to identify problems within their peers and aid them in finding the proper resources (Milin et al., 2016). It seems likely that attitudes and knowledge about mental health are deeply intertwined, however, these various factors are rarely measured together.

Psychometric Scales

While previous scales have examined important aspects of the stigmatization of those with mental illnesses and other related factors, there is a dearth of measures which collect data on individuals' knowledge of mental health resources and their application while also measuring stigmatization. There are, according to Wei et al. (2015),

> many gaps in the field, such as the unbalanced applica tion of knowledge and help seeking evaluation measures compared to the stigma/attitudes measures, the yet-to-be validated measures in each outcome category, and the lack of measures that measure all components of mental health literacy concurrently. (p. 15)

Indeed, while there are many scales which measure mental health knowledge and stigma, most either test for stigma and do not include a measure of mental health literacy, such as the Stigma Scale (King et al., 2007), the Mental Illness

Stigma Scale (Day et al., 2007), the Attitudes to Mental Illness Questionnaire (Luty et al., 2006), and the Beliefs Toward Mental Illness scale (BTMI; Hirai & Clum, 2000), or measure mental health knowledge but not stigma itself, such as the Mental Health Knowledge Schedule (Evans-Lacko et al., 2010) and the Mental Health Literacy Scale (O'Connor & Casey, 2015).

It is imperative that we identify and examine the full range of stigmatic beliefs in individuals so that we may eventually mitigate such beliefs. With these goals in mind, this study aims to develop a new mental illness attitudes and knowledge measure and examine its factor structure. Specifically, a majority of the existent stigma research focuses on attitudes toward populations experiencing mental health conditions and towards mental health treatment; it typically fails to include items related to suicidality, mental health knowledge, and resource knowledge. As such, the new measure will include traditional public stigma items, personal stigma items, and shame items, as well as individuals' mental health resource and applied knowledge and their attitudes towards suicidality.

Method

Participants

Participants were recruited through class announcements in a large freshman course. Of the 145 students who completed the questionnaires, 56.6% identified as female, 37.2% as male, and 6.2% reported being of a minority gender (e.g., agender, genderqueer, or of another nonbinary gender) or did not disclose their gender. In terms of sexual orientation, 71.7% of students reported identifying as heterosexual, or straight, 6.9% as gay or lesbian, 13.8% as bisexual, and 2.8% identified under the label queer. For the race and ethnicity of the sample, 33.1% of the sample identified as Latine/Latinx, 65.5% identified as non-Latine/Latinx, 11.7% as African American or Black, 77.2% as Caucasian or White, 10.3% as Asian or Asian American, 2.8% Native American, and 5.5% identified in other ways. IRB approval was granted for the collection of data, and participation was voluntary.

Materials

A 13-item demographic questionnaire was administered to students to gain information on gender, age, sexual orientation, race, ethnicity, and level of education. All the demographic items were in a multiple-choice format, save for items on age and academic major, which were open-ended.

To measure students' attitudes towards mental health, suicidality, and their knowledgeability concerning interventions and associated resources, we used a scale of our own construction based upon our review of the existing literature which identified a lack of scales which measure all of these factors concurrently. This scale consists of 27 items rated on a 5-point Likert-scale ranging from strongly agree, to neither agree nor disagree, to strongly disagree. Items measured respondents' stigmatizing/accepting beliefs of mental illness and suicidality (e.g., "Suicide is the coward's way out," "People with mental illnesses are dangerous to be around."), shame (e.g., "If I had a mental illness, people would judge me," and "Having a mental illness would reflect poorly on me."), familiarity with mental health resources and psychoeducation (e.g., "I know where to find mental health resources in my community," "I have participated in a program/programs aimed at enhancing my knowledge and skills regarding mental health.") and applications of this knowledge (e.g., "I know how to safely intervene in situations where someone is distressed," and "I know how to recognize signs and symptoms of mental illness in myself.").

Procedure

After being recruited for participation via class announcements, participants completed a battery of questionnaires online including a 13-item demographic questionnaire and our new measure of mental health attitudes and knowledge. Surveys were hosted through Qualtrics. The current study examined the factor structure of the mental illness attitudes and resource knowledge survey utilizing principal components analysis.

In our analyses, we examined responses to the new measure containing items regarding attitudes and knowledge about mental illness. To do so, we conducted a principal components analysis with varimax rotation to identify various latent factors measured by the scale.

Results

Factor Structure of Mental Health Attitudes and Knowledge Measure

Four factors were identified with eigenvalues greater than 2.0 and these explained 27.38%, 12.97%, 6.88%, and 4.90% of the variance, respectively. Two other factors with eigenvalues greater than one were identified, but since each had eigenvalues less than 2.0, contained few and often cross-loaded items, and were after the scree plot leveling off, they were not interpreted. Items and their factor loadings are shown in Table 1. Items that loaded < .5 on any factor or had significant cross-loading across multiple factors were excluded (8 items).

The first factor is comprised of ten items relating to stigmatic beliefs concerning mental health and suicidality, such as “If a friend or a loved one expressed that they were struggling with a mental illness, I would think less of them,” “Suicide is the coward’s way out,” and “Mental illnesses are all just in your head—if you try hard enough to get over it, you will eventually get rid of it.” These items all loaded above .55 (ranging from .561 to .796, M = .672) on what was named the “Stigma” factor.

The second factor included three items relating to shame regarding mental health and its associated stigma. Items included statements such as “Having a mental illness would reflect poorly on me,” “If I had a mental illness, people would judge me,” and “If I had a mental illness,

I would not think less of myself for it.” These items all loaded on the “Shame” factor above .70 (ranging from .701 to .764, M = .724).

The third factor is made up of three items regarding knowledge and awareness of mental health resources. Items included “I know where to find mental health resources in my community,” “I am aware of mental health outreach services near me,” and “I know where to find mental health resources online.” The items all loaded on this “Resource Knowledge” factor above .80 (ranging from .818 to .884, M = .853).

The fourth factor is comprised of three items relating to applied psychological knowledge and bystander intervention. Items included “I know how to safely intervene in situations where someone is distressed,” “I know how to recognize signs and symptoms of mental illnesses in others,” and “I know how to recognize signs and symptoms of mental illnesses in myself.” The items all loaded on the “Applied Knowledge” factor above .60 (ranging from .613 to .817, M = .731).

Table 1: **Item Factor Loadings for the Mental Health Attitudes and Knowledge Measure**

	Item	Stigma	Shame	Resource Knowledge	Applied Knowledge
T14.	If someone I was dating was diagnosed with a mental illness, I would trust them less because of it.	0.796			
4.	If a friend or a loved one expressed that they were struggling with a mental illness, I would think less of them.	0.760			
13.	If my friend were diagnosed with a mental illness, I would want to distance myself from them for my own emotional/physical safety.	0.754			

15.	If someone I knew told me that they had attempted suicide, I would think that they were crazy.	0.707			
16.	Suicide is “the coward’s way out.”	0.685			
7.	People with mental illnesses are dangerous to be around.	0.662	0.334		
5.	If a classmate or coworker expressed that they were struggling with a mental illness, I would not want to work with them anymore.	0.614	0.334		
8.	If someone I cared about told me they had a mental illness, they would still be the same person to me.	0.597			
1.	Mental illnesses are all just in your head—if you try hard enough to get over it, you will eventually get rid of it.	0.588			
11.	Mental illnesses develop because of individual weaknesses or mistakes, or because the person with the mental illness could not overpower it.	0.561	0.230		
19.	I know where to find mental health resources in my community.			0.884	
18.	I know where to find mental health resources online			0.856	
23.	I am aware of mental health outreach services near me			0.818	
6.	Having a mental illness would reflect poorly on me.	0.338	0.764		
3.	If I had a mental illness, I would not think less of myself for it.		0.708		
9.	If I had a mental illness, people would judge me		0.701		
25.	I know how to recognize signs and symptoms of mental illnesses in myself.			0.227	0.817
24.	I know how to recognize signs and symptoms of mental illnesses in others.			0.364	0.763
26.	I know how to safely intervene in situations where someone is distressed.		-0.208	0.285	0.613

The internal consistency was strong for three of the factor subscales: Stigma, $\alpha = .88$; Resource Knowledge, $\alpha = .88$; and Applied Knowledge, $\alpha = .81$. The internal consistency was marginal for the Shame factor subscale, $\alpha = .69$.

Relationships Among Mental Health Attitudes and Knowledge Factors

The Stigma and Shame factors were significantly positively correlated with one another ($r = .346$, $p < .001$). Additionally, the Resource Knowledge factor was significantly positively correlated with the Applied Knowledge factor ($r = .547$, $p < .001$). The Shame factor was found to be negatively correlated with both Resource Knowledge ($r = -.223$, $p < .007$) and Applied Knowledge ($r = -.228$, $p < .006$). Stigma was also observed to be negatively correlated with Applied Knowledge ($r = -.226$, $p <$

.002), but was not significantly related to Resource Knowledge (r = -.154, p < .069).

Discussion

This study is important as it developed and tested the factor structure of a measure that includes items tapping public and private mental health stigma beliefs, suicidality stigma beliefs, and knowledge of mental health resources and applied mental health knowledge in a single measure for college students. The new measure had a four-factor structure, consistent with our predictions, with scales tapping Stigma, Shame, Resource Knowledge, and Applied Knowledge. The items concerning negative beliefs about suicidality loaded onto the Stigma factor.

The focus of some of our scale items differs from other stigma measures, particularly the items on shame related to mental health stigma as opposed to embarrassment. For example, the Beliefs Toward Mental Illness scale (BTMI; Hirai & Clum, 2000), is a 24-item scale that indexes negative stereotypical views concerning psychological conditions. While the BTMI and other measures of social stigma towards mental illness tend to work on axes of “dangerousness”, “embarrassment”, “incurability”, and “poor social skills”, our measure approached stigmatization from a perspective of shame. Additionally, Yeap & Low (2009) developed a stigma measure that includes a mental health knowledge scale, an attitudes towards mental health scale, and an item which measures participants’ help-seeking tendency. However, the attitudes and knowledge subscales were not broken down into more specific subscales as we have done in the present study. Items like “If I had a mental illness, people would judge me,” and “If a friend or a loved one expressed that they were struggling with a mental illness, I would think less of them,” are items that express this perspective. This is important due to the distinctively different social functions of embarrassment—what Hirai and Clum’s (2000) measure indexed—and shame. Embarrassment tends to stem from the violation of one’s ideas about the self, while shame comes from the violation of a shared and unilateral social ideal (Babcock & Sabini, 1990).

The results of this analysis support the idea that mental health stigma as a factor is distinct from, but strongly related to, knowledge about mental health resources and appropriate responses to mental illness. Although multiple items in our scale were found to have cross loadings across 2 or more factors, these cross-loadings were not high enough to conclude that the two factors were the same, thus suggesting that the four factors which were identified are correlated in some way but are unique factors in relation to one another. The results also support the idea that, while some of the facets of stigma may be correlated with each other, not all of them do so.

The results of our correlational analysis of the factors provides important implications for further research, suggesting the potential for both vicious cycles and virtuous cycles. The Stigma and Shame factors were significantly positively correlated with one another, suggesting that the more negative attitudes one endorsed about mental illness and persons diagnosed with a mental illness, the more shame they reported concerning mental illness itself. Further, Shame scores were negatively associated with both the Applied Knowledge and Resource Knowledge factor scores, suggesting a vicious cycle in which those experiencing more shame about mental illness were less likely to have the knowledge needed to identify mental health difficulties in themselves and others or know about available help resources for such difficulties. Stigma was also negatively correlated with Applied Knowledge, and there was a trend for a negative correlation with Resource Knowledge. It may be the case that somewhat weaker negative correlation between Resource Knowledge and Stigma may in part reflect successful education outreach efforts by university counseling services and student affairs professionals.

On the hopeful side, the Resource Knowledge factor was significantly positively correlated with scores on the Applied Knowledge factor, suggesting that those who learned more about available resources also expressed more knowledge and confidence about knowing how to identify distress, support those who are distressed, and refer to appropriate resources. This may be evidence of a virtuous cycle of familiarity and knowledge begetting more knowledge, and reflects previous findings that mental health literacy has a positive correlation with help-seeking intentions (O'Connor & Casey, 2015).

Since this data is correlational, we cannot predict whether intervening at the level of stigma and shame will significantly impact knowledge, or if intervening at the level of resource and applied knowledge could significantly alter stigmatic beliefs and shame. However, due to the observed correlations between the factors, it would be prudent for future research to investigate whether such interventions into resource and applied knowledge factors could indeed significantly impact stigma and shame factors, or vice-versa.

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AUTHOR BIOGRAPHIES

KAYLA RAE AHLNESS

Kayla Rae Ahlness (she/her) is a senior and a Phi Kappa Phi member at Florida Atlantic Uni-versity, pursuing a B.A. in Anthropology with a minor in Biological Sciences. She has been ac-cepted into the M.S. in Biological Sciences program, beginning in Fall 2022 and has an inter-est in primatology and wildlife ecology. She is currently involved with the FAU primatology lab, developing a project for utilizing artificial intelligence to create life history profiles for hybridized Cercopithecus monkeys. She has authored/coauthored on three undergraduate research posters and wishes to pursue a career in research and conservation. In her free time, Kayla plays roller derby, plays the drums and enjoys playing board games with her hus-band and son.

CONNOR CANE

Connor Cane is a 2022 graduate of Florida Atlantic University High School. There, he conducted re-search in the FAU Primatology Lab of Dr. Kate Detwiler utilizing artificial intelligence to identify indi-vidual Cercopithecus monkeys. Connor has conducted primary field research in Gombe National Park, Tanzania, and presented his research at machine learning symposiums. In 2019, Connor was selected as one of five students to represent the United States at the United Space School - a two-week international research and planning program comprised of 50 students from 25 countries. Con-nor's passion is the application of new technologies in research to advance the fields of science and historical research.

CASEY HUDSPETH

Casey Hudspeth is a recent graduate from Florida Atlantic University (FAU). She graduated with a Bachelor of Science in Biological Sciences and a minor in Business Administration. Her curiosity in animal behavior and ecology led her to begin volunteering in Dr. Detwiler's lab, and later in beginning her own project concerning Gombe's hybrid Cercopithecus study group's ranging behavior. She presented preliminary results at OURI symposiums in 2020 and in 2021. She plans to continue her career path in ecology and conservation via internships at animal rehabilitation institutes and through graduate school.

CHARLENE S. FOURNIER

Charlene graduated with a BA in Psychology in 2018 and a MS in Biological Sciences in 2020 from FAU, where she was studying the behavioral ecology and genetics of African monkeys in Dr. Detwiler's lab. Being a licensed embryologist and andrologist outside of campus, she is now focusing her PhD dissertation on her newly found interest in this field. Charlene just began research in Dr. Asghar's lab, where she is involved in creating a microfluidic device to sort human sperm cells based on their progressive motility, which could have clinical implications in fertility clinics. Charlene had also been teaching Life Science labs to undergraduate students at FAU and is now the instructor of record for the course.

MELANIE SANDERS

Melanie Sanders is a South Florida-based educator, writer, and life-long learner who has covered topics in psychology and social-emotional learning (SEL). Other interests include health promotion, socio-emotional development, gender studies, and ethics. She recently graduated from Florida Atlantic University's Harriet Wilkes Honors College with a bachelor's degree in Psychology. Previously, Melanie has worked alongside initiatives such as OwlsCare Health Promotion and FAU Thrive as a peer mentor to raise awareness and education around topics such as consent, body positivity, eating disorder and suicide prevention, health equity, and more. Melanie is currently a first-year middle school teacher with sights to expand safety, acceptance, and mental health in and out of the classroom.

TRISTAN STINCHCOMB

Tristan Stinchcomb is a researcher and author who is interested in topics in the field of psychology, specifically focusing on clinical and counseling psychology and related research. Other interests include psychometrics, literary studies, and epistemology. Tristan received his bachelor's degree in Psychology from Florida Atlantic University's Harriet Wilkes Honors College with a minor in English Literature. Tristan currently works with the Brain Institute of Florida Atlantic University, completing outreach work to teach the community about issues pertaining to neuroscience and psychology, and is planning on attending graduate school to attain a Ph. D. in clinical psychology.