

Acupuncture as an Adjunct Therapy for Osteoarthritis in Chimpanzees (*Pan troglodytes*)

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Acupuncture is an ancient practice that is currently used to treat disorders ranging from osteoarthritis to cardiomyopathy. Acupuncture involves the insertion of thin, sterile needles into defined acupuncture points that stimulate physiologic processes through neural signaling. Numerous scientific studies have proven the benefits of acupuncture, and given this scientific support, we hypothesized that acupuncture could benefit the nonhuman primates at our facility. As our chimpanzee colony ages, we are observing an increase in osteoarthritis and have focused our initial acupuncture treatments on this condition. We successfully trained 3 chimpanzees, by using positive-reinforcement training techniques, to voluntarily participate in acupuncture treatments for stifle osteoarthritis. We used 3 acupuncture points that correlate with alleviation of stifle pain and inflammation in humans. A mobility scoring system was used to assess improvements in mobility as a function of the acupuncture treatments. The 2 chimpanzees with the most severe osteoarthritis showed significant improvement in mobility after acupuncture treatments. Acupuncture therapy not only resulted in improved mobility, but the training sessions also served as enrichment for the animals, as demonstrated by their voluntary participation in the training and treatment sessions. Acupuncture is an innovative treatment technique that our data show to be safe, inexpensive, and, most importantly, effective for chimpanzees.

The exact origins of acupuncture are obscure. Some evidence suggests acupuncture therapy originated more than 5000 y ago and includes the finding of sharpened stones and bones believed to be used to puncture skin as a treatment for various ailments.²⁵ However, there is little dispute that acupuncture was widely practiced by 100 BC— and was meticulously documented in the text from that era, *The Yellow Emperor's Classic of Internal Medicine*.³⁷ These early treatments were characterized by blood-letting,¹¹ but acupuncture has evolved over the millennia into needling practices that focus on stimulating tissues without the removal of blood.

During the past century, the acceptance of acupuncture as an effective alternative therapy has grown. The current body of scientific literature includes thousands of studies, primarily conducted with human subjects, that support the use of acupuncture for various disorders. Some of the documented and efficacious uses of acupuncture include treatment for migraines, osteoarthritis, orofacial pain, gastrointestinal disorders, cardiac arrhythmias, hypertension, and stress.^{6,16,17,22,23,27,28,30,33}

Acupuncture involves the insertion of thin, sterile needles into defined acupuncture points that stimulate physiologic processes through neural signaling.³¹ The majority of the defined acupuncture points correspond to neurovascular bundle locations, blood plexuses, and motor endplate zones.^{10,29,32} Once the needles are inserted into these highly innervated and vascular acupuncture points, the needles are rotated gently. This needle rotation creates a coupling between the needle and the underlying connective tissue, which then delivers a mechanical signal to the nervous tissue.²¹ This peripheral afferent signal then travels to the spinal cord, where it can cause numerous

effects including stimulation of the dorsal horn, resulting in endogenous opioid release and enhanced analgesia,³⁴ increased release of various peptides such as calcitonin gene-related peptide and vasoactive intestinal polypeptide, which have been shown to cause vasodilation, improved circulation, and enhanced immunomodulation;^{8,24} neural signaling to higher centers in the brainstem and cerebrum to influence hormonal regulation;^{19,40} and stimulation of visceral neural pathways to influence internal organ function.^{31,41}

Given the scientific support for the use of acupuncture, we hypothesized that this therapy could benefit our increasingly geriatric colony of chimpanzees. As our chimpanzee colony ages, osteoarthritis has been (and will be) observed with increasing frequency. The criteria for establishing a diagnosis of osteoarthritis in chimpanzees are similar to those used in humans and involve clinical symptoms, physical exam findings, and radiographic evidence.¹ Osteoarthritis has previously been observed in other chimpanzee colonies³⁵ and in skeletons from aged chimpanzees in the wild.⁵

Although we are interested in using acupuncture to treat various disorders, we have initially focused our treatments on animals with osteoarthritis. Numerous studies have reported that humans with osteoarthritis experience enhanced analgesia, beyond what the pain-relief medications provide, after acupuncture.^{2,3,13} Given the existing scientific evidence, we hypothesized that acupuncture therapy would provide enhanced analgesia for our chimpanzees, as measured by improvements in mobility.

Materials and Methods

Animals. Three chimpanzees were trained to voluntarily participate in acupuncture treatments. Chimpanzee J was a 44-y-old, wild-born female chimpanzee with a 4-y history of stifle osteoarthritis characterized by bilateral stifle crepitation and mildly to moderately impaired mobility. Her average

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mobility score was 3.25 before the initiation of acupuncture therapy. She had been treated intermittently with analgesics and antiinflammatory medications, depending on the severity of her osteoarthritis-related pain, but was not receiving medications during the current study. Chimpanzee S was a 45-y-old, wild-born male chimpanzee with a 10-y history of chronic stifle osteoarthritis, bilateral stifle crepitation, and moderately impaired mobility. His average mobility score was 4.5 prior to acupuncture therapy, the most severe score that has been assigned at the MD Anderson primate facility. Chimpanzee S received meloxicam (7.5 mg once daily) and tramadol (50 mg twice daily). Chimpanzee Y is a 40-y-old, wild-born male chimpanzee with a 3-y history of mild stifle crepitation and a mild mobility impairment (average score, 1.3). Chimpanzee Y did not receive any medications for the treatment of osteoarthritis.

The chimpanzees in this study were housed in mixed-sex, compatible social groups ranging from 5 to 10 animals in enclosures that provided both indoor and outdoor access. They had ad libitum access to water and a commercial primate diet (Harlan Teklad chimpanzee diet no. 7775, Harlan Teklad, Madison, WI) and received fresh produce daily. All chimpanzees at the Michale E Keeling Center are part of an extensive behavioral management program that includes both environmental enrichment and positive-reinforcement training.³⁸

All animals housed at The University of Texas MD Anderson Cancer Center, Michale E Keeling Center for Comparative Medicine and Research, are maintained in accordance with the *Guide for the Care and Use of Laboratory Animals*,¹⁸ and the facilities and program are fully accredited by AAALAC.

Acupuncture training. To achieve maximal benefit from acupuncture, it was necessary to perform multiple acupuncture sessions per animal. Sedating chimpanzees for sequential acupuncture treatments was not in the best interest of the animals. To effectively treat chimpanzees by using acupuncture, we first trained the chimpanzees to voluntarily accept acupuncture treatments without sedation. Animals were trained for this behavior by using positive-reinforcement training.⁷ The University of Texas MD Anderson Cancer Center, Michale E Keeling Center for Comparative Medicine and Research, employs 2 full-time trainers who regularly train the animals for various procedures. Two procedures that are routinely trained are stationing (holding still in a specified position) and 'needle stick' (which involves desensitization to needles for injection purposes). The chimpanzees involved in acupuncture training had previously been trained to both station and to accept a needle stick. This previous training greatly facilitated the training for acupuncture therapy; the only new behaviors that needed to be trained were to station for a prolonged period (approximately 10 min) and desensitization to the acupuncture needles. The chimpanzees were considered trained for acupuncture when they were able to hold a specific body part against the enclosure mesh, tolerate the insertion of acupuncture needles, and remain in that position for 10 min (the approximate length of time needed to complete an acupuncture treatment).

Acupuncture procedure. We used sterile, disposable, uncoated surgical stainless steel hwa-to acupuncture needles (diameter, 0.25; length, 25 mm; Suzhou Medical Instruments, Jiangsu, China) that were 0.25 mm in diameter and 25 mm in length for our procedures. To avoid losing our acupuncture needles into the enclosure if an animal moved from its targeted position at the front mesh, dental floss was tied around each acupuncture needle that was placed in the animal (Figure 1). This practice ensured that the needles would pull free from the skin and stay with the veterinarian administering the acupuncture treatment if the animal pulled away from the front of the enclosure.



Figure 1. Three acupuncture needles inserted into regional stifle acupuncture points, with dental floss tied around needles to prevent loss of needles into chimpanzee enclosure.

Three chimpanzees were trained to voluntarily participate in acupuncture treatments for stifle osteoarthritis. Because the arthritis was localized to the stifles, we used acupuncture points that correlated with alleviation of stifle pain and inflammation in humans (ST34, ST35, and ST36).³⁶ These acupuncture points lie along the stomach acupuncture meridian (demonstrated in Figures 2 and 3). The animals received acupuncture treatment once weekly. Initially, all 3 chimpanzees received unilateral acupuncture therapy. Two of the animals (chimpanzees J and S) progressed in their acupuncture training, and we were able to train them to present for bilateral acupuncture treatments. When chimpanzees received analgesic or antiinflammatory medications as treatment prior to the initiation of acupuncture therapy, these treatments were continued unchanged throughout therapy.

Mobility scoring. A mobility scoring system (Figure 4) was established to empirically assess chimpanzee mobility and locomotion. Mobility scores for the 3 subjects were determined prior to initiating acupuncture treatment and at 3-mo intervals thereafter. To generate a mobility score, 3 to 5 people involved with the care of the chimpanzees observed the animals and scored their mobility according to the mobility scoring system. Although the observers were not blinded to which subjects were being trained for acupuncture, they were blinded to the acupuncture training details and did not know when the animals had been fully trained or when they began weekly acupuncture therapy sessions. Mobility scores (between 3 and 5 scores per time point) were averaged to achieve the documented mobility score for each animal at each time point.

Statistics. All mobility measures were compared by using Mann-Whitney *U* tests that compared pretreatment baseline mobility scores with posttreatment scores at the relevant time points. All tests were one-tailed, given that our alternative hypothesis stated that mobility would improve as a function of acupuncture treatment. A probability level of *P* less than 0.05 was chosen for significance.

Results

Training. Three chimpanzees were trained to voluntarily present and hold for acupuncture treatment of osteoarthritis. Training sessions occurred weekly, except when holiday or vacation schedules interfered. Chimpanzee J required 4 acupuncture training sessions before she was completely trained to voluntarily present for acupuncture treatment. During her first 2 training sessions, she held position for 1 min each session. During the third session, she held position for 4 min. During her fourth training session, she successfully held position for 10 min.



Figure 2. Chimpanzee J receiving acupuncture therapy for stifle osteoarthritis (acupuncture points from left to right: ST36, ST35, and ST34).



Figure 3. Chimpanzee S receiving acupuncture therapy for stifle osteoarthritis (acupuncture points from left to right: ST36, ST35, and ST34).

Chimpanzee S required 5 sessions before he was completely trained for acupuncture treatments. During the first training session, he held his position for 4 min. At the second session, he held for 6 min, and during the third and fourth sessions, he held position for 5 min each. During the fifth session, chimpanzee S held position (with needles inserted) for 10 min.

Chimpanzee Y required only 3 training sessions before he presented for a full 10 min of acupuncture treatment. However, during his fourth treatment session, he regressed in his tolerance of the acupuncture needle stick. After this regression, he required an additional 5 training sessions before he once again held position for a full 10 min.

Mobility scores. The 2 older animals with mild to moderate mobility impairments due to osteoarthritis showed improvements in mobility after the initiation of acupuncture therapy. Chimpanzee J had a mobility score of 3.25 prior to acupuncture therapy. After 3 mo of unilateral acupuncture treatment, which included 8 acupuncture sessions, her mobility score improved to 2.33; this change in mobility score was not statistically significant. However, after 6 mo of treatment, including 15 total acupuncture sessions, her score improved further to 2.20 ($U = 18.0, P < 0.05$; Figure 5). She has recently been trained to present for bilateral acupuncture therapy, and we will continue to monitor her progress.

1	Never displays impeded locomotion or impaired mobility
2	Infrequent slightly or mildly impaired locomotion
3	Frequent slightly or mildly impaired locomotion
4	Infrequent moderately impaired locomotion
5	Frequent moderately impaired locomotion
6	Infrequent severely impaired locomotion
7	Frequent severely impaired locomotion
8	Continuously impaired locomotion

Figure 4. Scoring system for assessing mobility and locomotion.

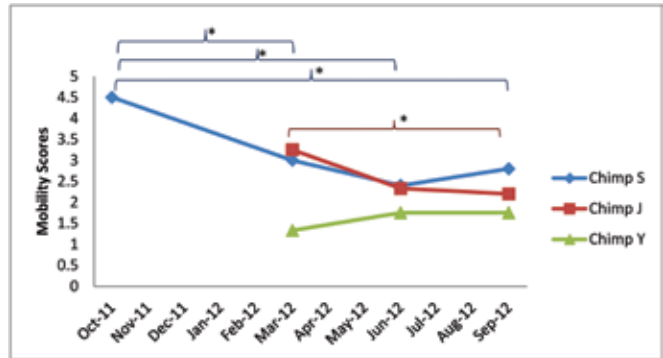


Figure 5. Mobility scores for chimpanzee S significantly ($P < 0.05$) decreased at all time points after the initiation of acupuncture therapy compared with October baseline mobility scores. Chimpanzee J demonstrated significantly ($P < 0.05$) improved mobility at the September time point compared with baseline mobility scores in March. Chimpanzee Y did not demonstrate any significant changes in mobility after the initiation of acupuncture therapy.

Chimpanzee S has had chronic moderate osteoarthritis for more than 10 y. His average mobility score was 4.5 prior to the initiation of acupuncture therapy. After 3 mo of unilateral acupuncture therapy performed once weekly, including 12 acupuncture treatment sessions, chimpanzee S showed an improvement in his mobility score from 4.5 to 3.0 ($U = 12.0, P < 0.05$). After an additional 3 mo of bilateral acupuncture therapy performed once weekly, for a total of 6 mo of treatment and 24 acupuncture sessions, his mobility score further improved to 2.4 ($U = 15.0, P < 0.05$; Figure 5), indicating statistically significant improved mobility and locomotion and, presumably, less pain. Given that his analgesic–antiinflammatory dosing was not altered at the start of acupuncture therapy, the observed improvements in mobility were likely directly attributable to enhanced analgesia provided by the acupuncture treatment. Of note, his acupuncture sessions were halted for 3 wk in July 2012, when the veterinarian performing these treatments was unavailable. When treatments resumed in August 2012, we attempted to increase the time between treatments to every other week, because the chimpanzee had improved dramatically during the first 6 mo of treatment. However, in September 2012, his mobility score increased to 2.8. Although this score of 2.8 still reflected a significant ($U = 15.0, P < 0.05$) improvement compared with the pretreatment baseline, the increase indicated that the mobility of chimpanzee S was better when acupuncture was performed weekly (Figure 5).

Chimpanzee Y experienced the mildest osteoarthritis among the 3 trained subjects, with a mobility score of 1.3 prior to acupuncture treatment. Given the mild nature of his mobility impairment, this chimpanzee did not have much room for improvement in his condition, and there was no statistically significant effect on his mobility after the initiation of acupuncture therapy (Figure 5). Acupuncture therapy was discontinued

in July, due to both lack of response and need for therapy; furthermore, the mobility score remained unchanged after the end of acupuncture treatment (Figure 5).

Discussion

The primary symptoms of osteoarthritis are pain and mobility impairment. Osteoarthritis affects a large proportion of people, with 10% of men and 18% of women over 60 y of age affected by osteoarthritis-related pain.¹⁵ There is no known cure, and treatment is primarily symptomatic.⁹ The Osteoarthritis Research Society International committee recently convened and performed a systematic review of the scientific literature, identifying 24 valid treatment options for osteoarthritis.⁴² Whereas 13 of these options were surgical or pharmacologic treatments, the 11 remaining options were nonpharmacologic and included weight loss, knee braces, and acupuncture.⁴² Given the studies supporting its efficacy,^{2,3,13} relatively low cost, and minimal side effects, acupuncture is an excellent treatment option that can be used either alone or in conjunction with pharmacologic treatments in cases of osteoarthritis.

As our chimpanzee colony ages, we are observing an increase in osteoarthritis, as is observed in geriatric human populations.¹⁴ In chimpanzees whose mobility is affected by osteoarthritis, there are potential concerns related to their social group housing. If their mobility becomes impaired to the point where they cannot effectively protect themselves in their current social groups, they may need to be removed from these groups (and large outdoor enclosures) for their own protection. A smaller social group consisting of similarly aged animals that are less active may become necessary to protect the osteoarthritic animal from unimpaired animals. Having shown that acupuncture can improve mobility in osteoarthritis-affected chimpanzees, we can now use this treatment modality to improve their wellbeing and potentially allow them to remain with their social groups and in their large outdoor enclosures.

Appropriate management of osteoarthritis-related pain may require daily administration of medications, and prolonged administration of the standard pharmacologic treatments for osteoarthritis can have significant side effects. For example, extended use of NSAIDs can cause gastrointestinal bleeding.⁴ Many of the nonpharmacologic treatments suggested by the Osteoarthritis Research Society International committee⁴² are impractical for chimpanzees. For example, chimpanzees will not tolerate knee braces, wear insoles, or participate in water exercise. However, we can train them to voluntarily participate in acupuncture treatment, and our results demonstrate that acupuncture effectively enhances mobility and potentially alleviates osteoarthritis-related pain and inflammation in chimpanzees. Therefore, acupuncture not only may provide additional pain-relief benefits, but its use potentially can minimize the use of drugs when concerns arise regarding safety.

In chimpanzee S, acupuncture improved mobility and enhanced the benefits achieved with analgesic and antiinflammatory medications. When acupuncture treatments were briefly halted, improvements in mobility were slightly reduced in chimpanzee S. His mobility scores were less favorable after a 3-wk break in treatment that was followed by reduction in treatment frequency to every other week. These results mirror similar studies of acupuncture treatment of osteoarthritis-related pain in humans in that the pain relief benefits did not persist after acupuncture therapy was discontinued.³ This pattern suggests that to maintain the analgesic benefits of acupuncture, the therapy must be continued.

Chimpanzee Y, which had the mildest osteoarthritis, did not show measurable benefit from acupuncture therapy. This result, in conjunction with the successes observed in chimpanzees J and S, suggests that animals with more severe osteoarthritis benefit more from acupuncture therapy in terms of mobility improvement. In cases of mild osteoarthritis, such as that of chimpanzee Y, acupuncture may not provide marked benefit, or perhaps the benefits in mild cases are difficult to measure by using mobility ratings.

We have shown that positive reinforcement training techniques can be used to successfully train chimpanzees in 3 to 5 sessions to voluntarily present and hold for complete acupuncture sessions. The animals we have trained readily participate in their acupuncture training and therapy sessions, often assuming the targeted position and behavior immediately when we enter the room to begin a session, even before the trainer has asked the animal for the behavior. Chimpanzee S will not only immediately present his leg for therapy, but after the needles are removed from the first leg, he turns around and presents the second leg. Once we have finished treating the second leg, chimpanzee S will often turn and present the first leg again, suggesting a positive association with the training and acupuncture therapy. Chimpanzee J shows similar willingness to participate in her treatment sessions, often assuming a position with her leg pressed against the enclosure mesh when she first glimpses the trainer and veterinarian entering the room. Such voluntary participation is crucial for successful acupuncture treatment, because it would be inappropriate to sedate the animals at the frequency required for acupuncture to be effective. In addition, this type of treatment (that is, using positive reinforcement techniques) allows the animals to have opportunities where they can make the decision to participate in their own care.

The observed benefits of acupuncture in chimpanzees include not only the measurable enhanced mobility and presumed decreased pain, as has been reported in humans,² but the training also serves as a form of enrichment for the animals. Food enrichment, such as small fruit pieces, are used as positive reinforcement during acupuncture training. In addition, the chimpanzees experience social enrichment during training sessions as they interact with the trainer and veterinarian performing the acupuncture therapy. For chimpanzees J and S, as the number of acupuncture therapy sessions increased, the amount of positive reinforcement (that is, grapes and other fruit pieces) required decreased. The potential cause for the decreased need of positive reinforcement may be related to desensitization to the acupuncture itself or, more importantly, may indicate that the inherent benefits of acupuncture provide a reward that outweighs the fruit rewards. Thus far, these findings have not been quantified.

An additional benefit of acupuncture treatment is our subjective observation of enhanced social interactions with the other chimpanzees in the subject's social group. It appears that once we enhance a chimpanzee's mobility and decrease its presumed pain, the animal interacts more with conspecifics in their social group. The increase in social interaction, enrichment, and health benefits observed with acupuncture therapy make it a potentially attractive adjunct therapy not only for osteoarthritis but also for many other health issues.

Acupuncture is also an attractive treatment option because of the established safety of the procedure.^{36,39} Acupuncture has minimal adverse effects, and when adverse effects are observed, they generally are reported in cases of deep needling (inserting the needle deep into the tissue) or after the insertion of an 'indwelling' needle for permanent acupuncture.²⁶ Indwelling

needle placement is discouraged among acupuncturists today,¹² and deep-needling techniques are advised only in the context of a thorough knowledge of anatomy and with care taken to avoid lungs and large blood vessels.²⁰ If the procedure is done correctly and care is taken to avoid needling deeply over the thorax, joints, and large blood vessels, acupuncture has been an extremely safe medical treatment.

Although our acupuncture treatments have focused primarily on osteoarthritis and demonstrated a measurable benefit, we have trained chimpanzees to present other body parts for the treatment of other disorders. We have trained chimpanzees to present a wrist for the treatment of cardiac arrhythmias (acupuncture points PC6, HT7), the lower abdomen for acupuncture points targeted to treat diarrhea or constipation (CV4, CV6, ST25), and the upper thorax for a point used in the treatment of pneumonia (LU1). We plan on expanding our acupuncture treatments to include wound care and cardiomyopathy as we train more chimpanzees to accept this relatively simple, novel, inexpensive, and most importantly, efficacious treatment strategy.

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