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Is Chimpanzee (*Pan troglodytes*) Wounding Frequency Affected by the Presence Versus Absence of Visitors? A Multi-Institutional Study

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Abstract: Visitor effect studies have had inconsistent results, due in part to the inability to control for all confounding variables such as time of day, seasonal weather patterns, and so forth. This study represents the first instance where chimpanzee (*Pan troglodytes*) wounding frequencies were investigated across extensive time periods in the presence and complete absence of visitors, thus eliminating many visitor-related variables. Additional variables were eliminated through the zoo selection process, based on institutional responses to a 29-question survey, providing a novel approach to the question of visitor effects. The aim of this study was to determine if visitors were associated with a change in chimpanzee wound event frequencies across four 51-day time conditions, three of which occurred prior to the COVID-19 pandemic, and one during the first wave of pandemic-related zoo closures. We analyzed the archival records of 21 chimpanzees housed at three U.S. zoos. Due to the small number of wound events across all study windows, frequencies of "no wound" events were analyzed. A chi-square goodness of fit test was performed to determine whether the frequency of "no wound" events was equal between the "open" and "closed" trials. Results indicate that the frequencies did not differ, suggesting that chimpanzee welfare, as it relates to wounding, may not be adversely affected by zoo visitors.

Keywords: *Pan troglodytes*; chimpanzee; visitor effects; zoos; welfare; wounding; COVID-19

1. Introduction

In recent years, zoos and aquariums have drastically increased their commitment to the science of animal welfare. While maintaining positive welfare outcomes for animal residents has arguably been a top priority for quite some time, these institutions are now embracing more objective, systematic measures of investigation into questions regarding the animal experience. Substantial effort and emphasis are placed on determining specific positive and negative drivers of these experiences. Daily data collection is now the norm within institutions accredited by the Association of Zoos and Aquariums (AZA), with welfare-related and species-specific indices of behavior a top priority [1].

One aspect of the animal experience within zoos and aquariums that has been the subject of increasing interest in recent years is the visitor effect e.g., [2–6]. Because zoo-housed animals encounter visitors on a regular basis [6,7], and because animal perception of these encounters can vary, there are potential welfare impacts related to visitor effects. Interestingly, results of visitor impact studies have been somewhat ambiguous, and have been interpreted to mean that visitors are associated with neutral [8,9], adverse [10–12], or enriching effects [13–15].

Most visitor-based researchers have investigated the effects of crowd size [11,14,16–32], length of time at the enclosure [23,29,30,33], zoo attendance [12,17,28,34–39], visitor attendance days [8,9,40,41], observer effects [42], and visitor attendance times [16] on animal behavior. Additionally, visitor behavior [6,20,23,29,31,33,43–45], including noise levels [6,11,18,19,22,25,28,31,40,43,44,46,47], have been a source of interest. However, these different visitor conditions have almost always occurred on a continuum of general abundance, ranging from few visitors to many; very rarely is there a condition that allows for researchers to investigate animal behavior absent of visitors entirely for any extended length of time and throughout the entirety of the day. Clearly, there is a need for additional experimental design in which researchers may further investigate the causal effects of visitor presence on animal behavior [48].

The initial wave of the SARS-CoV-2 (COVID-19) pandemic in early 2020 forced zoos to close for the first prolonged period of time in the United States (U.S.) and globally. Since then, several visitor effect studies of various zoo-housed taxa have been published due to the unique opportunity these closures provided [17,25–27,49–53]. Greater flamingos (*Phoenicopterus roseus*) showed no behavioral changes between the open and closed conditions, while Chilean flamingos (*P. chilensis*) showed a decrease in three out of eight observed behaviors (activity, movement, and feeding) when the zoo reopened; however, these changes were partially attributed to weather [27]. Red kangaroos (*Macropus rufus*) decreased space use and demonstrated changes in two out of seven observed behaviors when the zoo reopened versus when it was closed. They were found to be less active and stayed closer in proximity to one another, though similar to Kidd et al. [27], these changes were partially attributed to an increase in temperature and a change in season [26]. Nile crocodiles (*Crocodylus niloticus*) had more agonistic and conspecific bunting behavior (rubbing or pushing into one another) when the zoo was closed, and more conspecific contact when the zoo was open [51]. In a larger study across four zoos, slender-tailed meerkats (*Suricata suricatta*) and African penguins (*Spheniscus demersus*) showed no negative welfare impacts attributed to either visitor absence nor visitor return following COVID-related facility closures [53]. In a multi-species study, only two out of eight species showed significant behavioral changes when zoos reopened versus when they were closed. Here, during the "closed" condition, Grevy's zebras (*Equus grevyi*) used more comfort behaviors and spent more time than expected at the visitor viewing area, while the Chinese goral (*Naemorhedus griseus*) demonstrated increased environmental interactions [52]. Finally, a study of five bear species showed no observed behavior changes when the zoo was open versus closed [17].

Only one COVID-related study [49] utilized a physiological measure in addition to behavioral markers of change between the open and closed conditions. Results showed an increase in fecal glucocorticoid metabolite (fGM) concentrations of cheetahs (*Acinonyx jubatus*) and giraffes (*Giraffa camelopardalis reticulata* and *G. c. tippelskirchi*) as the zoo transitioned from closed to open. Still, it is important to note that fGM levels were higher in both species during the closed condition than they had been in the initial open condition. In fact, the cheetahs experienced a slight decrease in fGM as the zoo reopened. However, because both species had recently experienced significant social or medical episodes, the authors concluded that reported fGM changes were likely related to these variables more so than the institution's open/closed status.

To date, there are two nonhuman primate COVID-related studies [25,50]. Cognitive performance on touch screen memory tests of Japanese macaques (*Macaca fuscata*) showed no difference in participation rates or accuracy between open versus closed conditions, but there were significantly faster response latencies when the zoo was open [25]. Six western lowland gorillas (*Gorilla gorilla gorilla*) showed no group behavioral differences when a zoo was open versus closed; however, there were individual differences [50]. For example, auto-grooming occurred in 12% of observed behaviors of the silverback in 2019, when the zoo was open, and was not observed in 2020 when the zoo was closed. The subadult female was more active in 2019 versus 2020.

We investigated differences in chimpanzee (*Pan troglodytes*) wounding event frequencies and rates, given the presence and absence of visitors as the primary variable of interest. Today, approximately 252 chimpanzees live in 30 zoos accredited by the AZA [54] across the U.S. Chimpanzees are highly social, intelligent animals. As such, social housing is essential for their psychological well-being and welfare [55–57]. With social housing comes the potential for conspecific aggression [58,59] and injury [60]. We chose to explore wounding as a proxy for welfare partially because the study design was limited by its post-hoc nature. We relied on archival data that were routinely collected in a standardized manner prior to and throughout zoo closures. Moreover, the data had to be collected in such a way as to be comparable between institutions. As a result, other biological (e.g., cortisol) or behavioral measures were not available.

While wounding rates have often been referenced by researchers for management and housing considerations in chimpanzees [34,58,61–64], few studies have investigated the relationship between zoo visitors and wounding rates. As excessive wounds are often considered an indicator of compromised welfare [65], this is somewhat surprising. The limited number of such studies has resulted in ambiguous findings. Stoinski et al. [37] found that male gorillas had more contact aggression, but not increased wounding rates, on large versus small crowd days. Using long-term archival zoo wound records, Hosey et al. [34] found no correlation between daily wounds and increased visitor numbers for chimpanzees and ring-tailed lemurs (*Lemur catta*). This is in contrast with laboratory studies that found an increase in chimpanzee wounding when more humans were present on weekdays versus weekends [62,64], where the authors concluded that even the routine presence and activities of caregiving, veterinary, research, and other staff may result in increased incidence of wounding.

The aim of this study was to investigate changes in wounding frequencies and rates of chimpanzees living in three AZA-accredited zoos during time periods prior to and during the closures related to the COVID-19 pandemic. Due to the large number of chimpanzees housed in accredited zoos, combined with the institutionally-driven desire for optimal welfare of managed species, an increased understanding of visitor effects on behavior—especially those aspects of behavior often associated with adverse welfare experiences, such as wounds—is of deep and abiding interest.

2. Materials and Methods

2.1. Subjects and Facilities

At the start of this project, chimpanzees were housed in 29 AZA-accredited institutions across the U.S. [54]. All were contacted regarding participation in this study. In order to determine suitability for inclusion, zoos were provided a digital, 29-question survey (Supplemental Material S1), which posed questions regarding (1) specific information collected when recording wounds, (2) where/how records are stored, and (3) if and when the zoo was closed to visitors during the first wave of the COVID-19 pandemic in 2020. Additionally, the survey clarified whether certain confounding experiences had occurred during the proposed study period, such as changes to chimpanzee group composition, primary keepers, or enclosures. A "yes" response to any of these questions prompted careful deliberation; institutions were removed from consideration if further inquiry revealed a potential impact on chimpanzee behavior. The survey questions also asked about possible caregiving protocol changes during the pandemic versus before the pandemic, such as wearing personal protective equipment (PPE), and the presence/absence of positive reinforcement training; these variables were also controlled for, and any potentially impactful changes to procedure likewise precluded the institution from participation. Please see the decision table for zoo inclusion in Supplemental Material S2 for additional details.

Nineteen zoos responded to the initial survey that determined suitability. Based on these parameters, 15 were ineligible to participate in the study. Of the four eligible zoos, three submitted all required data. In order to ensure anonymity of the data, each zoo was assigned a letter, and each chimpanzee was assigned a number for data treatment.

Each of the three participating zoos housed seven chimpanzees between March 2019 and July 2020 (*n* = 21 chimpanzees). Zoo A consisted of three males and four females, ranging in age at the start of the study period from 23 to 35 years. Zoo B consisted of five males and two females, ranging in age from 19 to an estimated 49 years ± six months. Zoo C consisted of two males and five females, ranging in age from seven to approximately 51 years. Please refer to Table 1 for demographic and group composition data. Contribution to this study was entirely voluntary.

Table 1. Demographic and Group Composition Data for Each Enrolled Chimpanzee.

Zoo	Sex	Age
A	M	25
	M	25
	M	28
	F	23
	F	23
	F	26
	F	35
B	M	19
	M	23
	M	25
	M	28
	M	46
	F	39
	F	~49
C	M	7
	M	30
	F	8
	F	10
	F	18
	F	32
	F	~51

2.2. Time Conditions

There were four, 51-day time conditions, or periods. Table 2 defines each time condition. One time condition (2020-B) occurred during each zoo's pandemic closure in 2020. The remaining three conditions (2019-A, 2019-B, and 2020-A) were 51-day windows prior to the pandemic. The closed period (2020-B) had a time match to the previous year (2019-B) in order to control for potential changes in weather conditions and time of day [21,26,27,51], as well as month [51] and season [66], all of which have been shown to affect animal behavior to some degree. The period 2020-A was just before zoo closures occurred, and it likewise had a time match for the previous year (2019-A). The shortest zoo closure involved in the study was 51 days; therefore, each time period is 51 days in length. All closures occurred within three days of each other; all other matched time conditions (2019-A, 2019-B and 2020-A) were likewise within three days of each other as well.

Table 2. The Four Time Conditions and their Definitions.

Time Condition	Definition
2019-A	The time period in 2019 that matches 2020-A.
2019-B	The time period in 2019 that matches 2020-B.
2020-A	The 51-day time period in 2020 immediately prior to the first day each zoo was closed during the COVID-19 pandemic.
2020-B	The initial 51-day time period in 2020 when each zoo was closed during the COVID-19 pandemic.

2.3. Data Collection and Analysis

Each of the participating zoos used data management software designed for zoos and aquariums. PDF reports encompassing the four time periods of interest were generated and the data were coded onto Excel spreadsheets for treatment. Data were extracted from daily keeper reports, medical notes, and weekly summary reports.

Some records did not specify the number of wounds, and instead described the wounds as "multiple," "several," "various," "some," etc., or in the plural form, such as "bites," "lacerations," or "scratches." Wounds were therefore categorized as "0" (no wounds), "1" (single wound), or "2" (multiple wounds). Wound definition and categories are reflected in Table 3. Date and wound parameters are provided in Supplemental Material S3.

Table 3. Wound Definition and Categories.

Wound	Definition
Wound Definition	Any injury involving the skin, such as cuts, bites, punctures, scratches, abrasions, lacerations, sores, lesions, bleeding, amputations, loss of nail, open abscess, etc. There is no distinction for wound cause such as self, other, medical, or environment. Examples that do not meet the wound criteria are hair loss, cracked tooth, abscessed tooth, and swelling/inflammation.
Wound Categories	0—No wounds reported for a chimpanzee on one day. This category will mainly be determined by the absence of a record. A wound can only be logged once; therefore, if a wound re-opens, or if a sore develops near a previously logged wound, it is a category "0." 1—One wound reported for a chimpanzee on one day. 2—Two or more wounds reported for a chimpanzee on one day. Descriptions of wounds such as "multiple," "several," "various," "some," "a few," etc. will be logged as "2." Plural wound forms such as "bites," "lacerations," "scratches," etc. will be logged as "2."

The first author and an additional researcher independently coded all records using the percentages of agreement method [67]. Interobserver reliability was determined by adding the total number of observation agreements for each of two categories (date and wound) and dividing by the total number of observations for each of the two categories. The interobserver reliability for Zoo A was 99.9% for both date and wound category. Interobserver reliability for Zoo B was 100% for both date and wound category. Interobserver reliability for Zoo C was 99.9% for date and 100% for wound category. In the event of a disagreement, the coders reviewed data and arrived at an agreement on how to code them.

Because some wounds were coded as "multiple" without clarification regarding an exact number, we elected to utilize "wound event rates" for statistical evaluation. Wound event rates were determined by adding the combined frequencies of wound categories 1 and 2 for each zoo, for each 51-day time period, and dividing by 357 (51 days × 7 chimpanzees). The rates for the frequency of "no wound" events were also determined for each zoo, for each 51-day time period, by adding all "no wound" events and likewise dividing by 357. A chi-square goodness-of-fit test [68] was used to determine if the frequency of "no wound" events for each zoo was statistically different than expected in each 51-day time period. We investigated "no wound" events as opposed to wound events because all zoos had less than five wounds across at least one of the 51-day windows; these small frequencies violate a core assumption of the goodness of fit test—that observed values in each cell must be equal to five or more [69].

We then compared all "no wound" events across all time periods. Expected frequencies of "no wound" events for each zoo were estimated by adding the three "open period" cell frequencies (2019-A, 2019-B and 2020-A) and then dividing by three. This was then compared to reported "closed" "no wound" frequencies. Statistical analysis for chi-square goodness of fit was conducted using VassarStats (http://vassarstats.net (accessed on 6 March 2022).

3. Results

There were 37 wound events during the total study period. Zoo A had 29 wound events, Zoo B had 2, and Zoo C had 6. Table 4 shows the frequency of wound versus no wound events for each zoo during each time condition, and the corresponding daily rates.

Table 4. Frequency (*f*) of Wound and "No Wound" Events for each Zoo during each Time Condition, and the Corresponding Daily Rates per Chimpanzee.

	2019-A		2019-B		2020-A		2020-B	
Zoo	*f*	**Rate**	*f*	**Rate**	*f*	**Rate**	*f*	**Rate**
A								
Wound	12	0.034	3	0.008	12	0.034	2	0.006
No Wound	345	0.966	354	0.992	345	0.966	355	0.994
B								
Wound	1	0.003	0	0.000	0	0.000	1	0.003
No Wound	356	0.997	357	1.000	357	1.000	356	0.997
C								
Wound	0	0.000	1	0.003	4	0.011	1	0.003
No Wound	357	1.000	356	0.997	353	0.989	356	0.997

Wound events for the 21 individual chimpanzees ranged from 0–7. At Zoo A, all chimpanzees sustained at least 1 wound event, with a range from 1–7 per individual. At Zoo B, two individuals sustained one wound event each. At Zoo C, three individuals sustained one, two, or three wound events. Figure 1 shows the number of "no wound" events at each zoo across each time condition. Table 5 shows 1×4 chi-squares for each zoo. There was no significant difference between the reported frequency of "no wound" events and those expected to occur based on data derived from the "open" periods.
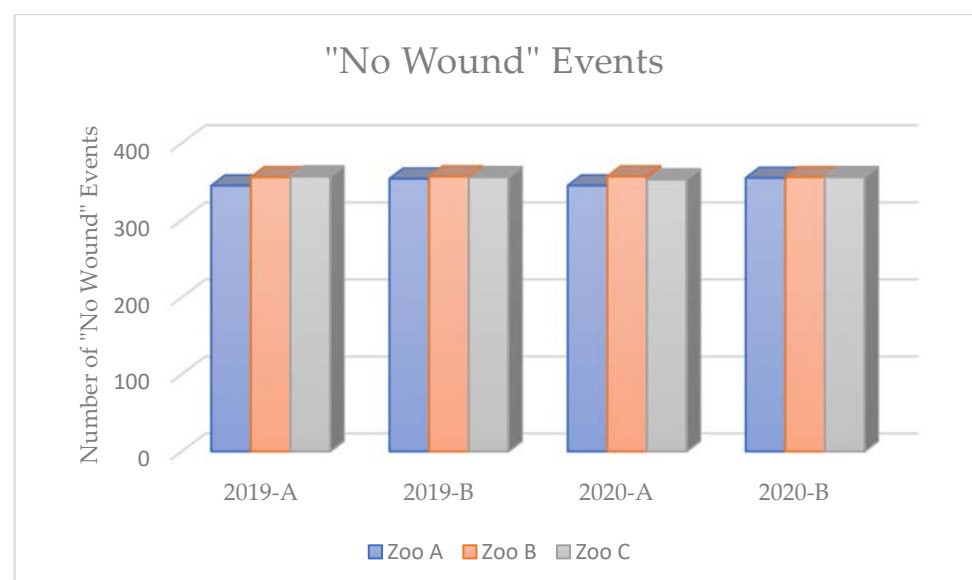

Figure 1. Number of "No Wound" Events across all Zoos and Time Conditions.

Table 5. 1 × 4 Chi-Squares for the Three Zoos.

Zoo	Results
Zoo A	X^2 (3, N = 1399) = 0.3, p = 0.96
Zoo B	X^2 (3, N = 1426) = 0.01, p = 0.9997
Zoo C	X^2 (3, N = 1422) = 0.03, p = 0.9986

4. Discussion

4.1. Summary

Zoo closures during the first wave of the COVID-19 pandemic provided a unique opportunity to investigate potential changes in chimpanzee wounding during the presence and absence of visitors. Here, we examined archival records of three U.S. AZA-accredited zoos across four 51-day time conditions. Three conditions occurred prior to the pandemic, when zoos were open to visitors, and one condition occurred during the first wave of the pandemic, when zoos were closed to visitors.

Zoo A did report more daily wound events when the zoo was open to visitors (*n* = 12, 12, 3) than when the zoo was closed to visitors (*n* = 2). However, considering that wound events were nearly equally low during the 2019-B (open) time condition, we may reasonably interpret this to mean that perhaps something other than visitor effect was responsible for the higher frequencies of wounding during the 2019-A and 2020-B time periods. For instance, factors such as individual animal traits, available space, and off-show holding access may have differed across facilities, resulting in different likelihoods of wounding. Zoos B and C reflected no change in daily wound event rate patterns between the open and closed conditions.

Chi-square results showed no significant difference between "no wound" event frequencies that occurred during the "closed" period and those that would be expected to occur under our chief variable of concern, which was visitor absence. This expected frequency of "no wound" events was extrapolated from the data patterns in the three "open" time periods for each zoo, suggesting that chimpanzee wounding was not associated with visitor effects in this case.

4.2. Environmental Factors

This quasi-experimental study enabled investigation into the frequencies and rates of chimpanzee wounding in the presence and absence of visitors, thus eliminating many—but not all—potential visitor-related variables that limit most visitor effect studies. Environmental variables may still have impacted results, despite our best efforts to control for them by using time-matched windows across the study period. Still, we do expect that the study design controlled for many of these potentially confounding variables—such as access to off-show areas, estrus-related impacts on behavior, available space, alternative management practices, and so forth—all of which can impact rates of wounding.

Additionally, there may have been environmental factors that helped mitigate visitor effects on the chimpanzees in this study. Here, the three zoos utilized were AZA-accredited; therefore, they followed a high degree of welfare standards [1,70]. Representatives of the three zoos reported that their chimpanzee habitats were naturalistic in design, and most had visual barriers that allowed the chimpanzees to move away from human or conspecific lines of sight, as desired. Well-designed enclosures with such visual barriers have potential to mitigate possible adverse visitor effects [5,6,12,14,18,20,36,37,57,70–72], as they provide primates with choice and control [5,14,20,36,57,70–72].

High-quality, high-frequency enrichment is also an essential element in successful primate husbandry programs [70,73–76], and can mitigate visitor effects as well. Wood [41] found that new versus one-day-old enrichment was associated with an increase in chimpanzees object use, feeding, and foraging. Carder and Semple [19] found that food enrichment was a mitigating factor for self-scratching and visual visitor monitoring of gorillas.

Enrichment and naturalistic habitats with visual barriers could potentially explain the lack of visitor effect in this study.

4.3. Wounding and Welfare Implications

Wounding studies have long been a source of interest to researchers and zoological professionals alike, due to the potential welfare implications of high rates of injury. Similar to this study, some researchers have reviewed archival data [34,37,58,61,62,64], and most have looked for differences in wounding rates associated with group composition [63,66,77–79]. Few studies have investigated wounding as a potential visitor effect, and none have included the complete absence of visitors. To date, this is the only study that has investigated chimpanzee wounding in the presence versus complete, extended absence of visitors afforded by the unique conditions of the COVID-19 pandemic. Given the very small degree of variance between wounding and no-wounding events across the different time periods, one possible interpretation of the data is that wounding rates do not offer the best measure of response to environmental changes in chimpanzees, and other variables should be considered instead of, or in addition to, wounding.

Because we utilized wound and "no wound" event frequencies as opposed to investigating total number of wounds, our data likely represent an underestimation of total wounds across all time periods. Still, data reported here are generally in line with reported rates of wounding from other studies [58,61–63], which range from 0.004–0.026. Comparatively, Zoos B and C reported lower-than-average wound event rates at 0.001 and 0.004, respectively. Zoo A, at 0.020, fell within the reported range, though on the higher end.

4.4. Limitations and Future Directions

The study was constrained by a number of variables, including a relatively small sample size. While 19 out of 29 (66%) zoos responded to the initial survey to determine suitability for inclusion here, only 4 zoos were eligible to participate. Of those four, three participated (75%). Participation rate was high, considering that zoos were still dealing with pandemic-related issues, including limited time and funding. Future studies might benefit from a higher participation rate once these constraints are lifted. In the meantime, we caution against overgeneralization of the findings.

Another limitation was the very low frequency of wound events over the study period. We limited the number of days in each time condition to 51, which was the shortest reported closure window; however, because time period comparisons were undertaken within— rather than between—zoos, this was an unnecessary precaution. The study could have been improved by considering the entire time each individual zoo was closed, as longer study windows may have yielded higher wound event frequencies.

Using archival records can present challenges, and study data were limited to what was previously recorded. Care staff from the three participating zoos reported in the 29-question survey that their wound recording criteria did not change during the study period. Nevertheless, the data used in this study derived from qualitative self-reports rather than from direct observations. When possible, future studies should make use of direct observations of wounding and/or other welfare measures rather than post-hoc self-reports, such as investigation into use of enclosure space in the presence/absence of visitors.

In addition, since wound records did not always specify the number of wounds, and instead described wounds in a way that could not be quantified, such as "multiple," "several," or "some," results relied on wound event rates rather than absolute numbers. If this study is replicated, researchers should consider analyzing total number of wounds, when possible, because that would generally yield higher wound frequencies.

Finally, discussions of wounding and welfare should be informed by the addition of physiological measures when possible. Due to the post-hoc nature of this study, the addition of physiological markers of welfare, such as fGM concentrations, was not possible, but, similar to Fink et al. [49], future studies might consider ways to include such measures.

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