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Postural analysis and diagnostic imaging of musculoskeletal disorders in captive Asian Elephants (*Elephas maximus*)

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Abstract

Captive Asian elephants (*Elephas maximus*) are prone to musculoskeletal disorders due to restricted mobility, suboptimal substrates, and chronic mechanical stress. This study integrated systematic postural assessments with radiographic imaging to evaluate foot and limb pathologies in 32 rescued elephants exhibiting gait or postural abnormalities. Forelimb deviations were observed in 43.8% of individuals and hindlimb deformities in 18.8%, with pathological toenails more prevalent in forelimbs ($n = 267$) than hindlimbs ($n = 161$), predominantly affecting central digits (T2 and T3). Radiographic analysis ($n = 20$) identified degenerative changes, primarily in carpal joints, followed by hock and elbow joints, including osteoarthritis, ankylosis, and fractures. These findings confirm a significant association between chronic postural deviations and joint pathology, highlighting the diagnostic utility of combined postural and radiographic evaluations for early detection and enhanced musculoskeletal care in captive elephants.

Keywords: Asian elephant, musculoskeletal disorders, radiographic imaging, postural assessment, animal welfare

Introduction

Captive Asian elephants (*Elephas maximus*) face unique challenges that predispose them to musculoskeletal disorders, including restricted mobility, inappropriate substrates, and suboptimal husbandry practices. These conditions contribute to abnormal posture, uneven weight distribution, and progressive foot and limb pathologies, which often remain underdiagnosed due to limited diagnostic access (Clubb & Mason, 2002; Regnault *et al.*, 2017) [2, 10]. Common ailments in captive elephants include pododermatitis, toenail overgrowth, onychia, sole abscesses, phalangeal osteomyelitis, osteoarthritis, and traumatic injuries (Fowler, 2001; Fowler, 2006; Houck, 1993; Schwammer, 2001; West, 2006) [3, 4, 5, 11, 13]. The elephant's unique foot structure, combined with its substantial body mass and extended lifespan, exacerbates the risk of degenerative musculoskeletal conditions under chronic mechanical loading (Panagiotopoulou *et al.*, 2012) [9].

Previous studies highlight the prevalence of these disorders. Mikota *et al.* (1994) reported that 50% of elephants in North American zoos developed foot disorders over an 84-year period, with 64% exhibiting non-foot-related musculoskeletal abnormalities [8]. Similarly, Chandrasekharan *et al.* (2009) documented 404 of 939 clinical cases in captive elephants involving non-specific conditions, including 55 arthritis cases, with working elephants particularly susceptible [1]. Lewis *et al.* (2010) found that 33% of surveyed zoos reported foot disorders, 36% noted arthritis, and 18% observed lameness within a single year [6].

Postural indicators, such as valgus or varus deformities, asymmetric weight-bearing, and chronic limb shifting, often signal underlying pathology (Miller *et al.*, 2016) [7]. While radiography is a cornerstone for diagnosing musculoskeletal disorders in elephants (Siegal-Willott *et al.*, 2011; West, 2006) [12, 13], studies correlating postural assessments with radiographic findings are scarce. This study addresses this gap by integrating systematic

postural evaluations with radiographic imaging to characterize foot and limb pathologies in captive Asian elephants, aiming to enhance early detection and inform welfare-focused management strategies.

Materials and methods

Study population and facility

This study was conducted at the Elephant Conservation and Care Center (ECCC), operated by Wildlife SOS, which provides advanced veterinary care for rescued Asian elephants (*Elephas maximus*). Thirty-two rehabilitated elephants were selected based on clinical signs of locomotor deficits, abnormal posture, or documented histories of foot and limb disorders.

Posture and gait assessments

Each elephant underwent systematic visual assessment on level ground, evaluating weight distribution, limb angulation, and compensatory postural adaptations. Gait analysis was performed during ambulation, noting stiffness, lameness, or limb dragging. Foot examinations identified abnormalities, including toenail cracks, splits, infections, pododermatitis, and contusions.

Radiographic imaging

Elephants were conditioned using positive reinforcement to facilitate cooperative radiographic procedures. Imaging was performed with a portable digital high frequency radiography unit (OTOM Mine Alnu, OTOM Co. Ltd.) and a 14×17-inch flat panel detector (LG). Standardized positioning protocols ensured diagnostic-quality images of the carpal, elbow, hock, and stifle joints, as well as digital and sole structures.

Data analysis

Data on postural abnormalities, gait, and radiographic findings were compiled. Descriptive statistics summarized the prevalence of abnormalities, with comparisons drawn between forelimb and hindlimb pathologies. Radiographic findings were categorized by joint and type of pathology (e.g., osteoarthritis, fractures).

Results

Systematic postural assessments revealed forelimb abnormalities in 14 elephants (43.8%) and hindlimb deformities in six (18.8%). Pathological toenails were significantly more prevalent in forelimbs ($n = 267$) than hindlimbs ($n = 161$), with central digits (T2 and T3) most affected, suggesting disproportionate biomechanical loading during locomotion (Figures 1–3). These findings align with prior reports of high foot and joint pathology incidence in captive elephants (Fowler, 2001; Lewis *et al.*, 2010) [3, 6]. Radiographic evaluations ($n = 20$) identified degenerative changes, predominantly in the carpal joints, followed by the hock and elbow joints (Figure 4). Observed abnormalities included osteoarthritis, ankylosis, mineralization, osteitis, enthesopathy, fractures, and bone remodeling (Figures 5–9). Carpal joint pathology likely reflects the forelimbs' role in bearing approximately 60% of body weight. Elephants with chronic postural deviations exhibited more pronounced radiographic changes, supporting a link between abnormal biomechanics and secondary osteoarthritis, consistent with prior studies (Fowler, 2006; Mikota *et al.*, 1994) [4, 8].

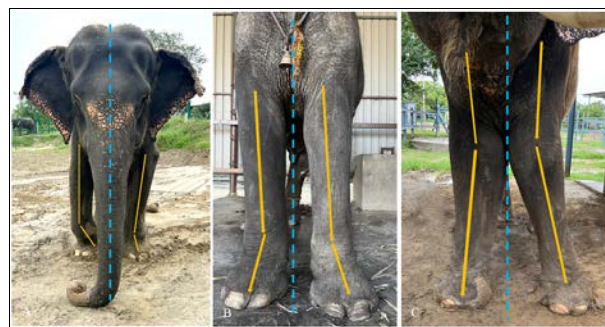


Fig 1: Blue dotted lines indicate plumb lines (perpendicular to the ground). Varus deformity of the right forelimb and valgus deformity of the left forelimb (A); Bilateral forelimb valgus deformity (B); Cubitus valgus deformity of the left forelimb (C)

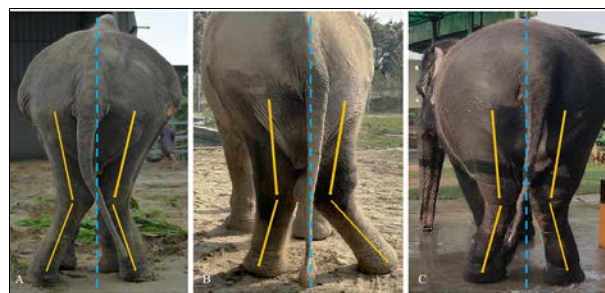


Fig 2: Blue dotted lines indicate plumb lines (perpendicular to the ground). The images illustrate varying degrees of genu valgum in elephants with differing health conditions: debilitated (A), geriatric (B), and obese (C).

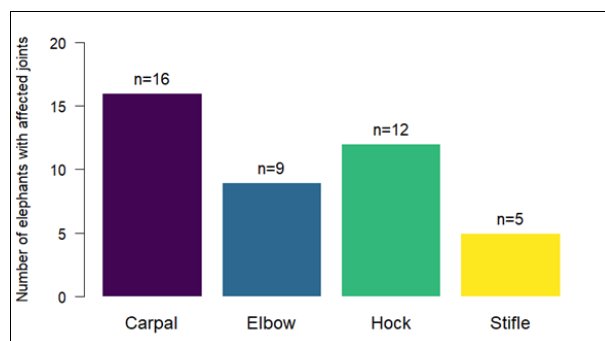


Fig 3: Distribution of affected toenails across all four limbs. Each bar is color-coded by individual toenail ID (T1 to T5), indicating the frequency of affliction per toenail within each limb

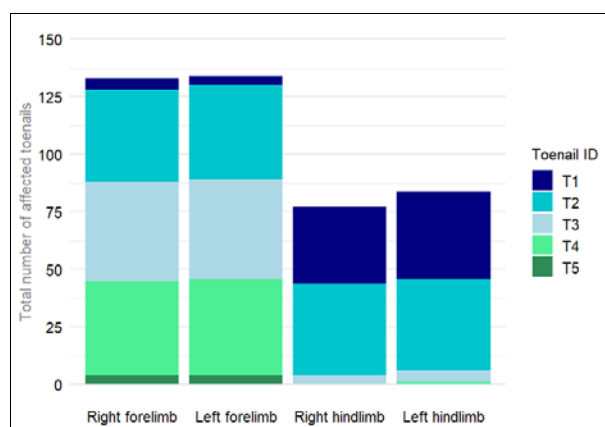


Fig 4: Frequency of joint afflictions, each bar illustrating the number of cases (n) with clinical signs of joint pathology

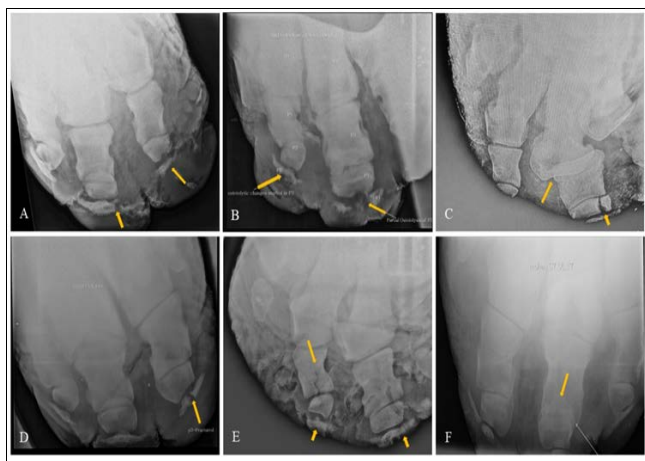


Fig 5: Various degrees of osteitis and osteolytic changes in the phalanges (A & B), Fracture of phalanges with osteitis at P2 and P3 (C), Fracture and osteolytic changes of P3 (D), Fracture of P1 with osteolytic changes in P3 (E), Severe osteitis at the phalangeal articulation of P1 and P2 (F)



Fig 6: Ankylosed elbow joint with severe abnormal mineralization of the coronoid process (A), Elbow joint osteoarthritis with abnormal increase in bone density and periarticular calcification (B), Ankylosed elbow joint with remodeling of the olecranon process and trochlear notch; coronoid process obscured due to abnormal fusion following fracture and dislocation of the proximal radius and ulna (C)



Fig 7: Ankylosis of the carpal joint (A), Carpal joint ankylosis with post-traumatic remodeling (B), Distal radial fracture with subsequent osteitis and inflammation resulting in carpal valgus deformity (C)

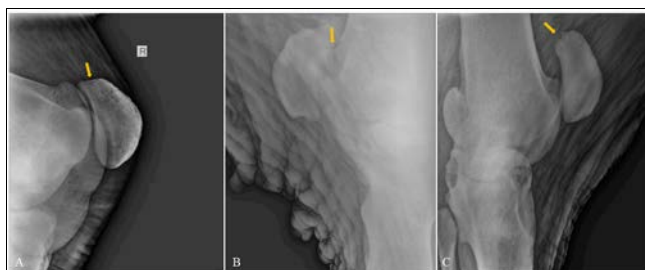


Fig 8: Fracture of the tibia and fibula at the tibio-tarsal articulation with post-traumatic remodeling characterized by excessive osteolysis and callus formation at the fracture site (A), Osteitis lesion involving the hock joint leading to ankylosis (B), Osteitis lesion localized to the calcaneus bone (C)

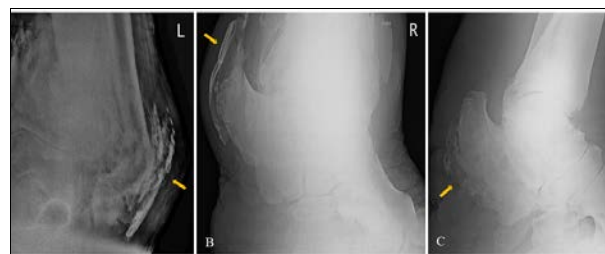


Fig 9: Patellar osteopenia (A), Degenerative joint disease affecting the stifle joint (B), Osteitic lesion involving the patella (C)

Discussion

The high prevalence of forelimb and central digit pathologies underscores the biomechanical stress imposed by captive environments. The carpal joint's susceptibility to degeneration reflects its critical role in weight-bearing, exacerbated by restricted mobility and suboptimal substrates. The correlation between postural deviations and radiographic abnormalities highlights the diagnostic value of integrating these approaches. This dual-modality strategy enables early detection of subclinical conditions, which may not manifest as overt lameness, thus facilitating timely interventions.

These findings corroborate earlier reports of musculoskeletal disorders in captive elephants (Chandrasekharan *et al.*, 2009; Mikota *et al.*, 1994)^[1, 8] and emphasize the need for proactive management, including optimized substrates, regular foot care, and routine diagnostic imaging. Limitations include the study's focus on rescued elephants, which may not fully represent all captive populations, and the lack of longitudinal data to track pathology progression. Future research should explore longitudinal studies and additional diagnostic modalities, such as computed tomography, to further elucidate musculoskeletal pathology in elephants.

Conclusion

This study demonstrates a significant association between postural abnormalities and musculoskeletal pathologies in captive Asian elephants, validated through radiographic imaging. The integration of postural and radiographic assessments enhances the detection of both subclinical and advanced conditions, informing targeted interventions to improve elephant welfare. Proactive management strategies, including appropriate substrates, optimized nutrition, and regular diagnostic evaluations, are critical to mitigating musculoskeletal disorders and enhancing the long-term health of captive elephants.

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Conflict of Interest

Not available

Financial Support

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