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Research Article
Plantar Thermographic Evaluation After Short-term Whole Body Vibration in Magellanic Penguins with and without Bumblefoot

[2]Ivan Felismino Charas dos Santos, [1]Stella Sakata, [2]Sheila Canavese Rahal, [3]Cristiane Lassálvia Nascimento, [2]Alessandra Melchert and [2]Carlos Roberto Teixeira

[1]Veterinary Physiotherapist, Ibituruna street, Vila Congonhas, 04624-100 São Paulo, Brazil
[2]Department of Veterinary Surgery and Anesthesiology, School of Veterinary Medicine and Animal Science, University Estadual Paulista (UNESP), Botucatu, 18618-970 São Paulo, Brazil
[3]Santos Aquarium, Santos Aquarium, Ponta da Praia, Santos, 11030-500 São Paulo, Brazil

Abstract

Background and Objective: The aim of the study was to investigate the acute effects of whole body vibration on the cutaneous temperature of the plantar surface of the feet in healthy penguins and in penguins with bumblefoots by using infrared thermography. **Materials and Methods:** Twelve captive adult magellanic penguins were divided into two groups: Group 1 seven healthy penguins (14 feet) and group 2-5 penguins with bumblefoot (6 feet). Three sessions of vibrating platform were carried out at the frequency of 20 Hz. Each session lasted 5 min totalizing 15 min. Infrared thermography was performed before (time 0) and at 5, 10 and 15 min after the whole body vibration session. **Results:** The increased thermal measurements in group 1 were observed at 5 min after vibration in metatarsal footpads and at 10 min in tarsus metatarsus areas. The metatarsal food pads of penguins with bumblefoot showed higher thermographic temperature in comparison to the metatarsal footpads of the healthy penguins. The right tarsus metatarsal areas in group 2 showed increased thermal measurements at 15 min from the baseline, but no statistical difference occurred in the right metatarsal foot pads. **Conclusion:** The acute use of whole body vibration in healthy penguins increased the cutaneous temperature of the plantar surface of the feet, but it was not observed in the metatarsal footpad of penguins with bumblefoot class II.

Key words: Vibration plate, penguins, thermography, bumblefoots, body vibration

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Corresponding Author: Ivan Felismino Charas dos Santos, Department of Veterinary Surgery and Anesthesiology, School of Veterinary Medicine and Animal Science, University Estadual Paulista (UNESP), Botucatu, 18618-970, São Paulo, Brazil Tel: +551438802022

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Captive penguins are susceptible to pododermatitis or bumblefoot disease[1,2]. The disease may be classified as type 1 (callus formation), type 2 (dermis and subdermis infection) and type 3 (chronic purulent infection)[3], or in five-part classification scheme[4]. A study comprising 100 magellanic penguins showed that Staphylococcus and Corynebacterium were the most prevalent bacteria isolated as part of permanent or transient microbiota and observed in all pododermatitis cases[5]. A puncture wound or soft tissue damage may be the entrance to bacterial infection[1,4]. The lesion must be treated to avoid more serious complications, such as soft tissue mineralization and osteomyelitis[1].

Prevention is the best way to manage the disease[3,6]. However, once the disease has development, several treatments such as antibiotics, foot protection, topical wound dressings, surgical debridement and photodynamic therapy have been reported based on the lesion severity[1-3,6,7]. In a considerable number of cases, the treatment is palliative and non-curative[1,6]. Therefore, other possibilities to treat or prevent the condition should be taken into consideration.

Whole Body Vibration (WBV) is a modality of physical rehabilitation or complementary treatment applied to several human diseases and it induces metabolic responses comparable to other exercise methods[8,9]. Regarding wound healing, WBV has promoted increase in angiogenesis and granulation tissue formation[10].

Thus, the aim of the present study was to investigate the acute effects of WBV on the cutaneous temperature of the plantar surface of the feet in healthy penguins and in penguins with bumblefoots by using infrared thermography and to evaluate the behavior of the penguins during the session. The hypothesis was that WBV might increase local blood flow, which could be detected by increasing the thermal measurement.

MATERIALS AND METHODS

This study was approved by the Ethics Committee of our Veterinary School (n° 171/2012-CEUA) and by the National Environmental and Wildlife Bureau (SISBIO 44274-1).

Twelve captive adult magellanic penguins (*Spheniscus magellanicus*), weighing from 2.52-3.88 kg (Mean 3.2±0.68 SD) were divided into two groups: Group 1 seven healthy penguins and group 2-5 penguins with bumblefoot (4 penguins with lesion located on the right footpad and one with lesion on left and right footpads). The penguins lived in the Municipal Aquarium of Santos (GPS: 23° 57' 39" S, 46° 20' 01'' W), located in São Paulo State, Brazil. They were housed in a 45 m^2 space with land and pool areas. Slate water was provided to the penguins and their diet was based on sardine (*Sardinella brasiliensis*) and manjuba (*Anchoviella lepidentostole*) q 12 h.

The inclusion criteria for penguins of group 1 were to be healthy based on complete physical examination and no history of surgical or clinical treatment. The inclusion criteria for penguins of group 2 were to have bumblefoot classified as class II, based on previously described staging system[4]. All penguins had microchip and leg ring for identification.

Before the WBV session, the penguins were allowed to rest and acclimatize to the ambient for 1 h. All procedures were conducted during the morning in the same room with controlled temperature (23°C) and air humidity (40%). Three sessions of vibrating platform (TheraPlate Revolution®; Texas, USA) were carried out at the frequency of 20 Hz. Each session lasted 5 min, thus totalizing 15 min. Velocity and amplitude varied from 12-40 m sec^{-2} and 1.7-2.5 mm, respectively. During the WBV sessions, the penguins were kept inside a plastic box [41 cm (height) ×56 cm (width) ×78 cm (length)] placed in the center of the vibrating platform (Fig. 1).

Infrared thermography was performed before (time 0) and at 5, 10 and 15 min after exposure to the WBV session. Images were taken with the penguins in ventrodorsal position. A thermal camera (FLIR Model i40; FLIR Systems, Boston, USA) was kept perpendicular to the footpads at a distance of 25 cm. Thermographic temperature measurements were taken from two different spots of each foot: Tarsus metatarsus area and metatarsal foot pad. The measurement spots were analyzed using thermographic software (ThermaGram Pro 95, Inframetrics).

The variability of thermographic temperature measurements among the moments (before and at 5, 10 and 15 min after the exposure to WBV session) in each group were evaluated by repeated-measures ANOVA followed by the Tukey post-test. After the distributions were evaluated by a Kolmogorov's normality test, unpaired student's t-test was used to compare the groups (healthy = 14 feet×bumblefoot = 5 right feet and 1 left foot). Differences were considered significant at $p<0.05$. The values were expressed in Mean±Standard Deviation (SD).

RESULTS

The penguins showed some degree of discomfort only during the first 2 min of WBV session. After getting used to the vibration, they remained comfortable until the end of the session. All penguins slept after the WBV platform session.

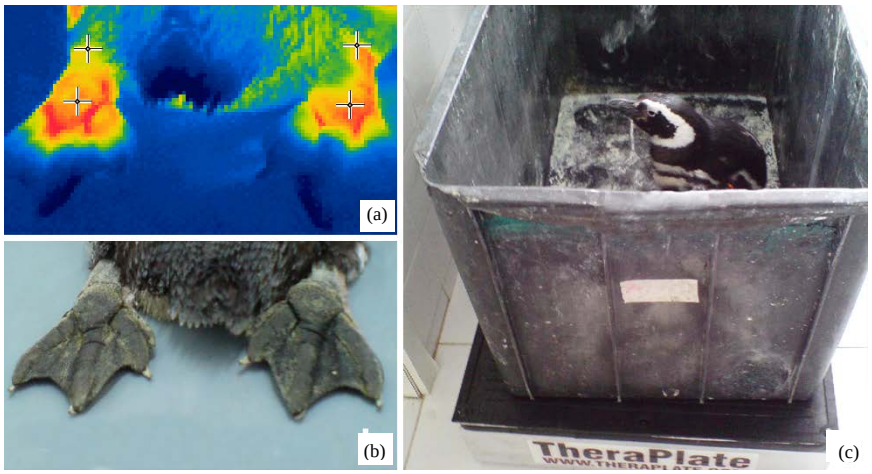

Fig. 1(a-c): (a) Infrared thermography image of healthy plantar surfaces of magellanic penguin, after 10 min of short-term WBV, (b) Macroscopic aspect of the penguin's feet and (c) Penguin inside of plastic box in the center of the vibrating platform during WBV session

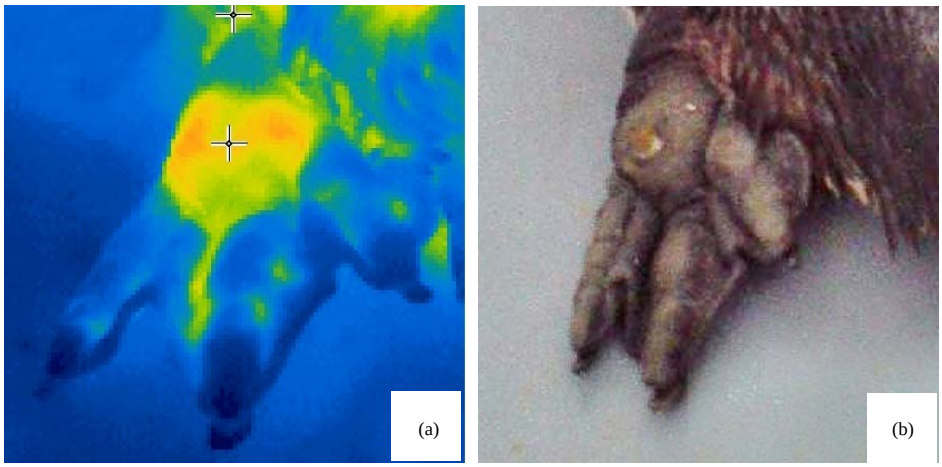

Fig. 2(a-b): (a) Infrared thermography image of plantar surface of magellanic penguin with bumblefoot class II, after 15 min of short-term WBV and (b) Macroscopic aspect of the penguin's foot

Table 1: Thermal measurements (°C) of the tarsus metatarsus areas and metatarsal footpads of the healthy penguins (Group 1) and penguins with bumblefoot (Group 2) obtained before (time 0) and 5, 10 and 15 min after exposure to WBV

	Group 1 (n = 14 feet)		Group 2 (n = 6 feet)	
Time	Tarsus metatarsus area (Mean±SD)	Metatarsal footpad (Mean±SD)	Tarsus metatarsus area (Mean±SD)	Metatarsal footpad (Mean±SD)
Zero (baseline)	30.3±3.8^{A}	28.2±5.5^{A}	30.0±5.9^{A}	34.0±2.7^{A*}
5 min	30.0±4.8^{A}	30.3±5.8^{AB}	32.2±4.5^{AB}	36.8±1.9^{A**}
10 min	33.4±4.5^{B}	33.1±3.1^{C}	34.3±4.4^{AB}	36.0±2.9^{A}
15 min	33.9±3.9^{B}	32.7±3.7^{B}	35.1±3.3^{B}	36.1±2.7^{A}

Different uppercase letters in columns represent statistically significant differences, *p<0.05×healthy penguins on baseline, **p<0.05×healthy penguins on 5 min

The thermal measurements of the footpads in healthy penguins and in those with bumblefoot are shown in Table 1. Group 1 (14 feet) showed increased thermographic temperature in tarsus metatarsus areas at 10 min (p<0.001) from the baseline (time 0) and from 5 min (p<0.001) and at 15 min from the baseline (time 0) (p<0.001) and from 5 min (p<0.001) (Fig. 1). Furthermore, the increased thermographic temperature in the metatarsal footpads

occurred at 10 min ($p<0.001$) from the baseline and from 5 min ($p<0.001$) and at 15 min from the baseline ($p<0.05$). Group 2 (6 feet) did not show statistical differences among the different moments for metatarsal footpads (Fig. 2). However, there was increased thermographic temperature for tarsus metatarsus area at 15 min ($p<0.05$) from the baseline (time 0).

The comparison between groups 1 and 2 showed that group 2 showed thermographic temperature values statistically higher than group 1 in the metatarsal foot pads at baseline (time 0) and at 5 min. No statistically significant difference was found between the groups at 10 and at 15 min. In addition, no statistically significant difference was found between the groups regarding the thermal measurements obtained in tarsus metatarsus areas.

DISCUSSION

Captive penguins generally spend considerably little time swimming[1]. This type of behavior has been observed in the penguins of the present study. The long periods of inactivity and standing position are considered factors that predispose the animals to pododermatitis[2,3,11]. Thus, some studies have used environmental enrichment techniques to increase swimming time and to stimulate more natural behaviors[11]. Other factors that may contribute to the disease are body weight, standing on hard or abrasive surfaces in the enclosure, as well as surfaces with fecal contamination or too much humidity[1,2]. The type of land area may also be a contributing factor to the development of the lesions seen in the present study.

Bumblefoot disease diagnosis includes gait, stance and attitude evaluation and foot examination[1,2]. Thermography has also been used as diagnostic procedure for subclinical bumblefoot and other inflammatory diseases and to evaluates the response to therapy[1,12,13]. Thermography was used in the present study to evaluate the acute effect of WBV on blood flow. The thermal measurements can give information about total blood flow function[13,14].

The WBV action mechanism is little understood and the study findings are sometimes controversial[14-16]. A meta-analysis study suggested that the effect on the peripheral blood flow is greater at WBV lower frequencies (5-25 Hz) than higher frequencies (30-50 Hz)[16]. Thus, 20 Hz frequency used in the present study meets the values that would have potential to increase the peripheral blood flow[16].

The increased thermal measurement in group 1 was observed in the metatarsal footpads 5 min after vibration and 10 min after vibration in the tarsus metatarsus areas. These findings differed from a study comprising healthy adult humans, in which the cutaneous temperature obtained though the thermography of the lower limbs decreased during and 10 min after WBV[14]. However, this study used frequencies such as 31, 35, 40 and 44 Hz, which may have influenced the results. According to the authors, the vasoconstriction response may have been associated with local and central mechanisms[14]. On the other hand, a study using different vibrations to the ear of mice at the frequency of 47 Hz found increase in the blood flow due to venule vasodilation[15].

The type of vibration is another factor that must be taken into consideration. Based on a meta-analysis study, side-alternating vibration seems to have effect on the peripheral blood flow, but this may not true regarding vertical vibration[16]. The vibration platform used in the present study allows vertical, longitudinal and oblique movements. The thermographic temperature in the present study did not increase at 15 min, thus suggesting the maintenance of the peripheral blood flow. In addition, it may indicate no added benefits from additional 5 min of vibration. The metatarsal foot pads of the penguins with bumblefoot showed higher thermographic temperature than the metatarsal foot pads of the healthy penguins. A study also observed higher thermal measurements in subclinical bumblefoot in chickens[12].

The right tarsus metatarsal areas in the group 2 showed increased thermal measurements at 15 min from the baseline, but no statistical difference occurred in the right metatarsal foot pads. It may suggest that the blood flow did not increase in the bumblefoot site. On the other hand, a study showed beneficial effects of low-intensity WBV used for 5 days per week on wound healing in diabetic mice by inducing a pro-angiogenic environment[10]. Three hypotheses must be considered, namely: The class II lesion is inappropriate to this therapy or more sessions are necessary to obtain increased blood flow detectable by infrared or the low number of feet may have influenced the statistical findings.

The stress may be taken into consideration in studies performed in penguins. The penguins in the present study remained comfortable most of the time. Decreases serum cortisol was observed in horses after acute short-term WBV exercise[17]. In addition, a WBV study in dogs showed that the method was well accepted and the animals slept after the WBV exercise, but some distress was observed when the frequency was increased[18].

The small sample size and the use of one session was a limitation of the present study. Further studies are necessary to confirm or not the benefits of the WBV as a complementary treatment for penguins.

The acute use of WBV in healthy penguins leads to increase in the cutaneous temperature of the plantar surface of the feet, but it is not observed in the metatarsal footpad of penguins with bumblefoot class II. The procedure is well tolerated by the birds.

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