Original Article

Overexposure of rats to radiation from infrared lamp: Effects on blood parameters

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Abstract

Background: Previous reports showed that infrared radiation (IR) involved in photoaging, photocarcinogenesis, free radicals' production, and depletion of bone marrow cells. Beneficial effects of moderate exposure to infrared lamp have been itemized to include enhancement of blood circulation, relief from muscular pain, and wound healing acceleration with scarce information on biological effects when it is overexposed. Therefore, there is a need to investigate the possibility of its overexposure on biological system, especially blood parameters. **Aim:** This study was aimed to determine the biological effects of overexposure to radiation from infrared lamp on blood parameters. **Materials and Methods:** Infrared lamp of 100 W acts as a source of the IR. Twenty male healthy Wistar rats of the age range between 10 and 12 weeks and weigh between 100 and 250 g were studied. All the animals studied also acts as a control group with their blood samples taken and recorded as initial counting values. The animals were later divided into three groups: A, B, and C according to their hours of exposure according to their weight. Animals in Groups A, B, and C were exposed to IR for 1, 3, and 5 h, respectively. Blood samples of each animal in the group were taken 24, 48, and 96 h after exposure. The total number of erythrocytes, leukocytes, lymphocyte, and neutrophils were counted and compared with the initial samples. **Results:** The results revealed that packed cell volume, white blood cell, and lymphocytes of all the exposed animals averagely decreased by 17.4%, 17.5%, and 11.3%, respectively, whereas neutrophil increased by 19.0% after exposure to infrared. **Conclusion:** This study established that overexposure to radiation from infrared lamp affects hematological parameters.

Key words: Anemia, blood parameters, infrared lamp, lymphocytes, overexposure, white blood cells

INTRODUCTION

Infrared radiation (IR) is in the electromagnetic radiation spectrum with optical wavelengths above red visible light between 750 nm and 100 μm. The IR spectral region is

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arbitrarily divided according to wavelength into IR-A or near-infrared (700–1400 nm), IR-B or mid-infrared (1400–3000 nm), and IR-C or far infrared (3000 nm to 0.1 mm) according to the International Commission on Illumination (CIE). Human skin is exposed on a daily basis to IR radiation (760 nm to 1 mm) from natural as well as artificial sources that are increasingly used for cosmetic or medical purposes. Sources of IR radiation include the sun, incandescent lamps, and radiation emitted by hot objects (International Commission on Non-Ionizing Radiation Protection, 2006).

Infrared lamps are commonly incandescent bulbs which are able to produce IR radiation. A variety of IR lamps is used in industry and medicine. It consists of all IR band in electromagnetic spectrum (IR-A, IR-B, and IR-C) with varying power rating. Philips type IR lamp used in this study has a power rating of 100 W with a wavelength spectrum pronounced peak at approximately 1000 nm in the IR-A range. This radiation characteristic makes it ideal radiant heat source for treating deeper-seated muscular ailments and sports injuries. It has a red lacquered front to reduce visible light emission, thereby virtually eliminating disturbing glare (Phillips Infrared Heat Lamp).

IR is generally absorbed superficially in skin and ocular tissues, but with varying penetration depths depending on wavelength. In the eye, cornea, lens, and retina can be at risk, depending on spectral band. Following absorption of the radiant energy, the interaction with tissue can be either thermal or photochemical. Indirect effects are also possible, ranging from whole-body heat stress (hyperthermia) to cellular effects (International Commission on Non-Ionizing Radiation Protection, 2006; Reshetnyak *et al*., 1996).

Several studies had established therapeutic applications of IR radiation on wound healing (Ibitoye *et al*., 2014; Woodruff *et al*., 2004), pain management (Gale *et al*., 2006), treatment of existing scars (Hildebrandt *et al*., 2010; Calles *et al*., 2010), improvement of blood circulation (Lin *et al*., 2007), and management of central nervous system disorder and macular degeneration (Cho and Ha, 2010; Fitzgerald *et al*., 2013). Most beneficial effects of IR reported in literature are mostly based on short duration and low intensity exposure (Ibitoye *et al*., 2014; Woodruff *et al*., 2004; Gale *et al*., 2006; Hildebrandt *et al*., 2010; Calles *et al*., 2010; Lin *et al*., 2007; Cho and Ha, 2010; Fitzgerald *et al*., 2013; Wilson, 2014).

Epidemiological data and clinical reports indicate that IR cannot be said to be totally harmless to biological systems (Krutmann *et al*., 2012; Grether-Beck *et al*., 2014). There are evidences that IR can cause erythema ab igne (International Commission on Non-Ionizing Radiation Protection, 2006; Lee *et al*., 2006), reduce the efficiency of DNA damage repair (International Commission on Non-Ionizing Radiation Protection, 2006), and acute lenticular changes (Pitts and Cullen, 1981). Wavelengths beyond the ultraviolet spectrum, in particular visible light and IR radiation, contribute to skin damage in general and photoaging of human skin in particular (Schieke *et al*., 2003; Poon *et al*., 2015; Cho *et al*., 2009). Nonthermal damage of exposure to IR has also been reported to affect bone marrow cells (Tanaka *et al*., 2010). Near-IR radiation can induce carcinogenesis and cause photochemical changes in biological tissues as previously observed (Karu, 1999). It has also been reported to have potential of strand breaks in mammalian cells (Tirlapur and König, 2001), modification of enzyme activity and protein transition in cells (Kujawa *et al*., 2004), and increase in production of reactive oxygen species (Zastrow *et al*., 2009; Darvin *et al*., 2010).

Infrared lamps are currently being used to relief muscular pain and to treat ailments such as lumbago, neuralgia and myalgia, and colds. Despite these benefits, there is a need to investigate the biological effects that might result from overexposure to IR lamp. The aim of this study is to investigate the effects of overexposure to radiation from IR lamp on blood parameters of Wistar rats

MATERIALS AND METHODS

Infrared Lamp

An infrared lamp of power rating 100 W HP 3614 (DAP BV 0005 Philip) of shorter-wavelength IR-A radiation (780–1400 nm) was used in this study. It has a wavelength spectrum with a pronounced peak at approximately 1000 nm in the deep-penetrating IR-A range. Radiation intensity of this bulb is approximately 140 mW/cm^2 at 30 cm from its front with 90% of energy transmitted as IR. This radiation characteristic makes it an ideal radiant heat sources for treating muscular ailments and sports injuries. It produced low intensity due to large surface area, which makes it safe enough not to produce desired hyperthermia effect on the Wister rats.

Experimental Design

After our Institution Ethic and Research Committee approval, twenty male Wistar rats of age range between 10 and 12 weeks and weigh between 100 and 250 g from the National Institute of Medical Research, Yaba, Lagos, Nigeria, were recruited for this study. All the animals were fed with standard rodent feed and water *ad libitum*. This study was conducted in accordance with our institution's ethics on the use of animals for experimentation, and we as well follow the guidelines stipulated in Guide for the Care and Use of Laboratory Animals.[26] The animals were placed in special cuboids plastic cages of length 60 cm to avoid overcrowding with metal top and sawdust as

bedding. The animals were divided into three groups: A, B, and C according to expected duration of exposures and weight of the animals. Group A comprises five rats exposed to IR for 1 h with weight between 100 and 150 g. Group B was made up of seven rats exposed to IR for 3 h with weight between 150 and 200 g, whereas Group C consists of eight rats exposed for 5 h with weight ranges between 200 and 250 g. Full blood counts before irradiation served as a control for each group. The skin temperatures were monitored with the aid of IR camera to avoid overheating, necrosis, and dermatological damage of the exposed animals. The average temperature values recorded was 42.8°C. Noncontact method was used to apply the IR rays to the animals at a distance of 30 cm from the source and the animals had enough space to move freely inside the cage.

Blood Sample Collection and Counts

The blood samples of each rat were collected before and after exposure to IR radiation. The blood samples were drawn from the vein that is visible with a micropoint capillary tube. The skin overlying the vein is cleaned using an alcohol pad, and then a needle is inserted through the vein below where the tourniquet is applied. After the exposure, the blood sample of the rats was taken on 3 successive days. This was done to assess the impact of the IR radiation on the blood counts using the standard laboratories procedures using manual differential analysis. Average values of packed cell volume (PCV), white blood cell (WBC), neutrophil, and lymphocytes levels for each group of the exposed animals were counted after 24, 48, and 72 h each.

Statistical Analysis

Data were then acquired for analysis using Statistical Package for Social Sciences (SPSS) version 20 (Armonk, NY, USA). Student's *t*-test was used to determine the significant difference of PCV, WBC, neutrophil, and lymphocytes of the animals before and after exposures. $P < 0.05$ was considered to significantly difference.

RESULTS

The mean (standard deviation [SD]) weight of animals studied used in this study was 186.3 (43.5) g with the mean (SD) age of 13.0 (0.8) weeks. Fifteen percent (3/20) of the animals died during the course of their exposure to IR radiation out of which two died for 5 h exposure, whereas one died after 3 h exposure. PCV, WBC, neutrophil, and lymphocyte of the Wistar's rats are presented in Figures 1-4.

In Figure 1, the initial measurements of the PCV of animals in Groups A, B, and C decreased by 21%, 14.6%, and 15.7%, respectively, after exposure to IR. There was also statistically significant difference between their PCV ($P = 0.02$).

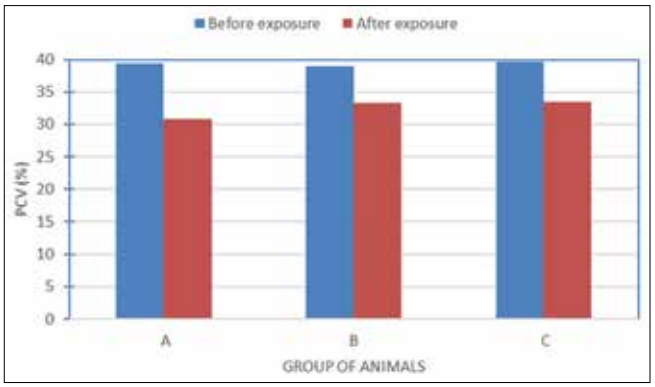

Figure 1: Packed cell volume distributions of exposed animals

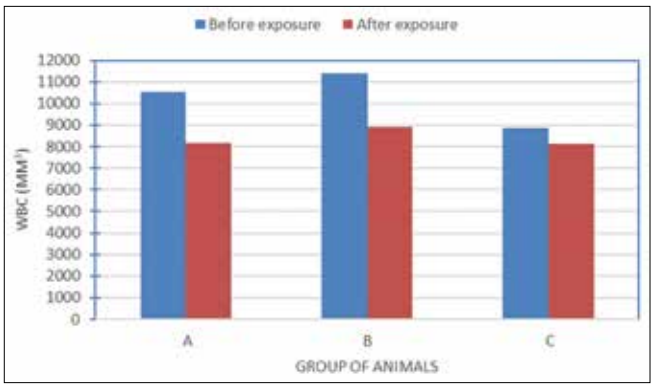

Figure 2: White blood cell distribution of exposed animals

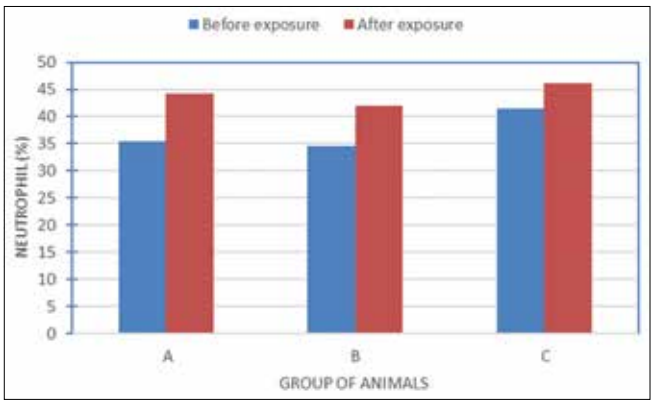

Figure 3: Neutrophil distribution of exposed animals

In Figure 2, WBC of animals in Groups A, B, and C decreased by 22.5%, 21.1%, and 8.4%, respectively, after exposure to IR. There was no statistically significant difference in WBC before and after exposure to radiation ($P = 0.08$).

In Figure 3, neutrophil of the animals in Groups A, B, and C increased by 24.5%, 21.1%, and 11.4%, respectively, after exposure to IR. There was statistically significant

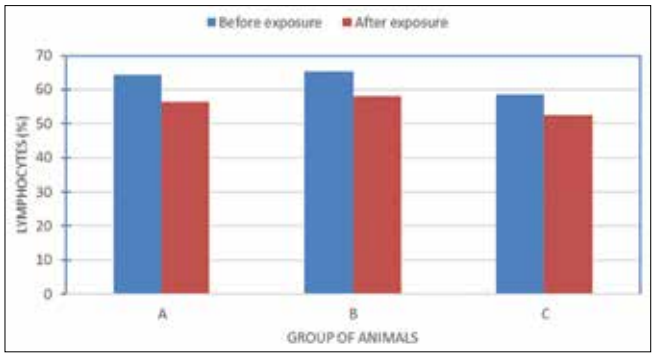

Figure 4: Lymphocytes distributions of exposed animals

difference in the neutrophil before and after exposure to radiation ($P = 0.03$).

In Figure 4, lymphocytes of the animals in Groups A, B, and C decreased by 12.4%, 11.2%, and 10.4%, respectively, after exposure to IR. There was statistically significant difference in the lymphocytes before and after exposure to radiation ($P = 0.01$).

DISCUSSION

The initial average values of PCV, WBC, neutrophil, and lymphocytes obtained for all the animals studied for this study were 39.2% ± 0.2%, 10260 ± 1289.8/mm^3, 35.5% ± 0.8%, and 63.9% ± 1.9%, respectively, which fall within the expected range of healthy rat.[16] No significant difference in the PCV ($P = 0.74$), WBC ($P = 0.47$), neutrophil ($P = 0.77$), and lymphocytes ($P = 0.63$) counts for all the rats before exposure. In this study, a significant difference was observed in PCV, neutrophils, and lymphocytes but not in WBC of the exposed animals. Duration of exposure and the weight of the animals significantly affect the hematological parameter of the exposed animals, especially PCV and WBC counts. Animals in Group A irradiated for 1 h had greater decreased in PCV than animals in Groups A and B. The trend was similar in WBC, lymphocytes, and neutrophils counts. High neutrophil levels are often caused by an infection, but other medical conditions and certain drugs can cause it as well. Inflammation or inflammatory conditions such as rheumatoid arthritis, vasculitis or inflammatory bowel disease, leukemia, and myeloproliferative neoplasms might be responsible for the dead of the three rats.

Information on the effects of overexposure to IR radiation on blood parameters is very scarce, whereas IR effects on skin and eye have been widely reported (International Commission on Non-Ionizing Radiation Protection, 2006; Calles *et al*., 2010; Lee *et al*., 2006; Pitts and Cullen, 1981; Schieke *et al*., 2003; Poon *et al*., 2015; Cho *et al*., 2009; Tanaka *et al*., 2010; Karu, 1999; Tirlapur and König, 2001; Kujawa *et al*., 2004; Zastrow *et al*., 2009; Darvin *et al*., 2010). Meanwhile, the study of IR radiation cells has shown to have the ability to modify enzyme activity and protein transition in cells. It has also been reported to have ability to reduce efficiency of DNA repair from damage, damage bone marrow cells, increases in intramitochondrial reactive oxygen species production, induce strand breaks and cell death by apoptosis, and carcinogenesis (Krutmann *et al*., 2012; Grether-Beck *et al*., 2014; Lee *et al*., 2006; Pitts and Cullen, 1981; Schieke *et al*., 2003; Poon *et al*., 2015; Cho *et al*., 2009; Tanaka *et al*., 2010; Karu, 1999). Long-term cutaneous effects can be observed in skin areas after chronic exposure to heat and IR radiation which may result in skin lesion phenomenon known as erythema ab igne (Lee *et al*., 2006). Similar to ultraviolet, overexposure to IR can result into photoaging and photocarcinogenesis (Grether-Beck *et al*., 2014; Schieke *et al*., 2003). It has been reported that chronic IR exposure can cause pronounced elastosis in mouse skin similar to damage caused by UV (Kim *et al*., 2009; Kligman, 1982). According to Cho *et al*., exposure to acute IR induces cutaneous angiogenesis and inflammatory cellular infiltration. It can also disrupt the dermal extracellular matrix by inducing matrix metalloproteinases, inducing inflammatory cellular infiltration, causing oxidative DNA damage, and altering dermal structural proteins (Cho *et al*., 2008). A decreased in WBC, lymphocyte, and PCV in this report may be attributed to anemia and congenital disorders characterized by diminished bone marrow function due to hyperthermic effects of the overexposure to IR radiation (Dewhirst *et al*., 2003). The type of effect, injury thresholds, and damage mechanisms vary significantly with the weight of the animals and exposure durations. Long-term whole body exposure below the thresholds for thermal damage to the eye and skin can overload the body's temperature regulating capacity and result in heat stress (International Commission on Non-Ionizing Radiation Protection, 2006). However, there is also evidence that increased in temperature can reduce the repair efficiency of existing DNA damage which may accelerate skin cancer formation (International Commission on Non-Ionizing Radiation Protection, 2006). Tanaka *et al.* reported that IR-induced muscle thinning, bone marrow damage, and had a cytocidal effect on cells, which is likely due to apoptosis (Tanaka *et al*., 2011). The changes in blood parameters according to this study might be as a result of bone marrow damage. Near-infrared laser light radiation has also been reported to induce long-term conformational transitions of red blood cell membrane which were related to the changes in the structural states of both erythrocyte membrane proteins and lipid bilayer and which manifested themselves as changes in fluorescent parameters of erythrocyte membranes and lipid bilayer fluidity (Kim *et al*., 2009;

Schroeder *et al*., 2007; International Commission on Non-Ionizing Radiation Protection, 2013). We infer from this study that overexposure to radiation from IR lamp may result to decrease in PCV, WBC, and lymphocytes with a concomitant increase in neutrophils.

CONCLUSION

The various hematological effects observed due to overexposure to radiation from IR lamp may be as a result of inflammatory cellular infiltration, disruptions in dermal composition, diminishing in bone marrow functions and anemia. Further research is needed to unveil biological interaction mechanisms that may lead to negative effects revealed in this study. Meanwhile, IR lamp is considered to be totally safe for therapeutic applications. There is a need for precaution on its overexposure to avoid observable biological effects as discovered in this study.

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Nil.

Conflicts of Interest
There are no conflicts of interest.

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