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Life "in the Pink". Brief Administration of BOOST Oxygen Beauty® Elevates Blood Oxygen Saturation and Enhances Facial Skin Colour

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Abstract

Objective: This study aimed to identify if a limited duration inhalation of BOOST Oxygen Beauty® would impact on blood oxygen saturation levels, and whether any observed effect would be reflected in changes to facial skin colour and tone. Methods: Ten white female participants completed this randomised double-blind placebo controlled crossover study. Each participant was free from any make-up, and provided baseline measures of haemoglobin saturation, and facial skin colour and tone based on the CIE L* a* b* colour space. Five deep inhalations from the oxygen product or air placebo canister were then taken and second readings of all variables recorded. This process was repeated three times. Following a ten-minute rest period new baseline measures were made followed by a repeat of the procedure for the second treatment canister. Results: Data were analysed using factorial repeated measures analysis of variance (Anova). A significant treatment * time point interaction effect indicated an increase in blood oxygen saturation for the oxygen treatment, $p = 0.007$, whereas no change was found in the placebo condition. Significant differences were found between the treatments for measurements of red following inhalation, $p = 0.033$, with oxygen inhalation producing higher levels. In addition, a significant treatment * time point interaction effect was evident for the blue b* dimension, $p = 0.009$, with oxygen inhalation producing lower values than placebo over time. Individual Typology Angle values revealed no change following oxygen treatment, indicating skin tone was not affected. Conclusion: This study shows for the first time that inhalation of a branded oxygen beauty product can significantly impact blood oxygen saturation, and facial colour, producing a redder hue. The potential for these changes to predict ratings of health, attractiveness and age is an interesting prospect.

Keywords

Skin Physiology, Oxygen, Delivery, Spectroscopy

1. Introduction

Evolutionary psychology has invested considerably in research on the determinants of human mate choice [1], with one recent stream considering the impact of skin tone. Across different ethnic groups there is a reported preference for women with lighter skin tones than the average within a given group [2]. Amongst white populations, research has demonstrated significantly higher ratings of physical attractiveness, health and fertility for paler skinned women [3], although the simply drawn and coloured stimuli possessed little ecological validity. Fink and colleagues [4] improved on this methodology significantly by employing digitally manipulated images of women's faces and provided supporting evidence for the "fairer sex", although interestingly strong face tone—hair colour interactions appeared of greater importance than facial skin tone alone. The colour of female facial skin has also been shown to vary in line with the ovulatory cycle, with redness increasing before ovulation and maintaining higher levels during the fertile phase [5], although the authors argue that the small variation is unlikely to be detectable by the human visual system. If the visual colour and tone of female facial skin are an honest marker of mate quality, however, it would go some way to explaining why women focus so closely on maintaining its condition and enhancing its appearance through cosmetic products and even surgical procedures [6].

The annual UK retail market for cosmetics stands at around £10 billion, and although colour cosmetics suffered an 11% decline to £1.5 billion between December 2017 and 2018, skincare maintained its value at £2.3 billion [7]. One relatively recent addition to the skincare arsenal is that of oxygenating moisturisers. The potential wound healing properties of supplemental oxygen have been recognised for some time [8], and the use of hydrogen peroxide as a disinfectant, to treat acne and as a skin lightener has been widespread in the general population, despite advice against such practices due to the potential negative side effects [9] as a consequence of its highly reactive nature [10] [11]. A clear benefit for many of the modern oxygenating skin products is the stabilised nature of the hydrogen peroxide component; something that has been demonstrated to possess good tolerability [12]. Others employ microencapsulation which offers an ideal and unique carrier system for cosmetic active ingredients [13]. The claims made in advertisements for the modern oxygenating moisturisers currently on the market include "helping to replenish dull, dehydrated skin and improve suppleness", "energizes and oxygenizes skin. It reduces the wrinkles, increases skin elasticity and enhances complexion", and "provides energy to the cells, increasing the amount of oxygen they receive … skin regains its energy, luminosity and

vitality, looking healthy and young". Interestingly, however, the authors of the current paper have been unable to locate published data that support such claims.

Given that claims are made regarding the beneficial effects of oxygen on skin tone, an alternative delivery system is worthy of consideration. Short duration inhalation of pure oxygen has been shown to significantly increase haemoglobin saturation in healthy adults [14], and similar effects have been found by increasing oxygen availability from 21% (ambient air) to 30% [15]. Clearly the availability of oxygen following such administration is manifest throughout the body, demonstrated clearly by the fact that blood oxygen saturation levels are measured in a finger tip of the non-dominant hand [16]. Importantly, increased blood oxygen saturation increases the "redness" of haemoglobin and it is this that underpins the technique of Near Infra Red Spectroscopy used to assess microvascular function in cerebral and peripheral tissues [17] [18]. It may be the case that circulating blood with a greater red hue as a consequence of oxygen breathing might be detectable in the surface skin colour, and this study aims to assess this possibility using reliable and valid skin colorimetry. It has been identified previously that the trichromatic visual system in humans is optimized to discriminate variations in blood oxygen saturation [19], and although evolutionarily these might be used to identify socio-sexual signals it is possible that in modern society this has been transformed into the subtler concept of attractiveness.

The presence and amount of melanin determine differences in skin colour and tone [20]. When exposed to sunlight, oxygen is involved in a series of reactions producing melanin that lead to a darkening of skin colour, commonly termed "tanning" [21]. In and of itself however, oxygen administration is likely to have a different acute effect. This is due to the systemic vasoconstricting effects of hyperoxia [22]. A potential consequence would be for skin to become paler in tone as the capillaries receive less blood as a consequence of the reduction in the diameter of the vessels that feed them [23]. Combined with the increased haemoglobin saturation the overall effect of oxygen inhalation on the skin might be to produce a pinker colour and lighter tone.

The hypotheses for the current study are therefore that inhalation of pure oxygen will:

1) Increase blood oxygen saturation.

2) Increase measure of redness in skin colour.

3) Increase in skin pallor.

2. Method

2.1. Design

A double blind, placebo controlled, repeated measures, crossover design was employed for the full procedure. Independent variables were treatment with two levels; Boost oxygen beauty® or air placebo, and time point with four levels; before and after administration phases of each of the treatments. Dependent va-

riables were blood oxygen saturation, measures of L* a* b* skin colour dimensions and the Individual Typology Angle classification of skin tone. Phase of menstrual cycle was recorded for each participant to provide an additional analysis of a factor previously reported to impact on skin redness.

2.2. Participants

Ten white females (mean age = 30.1 years SD = 7.8) randomly selected from a participation pool were each paid ten pounds for taking part in the study to compensate them for their time. All reported being in good health, were make-up free on the day of testing, and none had engaged in physical exercise on the day of testing.

2.3. Apparatus

2.3.1. Courage + Khazaka Skin Colorimeter CL 400

The C + K CL400 Colorimeter is a fully enclosed wireless colorimeter specifically developed for measuring skin colour. The device illuminates a 24 mm diameter patch of skin using 8 white LEDs, and measures the colour in the centre 8 mm using an XYZ colour sensor. The unit is specially calibrated and configured for the structure of the skin with an overall colour accuracy of 95%. The bundled MPA software converts the raw XYZ colour information into both RGB, and L* a* b colour languages. Defined by the Commission Internationale de l'Eclairage (CIE), the L* a* b* colour space was developed because colour-opponent theory states that two colours cannot be both red and green, or both yellow and blue at the same time. Interpretation of the three dimensions is simplified as L* indicating lightness, a* as the red/green dimension, and b* the yellow/blue dimension. When compared to baseline measures, post-treatment increases in L* indicate lighter skin tone, and decreases indicate darker skin tone; increases in a* represent redder skin colour, and decreases represent greener skin colour; and increases in b* values indicate yellower skin colour, whereas decreases would indicate bluer skin colour. The L* a* b space also allows the system to calculate the Individual Typology Angle (ITA) measured in degrees, which is the classification of skin colour based on the following range: ITA˚ > 55˚ very-light; 55˚ > ITA˚ > 41˚ light; 41˚ > ITA˚ > 28˚ intermediate; 28˚ > ITA˚ > 10˚ tan; 10˚ > ITA˚ > 30˚ brown; 30˚ > ITA˚ dark. Data were collected following the manufacturer's instructions.

2.3.2. Pulse Oximeter

Blood oxygen saturation was measured and recorded at baseline and following gas administration using a TempIR™ pulse oximeter according to the manufacturer's instructions.

2.3.3. Gas Treatment

Six-litre canisters of Boost Oxygen Beauty 98% pure oxygen, and identical placebo canisters of compressed air at 21% oxygen were provided by Boost Oxygen,

L3 Temple Court, Knight Road, Strood, ME2 2LT. Half the cans were marked on the base with a star. The research team was unaware until the completion of the study whether the star indicated the canister contained oxygen or placebo.

2.4. Procedure

Full ethical approval was gained from the Faculty of Health and Life Sciences ethics committee at Northumbria University prior to data collection. All testing took place in the same research room in the Department of Psychology. Participants provided informed consent and were tested individually. Each participant provided demographic data and confirmed that they had not applied any make-up that day and had washed with a simple soap that morning. No participant had engaged in any strenuous exercise during the day prior to attending the lab. Participants were allocated to either the "star canister first" or "star canister second" group using a random allocation list that ensured equal numbers in each group. The pulse oximeter was applied to the fore finger of the non-dominant hand and a baseline measure recorded. Baseline skin measures were taken for each cheek, and the forehead. Participants then took five deep inhalations from the first canister and second a second set of measurements recorded. Five more inhalations were taken and recordings repeated. Five further inhalations were taken and final recordings made. A rest period of ten minutes then followed and the recording of a second baseline and subsequent post-inhalation data made for the second canister. Participants were then thanked and debriefed. The procedure is summarised in **Figure 1**.

2.5. Analysis Strategy

A one way analysis of variance was used to assess the impact of phase of menstrual cycle (based on the forward-counting method to allocate people to follicular, ovulation, luteal, menstrual phases) on the a* measure, given that it has previously been linked to changes in skin redness [5]. For the main analysis of the impact of oxygen, all measures were compared for each dependent variable between the two groups for the corresponding treatment time points, and as no differences were found data were collapsed to provide for a 2 (treatment) by 4 (time point) repeated measures analysis of variance to be conducted for each of the colour dimensions and the oxygen saturation measure. For concision, only the interaction effects are reported here as the key aspect of interest.

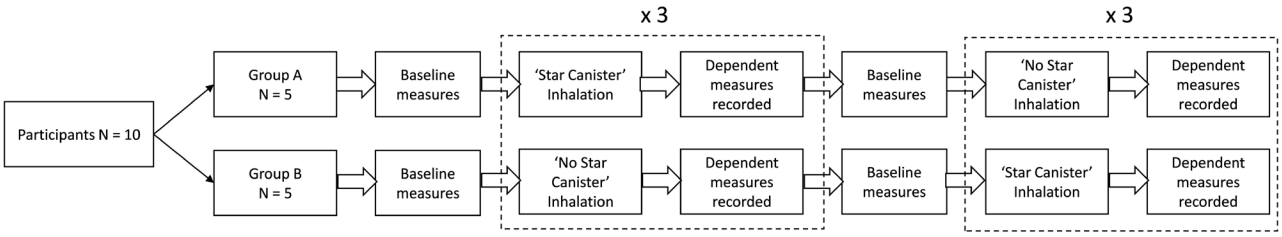

Figure 1. Schematic diagram of study procedure.

3. Results

3.1. Impact of Phase of Menstrual Cycle

A one way independent groups analysis of variance revealed that menstrual phase did affect mean baseline measures of the a* colour dimension F(3,6) = 5.624, p = 0.035, partial eta squared = 0.738 with higher values in the fertile ovulation phase (Figure 2). However, extreme caution should be taken over this finding as the cell sizes very small. See [24] for full consideration of this issue.

3.2. Blood Oxygen Saturation

The analysis revealed a significant Treatment*Time point interaction effect F(3,27) = 5.000, p = 0.007, partial eta squared = 0.357. The interaction is presented in Figure 3 and indicates a significant increase in haemoglobin oxygen saturation following oxygen inhalation with no change in the placebo condition.

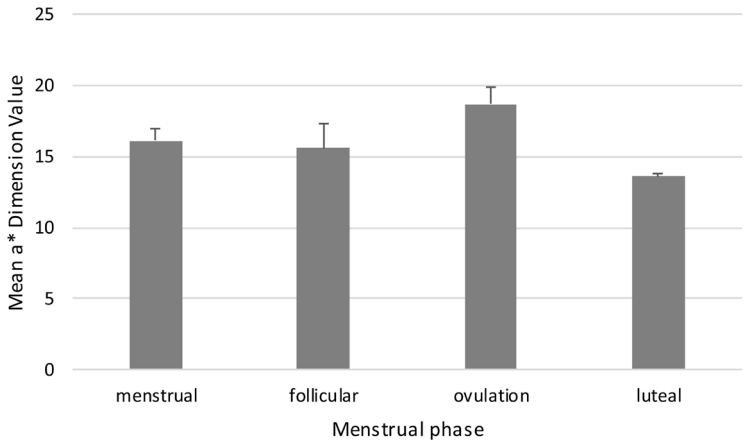

Figure 2. Mean a* colour dimension values at baseline for all participants split by menstrual phase. Error bars represent standard deviations.

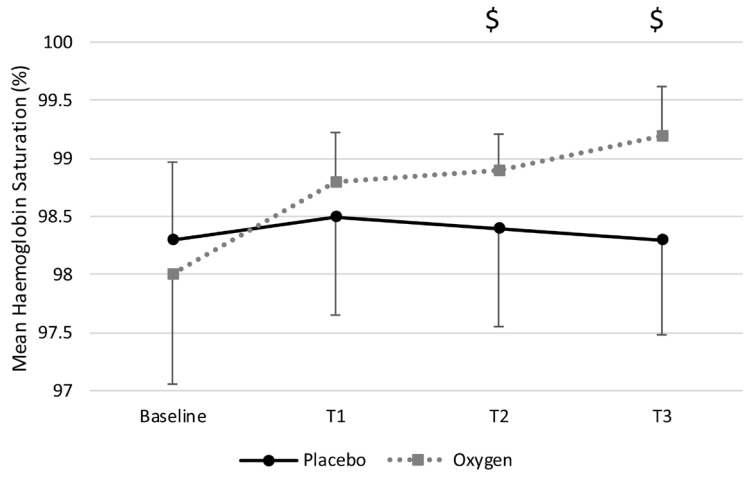

Figure 3. Mean haemoglobin saturation values for all participants in all phases of the study. Error bars represent standard deviations. $ denotes significant pairwise comparisons.

3.3. L* a* b* Skin Colour Dimension Measurements

The values for each colour were averaged across left and right cheeks and forehead, for each participant in each treatment and time point. The analysis revealed a significant Treatment * Time point interaction for the L* dimension, $F(3,27) = 3.408$, $p = 0.034$, partial eta squared = 0.299. Figure 4(a) indicates that oxygen breathing slightly darkens the skin compared to placebo at T2, although this difference is absent by T3. A significant Treatment*Time point interaction was also revealed for the a* dimension, $F(3,27) = 3.418$, $p = 0.033$, partial eta squared = 0.300. Figure 4(b) indicates that oxygen increases this "red" dimension at T2 and T3 compared to baseline and the placebo condition. A significant Treatment*Time point interaction was also revealed for the b* dimension, $F(3,24) = 4.826$, $p = 0.009$ partial eta squared = 0.376. Figure 4(c) indicates lower levels of "blue" in the oxygen breathing condition at T1 and T2 compared to placebo.

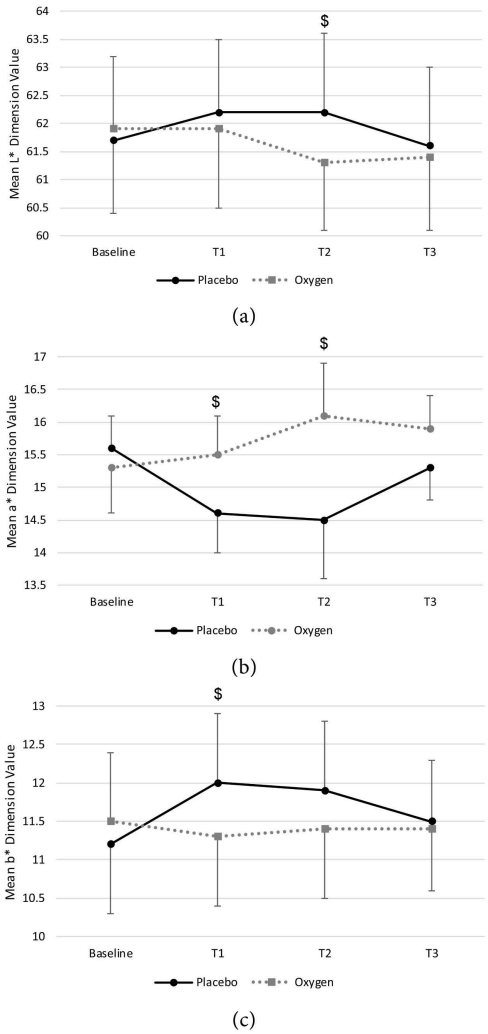

Figure 4. Mean L*, a*, b* colour dimension values for all participants in all phases of the study. Error bars represent standard deviations. $ denotes significant pairwise comparisons.

3.4. Individual Typology Angle

The L* a* b* space allows the system to calculate the Individual Typology Angle (ITA), measured in degrees), which is the classification of skin colour where lower values represent paler skin tone. The analysis revealed no Treatment * Time point interaction $F(3,27) = 0.626$, $p = 0.605$, partial eta squared = 0.073. The means are presented in Table 1 and clearly indicate no impact on this measure.

4. Discussion

The data demonstrate that a brief administration of Boost oxygen can significantly increase blood oxygen saturation in healthy female adults. In addition, and as predicted, the increased haemoglobin saturation impacts on skin colour by increasing its "redness". Oxygenated haemoglobin is bright red whereas deoxygenated haemoglobin is a dark reddish-purple. As the blood oxygenation level increases as a consequence of breathing oxygen, so the skins redness increases and the blueness decreases. These changes are reflected in the data presented here. The hypothesised lightening of the skin colour was not apparent however. Indeed, oxygen breathing produced a darkening of the skin as recorded by the decrease in the L* dimension values. This would suggest that the short duration hyperoxia is not sufficient to lead to vasoconstriction and reduction of blood supply to the skin's capillaries. Indeed, the major control system that affects skin blood flow is that associated with homeostasis, and body temperature is the main driver of cutaneous vasodilation [25]. This system may simply over-ride any impact of the short duration oxygen administration. However, why the observed darkening should occur is still not entirely clear as the increased redness is associated with less "blueness" compared to placebo. How these effects combine to produce a darker skin colour as measured by the L* dimension is perhaps a consequence of the complex ways in which the colour dimensions combine. Increases in a* and b* dimensions can be associated with both increases and decreases in L* values and as such goes some way to explaining

Table 1. Mean (SD) Individual Typology Angles (ITA) for all participants in all phases of the study.

Condition	Phase	Mean (SD)
Placebo	Baseline	45.7 (16.1)
	T1	45.0 (15.7)
	T2	44.9 (15.9)
	T3	45.2 (15.9)
Oxygen	Baseline	45.8 (15.2)
	T1	45.4 (15.9)
	T2	44.9 (15.1)
	T3	43.4 (16.6)

the findings here. No impact was found for the ITA values, although this is perhaps not surprising as this measure is a composite of the L* and the yellow element of the b* dimension to indicate overall skin tone on a constructed fair/tanned/brown dimension generally indicative of racial differences. However, the consistent measurements for the individual participants on this measure perhaps demonstrates the reliability of the colorimeter. Correlations substantially greater than 0.9 for participants across time points and conditions, and irrespective of their individual ITA values—that ranged from 26 in the "intermediate" band to 60 in the "pale" band of the range—suggesting strong internal consistency of the device.

Ageing is associated with a decrease in skin quality that derives from a combination of increased dryness and reduced perfusion [26]. It may therefore appear logical to apply moisturisers that "oxygenate" the skin to maintain healthy skin. However, although the epidermis will absorb the moisturiser, there are no blood cells in this outer protective layer and as such direct blood oxygenation is precluded. Hydrogen peroxide—the active component of oxygenating moisturiser—is in fact poorly absorbed through intact skin [27]. Rather it is a mild irritant, and may produce the "healthy" pink tones as a consequence of such action when applied in very low concentrations in a moisturiser. In contrast, we have shown here for the first time that an increase in skin redness can be achieved by increasing levels of haemoglobin oxygenation, and this may indeed provide some of the associated benefits desirous of the aforementioned moisturisers. A study that allowed participants to manipulate colour calibrated facial photographs along oxygenated and deoxygenated blood colour axes provided some interesting results [28]. Male and female participants were asked to adjust the colour of a range of white faces to achieve the optimal healthy appearance. Data indicated that increases in oxygenated blood colour were made to female faces, with more being added to those initially palest. The authors argue that the healthy appearance of faces is enhanced by increased blood colouration, suggesting that participants interpret skin blood colouration as a cue to underlying health. Interestingly, attractiveness is strongly correlated with perceived health [29], and is a major aspect in human mate choice, particularly by men [30]. The authors conclude, that the enhanced healthy appearance associated with increased oxygenated blood skin colour may have consequences for attractiveness and mate choice [28]. Returning to the findings of the current study, it may be the case that short duration oxygen inhalation can increase ratings of attractiveness for female faces as a consequence of the mechanism outlined above. This is an intriguing possibility that warrants investigation.

This study may have been limited by the small sample size, although the large observed effect sizes suggest that replication on a larger scale would be achievable. We did not attempt to record measures of attractiveness and it is possible that the changes we observed in skin colour might not be easily discriminated by the human visual system [5]. Precisely captured images before and after inhalation of oxygen could be used to test this possibility. Importantly, because the

impact of oxygen is almost instantaneous the images could be obtained with such temporal proximity as to prevent the confounding effect of other variables such as emotional state [19] and diurnal variability in skin colour [31].

5. Conclusion

To conclude, the current study provides the first demonstration that brief supplemental oxygen administration can enhance the facial skin colour in healthy adult women. The ease and speed of use may make such products attractive to those who aspire to a more "natural" look, but feel they would like to increase the health dimension of their facial skin. Approaches to skin treatment are ever increasing, and this may provide a novel addition to the arsenal.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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