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Impact of Nail Polish Colour on the Accuracy of Pulse Oximeter Reading in Healthy Individuals

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ABSTRACT

Objective: To assess the effect of single-layered common nail polish colour on change in pulse oximeter reading.
Study Design: Cross-sectional analytical study.
Place and Duration of the Study: Combined Military Hospital, Peshawar, Pakistan, from Sep 2021 to Apr 2022.
Methodology: Four hundred healthy females were included in the study that was normothermic, had an Oxygen saturation (SpO2) reading of 95% or more and do not have associated comorbidities, nailbed abnormalities or any history of trauma to limb. Individuals having any previous factors were excluded from the study. After informed consent, SpO2 was recorded using a portable infrared pulse oximeter in all four fingernails of the subjects at room temperature and then rechecked after the single-layered common nail polish was applied and dried. Red, green, black and purple were assigned to the index finger, middle finger, ring finger and little finger, respectively. In addition to oxygen saturation, other parameters, including age, gender, educational status, residence etc., were also recorded.
Results. There was a statistically significant difference in oxygen saturation readings via portable infrared pulse oximeter in all four fingernails after applying single-layered common nail polish colours (p-value<0.0001). However, there was no clinically significant difference in oxygen saturation reading recorded in any individual.
Conclusion: A single layer of common nail polish affected the SpO2 reading measured through a portable pulse oximeter. This should be kept in mind when evaluating such patients in emergency reception.

Keywords: Nail polish, Nail paint, Oxygen saturation, Portable pulse oximeter, Pulse oximeter

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INTRODUCTION

Takuo Aoyagi first invented the pulse oximeter in 1974, after he found that the pulsatile changes in oxygen saturation could be used to compute saturation from the ratio of ratios of pulse changes in red and infrared wavelengths. Since then, it has been used as a common tool which revolutionized continuous oxygen monitoring as part and parcel of patient care in operation rooms, intensive care units, wards and even at home.[1] Even during the COVID-19 pandemic, it facilitated the domiciliary monitoring of oxygen saturation to ensure the screening of those quarantined that needed inpatient care.[2] Oxygen saturation, as important as the other vital signs, is regularly monitored in intensive care units by the medical team. In case any saturation is detected below the targets, it is addressed accordingly by oxygen therapy.[3]. Moreover, it also helps us evaluate the response to therapy in follow-ups in outpatient care. Several different versions of pulse oximeters exist, which can detect oxygen saturation, not just from the fingernail but also from the toes, earlobes, nose and forehead.

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Nevertheless, several factors still have led to misinterpretation of the actual oxygen saturation the patient's blood holds. The factors that limit its use are motion artefacts, nail polish, anaemia, significant skin pigmentation, decreased blood perfusion to limbs due to any cause (such as cold peripheries, vasoactive drugs etc.) and arterial acid-base status. Even low temperature, Methemoglobinemia and high altitude can lead to underestimating oxygen saturation [4-6] Some conditions like Carboxyhemoglobinemia and carbon monoxide poisoning lead to overestimation of oxygen saturation readings as well.[7] Nail polish has been part of every society and has evolved throughout time.[8] Nail polish comprises several compositions and types. It includes common, breathable gel, acrylic, poly gel, dip powder and shellac. Each type has a different composition, thickness and life to pose a different challenge on its own to pulse oximetry measurements.[9] The erroneous reading in the pulse oximeter can impair the assessment of disease severity, especially in people with chronic lung disease admitted with an acute episode of disease.[10] As this might lead to an underestimation of oxygen saturation, the potential to overtreat or under-treat remains a potential threat to patient management. Intensive care units and emergency

departments receive patients with different colour nail polishes that challenge accurate measurement of oxygen saturation and thus make decision-making difficult. Removing the nail polish is a time-consuming task and needs to be prioritized for the sake of patient care. There can be several nail polish factors that can affect the pulse oximeter's reading. However, this study was done with the pure spirit to ascertain the impact each fingernail colour has on the actual oxygen saturation reading, as studies on it are still limited to date. This study will help us establish the reliability of the pulse oximeter's saturation estimation on people with single-layered common nail polish.

METHODOLOGY

It was a cross-sectional analytical study conducted at Combined Military Hospital, Peshawar Pakistan, over six months from September 2021 to April 2022. The Ethics Review Committee for Medical and Biomedical Research of Combined Military Hospital Peshawar Pakistan, approved the Study Protocol before the start of the study (Reference No 00210/21 dated Sept 21). Sample size calculation was done using Epitools sample size calculation to compare means. It was assumed that the mean SpO2 before and after the application of nail polish would be 98.37% and 98.00% with a variance of 0.66%, as determined previously by Hakverdioglu *et al*.[11] For this estimation, we had set desired power at 0.8 and confidence level at 95%.

Inclusion criteria: Females who had no nail bed abnormalities, no associated upper limb trauma, no comorbidities and oxygen saturation (Spo2) readings of ≥95% on plain nails were included in the study.

Exclusion criteria: Females having any comorbidities that could potentially affect the oxygen saturation readings (e.g., heart failure, anaemia, chronic lung disease, hemoglobinopathies etc.), any nailbed abnormalities or any trauma to the upper limbs or oxygen saturation reading SpO2<95% recorded at room air on plain fingernails were excluded from the study.

After their consent, their common demographic data were recorded. SpO^2 was measured through a portable pulse oximeter (Model No. MD300C21C; Beijing Choice Electronic Technology Co. Ltd) from all four fingers in a room with normal temperature after resting for 10 minutes and then was re-measured after a single layer of nail polish was applied and dried. The finger-wise difference in oxygen saturation of all four fingers of the right hand was recorded. The pulse oximeter remained unchanged throughout the study, and the nail polish used during the study was from the same company.

All the data were analyzed through Statistical Package for the Social Sciences (SPSS) version 21.00. The results were described as mean± standard deviation for the quantitative variables. A paired samples t-test was used to compare changes in SpO^2 before and after applying nail polishes. In addition, a one-way ANOVA test was applied to compare drops in SpO^2 with nail polish colours. The *p*-value ≤0.05 was taken as significant at the start of the study.

RESULTS

This study included 400 subjects with the mean age of 27.96±10.41 years. All subjects were females. Of them, 144(36%) were educated under matriculation, while 32(8%) were postgraduate. 272(68%) of subjects belonged to Peshawar, 64(16%) belonged to Kohat while rest belonged elsewhere in Khyber Pakhtunkhwa Province. The mean SpO2 of all four fingernails without nail polish (ASpO2) was 97.93±0.68%, dropping by 0.44±0.31% after applying different nail polishes. The effect of different nail polishes on SpO2 values detected by pulse oximetry is shown in Table-I. The mean change in SpO2 with red, green, black and purple nail polishes was 0.22±0.48%, 0.87±1.04%, 1.09±1.12% and 0.25±0.62%, respectively shown in Table-II. The comparison of the decrease in SpO^2 with nail polishes of different colours was shown in Table-III. It can be seen that this change was the same for red and purple colours, but the differences between all other colours were statistically significant.

Table-I: Comparison of Oxygen Saturation with and Without Application of Nail Polishes of Different Colours (n=400)

Colour of Nail Polish	SpO2 Without Nail Polish (%)	SpO2 With Nail Polish (%)	*p*-value
Red	98.00±0.63	97.87±0.75	<0.001
Green	97.94±0.68	97.05±0.98	<0.001
Black	97.93±0.71	97.30±0.87	<0.001
Purple	98.02±0.60	97.86±0.85	<0.001

Table-II: Comparison of Drop in SpO2 with Different Nail Polish Colours (n=400)

Colour of Nail Polish	Red	Green	Black	Purple	*p*-value
SpO2 with nail polish(%)	0.22±0.48	0.87±1.04	1.09±1.12	0.25±0.62	<0.001

Table-III: Inter Group Comparison of drop in SpO2 with Different Nail Polish Colours(n=400)

Group Comparison	Red vs. Green	Red Vs. Black	Red Vs. Purple	Green Vs. Black	Green Vs. Purple	Black Vs. Purple
Drop in SpO2	<0.001	<0.001	0.025	0.003	<0.001	<0.001

DISCUSSION

The portable pulse oximeter works by emitting (red and infrared) light through a light source that passes through a finger with a light detector opposite to it. The fingertip is fitted between the light source and the light detector while recording oxygen saturation. The nail polish affects the passing beam to the light detector and affects oxygen saturation reading. The Subjects in this study were females, as it was socially inconvenient to include males. There was a statistically significant decrease in oxygen saturation found in all fingernails after applying single-layer nail polish. This study concurred with a study conducted in 2019 in a Nursing Department in Adana, Turkey, although it considered the left hand as control and the right hand was considered for application of nail polish before recording.[2] Another study conducted on 30 healthy students of the nursing and midwifery faculty of Qom University of Medical Sciences in Iran showed that nail polish lowered the oxygen saturation readings of all colours except dark green and purple. That study was conducted differently in that it used glittered nail polish.[12] A study was carried out in Bangladesh by Hossain *et al*. in 2021 also provided no statistically significant results with red Nail polish. However, he compared the oxygen saturation of two different fingers of the same hand, i.e., the polished index finger and plain middle finger of the same hand of all healthy individuals.[13]

Raipure *et al*. in 2019, found a statistically significant but clinically insignificant fall in the oxygen saturation reading in a labour room in Nagpur, India. However, that study did not mention the nature and layers of Nail polish applied during the study.[14] The study also resonates with the finding that red colour showed minimum deviation from the mean than other colours. A study was published in 2019 in the Singapore Journal of medicine on the effects of gel-based manicures on pulse oximetry which showed an overestimation of oxygen saturation after applying gel-based manicures on nails, which is contrary to the findings of this study.[15] Haq and her team published a similar study in 2018 on the subject. They found a statistically significant difference in SpO2 readings with dark (Black and blue) coloured nail polish application compared to light nail (pink and blue) polish colors.[16] However, the sample size of that study was much smaller than this study, and the data were not normally distributed.

Furthermore, a study was published in the Journal of Emergencias in 2015, which concluded that black and blue significantly decrease oxygen saturation compared to other nail polish colours. This study, too, did not mention the nature and layers of nail polish that was used.[17] More studies published in a Nursing Journal and the Journal of the Association of Physicians of India in 2021 and 2022, respectively, have shown similar results as depicted in this study.[18-19] This study has also shown a statistically significant difference in all singlelayered common nail polish colours. All the previously mentioned studies that produced similar results also concord with and endorse this conclusion. It is, however, pertinent to mention that the study did not check the effects of layered nail polish on the reading of the pulse oximeter. It did not check the effect of nail polish on pulse oximetry on toenails. This study did not use a pulse oximeter attached to a cardiac monitor. This study included all healthy individuals; hence, whether it can cause any significant difference in readings of hypoxic patients or patients with other comorbidities is not studied in this study.

CONCLUSION

To conclude, this study has shown that single-layered nail polish causes a statistically significant change in the reading of oxygen saturations measured through a portable pulse oximeter on fingernails. This should be kept in mind when evaluating such patients in emergency reception.

Conflict of Intrest: None.

Author's Contribution

Following authors have made substantial contributions to the manuscript as under:

UN & FAS: Conception, Study design, drafting the manuscript, approval of the final version to be published.

AR & SS: Data acquisition, data analysis, data interpretation, critical review, approval of the final version to be published.

HG & MSA: Critical review, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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