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Effect of Yogic Exercises on Oxygen Saturation Levels at High Altitudes

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KEYWORDS
Hypoxia, Pulse Oximeter, Oxygen saturation, Pranayama, High Altitude, Yoga

ABSTRACT:
The risk of hypobaric hypoxemia, and the subsequent symptoms of Altitude sickness are increased by high altitude travel. The aim of this study was to analyse the effect of new type of yogic breathing-Maheshwarananda's new Modified Bhujangini Pranayama performed by active yoga practitioners--on the arterial haemoglobin saturation of oxygen (measured by the pulse oximetry - SpO_2) and the heart rate compared to normal spontaneous resting breathing. In the Himalayas, at 3,650m altitude, we conducted a pilot prospective study. SpO_2 was monitored along with pulse rate. After the yoga breathing exercises, within 3 days of measurement at 3,650m altitude the average SpO_2 value increased from 89.11±4.78 to 93.26±4.44. (P0.001). There were no significant differences in the pulse rate measured (P0.230), before and after yogic breath. The new Yogic breathing-Maheshwar Ananda's Modified Bhujangini Pranayama-is increasing the arterial haemoglobin saturation compared to normal resting spontaneous breathing. This type of breathing was not affecting the heart rate.

Introduction

High altitudes in the Himalayas can be a very exhausting and demanding environment, with a high risk of altitude sickness and hypobaric hyperoxia. During the first few days and hours of the sojourn the body begins compensatory mechanisms to reduce the hypoxia. The heart rate and ventilation are both increased but there is no increase in the stroke volume. It is common to see a reduced stroke volume a few days following acclimatization. This can be explained by increased oxygen carrying capacity in the blood unite due to haemoconcentration and hypovolemia. A prolonged stay at high altitudes results in an increased erythropoiesis, which leads to a higher haemoglobin production. This allows for the partial or complete replenishment of circulation blood volume as well as improvement of heart diastolic function. Hypobaric hypoxia, and the physiological adaptations that result from it, are dependent on not just the elevation itself but also the rate and intensity of the ascent. (Spatenkova, High altitudes in the Himalayas can be a very exhausting and demanding environment, with a high risk of altitude sickness and hypobaric hyperoxia. During the first few days and hours of the sojourn the body begins compensatory mechanisms to reduce the hyp, 2020)

Hypoxia is well-known to be a powerful condition that activates the sympathetic nervous system via known mechanisms (chemoreceptor and baroreceptor reactions, pulmonary hypertension due to vasoconstriction in the lungs) as well as less-known or yet undiscovered mechanisms. Hypoxia, also known as hypoxic shock, activates the sympathetic nervous system via well-known mechanisms, such as pulmonary hypertension caused by vasoconstriction, but it can also be triggered via lesser known or undiscovered mechanisms. In general, endogenous systems perform compensatory actions automatically, but also adjust parameters based on the actual state of the body and the anticipatory system based upon experience and memory. There is also a space of voluntary control, which can be used to partially alter the autonomous responses, such as the breathing patterns. This is something we would like to explore here in the context of yogic exercises and yogic breath. (Hannemann, 2021)

Bernardi has shown that breathing slowly and regularly, or using a technique derived from yoga can increase HbO_2 saturation in heart failure patients. Similar breathing patterns could be used by normal people to counteract hypobaric conditions, such as those encountered in high altitude travel. The researchers noted that yoga practitioners adapt well to high-altitude environments due to the voluntary ventilation patterns controlled by yoga supervisors. This results in a lower decline of oxygen saturation than normal spontaneous

breathing. Miles noted that Pranayama, a form of yoga breathing exercises, could play a role in physiological adaptations to high altitudes. It can also improve oxygen delivery to compensate for an acute hypoxia phase. The study also showed that the lower breathing frequency under yoga exercises reduced the hypoxic or hypercapnic chemoreflex sensitivity. This, along with breathing patterns and their effects on the body are discussed by studying Himalayan Sherpas and Himalayan Monks (as compared to a control group within the same ethnicity). Bhujangini pranayama, studied in this study is a form of yogic breath with deep and slow inspirations from both nostrils. Expirations are also slow. Himalayan monks and Sherpas exhibit a breathing pattern very similar to "yogic breath" which is slow. Himshree conducted a study with 200 soldiers in an altitude range of 3,445 meters. The results showed that yoga practitioners at the altitude had improved biochemical parameters compared to a control group. Yoga exercises that involve consciously and voluntary controlled breathing patterns have been shown to induce hypometabolic state and help trainees tolerate hypoxia. (Spatenkova, Bernardi has shown that breathing slowly and regularly, or using a technique derived from yoga can increase HbO 2 saturation in heart failure patients. Similar breathing patterns could be used by normal people to counteract hypobaric conditions, such as t, 2019)

This pilot study aimed to determine whether active yoga practitioners' increased saturation in arterial blood of oxygen (measured using SpO_2 sensors) when exposed to the Maheshwarananda Modified Bhujangini Pranayama. This study also aimed to determine the impact of yogic breath on heart rate. (Nagarathna, 2018)

Participants:

In September 2018, an international prospective pilot one-group research was carried out at Nanda Devi National Park, in the Alakhpuri Mountains of the Indian Himalayas. This study involved 34 participants with a mean age between 16-74. The majority of participants were from Slovakia, with 24 (70.59%). Czechia had fewer 9 (26.47%) and Croatia only one (2.94%). The 34 participants were all part of one group. (John, 2020)

Ethics Committee No. The University Hospital and Polyclinic F. D. Roosevelt Banska-Bystrica in Slovakia approved our easier, new modification of Maheshwarananda's Bhujangini Pranayama. (Arvind, 2022)

The following travel schedule was followed: (a.) two days in Rishikesh at 372 meters altitude (time: T0), upon arrival in New Delhi; (b.) two days in Badrinath at 3,300 metres altitude (time: T1), this altitude being reached in one day by bus; and (c.) six days in camp in an elevation of 3,650 meters (3 days of the 6 were measurement days: third day=T2, fourth day=T3, fifth day=T4, participants leaving camp on day 6th (Mike, 2020)

The inclusion criteria included (a) Yoga exercisers who have at least 5 years' experience with the Yoga in Daily Life system; (b), daily practice of modified Bhujangini breathing exercises in the camp over 3 consecutive days; and (c) those without chronic diseases, nonsmokers, lacto-vegetarians or teetotalers. (g) Treatments - medication during the study. All medications ended on day T4, two subjects received two doses each of Acetazolamide of We believe that, based on the inclusion criteria described, and in particular the extensive yoga experience the subjects had, our study group was homogeneous when it came to reproducible results regarding the breathing pattern. (Gamage, 2019)

Two parameters were measured: (a), SpO_2, and (b), pulse heart rate. Two physicians measured the parameters before and after Modified Bhujangini Pranayama on the right finger, with one subject at a time. They used the SPO25 model (SPO25 type, no. Hans Dinslage GmbH Uttenweller Germany, SPO18; two physicians worked at the same time, giving the instructions, watching, and observing the proper positioning of the oximeter on the finger, as well as the reading. We used the SpO_2 sensor, which has a declared accuracy of ±2% in the saturation ranges 70%-100% as well as ±2% heartbeats/minute within the 30 bpm to 250 bpm range. Measurements were taken at three different altitudes (a) 372, m, (b), 3,300, m and (c), 3,650m. (Molinaro, 2020)

Maheshwarananda's Modified Bhujangini Pranayama was tested. It differs from the standard Bhujangini breathing by the way the focus of mental concentration is directed. In the standard Pranayama exercise, the focus is on the sensations in the throat. However, in the modified version of the breathing technique the concentration is on the air flow and volume in the chest and lungs. Both yogic breathing techniques follow a similar pattern, with slow and deep inhalations through both nostrils, followed by a long, slow expiration. The duration of the expiration depends on the tolerance level to extended expirations. Yoga breathing and oximetry were measured in the yoga sitting position. The subjects sat on their knees, with either crossed legs, or on heels. The yoga breathing exercises took place outdoors, and everyone was dressed warmly and felt comfortable. (Chandrasekhar, 2022)

Protocol for the study

It was done in the morning, and at lunch time. The protocol consisted of three phases: This phase consisted of subjects sitting in a relaxed position with their backs straight and breathing normally. The measurements taken were the reference breathing pattern, which was the control pattern for our study. 3. Each individual then started Modified Bhujangini Pranayama, and completed

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20 cycles of breathing (this phase took 2-3 minutes, and the breathing frequency varied from 6-10 breaths per minute). (Russo, 2021)

Analysis

The data analysis in SPSS was done with the descriptive parameters. To verify that the data were normal, we used both the Shapiro Wilk and Jarque Bera tests. The significance of the measured values was determined by pair tests. *t*: two-sample paired test for mean and Wilcoxon-signed-rank-test. Nemenyi's method (after Friedman test/two tailed test), multiple pairwise comparisons were performed for SpO_2 after Pranayama. In pulse, a one-way repeated measures analysis of variance was performed with Tukey as a follow-up. This allowed for a 99% confidence interval. (Uttley, 2022)

The initial measured parameters during the normal resting breathing (phase 2 of the Protocol - before yoga breathing exercise) at individual altitudes are shown in table 1. Table 2 shows analysed parameters both before (phase 2, normal resting breath) and after (phase 4, yogic breathing) the yoga breathing. Table 1 shows the initial parameters measured during normal breathing at different altitudes (phase 2, before the Yoga breathing exercise). The table 2 displays the parameters analysed before and after (phase 2, normal breathing, before the Yoga breathing exercise) as well as the statistically significant increases in SpO_2. The average SpO_2 of the entire group increased at day T2, from 87.93 up to 93.21. At T3, it went from 89.00 down to 92.19 and finally at T4, from 90.38 up to 94.31. (Averaging T2, T3, T4 measurements led to an increase in SpO_2, from 89.11+-4.78 to 93.26+-4.44 *P*0.001) The results of the subgroups of age and gender were similar, showing that SpO_2 changed the same in all groups. (Yildiz, 2019)

Table 1

Parameter	T0 - 372 m		T1 - 3,300 m		T2 - 3,650 m		T3 - 3,650 m		T4 - 3,650 m	
	SpO_2 (% SpO_2)	Pulse (beats/min)	SpO_2 (% SpO_2)	Pulse (beats/min)	SpO_2 (% SpO_2)	Pulse (beats/min)	SpO_2 (% SpO_2)	Pulse (beats/min)	SpO_2 (% SpO_2)	Pulse (beats/min)
Total group	96.44±1.64	75.82±10.16	88.57±2.98	86.39±14.79	87.93±4.93	84.07±16.06	89.00±4.87	81.74±17.49	90.38±4.38	77.34±16.23
Male	97.00±1.15	69.00±12.36	88.22±4.15	81.78±17.25	87.33±4.09	80.11±19.64	89.38±2.88	66.63±14.28	91.00±3.24	67.56±16.52
Female	96.21±1.77	78.67±7.73	88.79±2.08	89.36±12.76	88.20±5.35	85.85±14.39	88.84±5.56	88.11±14.77	90.10±4.85	81.75±14.40
Age <45	97.18±0.87	74.46±11.34	90.27±1.90	87.64±14.91	87.90±3.38	84.70±15.39	90.89±2.76	81.33±18.32	91.10±2.64	75.30±18.98
Age 45–60	96.36±1.91	76.29±11.30	87.20±3.23	85.00±16.35	89.92±3.02	87.42±19.41	89.92±2.23	81.73±16.89	91.33±2.90	78.00±16.19
Age>60	95.67±1.66	76.78±7.33	88.00±2.94	88.00±7.17	84.57±8.24	77.43±9.14	85.29±7.85	82.29±20.05	87.71±7.28	79.14±14.02

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Table 2

Parameter	No.	Oxygen saturation (% SpO_2)		*P*-value	Pulse rate (beats/min)		*P*-value
		Before Pranayama	After Pranayama		Before Pranayama	After Pranayama	
3,650 m T2 (before eating)							
Total group	29	87.93±4.93	93.21±3.95	<0.001	84.07±16.06	82.59±16.00	0.158
Male	9	87.33±4.09	92.56±3.78	0.005	80.11±19.64	80.22±18.49	0.479
Female	20	88.20±5.35	93.50±4.09	<0.001	85.85±14.39	83.65±15.14	0.131
Age<45 yr	10	87.90±3.38	92.90±4.36	0.006	84.70±15.39	82.90±16.76	0.309
Age 45–60 yr	12	89.92±2.02	94.25±3.19	<0.001	87.42±19.41	83.75±18.69	0.007
Age>60 yr	7	84.57±8.24	91.86±4.60	0.017	77.43±9.14	80.14±1.10	0.141
3,650 m T3 (after eating)							
Total group	27	89.00±4.87	92.19±5.28	<0.001	81.74±17.49	82.33±15.35	0.367
Male	8	89.38±2.88	92.13±4.52	0.089	66.63±14.28	73.63±13.52	0.048
Female	19	88.84±5.56	92.21±5.69	0.001	88.11±14.77	86.00±14.88	0.103
Age<45 yr	9	90.89±2.76	93.89±2.62	0.007	81.33±18.32	83.67±17.31	0.254
Age 45–60 yr	11	89.82±2.23	91.45±5.59	0.125	81.73±16.89	81.55±14.03	0.472
Age>60 yr	7	85.29±7.85	91.14±7.29	0.007	82.29±20.05	81.86±17.00	0.455
3,650 m T4 (before eating)							
Total group	29	90.38±4.38	94.31±3.91	<0.001	77.34±16.23	80.52±17.85	0.068
Male	9	91.00±3.24	95.22±2.44	0.004	67,56±16.52	74.44±16.53	0.051
Female	20	90.10±4.85	93.90±4.41	<0.001	81.75±14.40	83.25±18.15	0.275
Age<45 yr	10	91.10±2.64	95.80±2.94	0.002	75.30±18.98	82.10±19.17	0.056
Age 45–60 yr	12	91.33±2.90	94.17±3.13	0.006	78.00±16.19	80.83±20.93	0.180
Age>60 yr	7	87.71±7.25	92.43±5.71	0.017	79.14±14.02	77.74±10.94	0.369
3,650 m T2–4							
Total group	85	89.11±4.78	93.26±4.44	<0.001	81.04±16.63	81.80±16.29	0.230
Male	26	89.23±3.67	93.35±3.76	<0.001	72.17±18.02	75.87±16.91	0.026
Female	59	89.05±5.23	93.22±4.74	<0.001	85.19±14.51	84.27±15.91	0.220
Age<45 yr	29	89.93±3.22	94.21±3.52	<0.001	80.41±17.44	82.86±17.16	0.129
Age 45–60 yr	35	90.37±2.45	94.34±4.17	<0.001	82.40±17.51	82.06±17.73	0.404
Age>60 yr	21	85.86±7.52	91.81±5.69	<0.001	79.62±14.45	79.91±12.75	0.441

These are the initial SpO_2 (normal breathing at rest - Phase 2 of Protocol) values for various altitudes. The initial values of SpO_2 over the next three days show a progressive rise in SpO_2 and this may be indicative of an early stage of acclimatization. The heart rate did not change statistically significantly before and after the Yoga breathing exercise.

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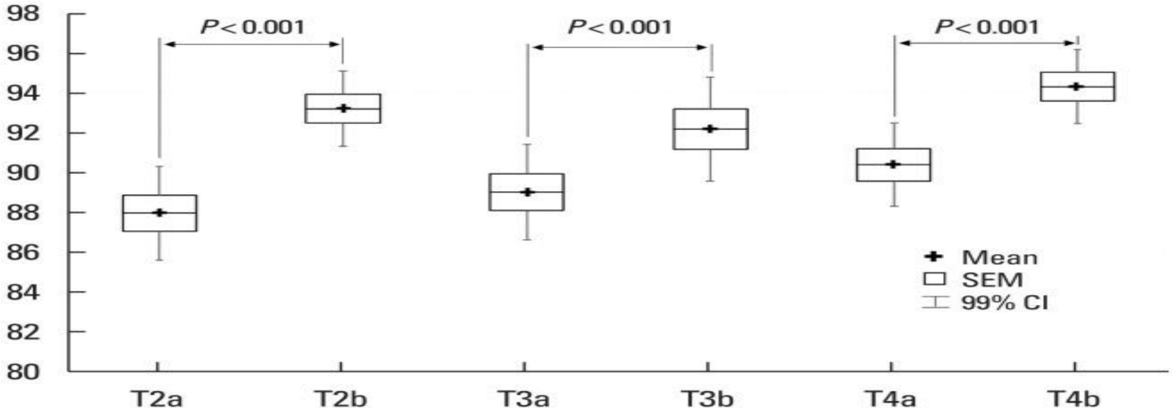
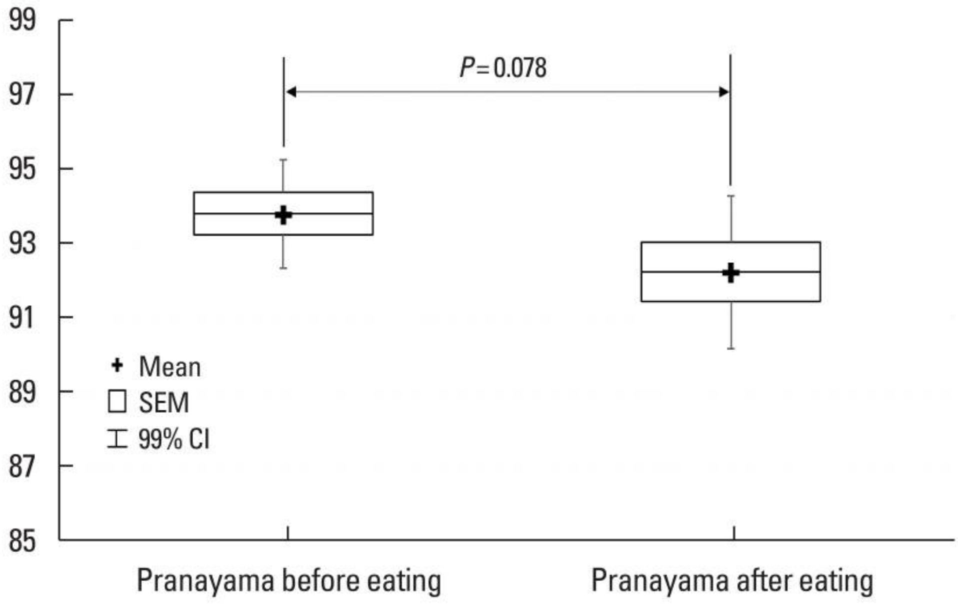
Figure: 1



The SpO_2 and pulse rate after the yogic breath are shown in Table 2. This shows that there is no significant trend. We also found that eating did not affect the SpO_2 change induced by the yoga breathing exercise in a statistically significant way.

Figure 2



The changes in oxygen saturation (SpOsub>2/sub>) and pulse rate after Pranayama breath exercise between individual days at 3,650m. Oxygen saturation (SpO_2), and pulse rate, after Pranayama exercise at 3,650m.

Parameter	Oxygen saturation (% SpO_2)		*P*-value	Pulse (beats/min)		*P*-value
	Sample 1	Sample 2		Sample 1	Sample 2	
T2 total vs. T3 total	92.96±3.99	92.19±5.28	0.8495	83.85±15.34	82.33±15.35	0.9298
T2 total vs. T4 total	92.96±3.99	94.52±3.92	0.1822	83.85±15.34	82.63±16.50	0.9572
T3 total vs. T4 total	92.19±5.28	94.52±3.92	0.0558	82.33±15.35	82.63±16.50	0.9974

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Findings and Discussion

High-altitude regions are very challenging, as they exhaust the physical resources of our body quickly and pose a risk for hypobaric hyperoxia, tissue hypoxia and altitude sickness. Under hypobaric conditions, any physical activity becomes harder and more demanding. It also challenges our bodies' late adaptation mechanisms, as well as the acute phase and physiological response. Yoga breathing exercises may be an interesting way to adjust accommodation for these challenging conditions. This is the first study of its kind to examine the effects of a new breathing technique - Maheshwarananda's Modified Bhujangini Pranayama- on arterial saturation (measured using SpO_2 sensors) at high altitudes. This new method of breathing relies on the subject concentrating their attention to feel the breath in the chest and lungs instead of the throat. This new type of yoga breathing is more practical and feasible, according to participants in our study and our experience. We worked with Yoga practitioners that had practiced the Yoga in Daily Life system for at least 5 years to ensure proper breathing exercises and reproducibility. We chose to work with yoga practitioners who were experienced because the Pranayama System is based on the right sitting posture. The subjects all practiced the position, which is inherent to yoga. (San, 2018)

After 20 breathing exercises of Modified Bhujangini, a statistically significant rise in SpO_2 was noted. These results can be interpreted as showing that breathing in this way can temporarily increase blood oxygenation. This would occur minutes after yogic breathing. We can conclude that Bhujangini pranayama can assist individuals in adjusting to higher altitudes, depending on how often they practice. This is reasonable because it's likely that similar breathing patterns will have similar effects to spontaneous breathing. Why do we not react similarly to high altitudes - by altering our breathing patterns to match the tested yogic breath and thus achieving higher arterial saturation? Our regulatory circuits are limited in their information intake, primarily from internal sensors that we do not consciously perceive. They also don't anticipate the human intentions or plans to spend days at altitude, or even weeks, or perform a highly motivating physical activity. In order to make instantaneous, accurate, and focused homeostatic interventions autonomous regulation mechanisms need real-time data gathered from body presso or chemo sensors. In order to integrate or fuse complex voluntary goals or plans into basic, automatic reactions in a way that is optimal, conscious interference with or overriding of autonomous modulations, including a breath pattern generation, could prove very beneficial under certain conditions. As an individual's time at high altitudes increases, it is fascinating to see how long-term adaptations begin (respecting the already lasting effects of altitude). It is possible that Himalayan monks and Sherpas developed this strategy, which has a similar respiratory pattern to "yogic breath". Although hypoxia can be a stressor that triggers stereotypical respiratory compensatory mechanism, signals from the limbic system, cortical regions (conscious modulation), hypothalamus, and other areas of the brain (circadian patterns, emotions, and motivations) are the ones which provide the information needed to refine the physiological regulation. This is especially true in extreme or less normal conditions. (Zaccaro, 2020)

This study aims to show that voluntary changes in breathing patterns can help with hypoxic situations. The practice of yoga, which focuses on breathing control through conscious awareness could be a safe way to implement voluntary supervision. Bernardi claims that adopting slow, deep breathing can cause the diaphragm muscles to better move, leading to an improvement in ventilation and complete mobilization. This is achieved by well-trained, experienced yoga practitioners following a prolonged exercise. Yoga-like breathing can have different effects on people depending upon their homeostatic system's instantaneous or long-term tune-up. Yoga exercises can improve oxygenation by modulating chemoreceptor responses. It has been shown that slow breathing can reduce the sympathetic response to altitude and alter vagal activity. (Mendo, 2021)

We also examined the effect of food on SpO_2 after yogic breaths. However, no association was found with SpO_2. This study also found that, at T2-4, the mean heart rates (measured along with SpO_2), were not significantly affected by yogic breaths (*P*0.230). It is clear from this finding that Bhujangini breathing has a minimal effect on the heart rate. The fact that the yoga breathing increased the SpO_2 without activating the sympathetic nervous system or increasing oxygen demand of the working myocardium is interesting. Despite a majority of papers that are focusing on the yogic breathing's effect on the heart rate speak about its decrease due to the yogic exercising; explaining that as a consequence of decrease in sympathetic/parasympathetic balance), some of them are also referring about its increase following the yogic breathing exercising. The heart rate may increase or decrease depending on the breathing technique used, the proportion of inspiration to expiration, the expiratory pressure, or the O_2 partial force. (Bhogal, 2019)

We would like to talk about some oximetry limitations, and how they affect our results. There is an ongoing scientific debate on precision and accuracy. Every device measures the real true values to a specific level of accuracy and precision. Food and Drug Administration requires that medical devices sold in the United States for use as a medicine have a root mean square (RMSQ), less than 3%, at levels SaO_2 within

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80%-100%. RMSQ is a combination of systematic error (bias) and random error. It is predictable that the systematic error will result in an offset to the true value. This offset can depend however on the real value of the measured quantity. Random error causes one measurement to be different from another, it is unpredictable and creates fluctuation in the value. Lipnick focused on sensors of similar grade to those we used) found that systematic errors, as expressed by "mean bias", (offsets from the true values), were SaO_2-dependent and, in general, largest for the SaO_2 range between 70%-80%. The offset for the SaO_2 between 80%-90% was between -2.73% and 5.44%, while the one from 90%-100% was around -0.85%-1.2%. This study shows that, despite differences in the magnitude of systematic error between sensor types, the actual impact of these errors on the measured value is a simple aberration or shifting of ideal measurement gauges by a constant (device-dependent) factor. Even if the scaling factor or function is unknown to us (or the experimenter), we can still perform the SpO_2 measurements without significant loss of accuracy. (Hassan, 2019)

Random error would, however, increase the sample size required to reject null hypotheses at a given significance level. The intrinsic error in the SpO_2 is only considered one type of natural fluctuation (or random observational error) that can affect the actual readings of SaO_2 (which could be affected by the location of SpO_2, the pulse quality, the duration of measurement, the skin coloration etc.). In our study, we found that the common statistical methods used to test null hypotheses already incorporate the inherent random error as well as other fluctuations that may have distorted the true values. (Shreffler, 2022)

Conclusion

The time delay between the reading of the SpO_2 by the pulse oximeters can vary from as little as 20 seconds (if it is placed on your earlobe or forehead) to up to two minutes if you place the oximeter on your finger. This is due to blood perfusion times into various parts of the body. We conclude that the delays between the SpO_2 and measurements were not affected by the time delay of the yogic breath.

We would also like to mention that only three measurements were made at 3,650m. Secondly, we didn't observe any fading of the measured effects of breathing on the SpO_2 after stopping the breathing exercises. This pilot study did not include an analysis of altitude sickness symptoms or the acclimatization process. We plan to conduct further studies in order to expand our findings, not just for experienced yoga practitioners, but also for a wider spectrum of people capable of breathing

Conflicts of interest

The author(s) declared no have conflict of interest concerning this work, authorship, and/or publications of this paper.

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