Evaluation of Oxa for Breathing Monitoring.

A product evaluation project

Abstract Nanoleq AG developed Oxa, an innovative smart textile that continuously monitors the respiratory system using respiratory inductive plethysmography (RIP) technology. The goal of this project was to validate Oxa's performance in measuring respiratory phase, rate, and tidal volume by comparing it with a medical-grade gold standard device and a commercially available smartwatch. The feasibility for monitoring the respiratory system with Oxa could be demonstrated. Oxa stayed within +-4% compared to spirometry. Smartwatches only provide average breathing rate, no live breathing signal. For slow breathing rates (which is the case at rest, during meditation or during sleep), one of the most widely used smartwatches estimated the breathing rate in average ca. 2.5 times too high.

Introduction The respiratory rate (BR) is a crucial vital sign used in various clinical settings. It can provide valuable insights into physiological states, exertion levels, and overall well-being. Oxa utilizes RIP, which measures chest and abdominal wall movements associated with inhaling and exhaling (Figure 1), to estimate the respiratory phase, rate, and tidal volume. These parameters have significant implications for monitoring physical effort, recovery, and stress levels.

Methods In this project, three healthy volunteers of the Nanoleq employee pool participated, and their respiratory data was collected using Oxa, a medical-grade gold standard spirometry device (Quark CPET), and a widely used smartwatch. Various breathing protocols were implemented, including Wim Hof breathing (Table 1), controlled breathing at different rates, and physical exercise (Table 2).

Results The results showed that Oxa accurately estimated respiratory phase by aligning with the in-flow and out-flow signals of the gold standard device. In terms of respiratory rate estimation, Oxa performed comparably to Quark CPET across different breathing rates (Figures 2, 3) and stayed within +-4% compared to spirometry for the entire test. During the Wim Hof breathing protocol, Oxa accurately captured the breath-hold moments and aligned with the in-flow and out-flow signals of the gold standard device (Figure 4). In the controlled breathing protocol, Oxa provided respiratory rate estimations in line with the gold standard, while the smartwatch showed limitations in accuracy compared to Quark CPET and Oxa (Figure 2), deviating by ca. 2.5 times from the medical reference. During physical exercise, Oxa successfully tracked the increase in respiratory rates corresponding to running speed, although slight underestimations were observed in certain intervals. For tidal volume estimation, Oxa's measurements correlated well with the reference device and captured increases in tidal volume during deep breaths (Figure 5). This indicated Oxa’s effectiveness in monitoring tidal volume trends.

Conclusion Overall, this project demonstrated the capabilities of Oxa as a wearable respiratory monitoring device. The voluntary participation of the three volunteers and the comparison with established medical and commercial devices helped validate Oxa's performance. By providing continuous analysis of the respiratory system, Oxa has the potential to enhance various applications, including sports science, stress monitoring, and respiratory health.

Table 1: Wim Hof Breathing Protocol

Activity
Deep and fast inhalation and exhalation (30 breath cycles)
Breath-hold for 90 seconds
Recovery inhalation
Breath-hold for 15 seconds
Repeat 3 times
Normal breathing

Table 2: Physical Exercise Protocol

Time (min)	Activity
0-5	Resting
5-10	Running (4 km/h)
10-15	Resting
15-20	Running (8 km/h)
20-25	Resting
25-30	Running (12 km/h)

Figure 1: Illustration of the RIP signal collected from Oxa and respective Inhale and Exhale phases.

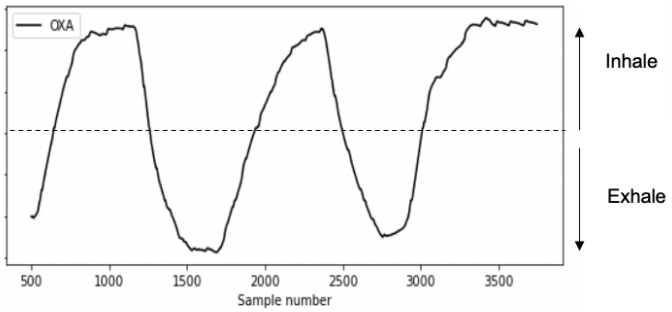

Figure 2: Respiration rate estimation comparison of Oxa (yellow), COSMED Quark CPET (purple) and a widely used smartwatch (brown) at low (5 B/min), moderate (10 B/min) and high (20 B/min) respiration rates.

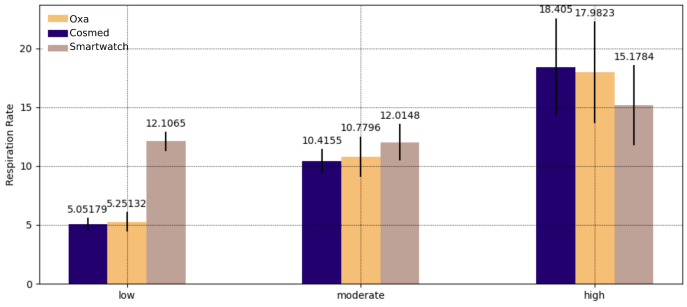

Figure 3: Respiration rate estimation comparison between Oxa (yellow) and COSMED Quark CPET (purple) during Physical Exercise Protocol.

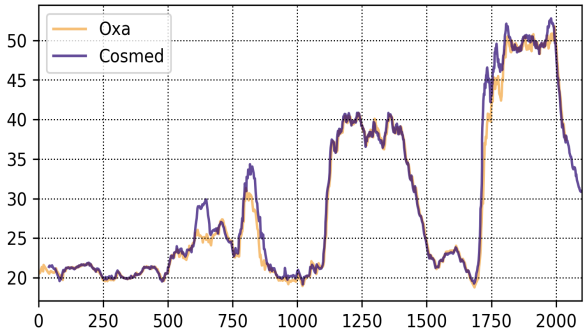

Figure 4: Comparison of Respiration Phase Estimation with Respiration Flow Signal provided by Quark CPET during Wim Hof Breathing Protocol. Top: Oxa RIP signal (black) with respiration phase estimations for inhale (purple), exhale (yellow) and breath-hold (white). Bottom: Flowmeter Raw Signal. Values above and below baseline correspond to inhale and exhale flows respectively, and values at the baseline show an absence of flow.

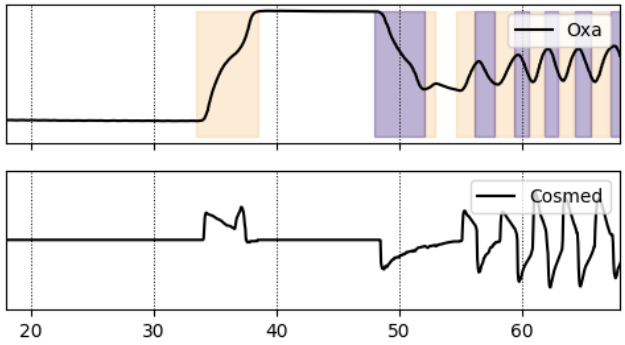

Figure 5: Tidal Volume Estimation Comparison between Oxa (top) and COSMED Quark CPET (bottom) during Physical Exercise Protocol.