**////Title: Key Advances in Measuring the Effect of Training in Competitive Swimmers**

**////Stand-first**:

Swimming was one of the nine original Olympic sports in 1896, and to this day, remains one of the most popular competitive and recreational sports. However, methods to track the effect of training programmes and physiological changes in swimmers have lagged behind those of other sports due to difficulties caused by the aquatic environment. Dr Ben Jones and his team from the University of Essex have used a novel underwater near infrared spectrometer to monitor the effects of a training programme on muscle oxygenation in teenage swimmers.

**////Body text:**

Near infrared spectroscopy (NIRS) is used in medical diagnostics such as brain imaging, as well as in exercise science to help athletes achieve peak performance. NIRS uses light in the near infrared wavelength which can diffuse through human tissues such as skin and bones, and it then interacts with haemoglobin – the protein in red blood cells which carries oxygen.

When haemoglobin is carrying oxygen, it is known as oxyhaemoglobin and absorbs less of the NIRS light than when it not carrying oxygen (deoxyhaemoglobin). NIRS is a hugely useful technology as it is non-invasive; measurements can be taken through the skin without any harm, as well as providing accurate results in less than a second.

Dr Ben Jones and his team of sports scientists from the University of Essex in the UK developed and tested a novel underwater NIRS spectrometer (known in short as uNIRS). Importantly, the uNIRS was designed to allow sports scientists and athletes to measure peripheral muscle haemodynamics, measurements that were previously impossible to take in the water.

The researchers tested the use of the uNIRS in a real-world training study, and in particular, its ability to effectively and efficiently monitor the effects of a training programme on muscle oxygenation and performance during swimming.

The device was developed as swimming is a popular type of exercise, but in comparison to other activities, has until recently been afforded very limited physiological measurement tools. Current approaches to monitoring the effect of swim training programmes include the assessment of heart rate, blood lactate levels, and rating of perceived exertion.

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Fourteen junior members from three different swimming clubs in Essex took part in the study. Nine boys and five girls with an average age of 15 enrolled, although two participants dropped out meaning that data from a total of 12 participants were analysed.

During all swim tests, the uNIRS technology was attached to the outside of each participant’s thigh using waterproof sports strapping tape and held securely in place. The swim test comprised five lots of 100 metres of freestyle swimming in a heated 25-metre pool, with a three-minute recovery period between repetitions.

During testing, the uNIRS was used for muscle oxygenation measurements. Heart rate was monitored using a wireless chest strap during and immediately after the test, the participants scored their ‘rate of perceived exertion’ out of a maximum score of twenty.

Swim tests took place before and after an eight-week training programme. The training programme consisted of five pool training sessions a week, including low, medium, and high-intensity aerobic training, as well as swim technique training. The participants swam an impressive average of 35 kilometres a week during the training period.

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The portable uNIRS device successfully measured the muscle oxygenation changes without the waterproof material interfering with the detection of the near infrared light, demonstrating the potential for such devices in future studies.

More specifically, the uNIRS showed that during the 100-metre swim sprint there was a rapid drop in oxyhaemoglobin which plateaued after about 20 seconds, while deoxyhaemoglobin rose throughout the sprint. During the recovery period, oxyhaemoglobin rose back up while deoxyhaemoglobin dropped. This distinct pattern shows that the uNIRS was successfully monitoring how the muscles take up oxygen from the blood during exercise and how this is replenished during rest.

The uNIRS is so sensitive (with measurements taken in the sub-second time frame), that the effect of the swimmers pushing off from the wall at the start of the sprint and turning at the end of a lap could be clearly observed in the data. When the swimmers tucked their legs in for the somersault at the end of a lap, the total haemoglobin and saturation index both decreased, then as the swimmers stretched out and start kicking again, the total haemoglobin increased and the muscles were re-saturated.

After the eight-week training period, significant changes were seen in both the sprint and recovery phases for the swimmers. In the test conducted after training, there was a significant increase in deoxyhaemoglobin during the sprint, which suggests that training helped increase the amount of oxygen muscles could take from the blood.

Another benefit of the training programme was seen in the faster recovery time for muscle reoxygenation, as during the rest periods of the swim test oxyhaemoglobin rose notably faster in the participants after the training programme than before. In the initial swim test before the training programme, the total saturation values recovered rapidly during the rest periods of the swim test but failed to return to the baseline. However, after training a complete recovery was seen.

Nine of the twelve participants improved their swim performance times, with a strong positive correlation seen between swim time improvement and increased reoxygenation rate. Dr Jones and the team explain that this is likely to be due to the importance of muscle oxygen availability during swim sprints.

The researchers also found the fact that the swimmers could continue to swim at maximum intensity after their tissue saturation index plateaued very interesting, as this suggests that the specific level of muscle deoxygenation isn’t a limiting factor.

Overall, this study has important implications for swim training programmes, with the strong correlation between uNIRS data and performance measures suggesting that the high-volume aerobic training programme was directly responsible for the improved swim performance. This conclusion is supported by other studies demonstrating that sprint swim events are dependent on oxygen metabolism efficiency.

Future work for the team could include attaching the uNIRS to an upper-body muscle (rather than the thigh) as these muscles are used extensively in swimming. In addition, the use of the uNIRS in swimming could also provide information on critical velocity and oxygen uptake kinetics.

This study is the first to look at peripheral muscle haemodynamics and muscle oxygenation in swimmers ‘in the field’, and in doing so, provides a gold standard as well as opening up further avenues for research in this area.

This SciPod is a summary of the paper ‘Underwater near-infrared spectroscopy can measure training adaptations in adolescent swimmers’, from PeerJ. DOI: https://doi.org/10.7717/peerj.4393

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