FOREARM MUSCLE OXYGENATION DECREASES WITH LOW LEVELS OF VOLUNTARY CONTRACTION

G. Murthy[1], N.J. Kahan[2], A.R. Hargens[3], and D.M. Rempel[1]

[1]Ergonomics Program, University of California, Berkeley and San Francisco, CA, USA, [2]Sports and Occupation Medical Associates, CA, USA, and [3]NASA Ames Research Center, Moffett Field, CA, USA

INTRODUCTION

Repetitive motion disorders of the hand and arm are caused by repeated exertion of a specific muscle, tendon, or joint. Such repeated activities, over time, may increase local tissue fluid pressure, decrease local blood flow and tissue oxygenation, and cause fatigue, pain and functional deficits of the involved limb (1,2). Low levels (less than 20% maximum voluntary contraction (MVC)) of prolonged static contraction of the upper extremity are common in many occupational settings and may cause muscle dysfunction **(3).** A current procedure to diagnose and study ischemic pain and muscle dysfunction is to measure tissue fluid pressure by catheter insertion **(4).** However, due to the invasive nature of this technique, it has been difficult to apply to identify **risk** factors for jobs and tasks. If muscle oxygenation can be accurately measured noninvasively, then it may be a valuable adjunct to current methods for identifying tasks and tools which pose risk for muscle fatigue and repetitive motion disorders. The purpose of our investigation was to determine whether near infrared spectroscopy was sensitive enough to measure oxygenation of the extensor carpi radialis (ECR) muscle of the forearm during low level sustained isometric contraction. This muscle is a common site for fatigue and pain associated with sustained or repetitive loading (5).

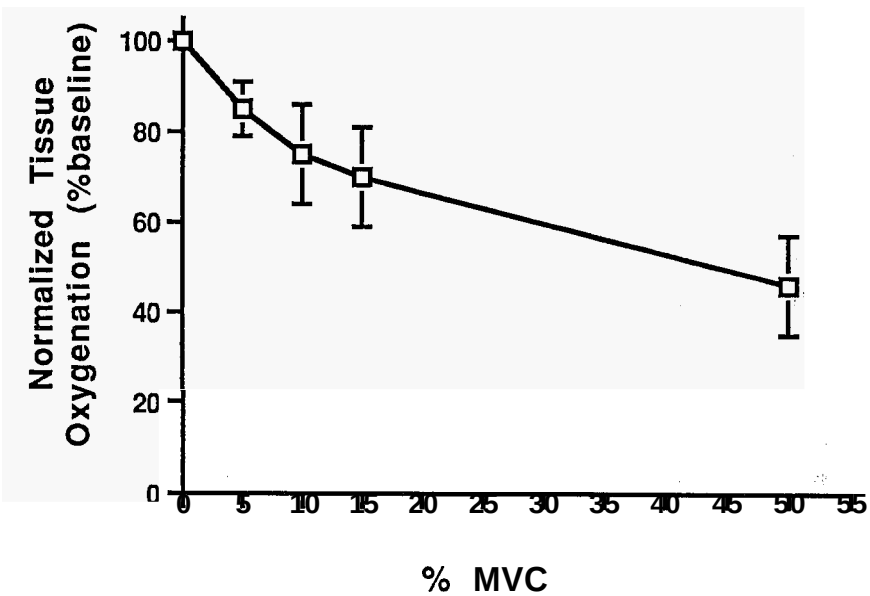
MATERIALS and METHODS

Six healthy male volunteers (age **38** ± 8, mean ± SD) participated in the study after giving their informed written consent. All subjects were in

good health and had no history of upper extremity problems or surgeries. This investigation was approved by the Human Research Institutional Review Boards at the University of California at Berkeley. Subjects were seated, with shoulder abducted to 45" and elbow flexed to 85". The forearm was pronated 45" and the forearm and wrist were supported throughout the protocol. Isometric wrist extension was measured with a load cell suspended from a strap wrapped around dorsal surface of the hand. Sustained loads were applied with weights hanging from the same strap, and were placed just proximal to the second and third metacarpalphalangeal joint. Relative levels of tissue oxygenation (TO_2) were measured noninvasively using near-infrared (NIR) spectroscopy (NIM Inc., PA, **USA).** The NIR principle exploits the disparity between absorption spectra of oxy- and deoxyhemoglobin and myoglobin and measures continuous changes in TO_2, independent of the overall tissue perfusion. The details of the NIR technique are published elsewhere (6). The NIR probe was placed over the ECR muscle of the subject's dominant forearm and secured with an ace wrap. After 15 minutes of relaxation, subjects performed 3 brief MVC consecutively. Percent MVCs were calculated from the highest value of these 3 MVC trials. About an hour following MVC, the subjects were ready to begin the protocol. During the first minute, while the subject was relaxed with arm and hand supported, baseline measurements were recorded. Next, subjects isometrically contracted the ECR at 5, 10, 15, and 50% MVC for 1 min. The order of the loads was randomized. During contraction, TO_2 plateaued and a mean value was calculated over this stable period. A 3 min recovery period followed each level of contraction. At the end of the protocol, with the NIR probe still in place, a tourniquet was placed over the dominant upper arm and was inflated to 250 mmHg. With the inflated cuff, subjects performed active-loaded wrist extension until exhaustion. The minimum value of TO_2 at the point of exhaustion was considered complete ischemia. For each level of contraction, TO_2 was normalized to baseline (100%) and complete ischemia (0%). TO_2 were analyzed using repeated measures ANOVA followed by Tukey's test with alpha set at 0.05.

RESULTS

TO_2 stabilized 20-50 seconds after onset of contraction. Mean TO_2 decreased to 85 ± 6% (SE), 75 ± 11%, 70 ± 11%, and 46 ± 11% at 5, 10, 15, and 50% MVC, respectively (Figure). Across all subjects, oxygenation levels at 10, 15, and 50% MVC were significantly ($p<0.05$) lower than baseline. There was no significant difference in TO_2 between baseline and 5% MVC level.



CONCLUSIONS

These results demonstrate that NIR spectroscopy can detect relative reduction in extensor muscle oxygenation even during brief low levels of isometric contraction. Tissue deoxygenation during prolonged isometric contraction may play an important role in the development of work-related muscle dysfunction. Muscle ischemia and reduced muscle oxygenation can cause muscle fatigue and pain (7). NIR spectroscopy appears to be an objective technique for measuring tissue oxygenation changes at low levels of muscle exertion that if validated over time and

with repetitive motion, may be a useful method for assessing low force repetitive tasks.

REFERENCES

1. Hargens, A.R. **1986,** *Tissue Nutrition and Viability*. New York: Springer-Verlag.
2. Rempel, D., Harrison, R. and Barnhardt, S. **1992,** Work-related cumulative trauma disorders of the upper extremity. *Journal of the American Medical Association,* **267, 838-842.**
3. Sjøgaard **G,** Savard G, Juel C. **1988,** Muscle blood flow during isometric activity and its relation to muscle fatigue. *European Journal of Applied Physiology* **57,** 327-335.
4. Hargens, **A.,** Akeson, W., Mubarak, S., Owen, C., Gershuni, D., Garfin, S., Lieber ,R., Danzig, L., Botte, M. and Gelberman, R. **1989,** Tissue fluid pressures: From basic research tools to clinical applications. *Journal of Orthopaedic Research,* **7, 902-909.**
5. Armstrong, T., Buckle, P., Fine, L., Hagberg, M., Jonsson, B., Kilbom, A., Kuorinka, I., Silverstein, B., Sjøgaard, G. and Viikari-Juntura, E. **1993,** A conceptual model for work-related neck and upper-limb musculoskeletal disorders. *Scandinavian Journal of Work and Environmental Health,* **19,** 73-84.
6. Chance, B., Nioka, S., Kent, J., McCully, K., Fountain, M., Greenfeld, R. and Holtom, G. **1988** Time-resolved spectroscopy of hemoglobin and myoglobin in resting and ischemic muscle. *Analytical Biochemistry* **174, 698-707.**
7. Hagberg, M. **1984,** Occupational musculoskeletal stress and disorders of the neck and shoulder: a review of possible pathophysiology. In: *Environmental Health,* Springer-Verlag.