Haemodynamic Responses to Sustained Contractions

Dr. A. R. Lind, National Coal Board.

During experiments to investigate the problem of muscular fatigue in sustained contractions, the blood flow through the forearm during hand-grip contractions at $1/3$ maximum voluntary contraction (MVC) was found to be considerable, rising throughout the contraction (Clarke, Hellon & Lind, 1958). Further experiments showed an increase in blood flow through the whole forearm at all tensions from 30 to 70% MVC as measured by a plethysmograph. Thereafter, using a technique first described by Barcroft & Millen (1939), the temperatures of both active and inactive muscles in the contracting arm were measured before, during and after contractions. When this was done with and without artificial arterial occlusion of the arm, it was possible to show that all or nearly all the increase in blood flow through the arm during sustained contractions went to the active muscles, while the flow through the inactive muscles did not increase (Humphreys and Lind, 1963). In view of the surprisingly high blood pressures found during these contractions, there must have been a marked vasoconstriction in the inactive muscles. Another series of experiments (Lind, Taylor, Humphreys, Kennelly & Donald, 1963) examined both central and peripheral haemodynamic responses of four subjects to hand-grip contractions using more direct methods of measurement. Blood pressure and cardiac output were measured by intravascular techniques while pulse rate was measured by e.c.g. Blood flow through both active and inactive forearms was measured by plethysmograph. The magnitude of the haemodynamic responses may be judged from the actual experimental values from one subject before, during and after a 20% MVC contraction. Whereas the stroke volume increases during rhythmic contractions, it did not increase in these sustained contractions, and the rise in cardiac output appeared to depend solely on the rise in pulse rate. Furthermore, only small changes in systemic vascular resistance were found, compared to the marked fall usually observed during dynamic exercise. The blood flow through the resting forearm did not change in spite of the high blood pressure during work, denoting a vasoconstriction in the non-active muscles.

Values obtained during contractions of 10% MVC were essentially similar except in degree, while at 50% MVC the only substantial qualitative difference in response was a markedly greater post-exercise hyperaemia in the working muscle, presumably demonstrating an inadequate supply of blood to the muscle during the contraction.

Table 1

	Before work	End of work	1 min after contraction	5 min after contraction
Cardiac output (l/min)	6.61	8.22	7.32	6.62
Mean blood pressure (mm Hg)	105	142	103	103
Heart rate per minute	80	99	80	79
Blood flow (ml/100 ml/min)				
1. Working forearm	1.5	9.3	14.1	6.0
2. Resting forearm	4.1	4.4	4.2	3.8

References

- BARCROFT, H. & MILLEN, J.L.E. (1939). The blood flow through muscle during sustained contraction. *J. Physiol.* 97, 17-31.
- CLARKE, R.S.J., HELLON, R.F. & LIND, A.R. (1958). The duration of sustained contractions of the human forearm at different muscle temperatures. *J. Physiol.* 143, 454-473.
- DONALD, K.W., HUMPHREYS, P.W., KENNELLY, B.M., LIND, A.R. & TAYLOR, S.H. (1963). Cardiovascular responses to sustained contractions. *J. Physiol.* 166, 18-19P.
- HUMPHREYS, P.W. & LIND, A.R. (1963). The blood flow through active and inactive muscles of the forearm during sustained hand-grip contractions. *J. Physiol.* 166, 120-135.