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Changes of Reactive Hyperaemia after Clinical Bed Rest for Seven Days

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ABSTRACT

As an indication of peripheral circulatory function reactive hyperaemia was studied in the forearm and calf muscle in 14 healthy young men before and after clinical bed rest for one week. Blood flow was measured after different arterial occlusion times with venous occlusion plethysmography. After bed rest peak flow values in the calf after arterial occlusion for 3 or 5 minutes decreased moderately (by about 20–23 %) and significantly. Peak flow in the forearm decreased as well although not significantly.

INTRODUCTION

Immobilization and bed rest are known to influence central circulatory function (5, 20) and blood volume (15), but the effect on peripheral circulation seems to have been less well investigated. The aim of the present investigation was to establish the possible influence of the bed rest regimen used on a modern acute ward on peripheral circulation studied as reactive hyperaemia in the forearm and calf muscles. The investigation is part of a more extensive study of the effect of clinical bed rest on a number of variables related to physical fitness (9).

MATERIAL AND METHODS

Subjects

Fourteen healthy men aged 21–32 years, took part in the investigation. They were confined to bed for 7 days in a special room on a ward for infectious diseases. The aim was to achieve the same degree of physical activity and caloric intake as encountered by hospitalized patients. Thus, the subjects were allowed to leave bed for personal hygiene. In addition, they sat in an armchair for a short period twice daily starting on the fifth day. Apart from this no physical activity was permitted. Eight of the subjects were on a standard hospital diet, while the other 6 had a starvation diet for the first 4 days, thereafter the standard diet. Fluid intake was unrestricted.

Procedure

Measurements were made on three occasions: one week before the start of the bed rest period, at the end of the bed rest period, and one month later during which time the subjects had maintained normal activity.

Measurements

Blood flow. Reactive hyperaemia in the forearm and calf muscles was measured by venous occlusion plethysmography and expressed in terms of ml/min · 100 ml tissue. A more detailed description of the technique and procedure used for blood flow measurements with venous occlusion plethysmography has been given previously by Graf & Westersten (13) and Graf (12). The forearm and calf plethysmograph, an air-filled rubber cuff, enclosed a 5 cm long segment of the muscular part of the extremity. A proximal occlusion cuff was applied to the upper arm or to the thigh, and a second occlusion cuff distal to the rubber cuff. The air-filled plethysmograph cuff was always inflated to 40–50 mm H_2O.

During ischaemia the proximal occlusion cuff was inflated to 100 mmHg above the systolic arterial blood pressure in the brachial artery, while the distal occlusion cuff was inflated to 90 mmHg. Reactive hyperaemia was measured after different arterial occlusion times: 1, 3 and 5 min. During blood flow measurements the proximal cuff was inflated to 60 mmHg (during reactive hyperaemia, this value was initially somewhat higher) and the distal cuff was simultaneously inflated to arterial occlusion pressure. The blood flow was recorded on a conventional amplifier and a direct-writing Mingograph (Siemens-Elema, Stockholm) for 2 min with measurements made every 10 seconds during the first minute.

The recommendations given by Graf (12) in order to avoid errors of measurements connected with the method were followed. Two models of venous occlusion plethysmographs were used, the difference being the way the pressure was applied to the proximal and distal occlusion cuffs on the extremities. Mean values for the blood flow for subjects using the two different models were statistically tested, and no significant differences were found.

Blood volume. Blood volume measurements were made by determination of the total amount of haemoglobin (THb) using the alveolar CO method, as described by Sjöstrand

Table I. *Mean values ±S.E.M. of blood flow at rest and peak flow during reactive hyperaemia in forearm and calf muscle after arterial occlusion for 1, 3 and 5 min (A.O.), and certain circulatory and anthropometric data, in 14 healthy men subjected to clinical bed rest for one week*

	A (before bed rest)	B (end of bed rest)	C (one month bed rest)
Forearm blood flow (ml/min · 100 ml tissue)			
Rest	1.9±0.3	2.0±0.4	1.8±0.4
1 min A.O.	14.6±2.1	11.7±1.3	12.8±1.1
3 min A.O.	24.6±2.6	22.4±2.6 (n=13)	24.7±1.8
5 min A.O.	28.4±3.0 (n=13)	25.8±2.4 (n=13)	30.3±1.8
Calf blood flow (ml/min · 100 ml tissue)			
Rest	2.8±0.3	2.3±0.3	2.8±0.4
1 min A.O.	17.1±1.4 (n=13)	14.6±1.0	**19.9±1.3
3 min A.O.	30.6±1.4	***24.5±1.1	***32.1±1.3
5 min A.O.	36.5±1.7 (n=13)	**28.2±1.5 (n=13)	***37.7±2.1
Blood volume (l)	5.24±0.14	** 4.96±0.12	**5.23±0.13
Total hemoglobin (g)	702±20	**664±22	*688±20
Hb (g%)	14.65±0.28	14.69±0.23	14.46±0.25
Red cell volume (l)	2.08±0.06	**1.97±0.07	*2.04±0.06
Plasma volume (l)	3.17±0.10	*2.99±0.06	**3.26±0.08
Body weight (kg)	70.5±2.2	**69.4±2.0	69.8±2.0
Extremity circumference (cm)			
Forearm	26.2±0.3	26.1±0.3	26.2±0.3
Calf	*35.8±0.5	**35.4±0.5	35.5±0.5
Isometric muscle strength (kp)			
Handgrip	*51.6±2.5	49.3±2.5	48.8±2.5 (n=13)
Knee extension	69.6±1.6	66.5±2.7	69.8±1.9 (n=13)
Plantar flexion	163.7±6.3	152.4±7.4	*158.2±8.0 (n=13)

*, **, and *** denote statistically significant differences ($p<0.05$, 0.01 and 0.001, respectively), and refer to the values of the columns between which they are interposed; asterisks in column A refer to comparisons between values of column A and C.

(21). The total blood volume was then calculated from the THb and the haemoglobin concentration (Hb) of blood from a cubital vein, punctured without venous occlusion. Duplicate determinations of THb were always made with an interval of one day, the coefficient of variation for the single determination being about 4% during the period of investigation. The determinations made at the end of the bed rest period were performed on the seventh day of bed rest and on the following day.

In addition, haematocrit was determined and the plasma volume (PV) and red cell volume (RCV) were calculated.

Isometric muscle strength. The maximal isometric muscle strength was tested under standardized conditions according to Bäcklund & Nordgren (2). In this paper only the values for handgrip, knee extension and plantar flexion are presented.

Statistical methods

In order to reveal differences between the observations on the three occasions Student's t-test for paired observations was used.

RESULTS

All results are summarized in Table I.

Blood flow in forearm and calf (Fig. 1). In forearm the resting blood flow did not change during bed rest. The mean values for peak flow during reactive hyperaemia decreased, although not significantly, after arterial occlusion for 1, 3 as well as 5 min.

In calf the resting blood flow decreased during bed rest, but the change was not statistically significant. The peak flow values recorded at the end of bed rest were significantly lower after arterial occlusion for 3 and 5 min ($p<0.001$ and 0.005, respectively), whilst the decrease after occlusion for 1 minute did not reach significance.

At the one month control peak flows in calf with arterial occlusion for 1, 3 and 5 min showed a significant increase when compared with the values re-

corded at the end of bed rest ($p<0.005$, 0.001 and 0.001, respectively).

Blood volume. The total blood volume was significantly lower at the end of bed rest than before ($p<0.005$) or one month later ($p<0.01$).

THb, PV and RCV showed the same pattern of response.

Body weight and extremity circumference. The body weight fell significantly during bed rest ($p<0.01$) and had not returned to the initial level after one month. The calf circumference decreased significantly during bed rest ($p<0.01$), and the one month control value was still significantly lower than the initial value ($p<0.05$).

Isometric muscle strength. The maximal strength of isometric plantar flexion was lower at the end of bed rest than when the subjects were ambulant; however, the difference was significant ($p<0.05$) only when compared with the one month control value.

The strength of knee extension did not change significantly.

Unexpectedly, the handgrip strength was significantly lower at the one month control compared to the initial value ($p<0.05$), while the value at the end of bed rest attained an intermediate position.

DISCUSSION

In the present study we have found a significant change of reactive hyperaemia in the calf but not in the forearm of 14 healthy young men after bed rest for one week. In order to avoid errors of measurement connected with venous occlusion plethysmography the recommendations given by Graf (12) have been closely followed, both in connection with the subjects and the evaluation of the inflow curves. The pressure system in the plethysmograph has been tested and some variation of the inflation pressures of the cuffs have been accepted, as in earlier works (3).

Delius et al. (6) found the same changes of reactive hyperaemia when measuring blood flow with venous occlusion plethysmography in the forearm and calf of 32 patients who had been operated upon for acquired or congenital heart disease. The authors drew the conclusion that the changes in blood flow after the operation could have been caused by a change in the sympathetic activity. Several authors have reported alterations in reactive hyperaemia in skeletal muscle after passive changes of body position from horizontal to different degrees of tilting and to the erect position. Paterson (19) found that reactive hyperaemia in the forearm decreased significantly during tilting, a finding which he believed could be caused by increased sympathetic activity. Mosley (17) found decreased reactive hyperaemia in the forearm of healthy subjects when changing from supine to erect position, a reaction which could be abolished by intra-arterial infusion of sympathetic adrenergic antagonists. Using microneurography Delius et al. (7) recorded increased sympathetic signals in human muscle nerves to forearm and calf after tilting from horizontal to 30–45 degrees.

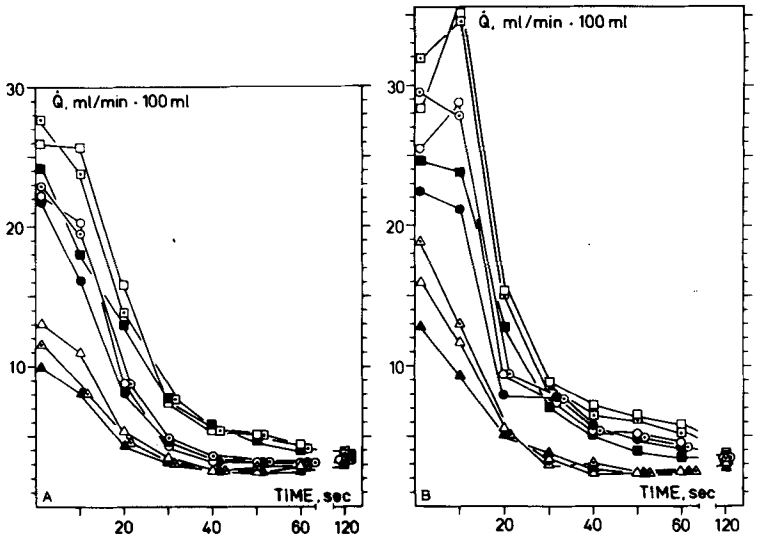

Fig. 1. Means of blood flow values (*ordinate*) in forearm (A) and calf (B) muscle at different times (*abscissa*) after arterial occlusion for 1, 3 and 5 min in 14 healthy subjects.

Occlusion times	1′	3′	5′
Before bed rest	△	○	□
After bed rest	▲	●	■
One month's control	◬	⊙	⊡

It is not clear from the literature whether an increase in sympathetic tone occurs in healthy subjects as a result of bed rest for one week. However, Hyatt (15) studied haemodynamic and body fluid alterations in healthy subjects during different periods of bed rest (10, 14 and 28 days), and in all the studies he found a decrease in plasma volume and orthostatic tolerance and an increase of peripheral vascular resistance. Hyatt considered increased sympathetic tone to result from the decrease in plasma volume. Since we have also found a significant decrease in plasma volume, it seems reasonable to us that this decrease may exert an effect on the low pressure baroreceptors and thus bring about a change in the sympathetic tone. The role of the low pressure baroreceptors during changes of blood volume have been clearly stated in different studies using lower body negative pressure (LBNP). Thus, Ardill et al. (1) found that LBNP significantly decreased the reactive hyperaemia in the forearm, and that sympathetic adrenergic antagonists prevented this effect. Johnson et al. (16) found that moderate LBNP (to −20 mmHg) only reduced right atrial pressure and forearm blood flow, while further lowering of the LBNP also changed aortic mean pressure, aortic pulse pressure and heart rate. According to this study the likely source of the stimulus for the reduction of the muscular blood flow is the low pressure baroreceptors. In recent experiments of similar design Sundlöf & Wallin (22) have come to similar conclusions with recordings of sympathetic signals by microenurography.

Apart from a change in the neurogenic component regulating the vascular bed in skeletal muscle, changes in the local components have to be considered. According to Folkow (8) myogenic activity is especially important in muscles which are responsible for posture. The soleus muscle is a tonic muscle, composed of mainly red (slow twitch) fibres (11), and according to EMG measurements (4) it plays a significant role in the maintenance of balance and posture. During bed rest this muscle is not being used as a postural muscle, because of changes gravity conditions. An alteration in myogenic activity as the main cause of the observed change in reactive hyperaemia might therefore explain the fact that the change was significant in the calf but not in the forearm.

Factors at the cellular and subcellular levels must also be taken into consideration. It has been shown in previous studies that immobilization may cause atrophy of skeletal muscle (14, 18). Disuse atrophy (cf. denervation atrophy and atrophy after tenotomy, for review see Goldspink (10)) is characterized by a reduction of the myofibril protein content, while the sarcoplasmic protein content seems to be uninfluenced (14). The observed decrease of calf muscle strength and circumference after bed rest in the present study is compatible withe the hypothesis that a reduction of the amount of contractile substance occurred despite the rather short immobilization time. However, other explanations of the strength reduction such as a decrease of the ATP content are also possible. The finding of a decreased calf circumference, on the other hand, could be explained just as well by a reduction in tissue water, a suggestion supported by the decreased plasma volume and body weight. A search of the literature revealed no definite evidence of whether the numbers or sizes of the blood vessels are subjected to a reduction proportional to that of the muscle cell in disuse atrophy. If such were the case a reduction of reactive hyperaemia would be expected with atrophy.

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