# CHANGED BLOOD SUPPLY IN THE FINGERS OF AN INACTIVE HAND FOLLOWING RAISING OF A LOAD WITH THE OTHER ONE

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(Presented by Active Member AMN SSSR, A. I. Nesterov)
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny
Vol. 49, No. 5, pp. 15-20, May. 1960
Original article submitted March 24, 1959

Many authors [1, 9, 10, 15] have shown that the blood supply to both arm and leg in man increases immediately at the end of physical exercise.

Weber [12-14] examined several thousand healthy human subjects and found an increased blood supply in an idle limb while work was being performed by the other. It was shown that movements of the foot in an unfatigued resting individual cause an increased blood flow to the hand, which falls away rapidly when the exercise is stopped .

Plethysmography of the limbs during physical work indicates the state of the blood supply to the skin and muscle, but chiefly to the muscle. Until now, insufficient information concerning the blood supply to the skin has been obtained.

In studies on 3 healthy men [11] it was shown that work performed by the legs on a bicycle-ergometer causes an increased blood supply both to the muscles of the forearm and to the subcutaneous tissue of the hand, the latter increase being the greater.

On the other hand, it has been shown [3] that when one arm is performing work there is a reduction in the number of functional capillaries of the idle arm. It has also been observed [2] that after fatigue has been induced in the hand, a spasm of the cutaneous capillaries may occur.

The present investigation was undertaken in order to explain certain changes in the digital circulation of one hand following cessation of work with the other.

## METHOD

Plethysmographic recordings were made from the terminal phalanx of a finger of the left hand before and after physical work.

To determine the nature and extent of the peripheral circulation we employed the method proposed in 1907-1909 by M. V. Yanovskii and A. I. Ignatovskii [4], and also by Hewlett and Van Zwaluwenburg [7]; this method consists in blocking the venous return from the hand while maintaining the arterial supply (the method of venous occlusion plethysmography).

The main advantage of this method is that it allows both the initial flow rate and its change in response to any stimulus to be determined.

It has been shown in experiments on dogs [8] that the values obtained by plethysmography with arrest of venous outflow are the same as those obtained when an electromagnetic flowmeter is used. Modern recording techniques and the method of evaluating the curves to a large extent make good the defects indicated by V. A. Val'dman and D. M. Abdulaev [1] and by other investigators.

In each subject the blood pressure was obtained while he was in the sitting position, by means of a mercury sphygmomanometer, and the plethysmograph was attached to the terminal phalanx of the finger and smeared with vacuum grease at the junction (Fig. 1A). Every minute the plethysmogram was recorded on film during a 20-second compression of the veins of the upper arm which was effected by rapidly compressing the air in the cuff to the diastolic pressure.

After 3-4 such measurements had been made, recording was discontinued and the subject was told to raise a weight of 5 or 8.5 kg with this right hand to the level of the axilla. The work was continued until the subject failed from fatigue. Thirty seconds after the end of the working period, veneous outflow was again blocked and the plethysmogram recorded, after which 2 or 3 recordings were made at one minute intervals. By this time, in most cases, the blood flow to the finger had returned to the initial rate.

To calibrate finger volume changes, in 11 human subjects, after the plethysmogram had been recorded, 0.02, 0.04, 0.06, 0.08, and 0.1 $cm^3$ of air were injected from a tuberculin syringe into the closed system. The volume of the phalanx of the finger from which the plethysmogram was obtained was determined by means of a measuring cylinder.

A diagram illustrating a plethysmograph curve is shown in Fig. 1b.

From the height $h_1$, the rate of blood flow to the finger phalanx was calculated, and from $h_2$ the average rate could be obtained. The increase in the initial rate after physical work is indicated by a plus sign (positive vascular response) and a reduction is shown by a minus sign (negative response); a zero indicates no response. The same indications were used to convey changes in the average rate of blood flow.

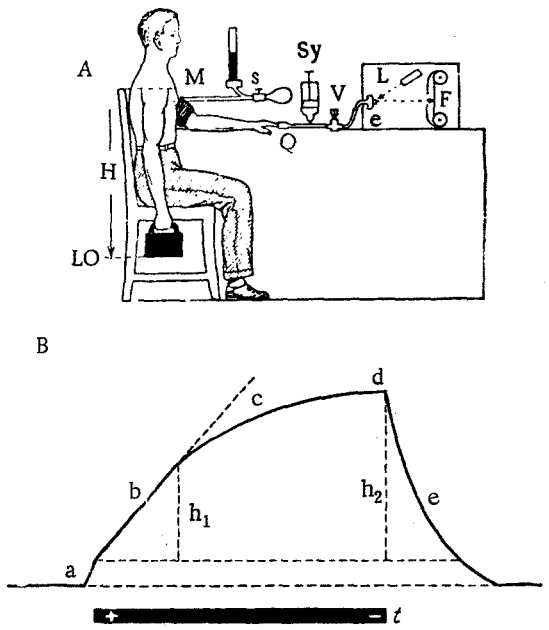


Fig. 1. Diagram of the apparatus (A) and the type of curve obtained for the blood flow to a finger phalanx (B), obtained by compressing the veins of the upper arm for a short time. Diagram A : S) Sphygmomanometer; M) cuff of sphygmomanometer; P) plethysmograph; V) valve for opening and hermetically sealing the transmission system; C) capsule of plethysmograph; Sy) 20 ml syringe for changing the volume (sensitivity) of the transmission system; L) lamp; F) film; H) height of 60 cm to which load (Lo) is raised. Diagram B: a) Artifact caused by inflation of cuff; b) initial change in volume of phalanx; c) subsequent increase in blood filling; d) no further change in volume of phalanx occurs; e) fall in curve following release of air from cuff; t) duration of occlusion of veins of upper arm (20 sec).

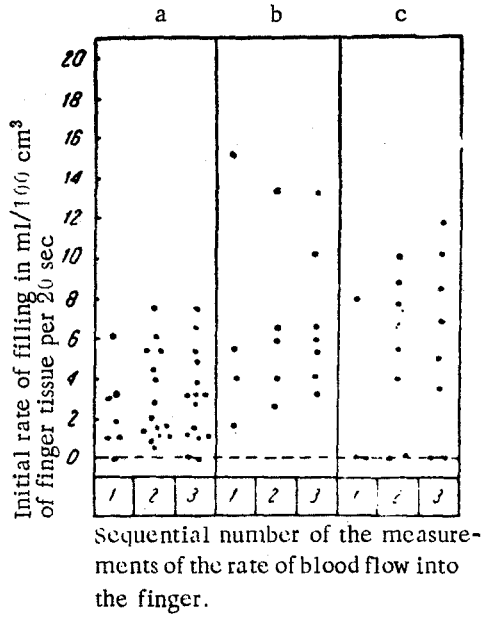


Fig. 2. Initial rate of filling of the terminal finger phalanx in subjects tested at rest after temporarily blocking the venous outflow. a) When a positive response to physical work was obtained; b) when a negative response occurred; c) response zero. Each point on the graph corresponds to the blood flow rate as determined in one measurement on one subject before beginning the exercise. A) Initial rate of filling in ml / 100 $cm^3$ of finger tissue per 20 sec; B) sequential number of the measurements of the rate of blood flow into the finger.

Nineteen healthy people comprising 14 women and 5 men aged from 18 to 49 years were investigated; none had a history of any cardiovascular or other disorder. Most were laboratory assistants, nurses, or technicians.

## RESULTS

After spending 10 minutes in becoming accustomed to the surroundings, the baseline plethysmogram at rest was "zero" or else showed some slight variation. The last 2 or 3 recordings before the beginning of physical exercise were quite consistent.

Results on the initial rate of filling of the terminal finger phalanx are shown in Fig. 2, where it can be seen that the initial rate at rest as a rule varied between 1 and 8 ml of blood per 20 seconds; the volume of the tissue of the finger was 100 $cm^3$. This flow rate represents 3-24 ml of blood per minute. These values lie within the published figures for the blood flow rate to the skin and underlying tissue [5, 6].

Only in 4 subjects at rest was there a transitory (Kon-a, Sam-n) or maintained (G-a) spasm of the skin vessels; occluding the venous outflow caused no change in the rate of filling of the terminal phalanx. In addition, a forced voluntary inhalation caused either a very small or no vascular reaction. Of the 4 subjects tested, an initial filling rate between 24 and 60 ml of blood per min per 100 $cm^3$ of finger tissue was found in 3 only (Sm-a, A-b, Art-a).

In most cases, after physical work the plethysmogram showed changes in the blood supply to the fingers of the opposite hand (see Table).

In 12 subjects, the physical exercises caused mainly an increase in the initial rate of blood filling; in seven the flow was either reduced or unchanged.

Of the 54 tests, there was an increased blood inflow after exercise in 34, and in four of these there was a first a transitory reduction. A reduced flow was observed in 11 cases, and in nine there was no change.

Therefore the characteristic response of the finger vessels of one hand, when a load is lifted by the other, is that the blood inflow increases (Fig. 3). Under certain

Changes in Rate of Blood Supply to the Fingers After Physical Work

| No. in sequence | Surname of subject | Sex | Age (in years) | Air temp | Number of tests | Physical exercise | | | Pulse rate in beats per min | | Principal change in the rate of blood inflow | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | weight of load (in kg) | number of times load was raised | duration of exercise (in seconds) | before exercise | after exercise | initial rate | mean rate | |
| 1 | D-a | F | 24 | 18—22° | 5 | 8,5 | 15—30 | Not measured | 72—88 | 88—100 | + | + | |
| 2 | T-a | F | 49 | 24° | 1 | 8,5 | 20 | » » | 48 | 60 | + | ⊖ | |
| 3 | B-v | M | 25 | 20—22° | 3 | 8,5 | 40—45 | » » | 64—68 | 76—80 | + | + | Variable baseline |
| 4 | St-a | F | 21 | 20° | 2 | 8,5 | 10—20 | » » | 80—96 | 96 | + | + | |
| 5 | R-a | F | 21 | 19—22° | 4 | 8,5 | 7—15 | » » | 68—76 | 68—76 | + | Not measured | Variable baseline |
| 6 | Sp-n | M | 26 | 18—22° | 3 | 8,5 | 40—45 | 45—60 | 40—52 | 44—56 | ⊖* | ⊖ | |
| 7 | Bu-a | F | 25 | 18—19° | 3 | 8,5 | 19 | 25—30 | 66—76 | 80—88 | + | + | |
| 8 | Ch-o | F | 29 | 18—19° | 3 | 8,5 | 20—25 | 55—60 | 64—68 | 68—70 | — | — | Subject embarrased and blushes |
| 9 | Aru-a | F | 24 | 22—23° | 3 | 5 | 24—30 | 30—50 | 76—80 | 76—92 | + | + | |
| 10 | Ku-a | F | 39 | 23° | 1 | 5 | 17 | 30 | 92 | 88 | — | — | Refused further tests |
| 11 | Sm-a | F | 20 | 22,5—23° | 3 | 5 | 9—14 | 20—35 | 72—80 | 72—92 | ⊖ | + | |
| 12 | A-v | M | 25 | 18—21° | 4 | 8,5 | 27—35 | 85—110 | 76—96 | 104—112 | ⊖ | + | |
| 13 | Art-a | F | 38 | 21,5—23° | 3 | 5 | 11—20 | 13—25 | 68—88 | 72—80 | ⊖ | ⊖ | |
| 14 | G-a | F | 20 | 19—23° | 3 | 5 | 9—16 | 15—30 | 72 | 72 | ⊖ | ⊖ | Maintained spasm of finger vessels |
| 15 | Kis-a | F | 18 | 18—19,5° | 3 | 5 | 18—21 | 35—45 | 72 | 72—76 | + | ⊖ | |
| 16 | K-v | M | 29 | 19—20,5° | 3 | 8,5 | 25 | 50—65 | 72 | 72 | + | + | |
| 17 | Kon-a | F | 28 | 18,5° | 1 | 5 | 15 | 35 | Not measured | 80 | + | + | |
| 18 | Sam-n | M | 21 | 19—20° | 3 | 8,5 | 20 | 45—50 | 76—80 | 76—84 | + | + | |
| 19 | Bar-a | F | 19 | 21—22° | 3 | 5 | 10—18 | 30—45 | 80—92 | 88—96 | + | ⊖ | |

* The sign ⊖ indicates that mainly negative or zero responses were obtained.

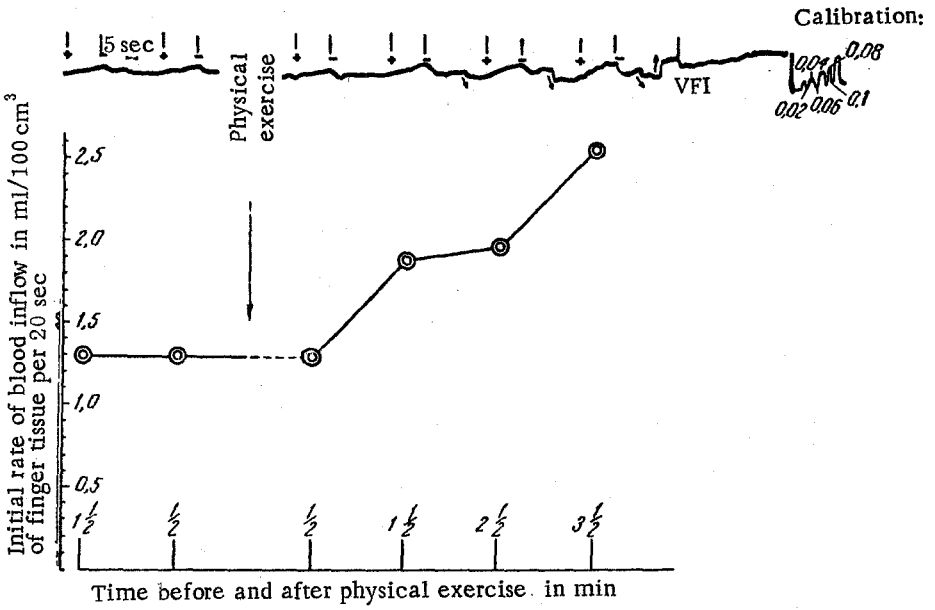


Fig. 3. Change in the initial rate of blood inflow into the terminal phalanx of one finger after raising a load with the other hand. Subject K-v. Experiment October 23,1956 at 10.56 a.m. Air temperature 19°. Load of 8.5 kg raised to height of 60 cm by the right hand 25 times in 65 min. ↓) Indicates raising the pressure in the cuff to 75 mm Hg; ⊥) moment when pressure is reduced to zero; ↑ ↓) displacement of recording; VFI) voluntary forced inspiration. (1) Initial rate of blood inflow in ml / 100 cm³ of finger tissue per 20 sec; (2) time before and after physical exercise, in min; (3) calibration : 0.04 ml; (4) physical exercise.

conditions which were not easy to determine it might happen that the response was abnormal or inhibited. Some of these cases may have been due to a high initial finger-flow rate (Fig. 2b and c). The emotional condition of the subjects must also be taken into account (see Table, Ch-o, Ku-a).

No relationship between the vascular response and the change in pulse rate was observed. Positive, zero, or negative vascular reactions occurred together with a slowing or with a considerable increase in pulse rate.

As a rule, a high initial flow was associated with a greater average flow rate. After physical exercise, the change in average rate did not always correspond to the change in the initial rate of filling, and the reason was probably that there was some variation in the volume of the venous bloodstream in the finger.

Thus, when raising a load with one hand, in the other, besides an increase in the blood supply to the muscle, there is also an increased flow to the skin. According to published results [3], when this occurs the capillary flow is reduced. It must therefore be supposed that when work is performed with one hand the skin flow to the other is increased chiefly by an increased passage of blood through the shunting arteriovenous anastomoses.


## SUMMARY

Venous occlusion plethysmography was used to study changes occurring in the finger circulation after physical exercise.

In healthy individuals, after raising a load with one hand there was usually an increased blood supply to the skin and subcutaneous connective tissue in the fingers of the other.


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