TRANSMISSION OF THE RATE OF SPREAD OF THE PULSE WAVE IN AN UNRESTRAINED HUMAN SUBJECT

(UDC 612.766:612.161)

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Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 58, No. 10, pp. 116-119
Original article submitted July 4, 1963

To determine the rate of spread of the pulse wave under dynamic conditions we used combined recording by radio of the cardiac potentials and photo-electric plethysmography of the fingers.

EXPERIMENTAL METHOD

We used an RST-1 radiosphygmotachograph, which is the latest development of the KRP-2m instrument developed in our laboratory [3]. It is built from transistors, and includes photocells, amplifiers, a multivibrator, a transmitter, and power supply. To pick up the cardiac potentials fluid suction electrodes are used, and the method of leading off has been described previously [1, 2].

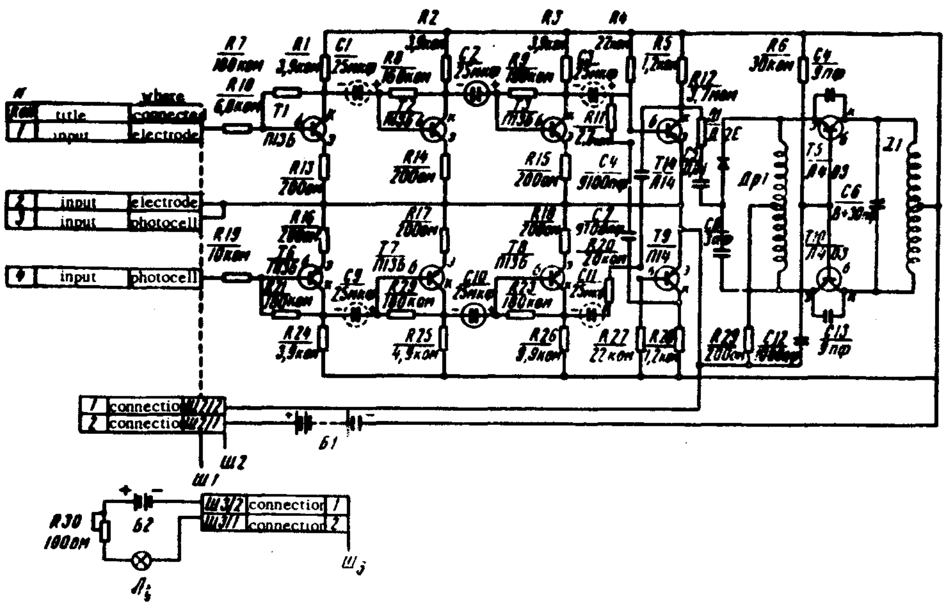

Fig. 1. Circuit diagram of the RST-1 instrument.

Changes in the Time of Spread of the Pulse Wave (t) to a Finger Artery (seconds) and Pulse Rate (p) Under the Influence of Muscular Activity

Subject	Index	Initial values (lying at rest)	Changes under the influence of:			Influence of "staircase" test			
			inspiration	expiration	vertical position of the body	results standing at rest	changes		
							during exercise	after exercise	
								after 30-40 sec	after 3 min
K	t	0.13	-0.01	-0.01	-0.01	0.12	-0.04	-0.02	+0.01
	p	54	—	—	+17	71	+21	+4	17
F	t	0.14	—	—	-0.02	0.12	-0.03	-0.02	—
	p	86	—	—	+14	100	+20	+20	-8
T	t	0.13	+0.02	+0.02	+0.05	0.18	-0.08	-0.08	—
	p	54	-2	—	+12	66	+26	+5	-3
S	t	0.12	—	—	+0.02	0.14	-0.05	-0.02	-0.01
	p	66	—	+5	+20	86	+34	+34	—
V	t	0.12	—	+0.01	+0.02	0.14	-0.05	-0.02	—
	p	54	-4	+9	+21	75	+25	+5	-15
P	t	0.12	—	—	+0.03	0.15	-0.05	-0.05	-0.02
	p	52	-6	-2	+8	60	+49	+40	-3
İ	t	0.13	—	+0.01	0.02	0.15	-0.07	-0.07	-0.02
	p	63	-9	+12	+12	75	+45	—	—
I	t	0.14	-0.02	-0.02	-0.02	0.12	-0.05	-0.04	—
	p	44	+2	+2	+25	71	+29	+21	-17
R	t	0.12	+0.02	—	—	0.12	-0.04	-0.02	-0.01
	p	86	—	-15	+6	92	+41	+17	—
ShCh	t	0.14	-9	—	—	0.14	-0.05	-0.02	—
	p	80	—	—	+20	100	+20	—	-14
mean	t	0.129	+0.001	+0.001	+0.009	0.138	-0.051	-0.036	-0.005
	p	63.9	-2.8	+1.1	+15.7	79.6	+31.0	+14.6	-7.7

To record changes in the extent to which the digital phalanges were filled with blood we used a photosensitive element consisting of a semi-conductor photo-sensitive resistance type FSK-2N and a miniature lamp placed on the opposite side of the finger. For more stable operation and to eliminate interaction between the two processes recorded we used 2 separate amplifiers. The photocell formed part of a potentiometer in the base circuit of the input stage. The amplified signals change the frequency of the multivibrator in the same direction and are taken to the transmitter consisting of P-403 triodes operating as push-pull oscillators. The signal of the R wave and of the photoplethysmogram pass through the system and are tranformed into pulses of approximately squarewave form, of various durations, having a steep leading edge; this arrangement facilitates determination of time intervals. The transmitter is frequency-modulated by the miltivibrator. Thus, the transmitter circuit of telemetred information is FM-FM.

Supply is taken from a group of 7 miniature alkali storage cells type D-006. The lamp is supplied from 2 miniature storage cells type B-02.

The total weight of the apparatus is 250 g; its range of operation in closed buildings is 50 m, and in the open up to 100 m.

The recording apparatus at the receiving end (investigators instrument) consists of a receiver modified by É. I. Rimskikh from an ultrashort ARS-2 automobile station receiver, a decoder, and an ink-writing ÉKPSCh.

Calculation of the time of spread of the pulse wave (t) to the end of the phalanx of the finger was made to an accuracy of 0.01 sec; it was measured from the onset of the QRS complex of the ECG to the rise of the pulse curve. This time interval is made up of 3 components: the time from the start of the ventricular complex of the ECG up to the moment of opening of the semilunar valves (0.10 sec), the true time of spread of the pulse wave from the root

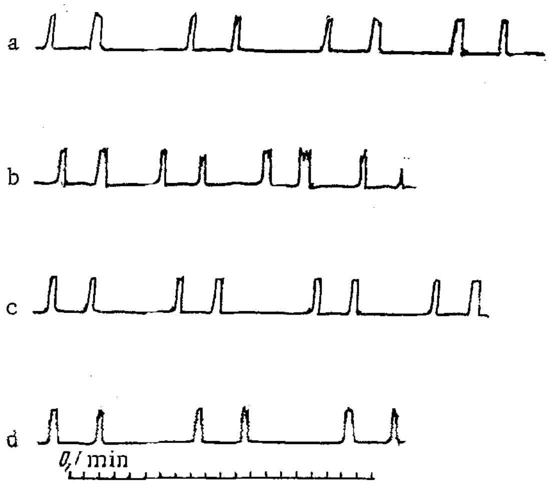

Fig. 2. Telemetric recording of the time of spread of the pulse wave in a worker T., aged 36 years, during the "staircase" test. a) Standing at rest; t = = 0.13 sec, pulse rate 66; b) during the "staircase" test at the end of the 2nd min; t = 0.08 sec, pulse rate 92; c) 30 sec after work: t = 0.08 sec, pulse rate 66-75; d) 3 min after work: t = 0.13 sec, pulse rate 63; time marker 0.1 sec. PP photoplethysmogram of finger.* For determination of t, 0.12 sec was subtracted from the time interval between the QRS wave and the BP.

of the aorta to the arteries of the terminal phalanges of the fingers (i.e., mostly along muscular vessels), and the time delay in the plethysmogram relative to the sphygmogram of the underlying artery (0.02 sec). Thus, in order to obtain an approximate value of the 2nd component in which we were interested,a time of 0.12 sec had to be subtracted from the total time between the QRS complex and the photoplethysmogram of the finger.

In the present communication we use the correction of 0.12 sec, although when the pulse is more rapid the amount should probably be rather less.

In previous experiments we had demonstrated the precise coincidence of the start of the R wave of the ECG as received on 2 channels with the subject at rest, 1 transmitted, and the other conducted along leads.

We assured ourselves of the coincidence of the onset of rise of the photoplethysmogram with the 2 kinds of recording. We also found that a slight deviation from precise tuning of the receiver to the transmitter frequency caused a change in the shape of the signal but did not influence the time of occurrence of the leading edge.

The ECG and the photoplethysmogram were recorded as follows: the subject lay at rest, and held his breath at the end of inspiration or expiration; also records were made one min after the subject had changed over to the standing position (to eliminate the clino-orthostatic reaction).

In 10 persons we studied the influence of muscular work, by performing a "staircase" test: the subject went up and down 2 steps for 2 min, corresponding to going up to the 5th floor and down again.

The quantity t was recorded with the body vertical before work, at the 2nd min after work had started, and 30 sec and 4 min after it had finished. We also made observations under natural conditions of muscular activity in a healthy man aged 49 years who was taking part in physical training for a group of elderly and middle-aged people ("health group") at the Central Sverdlovsk stadium.

Finally one observation was made in the rolling mill of a metallurgical establishment on a worker acting as operator in a task demanding great attention in a very hot atmosphere (air temperature 36°).

As can be seen from the table no great changes in pulse frequency or in time of spread of the pulse wave were observed. When the subject was standing the pulse was more rapid than when he was seated; no consistent changes in the time of spread of the pulse wave were observed.

Exercise caused quite noticeable changes. During rapid walking up the stairs there was a marked increase in pulse rate and a shortening of the time of spread of the pulse wave, the difference being highly significant statistically ($P < 0.01$). During the "staircase" test the time of spread of the pulse wave, which normally was about 0.14 sec was reduced by 0.05 sec, i.e., by more than a third. When measurements were made 30 sec after exercise already both indexes could be seen to have recovered considerably and the difference between these values and the initial figures had fallen to about half (as compared with the changes during muscular work). After 3 min the time of spread of the pulse wave returned in most cases to the original value, and the pulse became slower than it had been initially (difference was statistically significant: $P < 0.01$). This result is in line with what has been pointed out in the literature concerning the negative phase of the pulse after a short period of muscular work. Figure 2 illustrates the changes in the time of spread of the pulse wave, and the pulse rate, caused by the "staircase" test.

Similar results were obtained under natural conditions (running, playing basketball). It was found that the time of spread of the pulse wave was greatly reduced during muscular work.

* Publisher's note. This appears in the Russian caption, but not in the Russian figure.

Thus, as in the "staircase" test, under normal conditions of exercise there was an appreciable reduction in the time of spread of the pulse wave. This reduction was most marked during exercise, and there was a tendency to rapid recovery afterwards. The results obtained indicate that muscular activity is associated with an increased vascular tone. These changes develop generally in parallel with changes in the pulse rate. However, the rate of recovery of the 2 indices differ appreciably with respect to different kinds of exercise. In particular, during the "staircase" test the pulse rate was the first to return to normal.

Tests under industrial conditions enabled us to show that after the onset of work the time of spread of the pulse wave was increased from 0.1 to 0.16 sec with a negligible increase in pulse rate (from 75 to 80); in another test made 30 min later it returned to the original value and remained there until the end of the work.

SUMMARY

The description is given of a telemetric method of recording together the electrocardiogram and plethysmogram obtained photo-electrically as a means of investigating the rate of spread of the pulse wave in the unrestrained subject. We have found that distinct shifts occur during athletic activity and work. They are usually not easily discernible after the work has ceased, because of rapid restoration.

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3. V. V. Rozenblat and A. T. Vorob'ev. In book: Transactions of the 4th combined Urals conference of physiologists, pharmacologists, and biochemists. Chelyabinsk (1962), p. 206.

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
