

## On the Relationships between Minor Tremor and Ballistocardiogram in Man

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The minor tremor (MT), or microvibration, of the thenar muscles was recorded over in normal adults under various physiological conditions. In addition to MT, the ballistocardiogram (BCG), electrocardiogram (EKG) and respiratory movements were also traced simultaneously to determine the correspondence between MT and the pulsation of the heart. In the relaxed awake state, the dominant vibrations of MT were found out to appear in corresponding very well to I, J and K and L, M and N waves of BCG as well as R and T waves of EKG. These changes corresponding to BCG or EKG were, on the other hand, demonstrated to be potentiated and weakened by deepening and stopping breathing, respectively. In addition, both MT and BCG were shown to cause a marked increase in amplitude and frequency in cases of Master two step test as the load of EKG, in which facilitatory changes of circulatory and respiratory systems can be provoked. From the above-mentioned results, it seems likely that the facilitatory and inhibitory changes in the pulsation of the heart besides those in muscle tonus play an important role in the augmentation and inhibition in MT under various physiological conditions, and furthermore the respiratory changes in MT might be caused by respiratory changes of cardiac output in inspiratory and expiratory phases of respiration as well.

There have been reported by ROHRACHER<sup>1), 2), 3), 4), 5), 6), 9), 10)</sup> and INANAGA and his co-workers<sup>1), 2), 3), 4), 5), 6), 9), 10)</sup> many investigations concerning minor tremor (MT) or microvibrations on the human body surface which are invisible to the naked eyes. The correspondence between MT and heartbeat, on the other hand, has been recently indicated by OZAKI, Sato et al.<sup>10)</sup> and KIYOHARA et al.<sup>7)</sup> In the experiments of the former they revealed some intimate correlations between MT and heartbeat or electrocardiogram (EKG), and furthermore MT and electroencephalogram (EEG). It was suggested by them that the

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regulating systems of the heartbeat besides so-called muscle tonus might also play an important role in the augmentation and inhibition of MT under various physiological conditions. However, so far as the relationships between MT and ballistocardiogram (BCG)<sup>18)</sup>, in which the temporal course of body vibrations due to the pulsations of the heart can be traced through a ballistocardiograph, are concerned, no evidence has been demonstrated yet.

Therefore, the present study was undertaken to determine the correlation between MT and BCG in man and clarify the important role of the heartbeat in MT.

## METHODS

As subjects, normal adults (3 men and 2 women) were experimented on, being relaxed in a supine position with eyes closed and both arms extended loosely parallel to the body axis with palms somewhat abducted. The recording of MT was carried out according to the same procedure as that described in the previous report of OZAKI, SATO et al<sup>19)</sup>. That is, Rochelle salt pick-up (Nihon Kohden Co. Tokyo) was attached loosely to the body surface over the ball of the left thumb of the subject to transform MT to electrical oscillations. MT, transformed to electrical oscillations by the pick-up, was traced on a recording paper with the use of a multipurpose polygraph (Nihon Kohden Co.) at the same time as BCGs (H-F and L-R leads) which were led off by two dimensional ballistocardiograph (Nihon Kohden Co.). The frequency characteristic of the pick-up used was approximately linear from 3 to 100 c/sec. In addition to MT and BCG, there were carried out simultaneous recordings of EKG (lead II) and respiratory movements, which were led off by attaching to nasal cavity the respiratory pick-up of thermister type (Sanei Sokki Co. Tokyo). The time constant of the recording system was 0.3 for MT and BCG, and 2.0 seconds for EKG and respiratory movement records, respectively.

## RESULTS

### 1) MT and BCG in the relaxed awake state.

In Figure 1 are represented typical MT, BCGs and EKG tracings obtained after the subject was kept in the relaxed condition for about 30 minutes. In a simultaneous record of MT and BCGs or EKG, two groups of vibrations in MT were found out to appear corresponding very well to I, J and K and L, M and N waves of BCGs as R and T waves of EKG, whose correlation with MT was indicated in the previous paper of OZAKI, SATO et al<sup>19)</sup>. There was a short delay of the dominant vibrations of MT or I, J and K and L, M and N waves of BCG with respect to the R and T waves of EKG respectively, because

the deflections of EKG precede all mechanical events in the cardiac activity. The amplitude in I, J and K waves of BCG was observed to be considerably higher in H-F than in L-R lead. Figure 2 shows representative tracings of MT, BCG, EKG and respiratory movements. Besides the correlation between MT and BCG or EKG, both MT and BCG were recognized to change in amplitude slightly corresponding to each respiratory cycle during quiet breathing. According to inspiratory and expiratory phases, the dominant vibrations of both MT and BCG were observed to be a little higher and lower in amplitude, respectively. The corresponding changes between MT and BCG were, however, recognized more evidently in inspiration than in expiration, because of perhaps the increase of cardiac output in the phase of inspiration.

#### 2) MT and BCG during the deep breathing.

In Figure 3 are shown representative recordings of MT, BCG, EKG, and respiratory movements obtained before and during the deep breathing for about 15 seconds. During the deep breathing, MT was shown to increase in amplitude considerably corresponding to the facilitatory changes of the heart, such as an increase in amplitude of BCG and a shortening in R-R interval of EKG. The dominant components of MT, however, remained to appear corresponding to I, J and K and L, M and N waves of BCG or R and T waves of EKG, as shown in the relaxed awake state. On the other hand, the correspondence between the dominant components of MT or BCG and respiratory movements was observed more markedly during the deep breathing than in cases of the relaxed state. The respiratory changes of BCG and MT which were shown in inspiratory and expiratory phases were demonstrated to be accentuated by deepening breathing.

#### 3) MT and BCG during the cessation of breathing.

In Figure 4 are displayed typical recordings of MT, BCG, EKG and respiratory movements obtained before and during the cessation of breathing for about 15 seconds. During the cessation of breathing, MT was observed to cause a slight decrease in amplitude, as shown in Figure 4B. The amplitude in I, J and K waves of BCG, on the other hand, was not decreased but increased slightly in expiratory phase. The shortening in R-R interval of EKG was also provoked by stopping breathing. There disappeared such respiratory changes of MT and BCG, as were seen in the relaxed state and strengthened by deepening breathing. However, the correspondence between the dominant components of MT and I, J and K waves of BCG as well as R waves of EKG were always observed in all cases, although not recognized so markedly as in the relaxed state, because of probably a decrease in amplitude of MT during the cessation of breathing.

#### 4) MT and BCG following exercise.

In Figure 5 are seen the representative recordings of MT, BCG, EKG and respiratory movements obtained before and after the "two step" exercise test which was initiated by Master<sup>8)</sup> as the load of EKG and modified by UEDA et al.<sup>20)</sup> later. Immediately after the cessation of the test, MT was demonstrated to show a considerably complex pattern by a marked increase in amplitude and frequency, because of probably the augmented muscle tonus in addition to the facilitatory changes in circulatory and respiratory systems which were shown in Figure 5B. However, there was not recognized such a correspondence between the dominant components of MT and BCG or EKG as was illustrated in Figure 1, 2, 3 and 4. On the other hand, the respiratory changes of MT could not be observed also. In the recordings obtained 1 and 2 minutes after the test, MT, BCG, EKG and respiratory movements were observed to cause facilitatory changes respectively, though there was seen the tendency to return to the control level before the test slightly. In the tracings recorded 3-7 minutes after the test, however, MT, EKG and BCG tended to recover considerably, though not so clear in respiratory movements only, as shown in E, F, G and H of Figure 5. In these phases, there were again recognized the corresponding changes between the dominant components of MT and BCG or EKG.

## DISCUSSION

In the investigation of SUGANO and INANAGA<sup>19)</sup>, they reported that MT was not related to the main rhythms of the living body, such as the vibrations due to the heartbeat, the respiratory and intestinal movements in man and animal. In the recent study of OZAKI, SATO et al.<sup>10)</sup>, on the other hand, it was found by applying the correlation and frequency analyses to MT that the dominant vibrations of MT corresponded to the two main vibrations caused respectively by the first and second heartbeat in rabbit as well as in man. They, furthermore, demonstrated that no correlation between MT and the pulse and/or the blood flow in the peripheral arteries could be found in their experiments during application of pressure on the upper arm above systolic pressure to suppress the radial pulse. There was performed, however, no experiment as to the relationship between MT and BCG in which the body vibration owing to the pulsation of the heart can be led indirectly through the ballistocardiograph.

In our present experiments explained above, therefore, the correspondence between MT and BCG was examined under various physiological condition, in order to determine the relationship between MT and the pulsation of the heart. In all cases examined, the dominant components of MT were demonstrated to appear corresponding to I, J and K and L, M and N waves of BCG very well, as shown in Figure 1.

This fact indicates that there is a direct relationship between MT and the pulsation of the heart. Accordingly, the facilitatory and inhibitory changes in the heartbeat, to be caused by various agents, in addition to so-called muscle tonus will also play an important part in augmenting and inhibiting MT, which was postulated by SUGANO and INANAGA<sup>19)</sup> to be caused by minor contraction of skeletal muscle due to the spinal reflex transmitted through the gamma motor system.

It was also found in our experiments that there were a correspondingly slight augmentative and inhibitory changes in amplitude of MT during each phase of respiratory cycle such as inspiration and expiration. These respiratory changes in MT were furthermore demonstrated to be strengthened by deepening breathing and lost by stopping breathing for a time. In consequence, these findings suggest that MT has some relations with the respiratory movements. In comparative studies of MT, BCG and respiratory movements in simultaneous records, however, there were observed to appear the augmentative and inhibitory changes in MT corresponding to I, J and K and L, M and N waves of BCG or R and T waves of EKG, according to relatively slow rhythm of respiratory movements, that is inspiratory and expiratory phases respectively. This suggests that the respiratory changes in MT probably may be in part caused indirectly through the variations in cardiac output produced during the respiratory cycle. Accordingly, it seems likely that the amplitude and frequency in MT, which was suggested by OZAKI et al<sup>19)</sup>, to be used as indicators of depression and augmentation of activities in the central and peripheral neuromuscular system, also may be somewhat related to the augmentative and inhibitory changes in the respiratory movements through augmented or decreased cardiac output during breathing, although excluded in the study of SUGANO and INANAGA<sup>19)</sup>. Therefore, there was moreover examined in our present experiment the variations in MT following muscular exercise due to Master "two step" exercise test, which has been frequently examined by doctors as the load of EKG to facilitate the circulatory and respiratory systems. By means of this test, MT was demonstrated to cause a considerably marked increase in amplitude and frequency according to circulatory and respiratory changes produced by muscular exercise, such as the augmented amplitude in BCG, shortened R-R interval in EKG and increased amplitude in respiratory movements. The complex changes of MT, seen immediately, 1 and 2 minutes after the end of the test, is suggested to be due to the augmented muscular components of MT produced by the augmented muscle tonus, besides the increases in circulatory and respiratory components of MT mentioned above, because of no correspondence between MT and cardiac or respiratory changes following the exercise test. On the other hand, MT has been well known by ROHRACHER<sup>1,3), 1,5)</sup> to have some relations with the auto-

onomic nervous system. Accordingly, it seems likely that MT to be caused by minor contraction of skeletal muscle originally might be accentuated or weakened by cardiac and respiratory changes through facilitatory and inhibitory activity in the autonomic nervous system under various physiological conditions, such as muscular exercises and increased psychosomatic tonus. Therefore, the role of the autonomic nervous system to MT explained by ROHRACHER may be possible through not only the neuromuscular system itself but also the innervating action of this system on the circulatory and respiratory systems. Further studies should be, however, performed to clarify the relation between MT and autonomic nervous system, whose innervation to skeletal muscle has not been demonstrated yet.

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Fig. 1

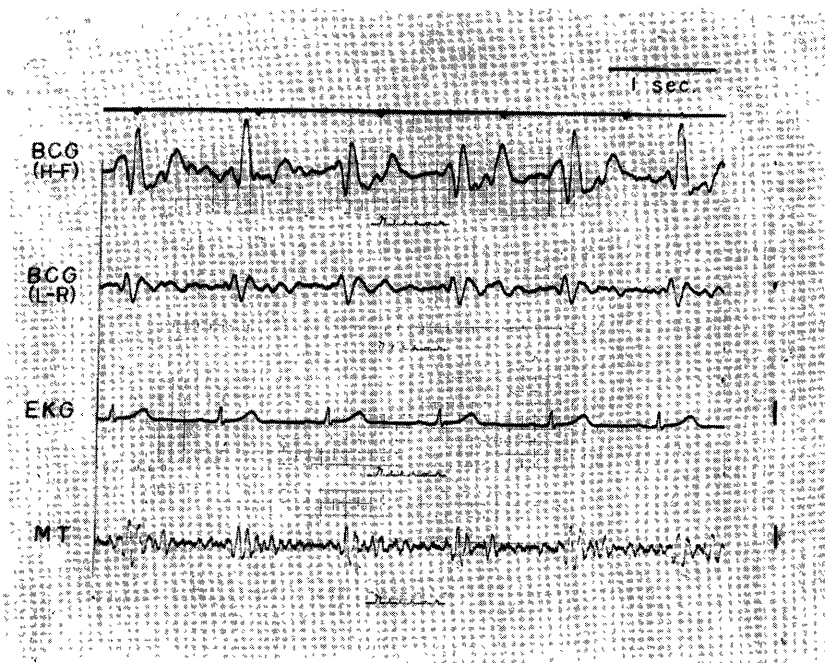


Fig. 1. BCG (H-F), BCG (L-R), EKG (2nd lead) and MT (1. thenar) tracings in relaxed awake state.

Time in 1 sec.

BCG (H-F) and (L-R) represent the direction of head-feet and left-right in ballistocardiographic lead, respectively. Each calibration in right side indicates 1 mV respectively. Note the correspondence between the first and second components of MT and I, J and K and L, M and N waves of BCG or R and T waves of EKG.



Fig. 2

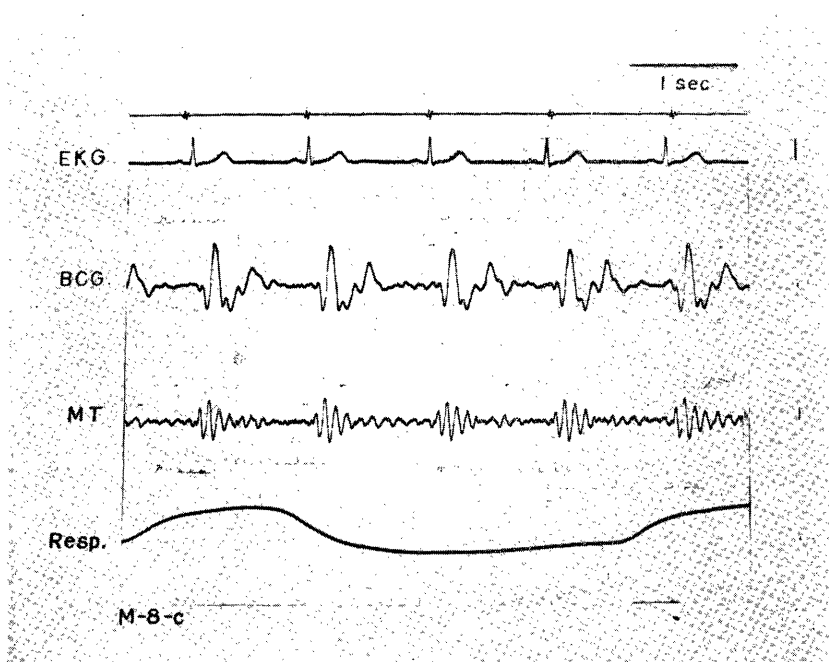


Fig. 2. EKG (2nd lead), BCG (L-R), MT (1. thenar) and respiratory movements (Resp.) tracings in relaxed awake state.

Time in 1 sec.

Each calibration shows 1 mV respectively. Note the respiratory changes in BCG and MT in cases of inspiration (upward) and expiration (downward).

Fig. 3 A

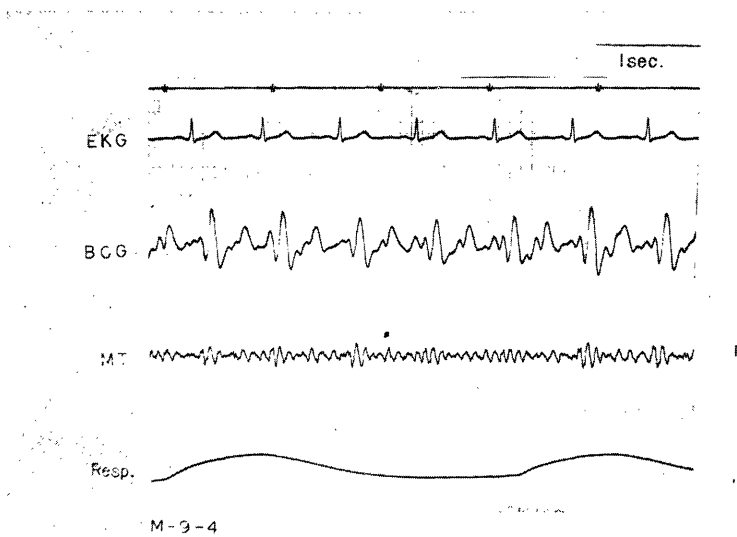


Fig. 3 B

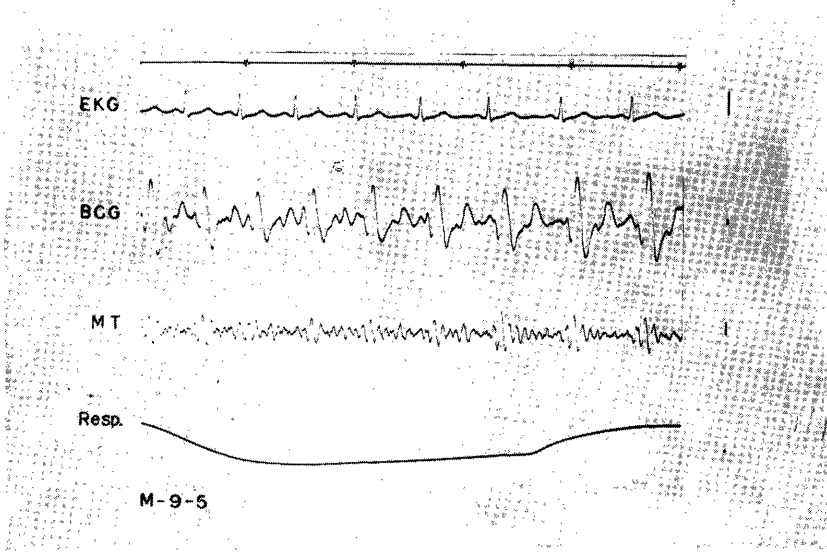


Fig. 3 C

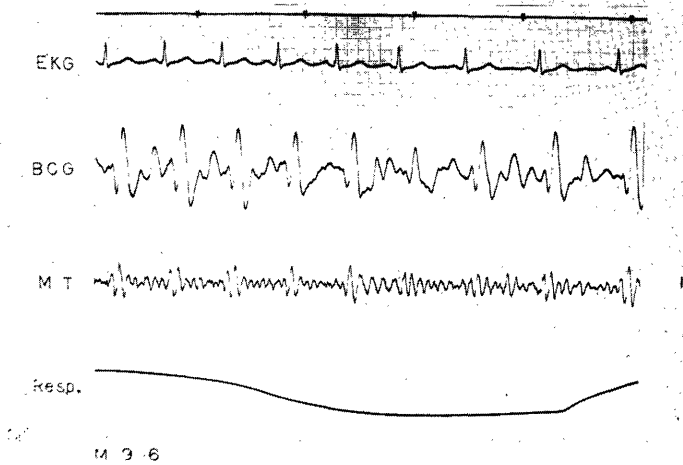


Fig. 3. EKG (2nd lead), BCG (L-R), MT (1. thenar) and respiratory movements (Resp.) tracings before and during deep breathing. Time in 1 sec.  
A : Control tracings before deep breathing.  
B and C: Successive tracings during deep breathing. Note the augmentative changes in MT corresponding to an increase in amplitude of BCG and a shortening in R-R interval of EKG during inspiration.

Fig 4 A

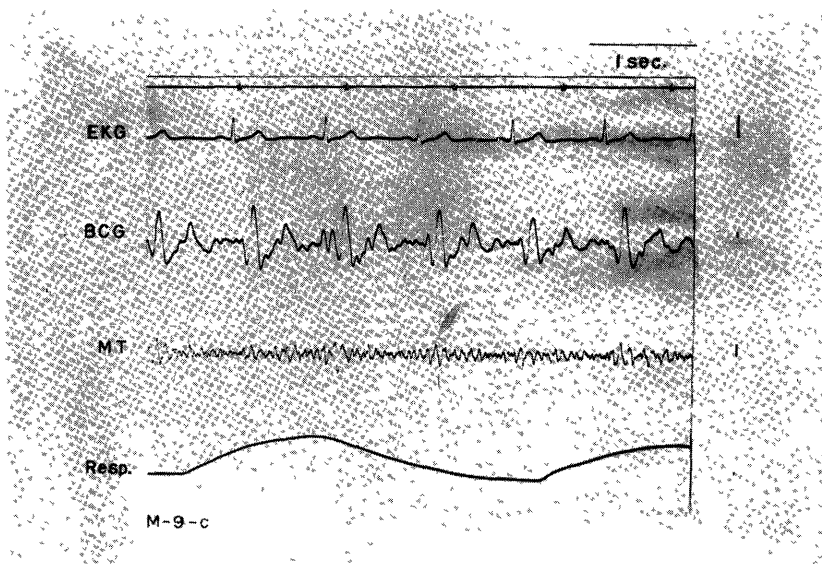


Fig 4 B

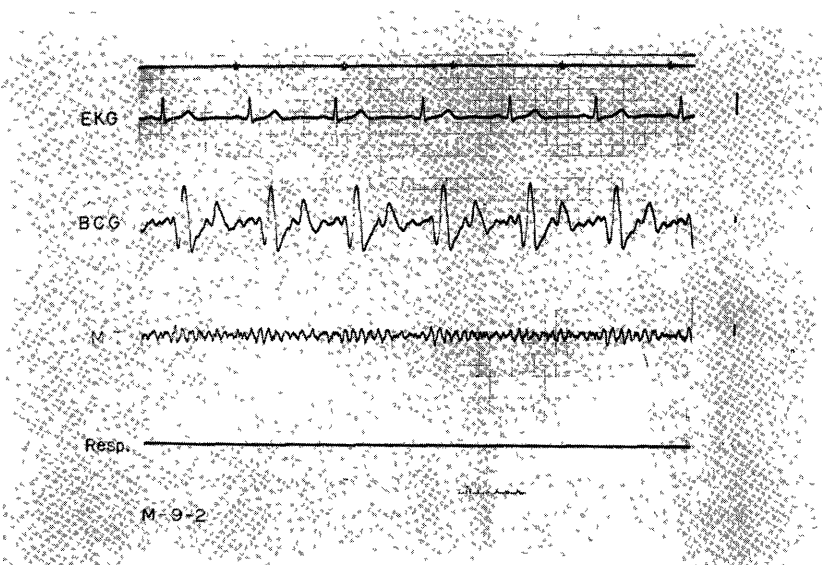


Fig 4 EKG (2nd lead), BCG (L-R), MT (1 thenar) and respiratory movements (Resp) tracings before and during cessation of breathing

Time in 1 sec

A Control tracings before cessation of breathing

B Tracings during cessation of breathing in inspiratory phase

Each calibration shows 1 mV respectively. Note the inhibitory changes in MT during cessation of breathing

Fig. 5 A

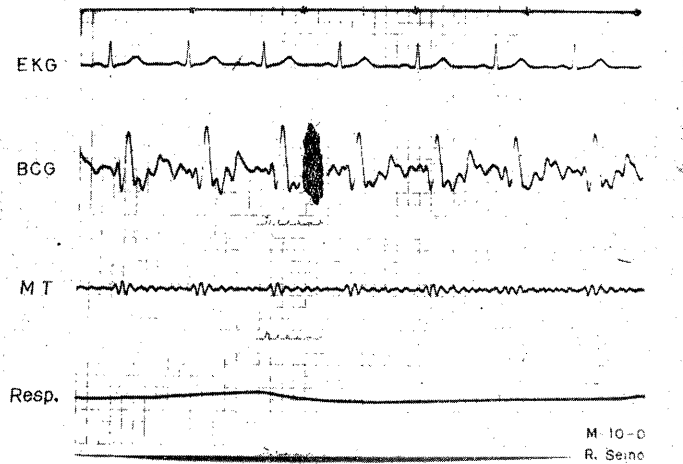


Fig. 5 B

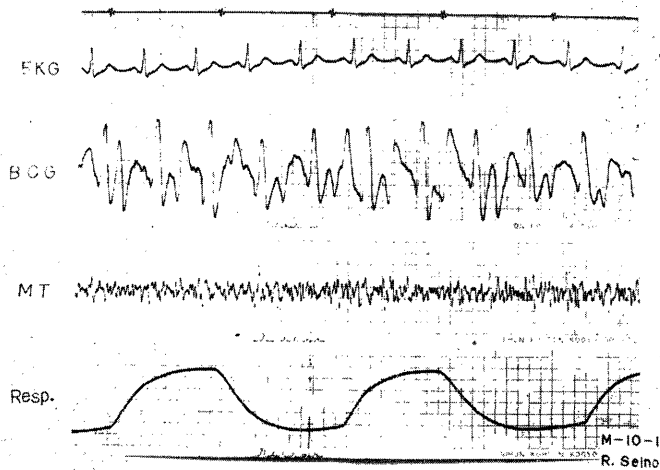


Fig. 5. EKG (2nd lead), BCG (L-R), MT (1. thenar) and respiratory movements (Resp.) tracings before (A) and after (B-H) Master two step test.

Time in 1 sec.

A : Tracings taken before beginning of Master two step test.

B, C, D,

E, F, G and H: Tracings taken immediately, 1, 2, 3, 4, 6 and 7 minutes after end of the test. Each calibration shows 1 mV respectively. Note the augmentative changes in MT immediately after the test.

Fig. 5 C

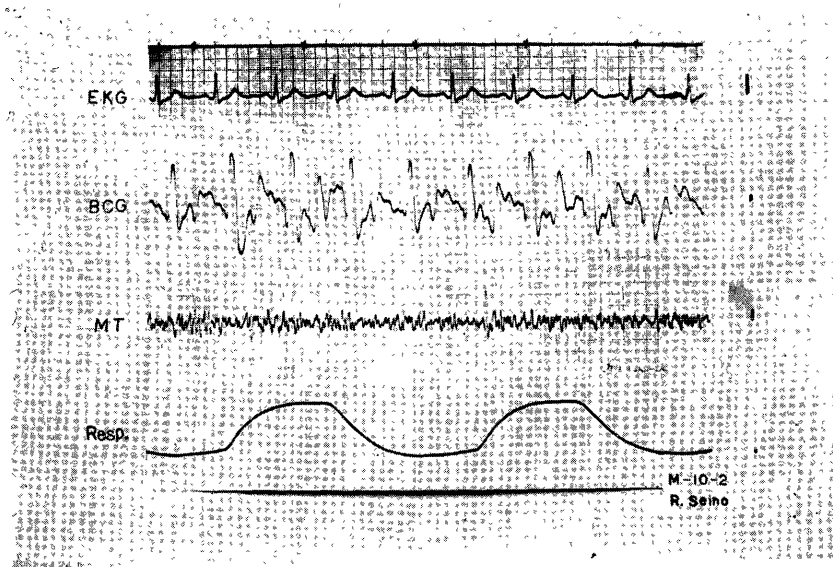


Fig. 5 D

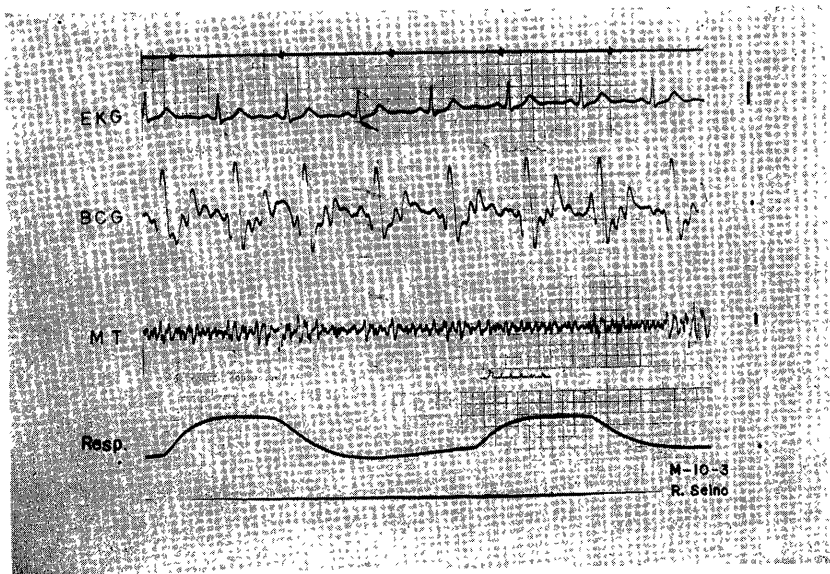


Fig. 5 E

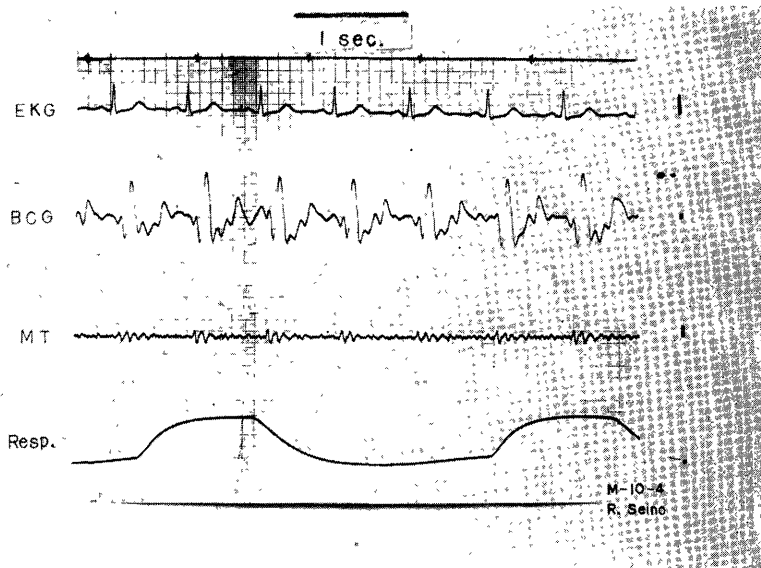


Fig. 5 F

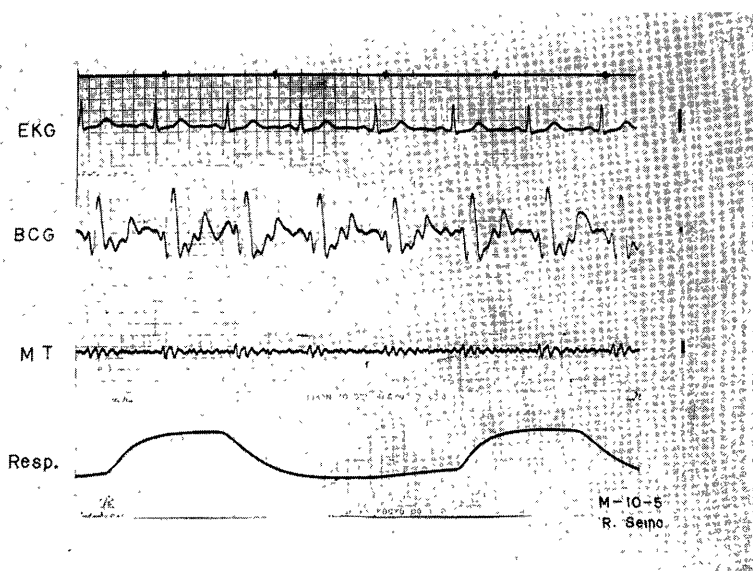


Fig. 5 G

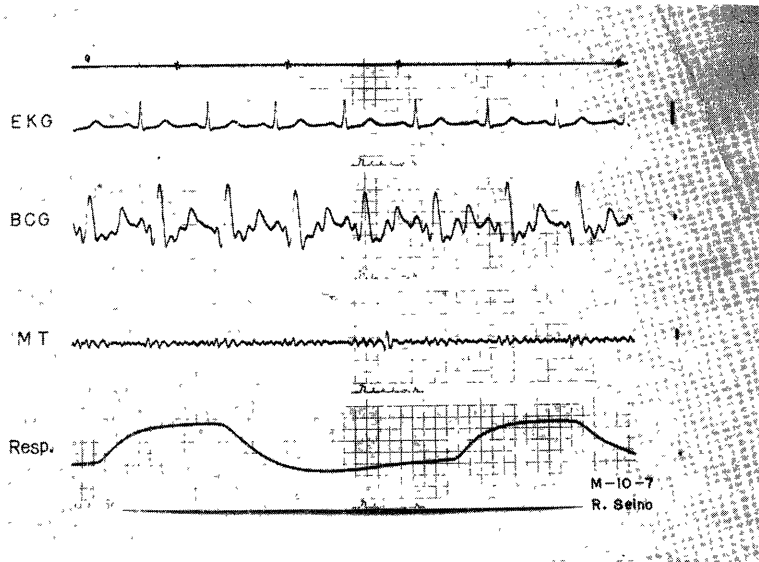


Fig. 5 H

