# Acceleration Registrography in Standing Position—Results in Normal Human Beings

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Kitahara[1] presented a recording method of momentary sways of the human body with an accelerometer and named it, "Acceleration Registrography". Since then, many investigators[2)-6)] have much interest in useing the method as a clinical test of the vestibulospinal reflex. Tsujikawa[6] previously reported a method of "Acceleration Registrography" of static condition of the human body and named it, "Static Functional ARG Test".

The purpose of this paper is to present the method of the "Static Functional ARG Test" and the results in normal human beings.

## MATERIAL AND METHOD

1. The subjects tested are in 20 normal adults aged from 22 to 33.
2. To record the momentary sways of the human body, the following apparatus are used; a) Accelerometer and Strainmeter (Fig. 1), and b) Ink Writing Oscil lography. The accelerometer is fixed on the top of the helmet as the effective plane of the accelerometer just right angle with the frontooccipital axis of the head. It is connected to the strainmter and oscillography via a bridge box.

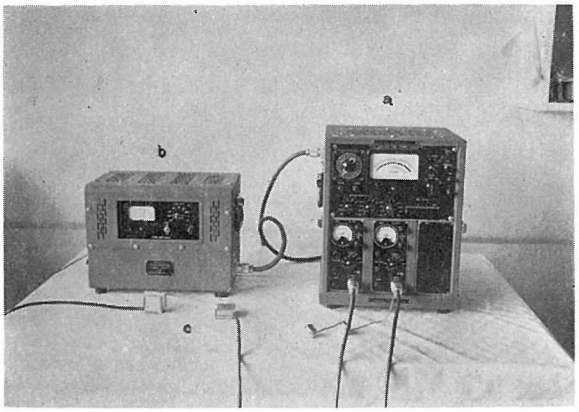


Fig. 1 Strainmeter (DM-3H) and Accelerometer (120A-1D)
a) Strainmeter b) Power Supply, and c) Accelerometer

Thus, "Acceleration Registrograms (ARGs)" of the side to side sways of the head of the test subjects are obtained. Fifteen millimeter of amplitude in each ARG is calibrated as to indicate $600 \times 10^{-6}$ strain (0.25 g). Falling to the right makes an upward deflection and to the left, downward deflection in each ARG.

Each subject wearing the helmet stands on normal position and Mann's position for 40 seconds. Also, he stands on the plank of the electric driven goniometer (Fig. 2) till he falls down from the plank. In each test the body sways

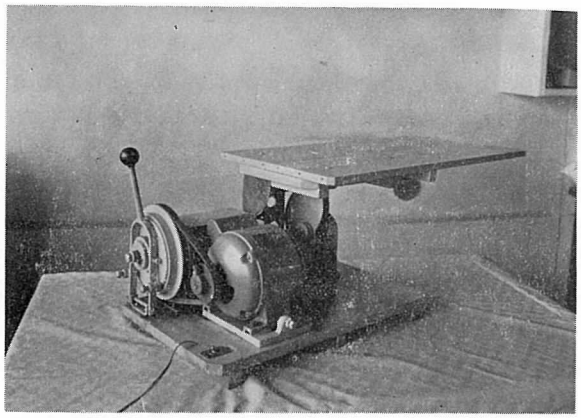

Fig. 2 Electric Driven Goniometer (Honjo)
The plank of the goniometer moved by electric driven gears is inclined at a constant angular speed of 1° per second.

of the test subjects are naturally recorded into "Acceleration Registrograms (ARGs)".

3. Waves of each ARG are composed of two basical elements, deviation and amplitude. We estimate deviation and amplitude in each ARG at a constant interval of two seconds, and sum them up every ten seconds; the first (Section I), the second (Section II), the third (Section III) and the fourth (Section IV). The same procedure is performed on all ARGs of 20 subjects tested. After that, we calculate a mean value and standard deviation, and also do the t-test for statistical evaluation.

## RESULT

1. Acceleration Registrograms (ARGs) in Normal Standing Position

ARGs in normal standing position with eyes opened (Fig. 3) are composed of even waves associated with a slight deviation and ARGs with eyes closed (Fig. 4) are essentially the same in nature. They have the following common characters; 1) Slight deviation, 2) Short amplitude (less than 0.1 g), and 3) 40 seconds record

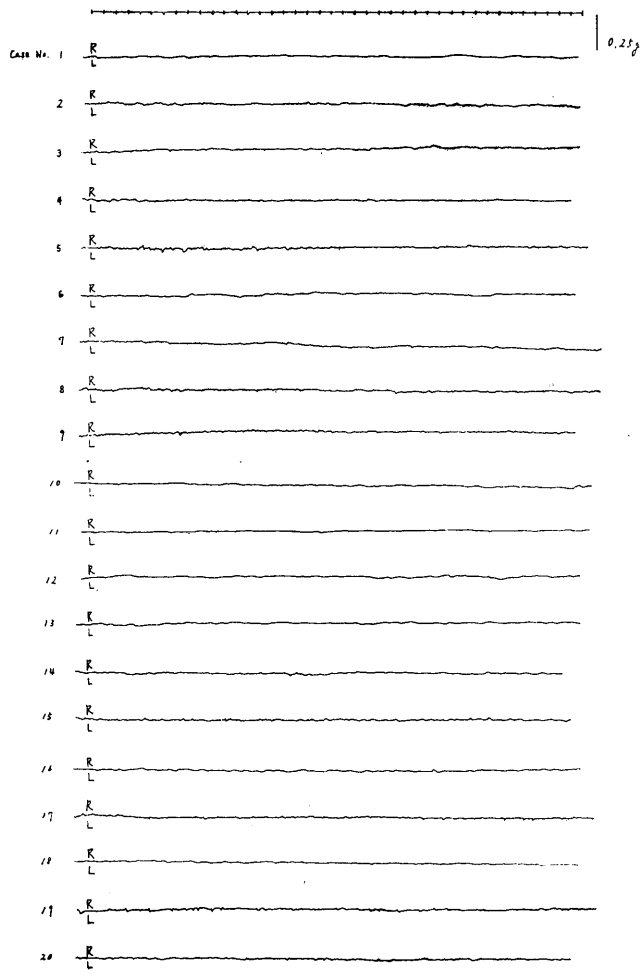

Fig. 3 ARGs in normal standing position with eyes opened.

without falling.

Table I-1 indicates the periodical changes of the deviation of the ARGs in the normal standing position. The deviation reveals a tendency to increase as time goes on, and the deviation during the eyes closed is generally larger than that of the eyes opened.

Table I-2 illustrates the periodical changes of the amplitude of the ARGs in the normal standing position. In both of the eyes opened and closed, the amplitude of Section I is twice larger than the others (Sections II-IV).

By the t-test (Table 2), the following results are demonstrated; 1) Significant difference is proven in the amplitudes between Section I and the others, however,

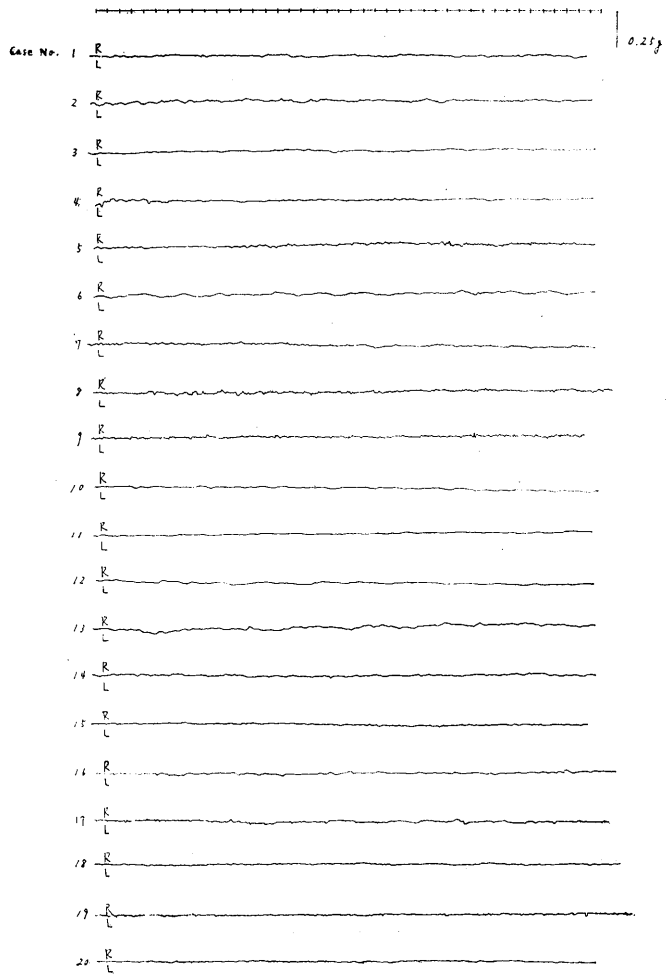


Fig. 4 ARGs in normal standing position with eyes closed.

Table 1 Deviation and Amplitude obtained from ARGs of normal standing position. Mean value in each Section

| | Section / Eyes | I 0″−10″ | II 10″−20″ | III 20″−30″ | IV 30″−40″ |
|---|---|---|---|---|---|
| 1. Deviation* | Opened | 0.95±0.07 | 1.45±0.10 | 1.23±0.11 | 2.50±0.15 |
| | Closed | 1.30±0.03 | 1.85±0.09 | 2.05±0.13 | 2.85±0.18 |
| 2. Amplitude** | Opened | 2.05±0.22 | 1.08±0.11 | 0.91±0.13 | 1.08±0.15 |
| | Closed | 2.08±0.22 | 1.08±0.16 | 1.00±0.11 | 1.55±0.13 |

Notes: *) distance from the basal line (unit=mm).
**) acceleration (unit=0.01 g)

Table 2 Results of the t-test ($\alpha=0.05$, $t=2.023$) concerning the amplitude of ARGs in normal standing position.

1. Correlation between two sections, respectively.

| | I : II | I : III | I : IV | II : III | II : IV | III : IV |
|---|---|---|---|---|---|---|
| Eyes Opened | 2. 2436* | 2. 7708* | 2. 1704* | 0. 6952 | 0. 7503 | 0. 4956 |
| Eyes Closed | 2. 3384* | 2. 5812* | 2. 4410* | 0. 3884 | 1. 5172 | 1. 0632 |

2. Correlation between the groups of eyes opened and closed in each Section.

| I | II | III | IV |
|---|---|---|---|
| 0. 3128 | 0. 5518 | 0. 7035 | 1. 2720 |

Notes: *; Statistically, significant. No mark; Statistically, non-significant.

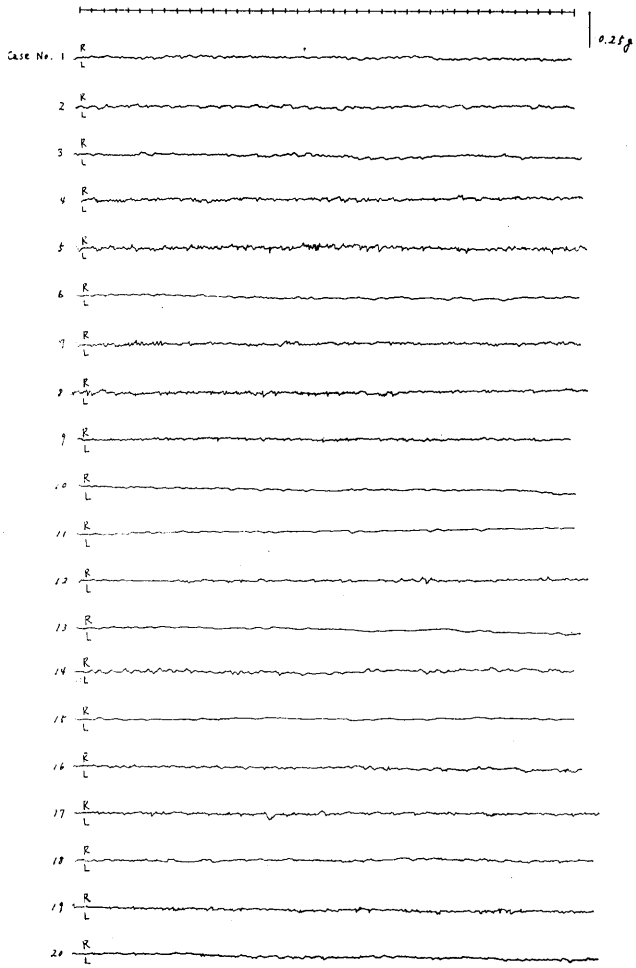


Fig. 5 ARGs in Mann's position with eyes opened. Cases of the left foot situated anteriorly.

it is denied among Sections II, III and IV. 2) In each Section no significant difference is proven in the amplitudes between the groups of eyes opened and closed.

2. Acceleration Registrograms (ARGs) in Mann's Position

Regardless of the foot situated anteriorly, ARGs in Mann's position with eyes opened (Figs. 5 and 7) are essentilly similar to ARGs of normal standing position. The former is composed of somewhat larger waves in amplitude than the latter. And ARGs with the eyes closed (Figs. 6 and 8) reveal larger waves than that of eyes opened. However, these waves are entirely of medium amplitude. ARGs in Mann's position, both of eyes opend and eyes closed, have no falling pattern.

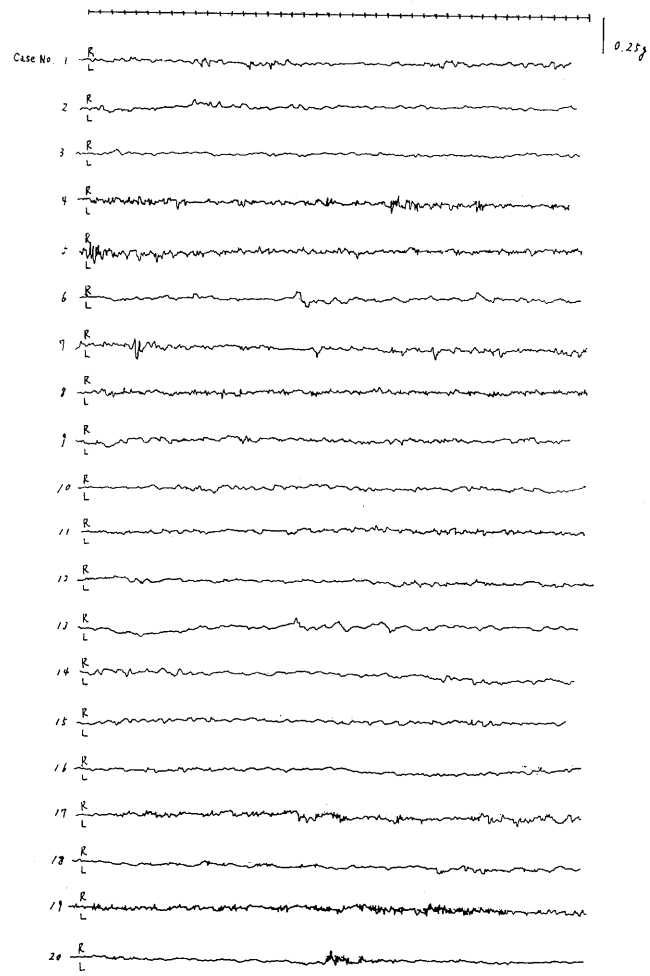


Fig. 6 ARGs in Mann's position with eyes closed. Cases of the left foot situated anteriorly.

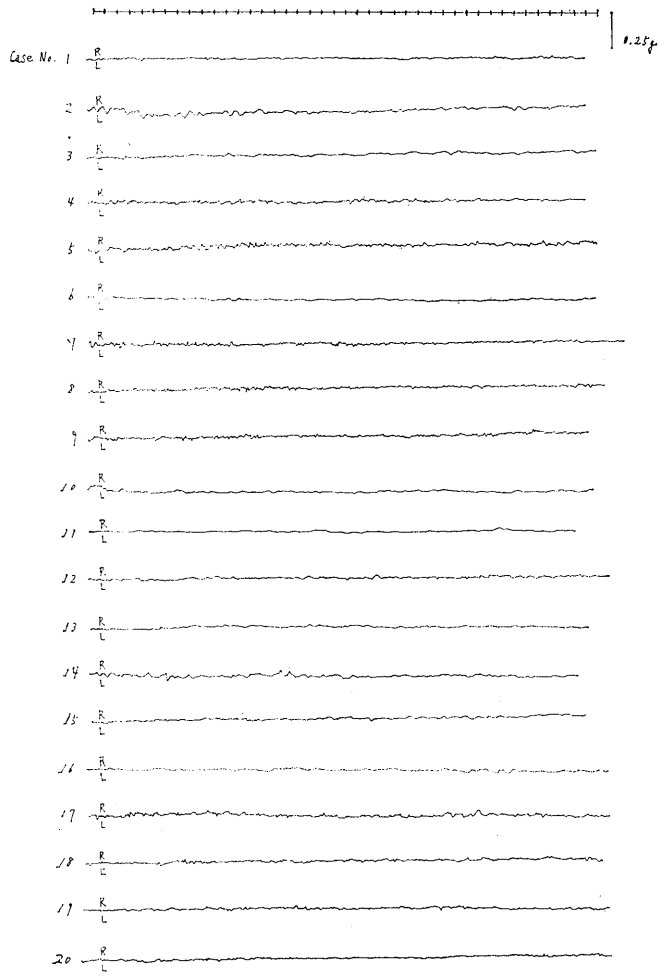


Fig. 7 ARGs in Mann's position with eyes opend. Cases of the right foot situated anteriorly.

Table 3 Deviation and Amplituated Obtained from ARGs in Mann's Position. Mean value in each Section.

| | Foot situated anteriorly | Section / Eyes | I 0″−10″ | II 10″−20″ | III 20″−30″ | IV 30″−40″ |
|---|---|---|---|---|---|---|
| 1. Deviation* | Left | Opened | 0.58±0.08 | 0.93±0.12 | 1.50±0.13 | 2.30±0.22 |
| | | Closed | 1.67±0.10 | 1.08±0.20 | 2.00±0.19 | 2.70±0.25 |
| | Right | Opened | 1.15±0.13 | 1.55±0.14 | 1.58±0.14 | 1.88±0.16 |
| | | Closed | 1.85±0.15 | 1.88±0.08 | 2.00±0.10 | 2.88±0.12 |
| 2. Amplitude** | Left | Opened | 2.55±0.15 | 1.33±0.13 | 1.55±0.15 | 1.80±0.16 |
| | | Closed | 4.55±0.19 | 2.91±0.15 | 3.13±0.21 | 3.30±0.24 |
| | Right | Opened | 2.51±0.17 | 1.25±0.13 | 1.13±0.08 | 1.71±0.15 |
| | | Closed | 4.33±0.37 | 2.46±0.17 | 2.91±0.27 | 3.33±0.01 |

Notes: *) distance from the basal line (unit=mm)
**) acceleration (unit=0.01 g)

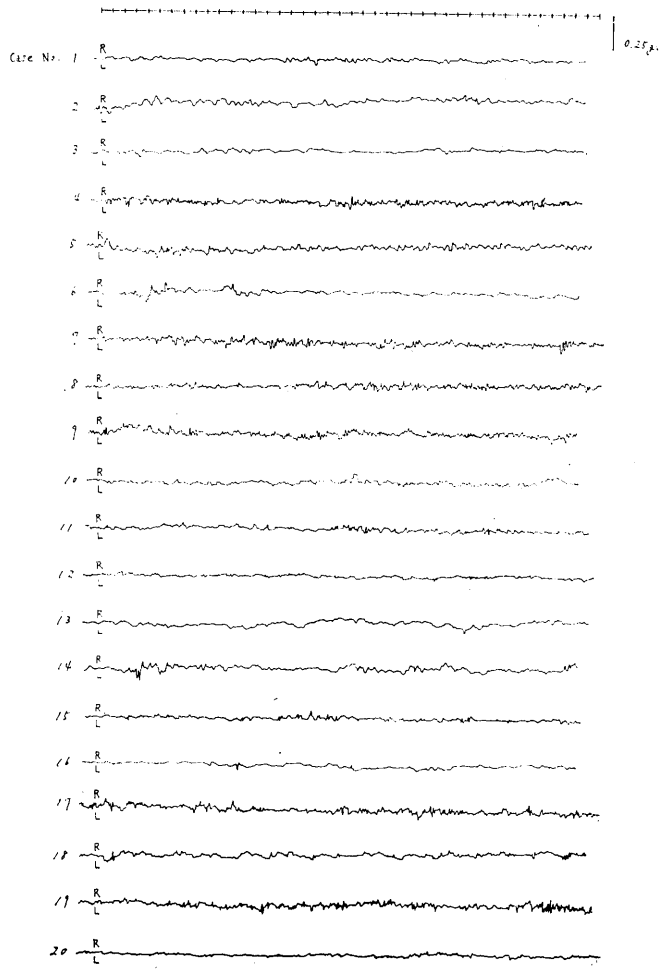

Fig. 8 ARGs in Mann's position with eyes closed. Cases of the right foot situated anteriorly.

Table 3–1 illustates the periodical chages of the deviation of the ARGs in Mann's position. The deviation reveals a tendency to increase as time goes on, and the deviation during the eyes closed is generally larger than that of the eyes opened.

Table 3–2 shows the periodical changes of the amplitude of the ARGs in Mann's position. In both of the eyes opened and closed, the amplitude of Section I is twice larger than that of Sections II and III. In each Section, the amplitude of the group of the eyes opened is larger than that of the eyes closed.

By the t-test (Table 4) the following results are summarized; 1) Significant difference is proven in the amplitude between the groups of Section I and the others,

Table 4 Results of the t-test ($\alpha=0.05$, $t=2.023$) concerning the amplitude of ARG is in Mann's position.

1. Correlation between two Sections, respectively.

| Eyes | Foot situated anteriorly | I : II | I : III | I : IV | II : III | II : IV | III : IV |
|---|---|---|---|---|---|---|---|
| Opened | Left | 3. 5031* | 2. 8059* | 2. 2614* | 0. 7268 | 2. 2250* | 2. 0055 |
| | Right | 2. 7013* | 3. 1657* | 2. 6321* | 0. 4928 | 2. 0019 | 2. 4102* |
| Closed | Left | 3. 2561* | 2. 9974* | 2. 6834* | 1. 3200 | 0. 6898 | 0. 9230 |
| | Right | 3. 0968* | 2. 8644* | 2. 6432* | 1. 3130 | 2. 6185* | 0. 6659 |

2. Correlation between the groups of eyes opened and clased in each Section

| Foot situated anteriorly | I | II | III | IV |
|---|---|---|---|---|
| Left | 3. 5338* | 3. 7998* | 2. 8631* | 2. 9092* |
| Right | 3. 8520* | 3. 0513* | 3. 5541* | 3. 0024* |

3. Carrelation between the groups of the left and right foot situated anteriorly ineach section

| | I | II | III | IV |
|---|---|---|---|---|
| Eyes opened | 0. 3104 | 0. 2981 | 2. 205* | 0. 4638 |
| Eyes closed | 0. 2598 | 2. 3317* | 0. 3476 | 0. 3792 |

Notes: *) Statittically, significant.
No mark; Statistically, non-signifycant.

however, it is denied among Sections II, III, and IV. 2) In each Section significant difference is proven in amplitude between the groups of eyes opened and closed. 3) In each Section no significant difference is proven between the groups of the left and the right foot situated anteriorly.

3. Acceleration Restrograms (ARGs) in Normal Standing Position on the Plank of the Goniometer (Gonio-ARGs)

As shown in Figs. 9, 10, 11 and 12, Gonio-ARGs are essentially different from ARGs in standing position due to the waves of large amplitude (more than 0.25 g) which indicates a falling of the test subject from the plank of the gonimeter. Regardless of the side of inclination of the plank, with or without eye closure, the deviation of Gonio-ARGs is divided into three types; a) to the left, b) to the right, and c) no deviation. We analyze the Gonio-ARGs with curves which are recorded before the inclination angle of the goniometer indicates 20 degrees. Thus, Gonio-ARGs with the eyes opened and closed are mainly composed of waves of short amplitude, while having medium amplitude are recognized, but they are not observed

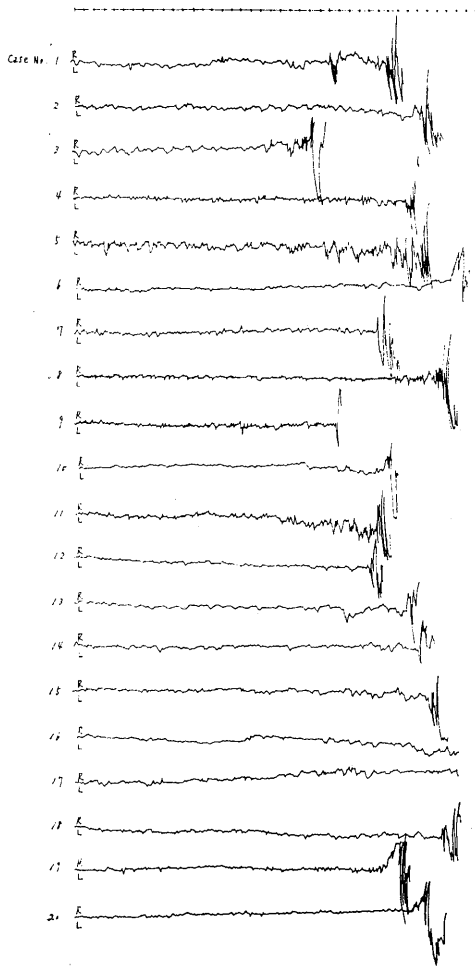

Fig. 9 Gonio-ARGs with eyes opened. Cases of left inclination.

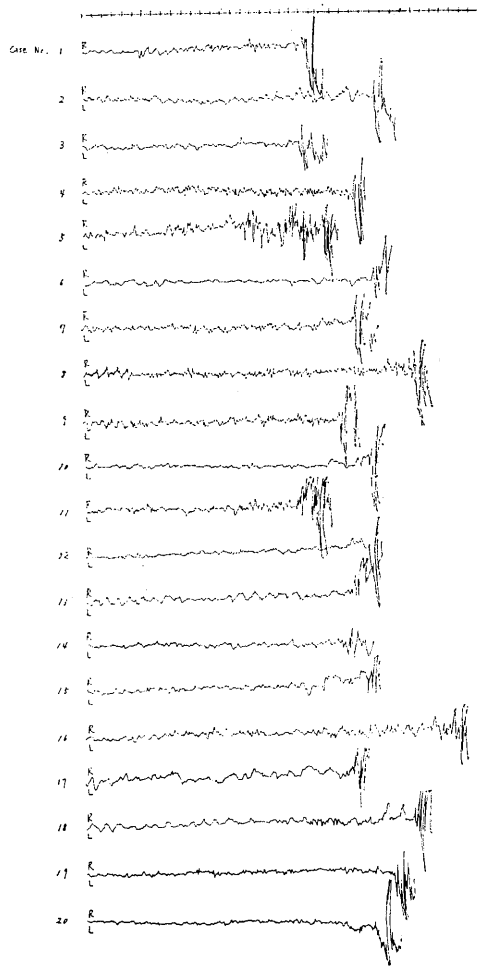

Fig. 10 Gonio-ARGs with eyes opened. Cases of right inclination.

continuously.

Table 5-1 indicates the periodical changes of the deviation of the Gonio-ARGs, and the findings are summarized as follows; 1) Inclination of the head at Section I is twice larger than that of Section II. 2) Inclination of the head at the time of eyes closed is larger than that of eyes opened.

Table 5-2 illustrates the periodical changes of the amplitude in Gonio-ARGs. In both of the eyes opened and closed, the amplitude of Section I is larger than Section II. In each Section the amplitude of the group of the eyes opened is larger than that of the eyes closed.

By the t-test (Table 6) the following conclusions are obtained; 1) No significant

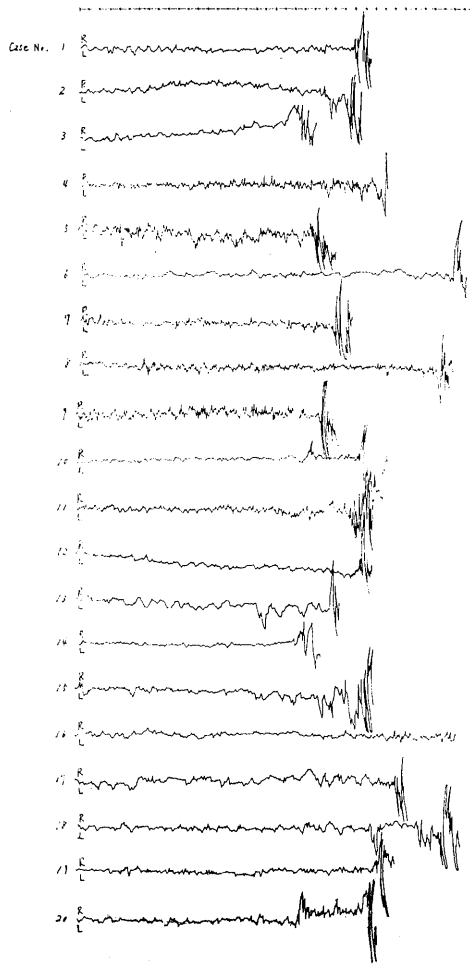

Fig. 11 Gonio-ARGs with eyes closed. Cases of left inclination.

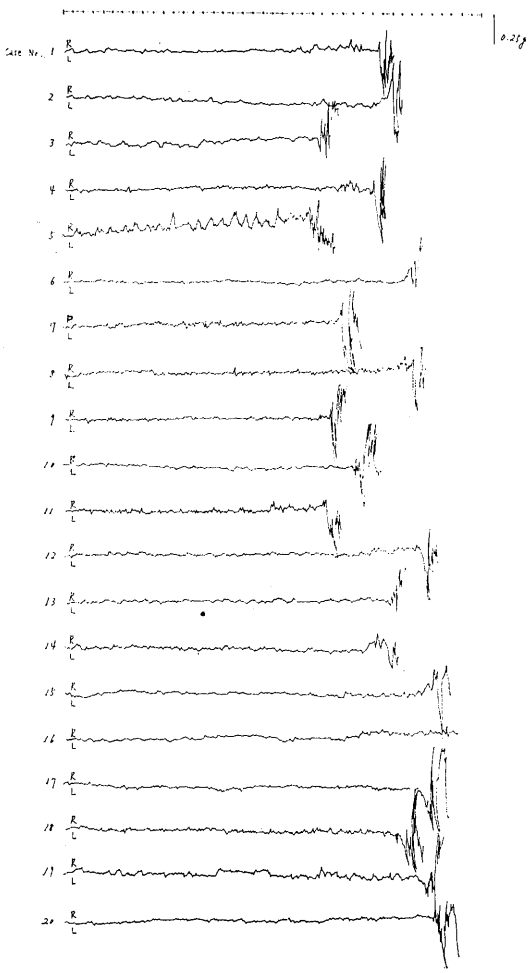

Fig. 12 Gonio-ARGs with eyes closed. Cases of right inclination.

difference is proven in amplitude of the Gonio-ARGs with eyes opened between the groups of Sections I and II. On the other hand, significant difference is proven in amplitude of the Gonio-ARGs with the eyes closed between the Sections I and II. 2) In each Section significant difference is proven in amplitude of the Gonio-ARGs between the groups of the eyes opened and closed. 3) In each Section no significant difference is proven between the groups of the left inclination and the right inclination.

Table 5 Deviation and Ampltiude obtained from Gonio-ARGs.
Mean value in each section.

| | Side of Inclination | Section / Eyes | I 0°—10° | II 10°—20° |
|---|---|---|---|---|
| 1. Deviation* | Left | Opened | 2.23±0.23 | 5.83±0.34 |
| | | Closed | 3.20±0.28 | 8.56±0.53 |
| | Right | Opened | 3.54±0.30 | 5.75±0.44 |
| | | Closed | 3.50±0.29 | 8.73±0.46 |
| 2. Amplitude** | Left | Opened | 4.13±0.33 | 4.33±0.41 |
| | | Closed | 6.75±0.78 | 9.30±0.64 |
| | Right | Opened | 4.05±0.47 | 4.47±0.57 |
| | | Closed | 6.78±0.58 | 9.66±0.57 |

Notes: *) distance from the basal line (unit=mm)
**) acceleration (unit=0.01 g)

Table 6 Results of the t-test ($\alpha=0.05$, t=2.023) concerning amplitude of Gonio-ARGs.
1. Correlation between the two sections.

| Eyes | Side of inclination | I : II |
|---|---|---|
| Opened | Left | 1.3328 |
| | Right | 0.9769 |
| Closed | Left | 2.5637* |
| | Right | 3.0019* |

2. Correlation between the groups of eyes opened and closed in each section.

| Side of inclination | I | II |
|---|---|---|
| Left | 3.2117* | 4.8296* |
| Right | 3.4099* | 3.9160* |

3. Correlation between the groups of the left and right inclination in each section.

| Eyes | I | II |
|---|---|---|
| Opened | 0.1580 | 0.5316 |
| Closed | 0.8221 | 1.2211 |

Notes: *) Statistically, significant.
No mark; Statistically, non-significant.

## DISCUSSION

It is generally accepted that Romberg test, Mann's test and goniometer test are

useful to detect the disturbance of human equlibrium. Doing these tests, the examiners judge the results from the grade of body sways and/or falling of the test subjects. Usually, they do such tests by observing with the naked eyes. Judgements, whether or not the disturbance of the human equilibrium is present, are dependent upon the examiners' subjectivity, impression or feeling. So, occasionally they make inaccurate conclusion to the results of these tests.

The author presents a new recording method of the body sways of the human beings, while doing the static functional test, by means of "Acceleration Registrography" and names it, "Static Functional ARG Test". Thus, the disequilibrium of the human subjects is detected easily and accurately by the test.

1. Fixation of the Accelerometer

To make "Acceleration Registrograms (ARGs)" of the momentary sways of the human beings, the examiners must fixate the accelerometer to the head of the test subjects. They put a helment on the head of the test subject. They make several holes on the helmet for reducing the weight and fixate the accelerometer on the top of the helmet as the effective plane of the accelerometer just right angle with the frontooccipital axis of the helmet. Kitahara[1] and Uno[3] fixate the accelero meter at the median part of the forehead by means of head band. According to the author's method, the accelerometer is able to fix at the center of the head.

2. Duration of the Recording

We make "Acceleration Registrograms (ARGs)" in standing position for a constant duration of 40 seconds. ARGs in normal standing position and Mann's position with eyes opened and closed reveal a tendency to increase in deviation as time goes on, and they have larger waves in the first 10 seconds (Section I).

Kakuta[7] described that the body sways in Mann's position become maximum about 10 seconds later. However, from the author's observation, the momentary body sways of normal persons are the largest in Section I and they become shorter in other three sections (Sections II, III and IV). The author considers that the above mentioned phenomenon is due to "Physiological adaptation" which means the reducing reactivity of the body against the several kinds of irritation in process of time.

3. Effects of Heart Beats and Respirations

It is well known fact that the heart beats and respirations have great effects upon the head sways of the human subjects. Kitahara[1] finds that the waves of ARGs have some components induced by the heart beats, and he describes that the acceleration in side to side sways of the head is less than $9.3 \pm 1.6$ cm/sec$^2$ ($0.0095 \pm 0.0016$ g). The present author can also find out that there are small peak waves in ARGs repeated at a regular interval which are consistent with heart beats. However, these waves are all less than 0.017 g in amplitude. So, these are neglegible at the time of clinical evaluation. Because the author puts a matter in question,

whether or not the curves of ARGs have waves of 0.1 g or more in amplitude.

4. Optical Sensation.

"Acceleration Registrograms (ARGs)" in normal standing position reveal no significant difference in amplitude between two groups of eyes opened and closed. However, regardless of the foot situated anteriorly and/or the side of inclination of the plank of the goniometer, ARGs in Mann's position and Gonio-ARGs make a significant difference in amplitude between the eyes opened and closed. These facts indicate that the optic effects are latent in normal standing position and evident in other two positions.

5. Stability of the Human Body in Each Position

Regardless of the foot situated anteriorly, "Acceleration Registrograms (ARGs)" in Mann's position reveal no significant difference in head sways. Thus, when we are maintaining a static condition, even at the Mann's position, there is no necessity for thinking over the "whip-foot". Gonio-ARGs show no significant difference between the two groups of the left and right inclinations. This fact is clearly understood, because the test subjects in normal standing position are inclinated to the left and the right in just the same condition.

Kitahara and Uno[2] find that Gonio-ARGs make an opposite deviation from the side of the inclinations of the plank of the goniometer and they further state that this fact is a peculiarity in almost of all normal human subjects. However, the author considers that Kitahara and Uno's description is not true absolutely. As far as the author's observation, there are three different types of deviation in Gonin-ARGs; that is to say, a) to the left, b) to the right, and c) no deviation. This phenomenon is clearly proven at the time of eyes opend, on the other hand, many Gonio-ARGs in eyes closed make the deviation to the same side of the inclination of the plank of the goniometer.

Comparing with the inclination angles of the plank of the goniometer and the head of the test subjects, the former is always larger. The reason is that the human beings are not a hard mass and they are livings with righting reflex.

6. Peculiarity of Static Functional ARGs in Normal Human Subjects.

To standardize the "Static Functional ARG Test", the present author summarizes the findings obtained from the normal subjects as follows; The waves of normal standing position are composed of waves of short amplitude (less than 0.1 g) either the subject closes his eyes or not. The waves of ARGs in Mann's position are mainly composed of short amplitude either the subject closes his eyes or not. Occasionally, a few waves of medium amplitude (0.1–0.25 g) are recognized, but they are not observed continuously. When the subject stands on the plank of the goniometer, the waves of ARGs are mainly composed of short amplitude, while a few waves having medium amplitude are recognized, but they are not observed continuosly.

7. Static Functional ARGs in Congenital Deafmutism.

Tsujikawa, et al.[8)-10)] reported that the "Static Functional ARG Test" is useful to find out a latent disequilibrium of the human subject and also is of great value to check the effects of medical treatments in ataxic diseases. Now, the author presents "Static Functional ARGs" of several cases of congenital deafmutism, and makes a difference between ARGs of deafmutism and normal subjects clear. The arrangement of ARGs of each case is in the order as shown in Table 7.

Table 7 Arrangement of ARGs. ARGs of cases are arranged in the following order. Odd number indicates ARGs of eyes opened and even number indicates ARGs of eyes closed.

| Kinds of ARGs | Number of ARGs | |
|---|---|---|
| ARGs in normal standing position | 1 | 2 |
| ARGs in Mann's position (left foot situated anteriorly) | 3 | 4 |
| (right foot situated anteriorly) | 5 | 6 |
| Gonio-ARGs (left inclination) | 7 | 8 |
| (right inclination) | 9 | 10 |

Cases 1, 2 and 3 reveal non-reaction in Bárány's rotation test and caloric test with 20 ml of ice-floating water.

Case 1. K.Y., 24 years, male.

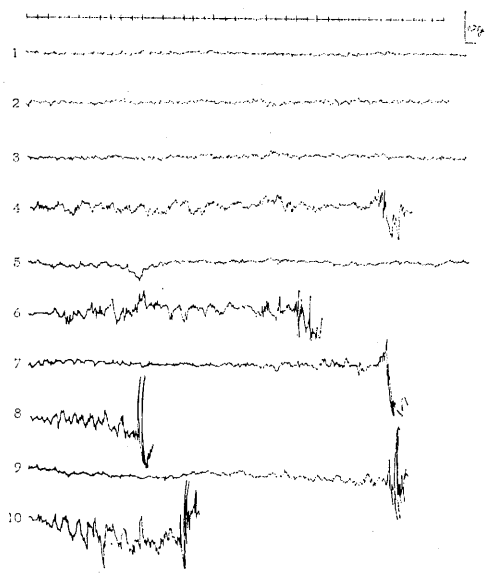

Fig. 13 Case 1. K.Y., 24 years, male.
Diagnosis: Congenital Deafmutism.

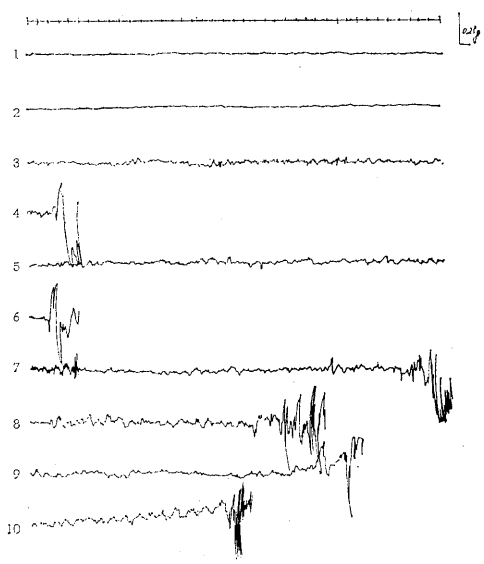

Fig. 14 Case 2. Y.H., 32 years, male.
Diagnosis; Congenital Deafmutism.

"Static Functional Acceleration Registrograms (ARGs)" of this case are shown in Fig. 13 and they are summarized as follows; ARGs in normal standing position reveal normal pattern. ARGs in Mann's position with eyes closed reveal continuous waves of medium amplitude (0.1–0.25 g) with falling pattern. Gonio-ARGs with eyes opened reveal normal pattern and with eyes closed are composed of continuous waves of medium amplitude with early falling pattern.

Case 2. Y.H., 32 years, male.

"Static Functional ARGs" of this case are illustrated in Fig. 14. ARGs in Mann's position with eyes closed reveal early falling pattern. Otherweise, normal.

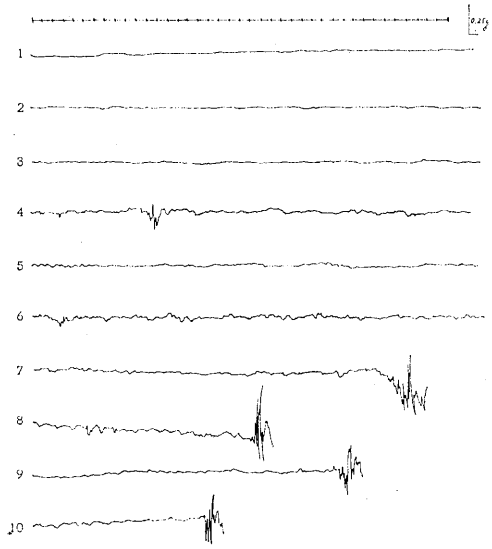

Fig. 15 Case 3. E.T., female.
Diagnosis: Congenital Deafmutism.

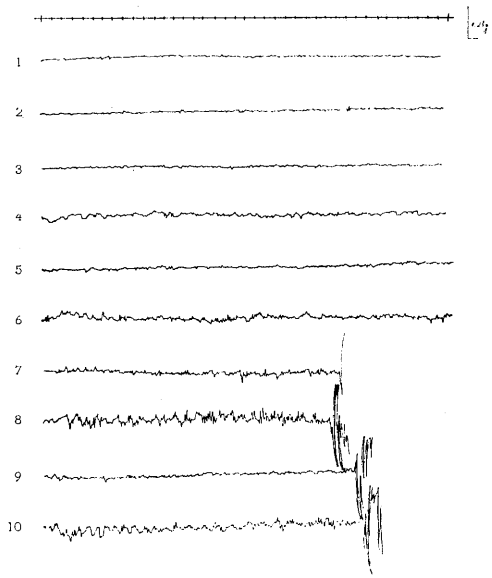

Fig. 16 Case 4. S.I., 33 years, male.
Diagnosis: Congenital Deafmutism.

Case 3. E.T., 32 years, female.

As shown in Fig. 15, "Static Functional ARGs" of this case reveal essentially a normal pattern.

Cases 4 and 5 reveal hypo-function in Bárány's rotation test and caloric test with 20 ml of ice water.

Case 4. S.I., 33 years., male.

"Static Functional ARGs" of this case is illustrated in Fig. 16 and the findings are summarized as follows; Gonio-ARGs with eyes closed are composed of continuous waves of medium amplitude without early falling pattern. Otherwise, normal.

Case 5. F.H., 41 years., female.

As shown in Fig. 17, "Static Functional ARGs" of this case are mostly composed of continuous waves of medium amplitude. Only, ARGs in normal standing position reveal normal pattern.

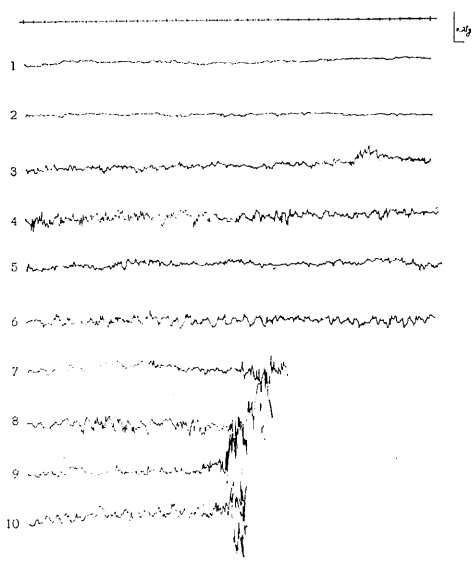

Fig. 17 Case 5. F.H., 42 years, female.
Diagnosis: Congenital Deafmutism.

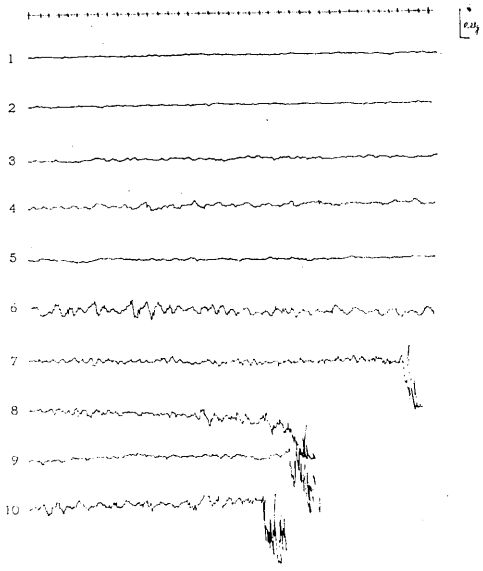

Fig. 8 Case 6. T.H., 44 years, male.
Diagnosis: Congenital Deafmutism.

Case 6. T.F., 44 years., male.

This patient reveals normal reaction in Bárány's rotation test and caloric test with 20 ml of ice-floating water. "Static Functional ARGs" are shown in Fig. 18 and they are summarized as follows; ARGs in Mann's position, when his right foot is situated anteriorly, and Gonio-ARGs with eyes closed reveal continuous waves of medium amplitude. Otherwise, normal.

## SUMMARY AND CONCLUSION

The author presents a method of "Static Functional ARG Test" and results of the test in normal human beings.

1. The waves of Acceleration Registrograms (ARGs) in standing position are composed of waves of short amplitude (less than 0.1 g) either the subject closes his eyes or not.
2. The waves of ARGs in Mann's position are mainly composed of waves of short amplitude either the subject closes his eyes or not. Occasionally, a few waves of medium amplitude (0.1–0.25 g) are recognized, but they are not observed continuously.

3. The waves of Gonio-ARGs are mainly composed of waves of short amplitude, while a few waves having medium amplitude are recognized, but they are not observed continuously.
4. The influence of vision upon the waves of ARGs in normal standing position is hardly proven, and great influence of vision upon the waves of ARGs is clarified when he stands in Mann's position or on the plank of the goniometer.

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