Investigation of Galvanic Test

—— Analysis of Galvanic Body-Sway using with Medical Data Processing Computer——

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ABSTRACT

The purposes of this investigation are to observe the body-sway induced by galvanic stimulation, and to analyse them using a medical data processing computer for detection of abnormal galvanic response in the desequilibrium. The electric stimulation was delivered by anodal unipolar and double electrodes. Body-sway responses were recorded with two accelerometers fixed on the top of a helmet, one for transverse and other for sagittal plane. Signals from the accelerometers were analysed using with a medical data processing computer, designing for calculating averages. This paper reported the data from 40 healthy subjects examined. The latent period till body-sway began after closing the electric circuit was 0.2–0.5 sec., in both sexes. Pattern of body-sway of subjects during the electric stimulation were classified in three types. With unipolar stimulation, there was not a case in which the head deviated toward the nonstimulation side. "Initial Wave" was observed in 33 subjects. In contrary, the double electrode test showed no regularity of body sway in the transverse and sagittal plane.

INTRODUCTION

Since the report of Hitzig[1] about nystagmus being caused by electrifying the head in 1877, the various physiological, histological studies have been done by several investigators. According to the previous literature, most of researchers concentrated their mind on the nystagmus induced by galvanic stimulation and they introduced their speculation or theories about the mode and site of galvanic action in the head and body, but few of them studied body sway during electrifying the head. Galvanic nystagmus is relatively easier to observe as far as the examiner is concerned, but it will be needed the electric current over 4–5 mA to cause nystagmus, so it will ache much at the part of the electrodes applied and it will give the test subjects so much discomfort. On the contrary, weaker electric current is enough to cause body-sway, so it does not give any pain to the subjects. However, there is some difficulty in differentiate between the natural body sway and "the induced" body sway during observation. To avoid this shortage, the author has devised the method to make it easy to analyse proper body-sway (head-sway) during electrifying with the accelerometers and with the medical data processing computer. It will also show the head movement in pattern.

In this paper, the author reported the method and the results in normal subjects, and made some discussion on the findings.

METHOD AND MATERIAL

I. Test subjects

Japanese healthy adults (age 18–25 years old, 20 male, 20 female) those who presenting no history of desequilibrium, hearing impairment or other otoneurological symptoms were examined.

II. Instruments

As shown in photograph (Fig. 1) and block diagram (Fig. 2), the instru-

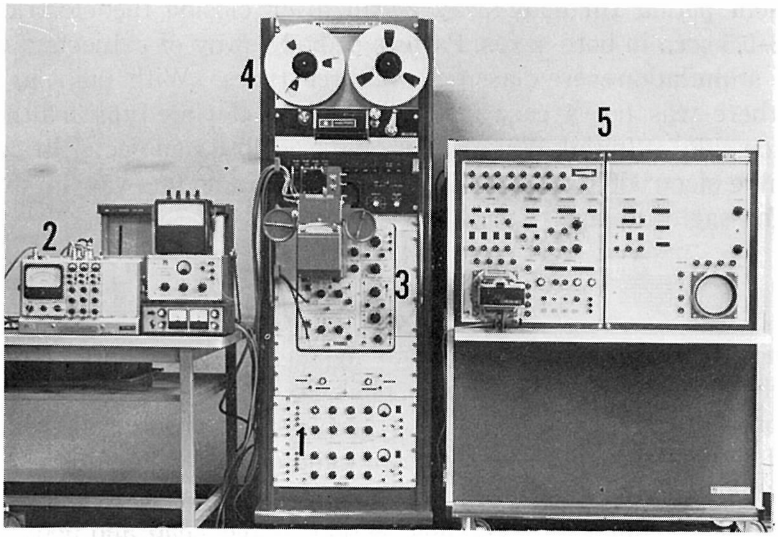

Fig. 1 Stimulating and recording apparatus. 1) Electronic stimulators, 2) strain meter, 3) oscilloscope, 4) data recorder and 5) medical data processing computer.

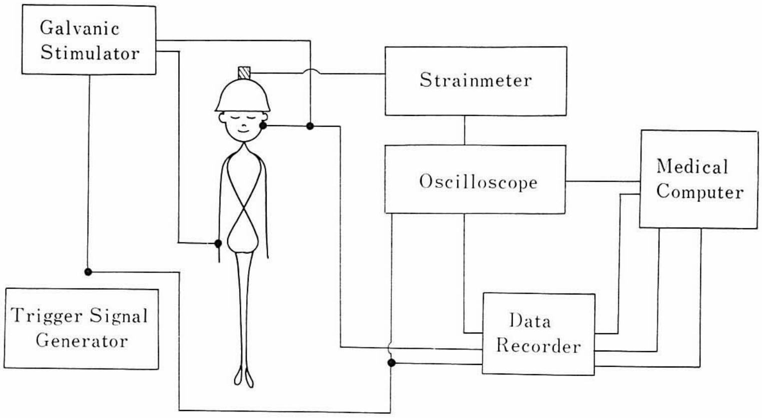

Fig. 2. Block Diagram

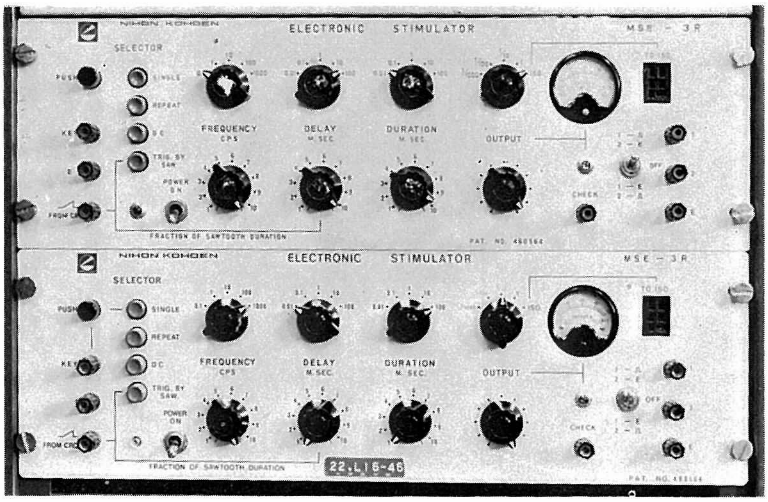

Fig. 3 Two electronic stimulators. The upper one is used as stimulator of electrifying the head and the lower one as generator of trigger signal.

ments consist of 1) electric stimulation system, 2) accelerometer, 3) strain meter, 4) recording instruments, and 5) medical data processing computer. The brief explanations about each of them are the following:

1) Electric stimulation system

i) Stimulating current generator

Two electronic stimulators (NIHON KODEN MSE-3) are used (Fig. 3). One of them is used as generator of trigger signal and another as stimulator of electrifying the head. In other words, we used the first stimulator for the trigger signal at intervals of 25 seconds, triggering the next stimulator and oscilloscope operation. The delay time is set at the next stimulator to cause stimulating current in one second after trigger's operation. The electric current caused by each stimulator were recorded to the data-recorder as well as the signals of head-sway response.

ii) Electrodes

Stimulating electrodes are 3×3 cm in size made of silver, which are fixed with a rubber band at the skin of postauricular area on both sides (Fig. 4) and indifferent electrode which is ordinary used for electrocardiogram is fixed at the contralateral forearm. Each electrode was soaked in the saturated saline solution and set at the each proper place. In this way resistance between the stimulating and indifferent electrodes was in 3–5 KΩ.

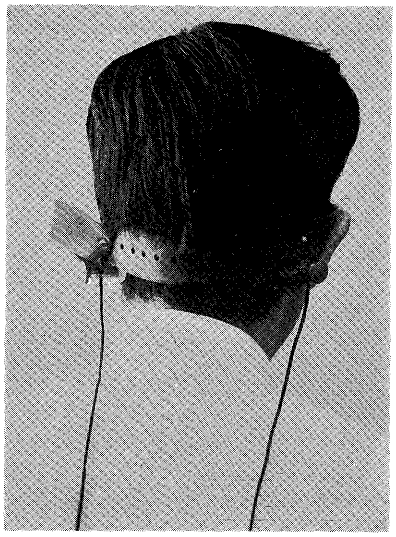

Fig. 4 Stimulating electrodes fixed with a rubber band on the skin of post-auricular area on both sides.

2) Accelerometers

Two sets of small accelerometer (KYOWA DENGYO AS-1C) were used. Mechanical characteristics of them are shown in Table 1. These are fixed on the top of a light weight helmet (Fig. 5), making its direction of operation in transverse and sagittal plane of the head. Then, this helmet is put on the subject's head and fastened firmly with a chin strap, which makes it possible to record the acceleration in the directions of transverse and sagital planes, simultaneously.

Table 1.
Mechanical characteristics of the accelerometer

Model	AS-1C
Capacity	1g
Frequency Range	0-57Hz
Input & Output Resistance	Input 121.7 Ohm
	Output 121.7 Ohm
Sensitivity	F.S. 0.4605 mV/V (Strain 921×10^{-6})
Non-linearity	1.0%F.S.

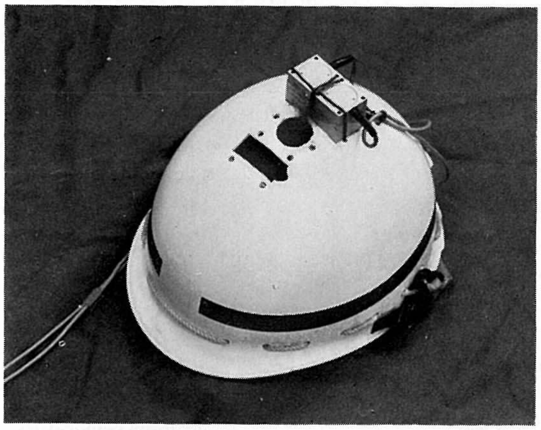

Fig. 5 Two accelerometers fixed on the top of a helmet.

Table 2.
Mechanical Characteristics of the dynamic strain amplifier

Model	DPM-3AT
Input Resistance	60-1000 Ohm
Sensitivity	3mA/100×10^{-6} strain (load 7 Ohm) 3V/100×10^{-6} strain (load 500 K Ohm)
Output	Linearity 1% ±15 mA (load 7 Ohm) Linearity 1% ±10V (load 500 K Ohm)
Frequency Range	0-1000 Hz
Bridge Voltage	2V

3) Strain meter

Two compact dynamic strain meters (KYOWA DENGYO DPM-3AT) were used. Their mechanical characteristics was shown in Table 2.

4) Observation and recording

The author observed the out-put from the strain meter with oscilloscope (NIHON KODEN VC-7), and simultaneously recorded it in the magnetic recording tape with four channel data-recorder (NIHON KODEN DTR-1204). As the condition of the recording, the author set the wave of the oscilloscope to move upwards when the head leans toward right, downwards when it does left; on the same way, upward deflection means the head moved backward, and downward deflection on forwards, respectively.

Table 3.
Main mechanical characteristics of Medical Data Processing Computer [ATAC-501-20]. (See the references)

1. Programs:
   - a) AVERAGE
   - b) MEMOSCOPE
   - c) TIME HISTOGRAM
     - NON-SEQUENTIAL: INTERVAL; DISTRIBUTION; DWELL; LATENCY
     - SEQUENTIAL: INTERVAL; DISTRIBUTION; DWELL; LATENCY
   - d) P.H.A HISTOGRAM
     - P.H.A (Pulse Height Analysis)
     - AMPLITUDE HISTOGRAM
   - e) TRANSFER
     - TRANSFER
     - RUNNING AVERAGE
     - INTEGRATION
     - DIFFERENTION
   - f) CORRELATION
     - PULSE: AUTO; CROSS
     - ANALOG: AUTO; CROSS
     - ANALOG-PULSE CROSS CORRELATION
2. Number of Inputs
   - In Averaging and Memory Scope
     - a) One Input: 1,024 Addr./Input
     - b) Two Inputs: 512 Addr./Input
     - c) Four Inputs: 256 Addr./Input
   - In Histogram
     - Max. 512 Adress (One input only)
3. Input:
   0.5 Vp-p to 50 Vp-p, with attenuator and fine control.
4. Memory Capacity:
   2^{16} counts (65536 counts) per adress.
5. Vertical Range:
   2^4 to 2^{16} (13 steps)
6. Analysis Time:
   20 μsec to 40 m sec per adress and EXT. (total 12 steps)
7. Trigger Generator:
   - a) TRIG. MODE: MANUAL; EXT; INT; RECUR.; AUTO (total 5 modes).
   - b) INT.--- 0.1 sec to 100 sec. (continuous variable).
   - c) TRIG. OUT---PROMPT and 16 addr.
8. Counter: (4 digits with indicating tubes)
   - a) Spike and sweep number
   - b) Preset system
   - c) Time check system of start delay and stop delay.

8\. Output:
   Both analog and digital.

9\. Output Indicator:
   5 inch CRT Oscilloscope (built-in)

10\. Input Indicator:
   5 inch CRT Oscilloscope (built-in)

5) Data Analysis

A medical data processing computer (NIHON KODEN ATAC-501-20) was used. Its mechanical characteristics was shown in Table 3. As the condition of instrument, program of computer are set for calucu!ating average of each component of head movements, of which the first channel for the transverse component and the second for the sagittal component of head movement. One of the remaining channels is used for marker of stimulation. In this program, the address number of each channel will be 256. Of the computer's calibration, the input power is arranged so that 150×10^{-6} strain becomes four graduations on Brown tube screen. Trigger mode is set on EXT, and is prepared to begin work at the trigger sign recorded in the magnetic recording tape of data-recorder. In this procedure, average data was obtained from the eight trials. It is known that the averaging times is more, the better results obtained. Because it takes relatively long time of about 25 seconds for one recording of this galvanic test, the author chose the program of eight times addition for lessening the fatigue of the test subjects. So it takes about three minutes to finish the test for each person.

III. Posture during Test

The test subjects are always required to stand upright on both feet closed side by side, with his arms at his side, and to keep his eyes closed. As mentioned before, it will take about three minutes for one series of eight times stimulations, so the author arranged to give the rest of five minutes at least for person, who sitting on the chair after every examination.

RESULTS

The author obtained the average results of 40 healthy subjects with the medical data processing computer, showing as the follows. And Fig. 6-a showed the original wave of the representative example on oscilloscope and Fig. 6-b is the averaged pattern from Fig. 6-a.

I. Body-sway during electrifying through the unipolar test

1) Latent period till the first head sway begins after closing the electric circuit

A certain length of latent period is observed till the head sway occurred after closing the electric circuit (Fig. 7 Interval between (a)-(b)). The results showed that 0.1 sec. of latent period is seen as the shortest response, and 0.8 sec. the longest, and the 0.2 sec. $-$0.5 sec. are seen in most of the test subjects (Fig. 8).

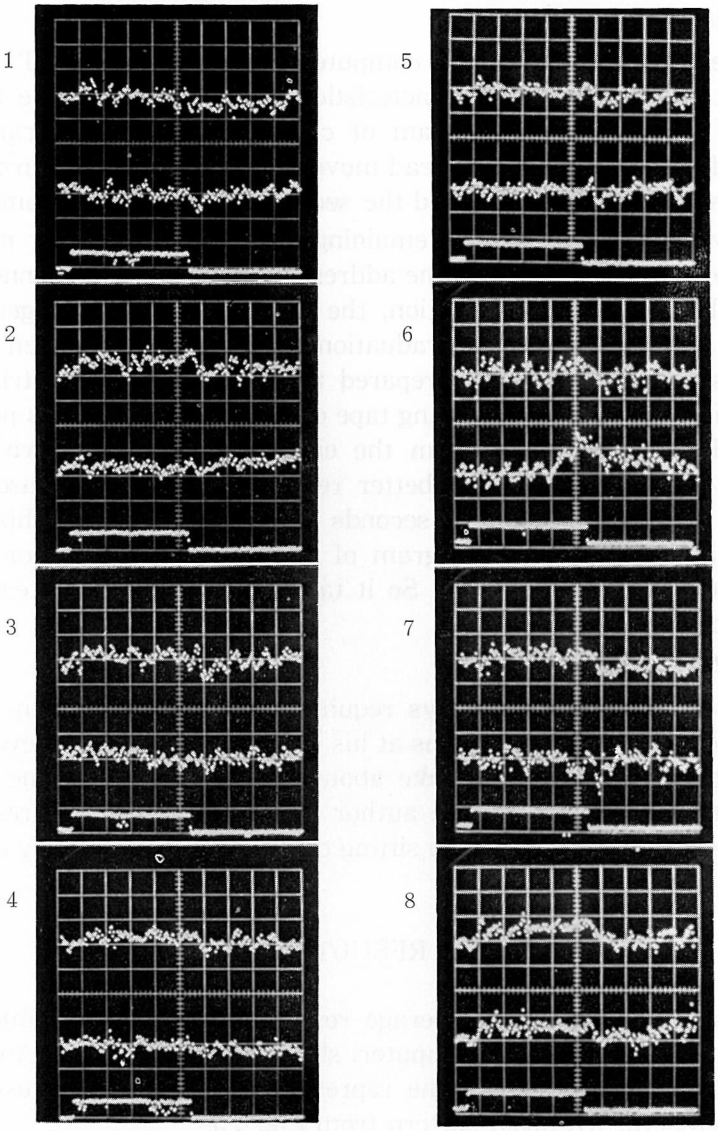

Fig. 6-a The pictures (1-8) are the factual wave of head movement in each anodal stimulation to the right sided ear of the same subject. Each wave shows different head movement in spite of same stimulation.

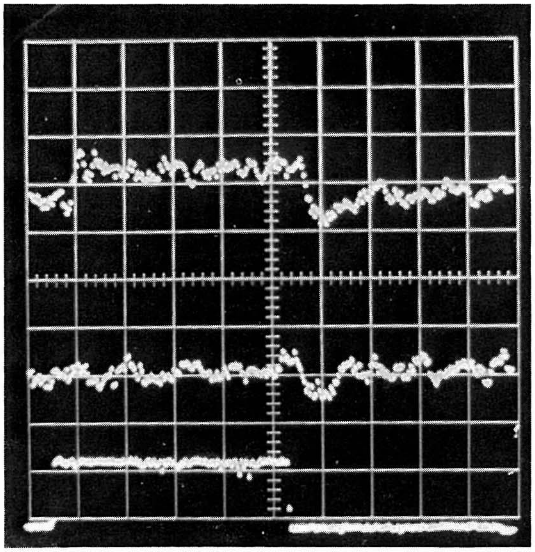

Fig. 6-b The averaged wave of the eight traces of Fig. 6-a using a medical data processing computer.

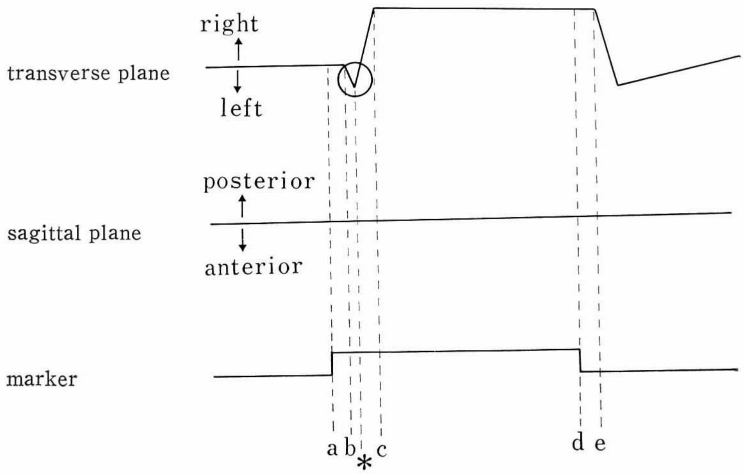

Fig. 7. The Wave Patterned of Fig. 6

The point closing of the electric circuit (a), starting of head sway (b), stabilizing of head sway (c), opening of the electric circuit (d), starting of head sway (e), and "Initial wave" (*)

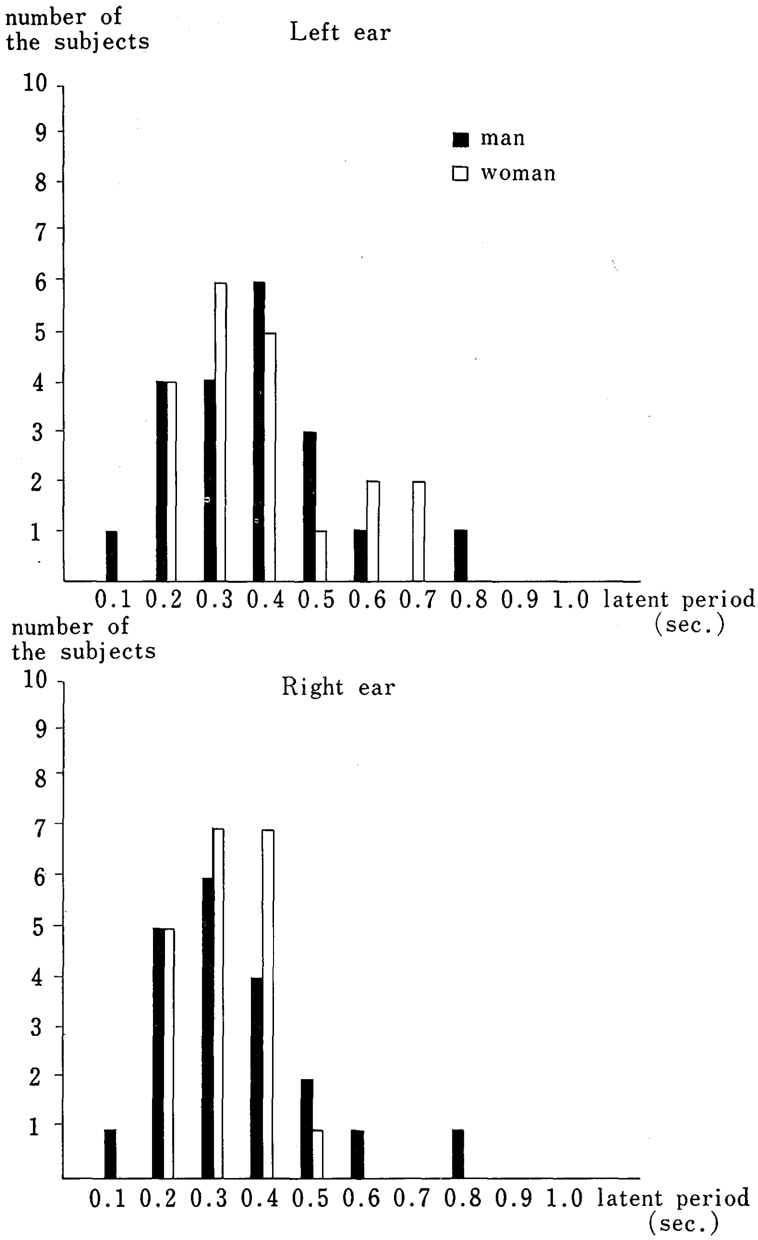

Fig. 8. The latent period till the first head-sway begins after closing the elctric circuit

2) Head position during electrifying

As mentioned before, after a certain latent period after closing the electric circuit, the head rapidly deviates definitely toward the side of stimulation (Fig. 7 Interval between (b)-(c)). The period until being steady once again after this rapid deviation is 1.0 sec. as the shortest recovery, and 3.0 sec. as the longest recovery. However, any constancy was not observed because there were so many variation. As the result of analyzing the pattern of head deviation following after the head-sway is stabilized, those patterns are generally classified in the following three types as indicated in Fig. 9. Namely the first is the type which regains the head position gradually after reaching the stabilizing point (Type A). The second is the type which keeps almost the same position of the stabilizing point (Type B). The third is the type which leans further towards the side of stimulation than the stabilizing point (Type C). Results are classified based on the pattern expression (Table 4). First, the case which show the same type on each ear is 33 subjects out of 40. The contents are 12 Type A

Table 4.
Classified results based on the pattern

Same type on each ear stimulation		33 subjects
Type A on each ear		12
male	8	
female	4	
Type B on each ear		17
male	4	
female	13	
Type C on each ear		4
male	3	
female	1	
Different type on each ear stimulation		7 subjects
Type A on one ear and Type B on another		5
male	4	
female	1	
Type B on one ear and Type C on another		1
male	0	
femal	1	
Type A on one ear and Type C on another		1
male	1	
female	0	

subjects (male 8, female 4), 17 Type B subjects (male 4, female 13), and 4 Type C subjects (male 3, female 1). From the general aspect, the samples which are classified in Type B are the majority in number. From the sexual standpoint of view, Type A subjects are mostly seen in the male's group and Type B in the female's. Next, the samples which show the different types on each ear are 7 out of 40, and the contents are 5 subjects with one ear Type A and the other Type B (male 4, female 1), 1 subject

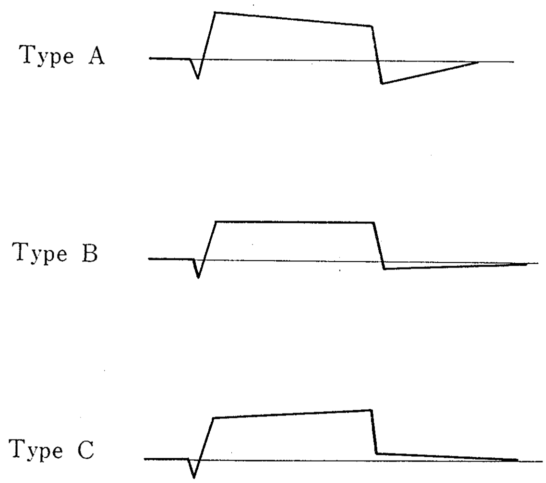

Fig. 9. Head deviation following after the head-sway is stabilized, those patterns are generally classified in the following three types. The first is the type which regains the head position gradually after reaching the stabilizing point (Type A). The second is the type which keeps almost the same position of the stabilizing point (Type B). The third is the type which leans further towards the side of stimulation than the stabilizing point (Type C).

Table 5.
Results of "Initial wave"

Observed on each ear stimulation		19 subjects
male	8	
female	11	
Observed on only one ear stimulation		14
male	7	
female	7	
Not observed on any ear stimulation		7
male	5	
female	2	
		40 subjects

with one ear Type B and the other Type C (male 0, female 1), and 1 subject with one ear Type A and the other Type C (male 1, female 0). So the cases which show Type A one ear and Type B on the other are observed in high percentage. According to these results, it is noticed that most of the normal person show Type A and B, and the person who show Type C is very rare. And besides, any regularity about the head-sway in sagital directions was not particularly recognized in this experiment.

3) "Initial wave"

Shortly before the definite deviation towards the stimulation side after starting electric stimulation, there was a rapid and little head-sway to the non-stimulation side (Fig. 7) in many subjects. Sekitani[25] recognized the same finding in his experimnte and named it as "Initial wave". Among the test subjects in this experiment (Table 5), persons who were observed to have "Initial wave" on each ear stimulation are 19 out of 40 (male 8, female 11), and the ones who were observed to have it on only one ear are 14 (male 7, female 7), and the ones who were not recognized to have it on any ear are 7 (male 5, female 2). These result suggested that the "Initial wave" is more frequently seen among the normal person and particularly among the female.

II. Head-sway after opening the electric circuit through unipolar test

1) Latent period till post-stimulatory head-sway begins

At a certain length of latent time after finishing electrifying the head, the head-sway begins toward the non-stimulation side (Fig. 7 between (d)-(e)). This latent period is 0.4 sec. in the shortest one and 1.0 sec. in the longes one, but the 0.5-0.8 sec. are seen in most of the test subjects. Besides it suggested that male has a little longer latent period than female (Fig. 10).

2) Head position after opening the electric circuit

As shown in Fig. 7, at a certain length of latent period after finishing electrifying, the head inclines rapidly to the non-stimulation side. The response patterns were also classified in 3 Types. In case of Type A, the head deviates markedly to the opposite side and then gradually regains the head position as it was before electrifying, and in case of Type B, the head deviates a little to the non-stimulation side, but in the cases of Type C it rarely deviates to the opposite side, but returns to the head position before electrifying smoothly. And in this case, the regularity of the head-sway in sagittal plane was not recognized.

III. Head-sway during double-electrode test

In this experiment, any regularity of the head-sway was not recognized in the transverse and sagittal planes through the double electrode test in

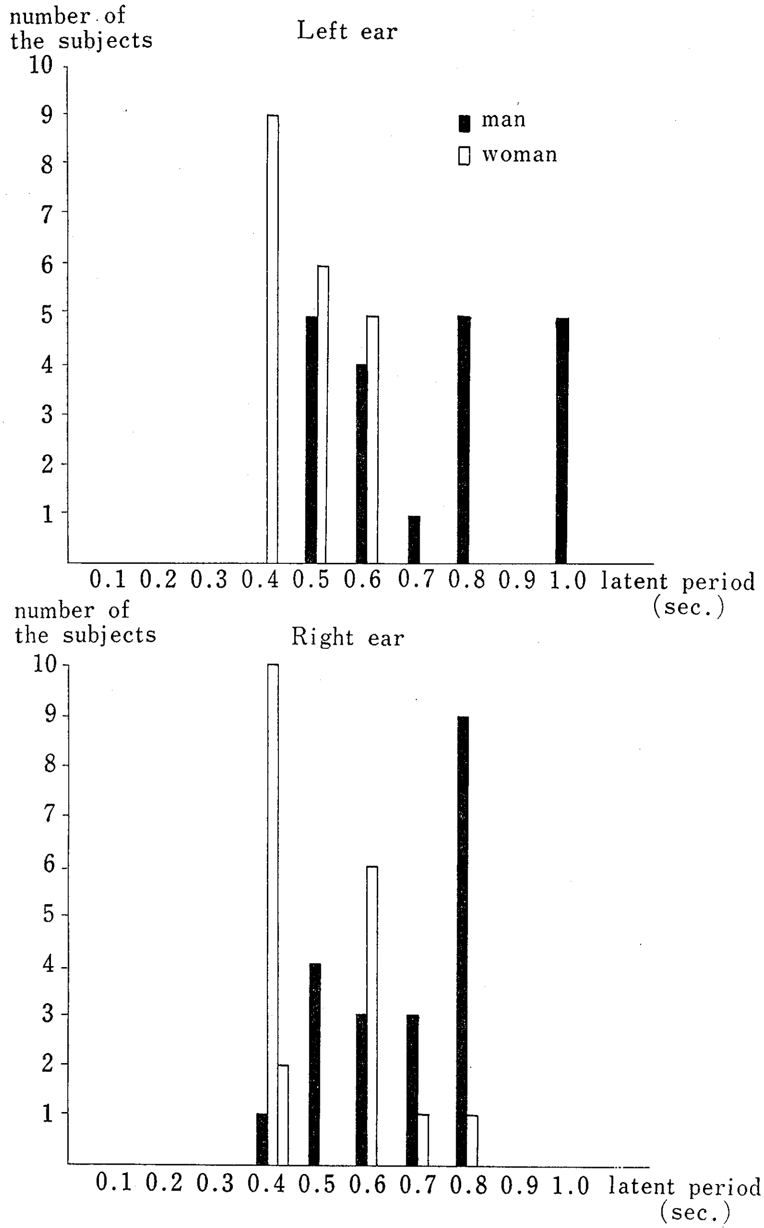

Fig. 10. The latent period till post-stimulatory head-sway begins after opening the electric circuit.

all subjects, although the head has shown little sway. This supports the opinion told so far that if there is no difference between left and right of inner ear response, the head-sway does not occur.

DISCUSSION

According to the literature on this phenomenon, it is well known that Volta was the first reporter to mention about vertigo induced by electrifying a head in 1792. Further, in 1803, Ritter, Augustin and others had developed and published their own studies, respectively, about performing "electrotherapy" to the various diseases and causing vertigo by electrifying a head at that time[2]. In 1871, Hitzig[1] observed and reported that the nystagmus was induced from electrifying a head. According to Fischer[3], it is said that since Neumann (1907) used first the Galvanic test clinically, Barany (1907), Mackenzie (1917), Ruttin (1926), Brunings (1911) and others have reported their studies about it. In Japan, there were some physiological, pathological, experimental, or clinical studies by Ishihara[4](1917), Minami[5](1931), Koide[6] (1931), and Nara[7] (1934). Ever since, there are many fundamental experiment and clinical observation studies about galvanic reaction, but recently the report in this field is unexpectedly rare.

Up to the present time, there were many researchers observing nystagmus induced by the electric stimulation. For example, in foreign countries there were several reports by Ingelstedt & Walander[8] (1949), Richter & Pfaltz[9](1958), Peitersen & Zilstorff-Pedersen[1] (1963) and Pfaltz & Koike[10](1968), and in Japan the reports by Mashida[11](1960), Hozawa[12] (1961), Fukuda[13](1962), Utsumi[14](1963), and Tokita[15](1967) were available. There were less researchers to do experiments with the observing point of vestibulospinal reflex and some of the studies were reported. That is, Barany[16](1907) and Quix[17](1926) made the deviation of Past pointing test by galvanic stimulation and the condition of falling on "balance board" by Blonder[18](1937), and Dix and others[19](1949) observed the sway to the anodal side in case of galvanic stimulation and made it observing point. Besides, the reports of Peitersen & Zilstorff-Pedersen[1](1963) and Coats[20] (1969) [21](1973) are seen. In Japan, Mashida[11](1960) reported about falling reaction at Mann's posture, deviation in writing test and in stepping test. And Suzuki[22] (1961) applied the electric stimulation to the labyrinth of rabbit and reported about the head deviation and change in E.M.G. of muscles of the neck.

Since Kitahara[23](1959) first reported in Japan about the method for recording body movement using with accelerometer, several studies were done for body equilibrium. Honjo[24](1964) introduced the method to record and analyse the head-sway during electric stimulation with the use of an accelerometer and in his laboratory Sekitani[25](1965) reported on Galvanogram based on the results obtained from the experiment and also Matsumoto[26] (1970) reported the results recorded and analysed from the patient with vertigo according to similar method. Furthermore, Honjo[27] (1970) used high-speed cinecamera to record the head sway during galvanic test, and observed and analysed, and then compared the results through unipolar, bipolar and double electrode test.

In this way, the qualitative and quantitative method to record the head-sway caused by galvanic stimulation has been developed. However, there is some actual difficulty during the test in differentiation between an ordinary head oscilation of the human body and the induced head-sway by galvanic stimulation. Accordingly, author devised the method to magnify and detect only the induced body-sway from averaging using with a medical data processing computer[28].

Author will discuss on the following points:

I. Head position during galvanic stimulation

A latent period before the head sway induced by galvanic stimulation was observed. The time of the latent period ranged from 0.2 to 0.5 second in this experiment. It is thought to be the time to transmit with in the reflex system till the reaction influence to the muscle after stimulation. Immediately following this latent period, the head is inclined markedly toward the stimulated side. Thus, in the present study there are many cases which the head once inclined a little toward the non-stimulation side and then, markedly toward the stimulation side. This was thought to be the same phenomenon which Sekitani[25] noticed in his studies and named it "Initial wave". Tokita[19] studied galvanic nystagmus and suggested that the phenomenon of the electrical excitation and the change of electrotonus would be speculated to explaine the galvanic phenomenon in the vestibular nervous system. If this fact is supposed to be appliciable to vestibulo-spinal reflex, author can guess that "Initial wave" is caused by electric stimulation, and the remarkable deviation of head arised next is caused by electrotonus. By the way, the head positions during electrifying in this study are classified into three types, and especially the cases of Type A and Type B are mostly seen. It is not clear only with the present observations why they show such different types, but the following speculation will be made. The subject's 1) statokinetic reflex, 2) accommodation or habituation to electric stimulation, 3) a slight increase or decrease of the stimulation electric current by the change of resistance between the skin and electrode. Concerning to the third point mentioned above, we measured and correct the current during each test observing with precise currentmeter, but strictly speaking it may become a problem because it revealed unstable currency through the skin. And yet, there is no case of the head-sway toward the non-stimulation side during electrifying, and this fact coincides with many of the results by various authors. And any regularity was not especially recognized in this experiment about the sway in sagittal plane. According to this author's preliminary study applying some different strength of electric current, the sway of the head in sagittal plane was recognized clearly when it was over 0.8–1.0 mA, but not clearly when it was less than that. As the strength of the electric current used in this study was rather weak, that is 0.6 mA, any regularity was supposed not to be recognized. And according to the results through the double electrode test, any regularity in right and left and sagittal plane was not recognized at all. This fact coincides well with the results of many authors. The author emphasized in the previous study[29] using with the double galvanic test thet the necessity of applying the accurate electrical current to both ears without any fault, because there are some cases showing considerable difference of the right and left resistance between the skin and the electrode. The author also admitted clearly this phenomenon. And considering that point in this study, author got the results mentioned above from normal human.

II. Head position after galvanic stimulation

A latent period is also recognized before beginning a head-sway after opening the electric circuit. In this condition the latent period is 0.4–1.0 sec., which is a little longer than the one after closing the electric circuit, and in most of the cases they showed 0.5–0.8 sec. And this fact coincides well with one which the author has reported in the previous paper. After this latent period, the head returns rapidly to the position as it was before closing the electric circuit. As mentioned before, in Type A, it deviates once toward the non-stimulation side, and then returns gradually to the position of the beginning, in Type B, it deviates a little to the non-stimulation side, and in Type C, no case of its deviating is reognized to the non-stimulation side. It is supposed that the head position at the time of finishing electrifying has much affection on the following post-stimulatory head position and it will also affect to the strength of electric stimulation at the end point. In this occasion, any regualrity was not observed in the sway in the sagittal plane and through the double electrode test.

As mentioned above, a regularity of body-sway in normal subjects is recognized and in some ill cases considering the regularity in mind, it can be a testing method to use for the purpose of differential diagnosis of diseases. But it is absolutely impossible to make a complete conclusion from only with the present findings on the mechanism of this regularity can be observed. Further investigation will be clarify the question.

CONCLUSION

The body-head sway induced by galvanic stimulation with unipolar electrode and with the double electrode test was recorded and analyzed by means of accerellogram and a medical data processing computer. The following results were obtained from 40 healthy human adults.

1. The latent period of head-sway after closing the electric circuit was 0.2–0.5 sec., in both male and female.

2. Accerello-resistrogram of the body-sway during galvanic stimulation were recorded and these patterns were divided into three types, which were called as Type A, Type B, and Type C. Type A were mostly seen in male,s cases and Type B were mostly seen in female's cases. Most of the normal subject showed the same Type in both sides.

3. Deviation and leaning of the body-head to the stimulation side during unipolar stimulation was observed in all subjects.

4. Thirty three cases in the 40 showed a rapid and little head-sway to the non-stimulated side, so-called "Initial wave".

5. The latent period till head-sway began after opening the electric circuit was 0.5–0.8 sec..

6. Through the double electrode test, any regularity of body-sway in the transverse and sagittal plane was not observed.

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