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DYNAMIC MEASUREMENT OF WALKING POSTURE WITH BODY INCLINATION AND LANDING IMPACT

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Abstract: People have the body inclination in motion everyday life, but it is difficult to know it. Unbalance of body caused various problems to the body. In order to aware of the body inclination, the measurement of the dynamic physiology parameter in motion is required. The body area network system is very effective measurement system to monitor the body inclination dynamically. This paper shows the system construction and measurement results.

Keywords: body inclination, landing impact, body area network, dynamic measurement

1. INTRODUCTION

Almost all persons have the distortion of a posture in their daily life, but it is difficult to find it. If the distortion of a posture is not corrected, a hip joint, a pelvis, and the spinal column are distorted. As a result, the stiffness of the shoulders, lumbago and an ache in the knees, and the worst, a nervous system also influenced, in addition a slipped disk is caused. In order to prevent this, it is necessary to aware of inclination of the body and the load to the body, and to correct them. The purpose of this system is that to correct inclination of the body and reduce the load to the body by observing the dynamic physiology parameter under movement in everyday life.

2. SYSTEM CONFIGURATION

The Body Area Network (BAN) system has 5 sensor modules; shoulder, wrist, waist and both ankles. Each module has processors that permit to converts, process and send to the main module by wireless network as Fig.1.

BAN system measures a subject's various living body parameters by each module, and repeats the judgment of a state and advice by it. Then, if the serious abnormalities for a subject occur, the others –for example, a doctor and a family – can know it through a cell phone in real time automatically.

In order to measure the body distortion and landing impact, three sensors; waist and both ankles are used. Three sensors have PIC, 3-axis accelerometer and X-Bee. Fig.2 shows the axis structure of accelerometer.

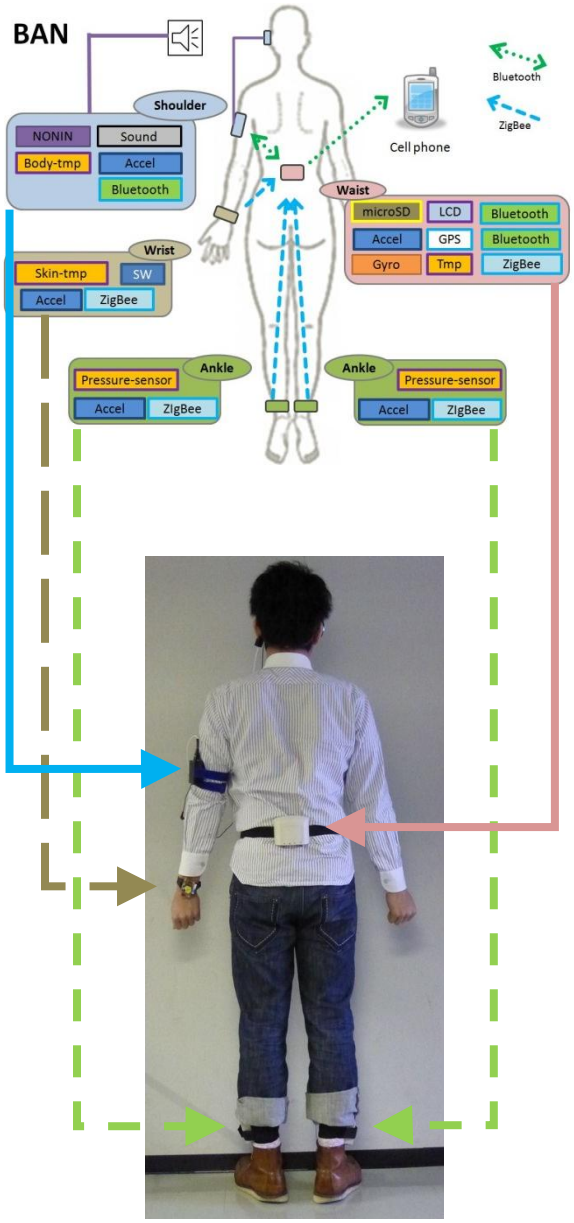


Fig.1 Outline of Body Area Network system

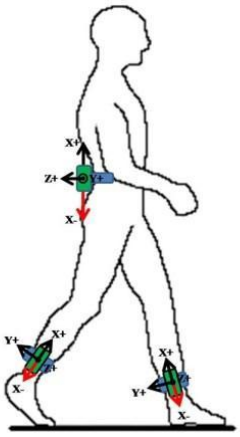


Fig.2 Axis structure

Two foot-sensors measure the size of the landing impact at ankles in walking, and the data got by two foot-sensors are sent to main module by X-Bee, and the data and a data got by main module are written in microSD. Each data are got at 50 Hz by PIC and written.

Since transmission of the data between each module can carry out on wireless and also the module is comparatively small, it is possible to acquire the dynamic parameter in everyday life.

3. ANALYSIS METHOD

3.1 Analysis method

The distortion of the body and the landing impact are computed from the acceleration data obtained by the module.

The distortion of the body is computed by calculating the average value of the wave of a definite period of time. The wave is a waveform of Y-axis acceleration passed in a low-pass filter. Gap of a bodily central axis and the central axis of deflection is considered as distortion of the body as shown in a Fig.3.

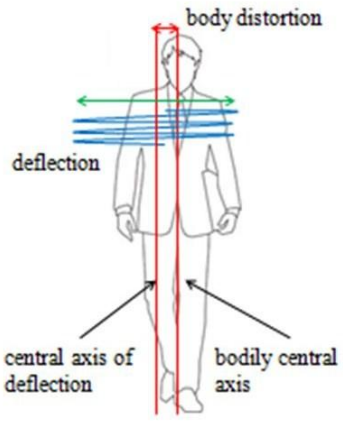


Fig.3 Body distortion in walking

The landing impact is by calculating the average value of the wave of a definite period of time. The wave is a waveform of the synthetic value of X and Y-axis acceleration passed in a band-pass filter.

3.2 Verification experiment of body distortion

The usefulness of this system was verified by experiment with Treadmill and sandals processed as shown in a Fig.4 and Fig.5. The body leans to the right by the sandals.

Fig.4 Treadmill used for the experiment

Fig.5 Verification experiment of body distortion

Fig.6 is a measurement result when walk for 3 minutes at 4 km/h on a Treadmill. The 10-second average of acceleration is shown.

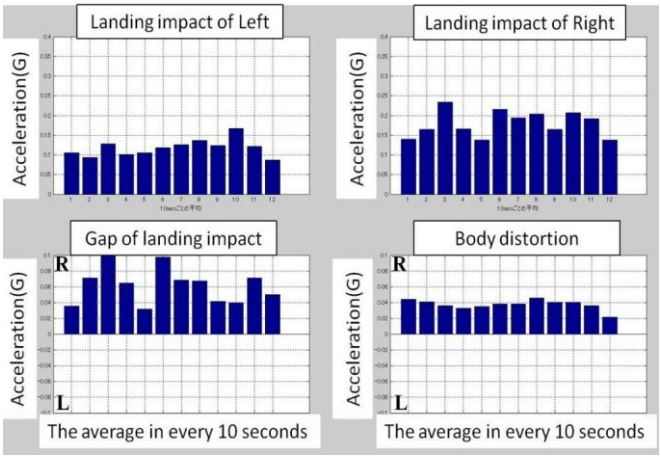


Fig.6 Measurement result of experiment of distortion

This figure shows that the body distorted to the right and the load concerning a right leg is larger than a left leg.

The usefulness of this system was proved from the experimental result.

3.3 Judgment of the tendency of distortion

The tendency and degree of distortion of the body are judged from a measurement result. It decided to judge the tendency of distortion as Fig.7 and Table1.

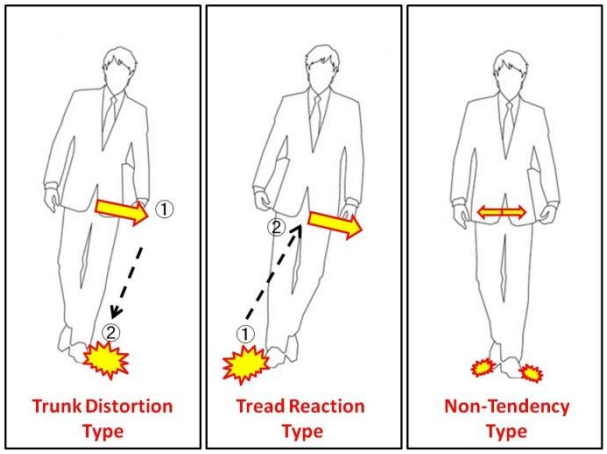


Fig.7 3-tendency type

Table1 Tendency of distortion

Body Distortion / Landing Impact	Right	Left
Right	Trunk Distortion Type	Tread Reaction Type
Left	Tread Reaction Type	Trunk Distortion Type

In this system, the tendency of distortion is judged from Table1. The case the body is distorted to the same side of a leg with a greater landing impact is set to "Trunk Distortion Type". And the case the body is distorted to the reverse side of a leg with a greater landing impact is set to "Tread Reaction Type". This can be judged easily by using the mark of the product of Body distortion and Landing impact.

The degree of the whole tendency is computed as shown in Eq. (3).

X=Number of division of TDT or TRT (1)

Y=Number of whole division (2)

("TDT" means Trunk Distortion Type and "TRT" means Tread Reaction Type.)

$$\text{Degree of the tendency} = \frac{X}{Y} \times 100[\%] \quad (3)$$

When the rate of TDT in degree of the whole tendency is not less than 60%, it is judged with the distortion tendency of a walking posture is "Trunk Distortion Type".

When the rate of TRT in degree of the whole tendency is not less than 60%, it is judged with the distortion tendency of a walking posture is "Tread Reaction Type".

When the degree of the whole tendency is not less than 40% and 60% or less, it judges with Non- Tendency Type.

This system takes out a judgment result according to the following flow chart as Fig.8.

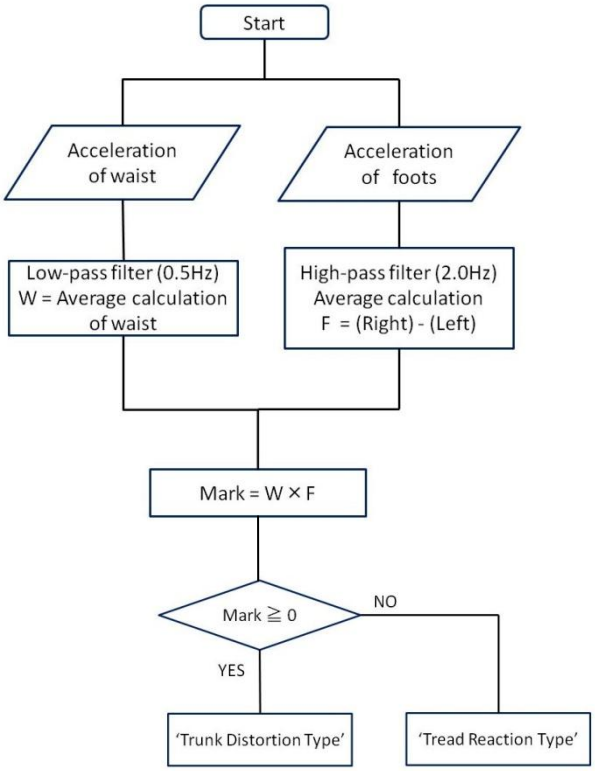


Fig.8 Flow chart of judgment of the tendency

3.4 Verification experiment of body inclination]

The usefulness of this system was verified by experiment with the Kinect for Xbox 360 (Microsoft) as shown in a Fig.9 and Fig10.

In this experiment, inclination of the upper half of body in walking is mainly seen and the relationship of the body distortion and the body inclination is investigated.

Fig.9 Kinect used for the experiment

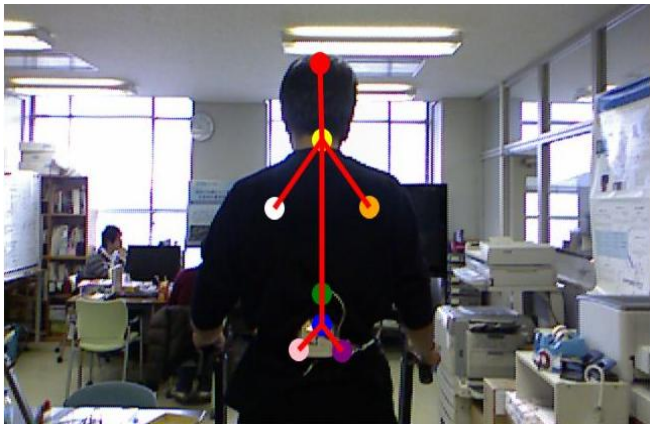
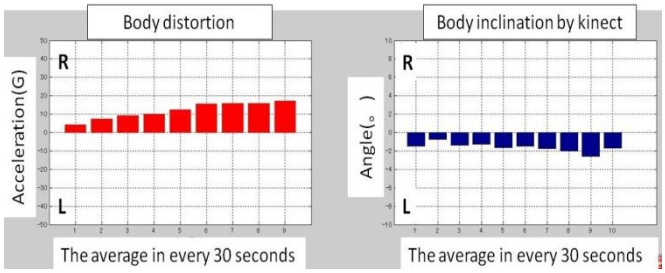


Fig.10 Verification experiment of body inclination

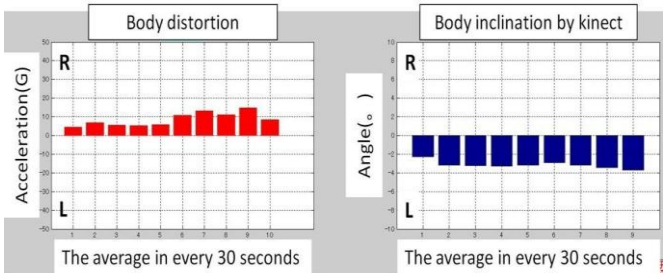
Fig.11 and Fig.12 is a measurement result when walk for 5 minutes at 4 km/h on a Treadmill. The 30-second average of body inclination by the kinect is shown. Subjects have worn normal shoes.

The body inclination is the angle of inclination of a yellow point and a green point of fig.6 and inclination of a state of rest is set to 0[°].



(Subject a – Male, Age 23)

Fig.11 Measurement result of subject a



(Subject b – Male, Age 22)

Fig.12 Measurement result of subject b

Two figures show that the axis of waist is distorted on the right from the center of body, and the posture leans to the left. It means that when the bodily center of gravity is distorted, the upper half of the body inclines to the counter direction of a body distortion, in order to maintain balance.

4. MEASUREMENT OF BODY DISTORTION

4.1 Measuring method

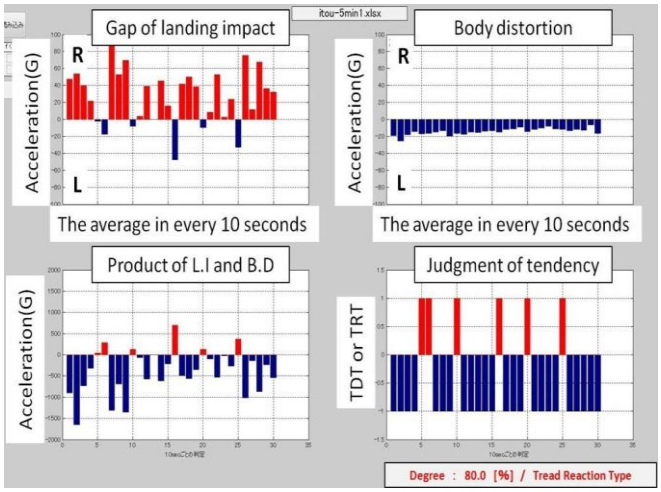
3-sensor modules are fixed to the waist and legs with a belt. Walk for 5 minutes at 4 km/h on a Treadmill with normal shoes.

4.2 Measurement result

The processing result of having done average value calculation every 10 seconds is shown below. Judgment of tendency expresses the judgment for every section, a red stick is Trunk Distortion Type and a blue stick is Tread Reaction Type.

4.2.1 Tread Reaction Type

Subject A, B, C, D are Tread Reaction Type. As for them, the body is distorted to the reverse side of a leg with a greater landing impact.

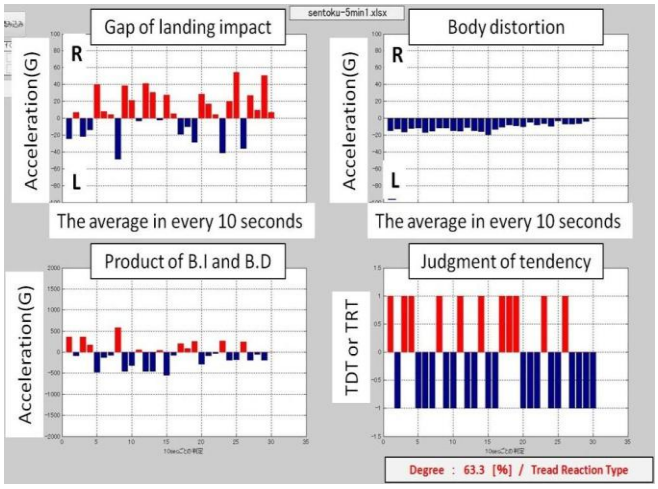


(Subject A – Male, Age 23)

Fig.13 Judgment result of subject A

Fig.13 shows that the burden placed on a right ankle is heavier than a left ankle, and the body leans to the left a little.

It has judged with the tendency of Tread Reaction Type having come out of a system by 80% of strength. The judgment result by a system and the view which looked at the graph is in agreement.

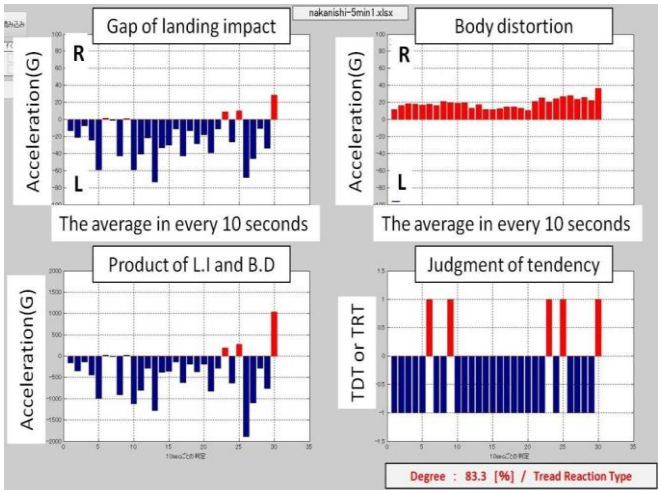


(Subject B – Male, Age 23)

Fig.14 Judgment result of subject B

Fig.14 shows that the burden placed on a right ankle is slightly heavier than a left ankle, and the body leans to the left a little.

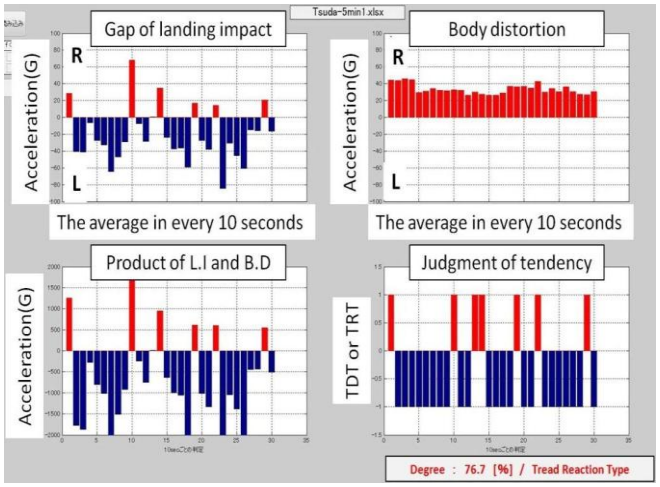
It has judged with the tendency of Tread Reaction Type having come out of a system by 63.3% of strength, but since there is also little deviation of Gap of landing impact and body distortion is also very small, bodily balance has not collapsed greatly in fact. The degree of the whole tendency is not so large.



(Subject C – Male, Age 22)
Fig.15 Judgment result of subject C

Fig.15 shows that the burden placed on a left ankle is heavier than a right ankle, and the body leans to the right.

It has judged with the tendency of Tread Reaction Type having come out of a system by 83.3% of strength. The judgment result by a system and the view which looked at the graph is in agreement.



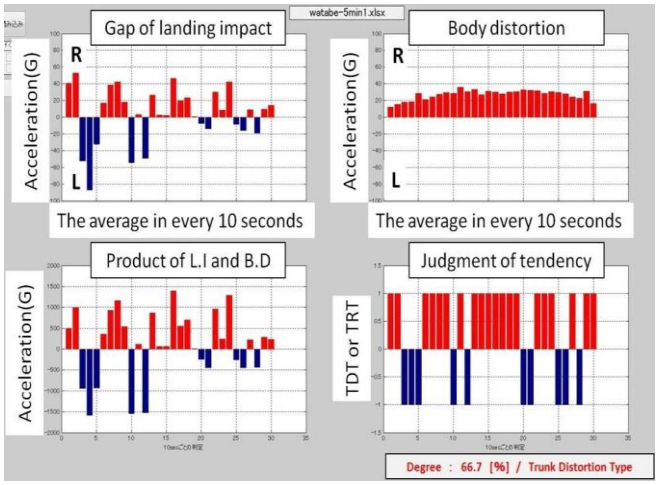
(Subject D – Male, Age 22)
Fig.16 Judgment result of subject D

Fig.16 shows that the burden placed on a left ankle is heavier than a right ankle, and the body leans to the right greatly.

It has judged with the tendency of Tread Reaction Type having come out of a system by 76.7% of strength. The judgment result by a system and the view which looked at the graph is in agreement.

4.2.2 Trunk Distortion Type

The subject E is Trunk Distortion Type. As for him, the body is distorted to the same side of a leg with a greater landing impact.



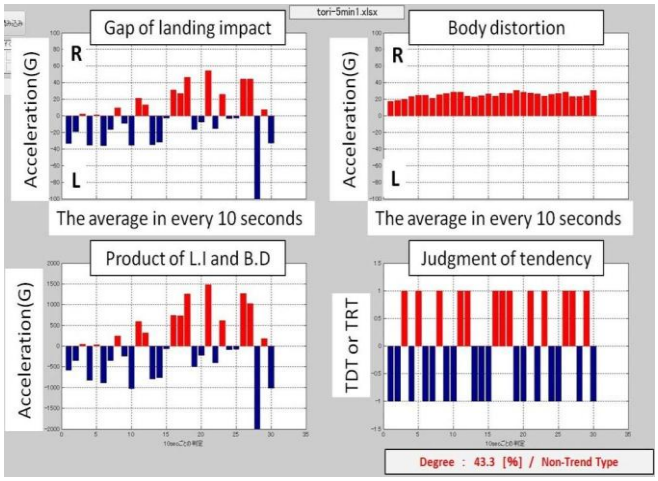
(Subject E – Male, Age 24)
Fig.17 Judgment result of subject E

Fig.17 shows that the burden placed on a right ankle is slightly heavier than a left angle, and the body leans to the right.

It has judged with the tendency of Trunk Distortion Type having come out of a system by 66.7% of strength. The judgment result by a system and the view which looked at the graph is in agreement, but Gap of landing impact is not greatly partial.

4.2.3 Non- Tendency Type

The subject F is Non- Tendency Type. As for him, the tendency has not clarified.



(Subject F – Male, Age 23)
Fig.18 Judgment result of subject F

Fig.18 shows that although the body leans to the right, the burden placed on both ankles is scattering.

It has judged with a system being a Non-Tendency Type. Gap of landing impact seldom inclines toward body distortion having come out clearly. The attitude of the tendency has changed in the portion in the first half a portion and the second half. A longer time test performed, the tendency in a long period of time may come out.

4.3 Gap of landing impact

The tendency of various walking postures was seen by 6 measurement results. The judgment result by a system and the view which looked at the graph is in agreement in general. Gap of landing impact is uneven although Body inclination is stable. There were more subjects of Tread Reaction Type than the subject of Trunk Distortion Type.

5. OTHER FUNCTIONS OF THE BAN SYSTEM

5.1 Measurement of a heart rate

In BAN system, the heart rate in exercise can be measured by the shoulder module. The heart rate and other data can be measured simultaneously as Fig.19. The red line is heart rate. The blue line and green line are accelerations of waist. Signs that the heart rate and the swing of waist are related can be seen. The BAN system grasps the state of the whole body and brings it close to an ideal moving posture by these functions.

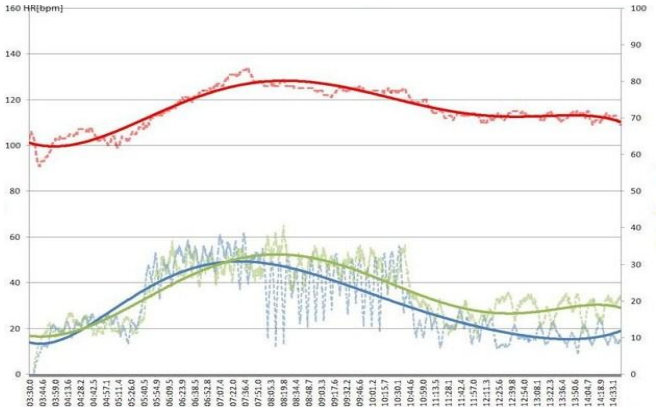


Fig.19 Measurement of a heart rate

5.2 Advice with a voice by sound module

In BAN system, advice with a voice by sound module can be given in real time, in order to perform high quality movement and when telling bodily abnormalities. For example, it can be told when the body swing exceeds a standard value as Fig.20. The green lines are timing out of voice advice has come. The blue line is the body swing. The red line is the standard value. It turns out that the body swing has been intentionally improved by advice.

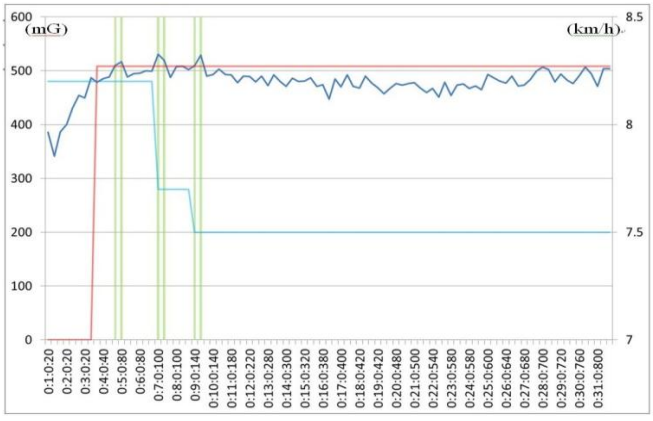


Fig.20 Advice with a voice by sound module

6. CONCLUSION

The usefulness of this system has proved to some extent by some experiments, but this system has some problems. First, since this system is functioning only off-line, it is necessary to improve so that it may function on-line. Next, it is necessary to return the advice for keeping bodily balance from a measurement result to a subject in real time.

Since a dynamic parameter as a big feature of this system can be observed, various verifications which cannot be observed from the data of the time of stillness may be able to be performed. For example, when tiredness arises by walking experiment of long time, the tendency of the body distortion may appear still more notably. About this, it is verifiable by using the data measured by the shoulder module in Fig.1. The heart rate in moving can be measured by the shoulder module as Fig.19.

In addition, when it is going to revise the body distortion in moving, the landing impact placed on ankles may become large. About this, it is verifiable by using the sound module in Fig.1. The body distortion can be made to improve intentionally by giving advice with a voice by sound module as Fig.20.

7. REFERENCES

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