XXI IMEKO World Congress "Measurement in Research and Industry"
August 30 – September 4, 2015, Prague, Czech Republic

AUTONOMOUS WEARABLE SYSTEM TO CARE PHYSICAL CONDITION IN DAIRY ACTIVITY

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Abstract – Walking is a fundamental activity for us in our life. Also, it is a suitable action to estimate the health condition. Most people unconsciously walk in the condition of an unbalance body which might cause a physical trouble to the body. This paper describes the autonomous wearable Body Area Network (BAN) system to care physical condition. By data fusion of various dynamic parameters collected from wearable sensing nodes, system gives suitable advices in terms of feedback information in order to care user's body behaviors.

Keywords: body are network, care system, autonomous system

1. INTRODUCTION

In recent years, quality of life(QOL) is the greatest concern for many people. People hope to maintain and improve their QOL. The elements are various and different for each person. These elements are concerned with the situations of living, health, family, friends, job, money, meal and hobby. In particular, health is the most basic and essential element to improve QOL. In the current health management system, the medical check-up at hospital is mainstream. Accordingly, the medical check-up is not able to monitor health in daily life. In order to maintain the daily health, it is necessary to know human body behaviors and health conditions. The consciousness to these attentions prevents dangerous physical trouble and disease.

In this paper, the wearable BAN system to care physical condition is shown. These days, wearable computer like i-watch is popular to care physical condition and human behavior. They display value of vital signs according to vary physical condition only. Therefore, the way of their improvement is uncertain for user. In comparison, the BAN system can monitor human body behaviors and vital signs, thus providing advices in terms of feedback information to the users. By monitoring and advising, the wearable BAN operates autonomously to care physical condition as a closed system.

2. SYSTEM CONFIGURATION

2.1. Construction of autonomous care system by wearable BAN

Fig.1 shows the construction of autonomous care system by wearable BAN. This system consists of 3 modules; Hub module, Wireless Sensing Node(WSN), Audio/Video Human Interface(AVHI). Functions of these modules are different to each other.

The roles of WSN are sensing, data processing, and data transmission. In this system, each sensing node consists of sensors and microprocessor. They collect the data of human body behavior and vital signs (heart rate, SPO2, skin temperature etc.). These data are processed at each WSN. Then WSN send the parameters to HUB module regularly.

The HUB module takes a role of data receiving, processing and interchange. By data fusion and processing collected parameters, the characteristic of human behavior and physical condition are estimated. The HUB module produces many kinds of advice according to the characteristic and sends them to the user through the Audio/Video Human Interface (AVHI) module.

When AVHI sends advice to human in terms of sound and image, the system does not prevent a human's activity. The user who is monitored by wearable BAN system will be noticed about human body behavior and physical condition in real time. The user is able to act consciously to them and then improve their walking posture. And again, the system senses user's behaviors and physical condition. User and wearable BAN system configure a closed system cooperatively. By the cooperation, the autonomous care system for behaviors and physical condition in daily life is realized. The system enables user to correct behavior in walking autonomously.

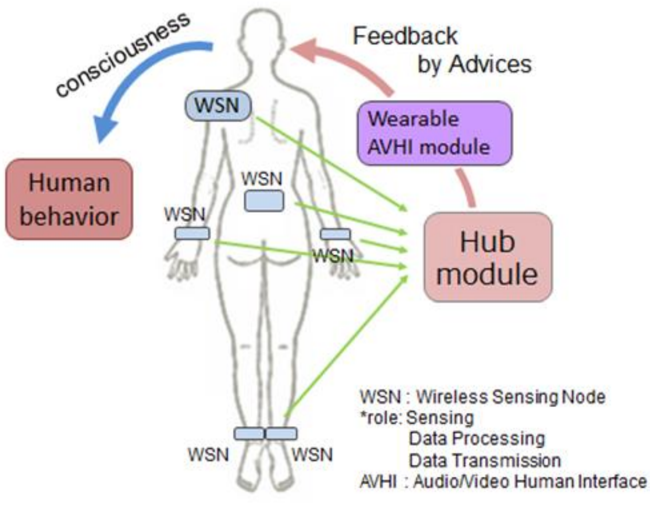

Fig. 1. Autonomous care system by wearable BAN

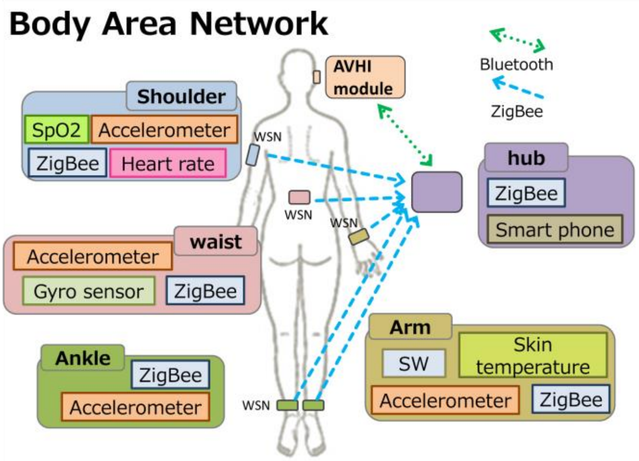

Fig. 2. System Construction

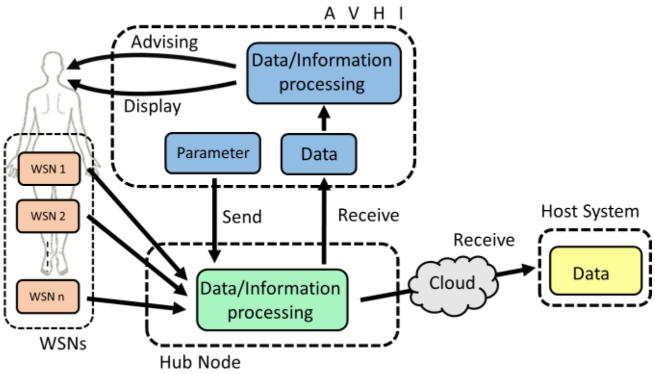

Fig. 3. Function of BAN System

Fig.2 shows the system construction of wearable BAN. The system is constructed with 3 parts; HUB module, WSN and AMHI. Fig.3 shows the function of BAN system. There are several kinds of WSN in the BAN. They are shoulder module, waist module, right/left arm module, right/left ankle module and AVHI. These modules are wearable. Each WSN except AVHI consists of a microprocessor (PIC: Peripheral Interface Controller), a near field communication device (Zigbee) and some sensors. PIC and Zigbee device are present in every modules, but the kinds of sensor are different each other. WSN measures the dynamic data of human behavior (acceleration, rotation, impact etc.) and vital signs by mounted physical sensors. Analyzing the dynamic data, the WSN estimates the characteristic parameters and sends them asynchronously to the HUB module. Their format is heterogeneous for each parameter. WSN and HUB modules are connected wirelessly by Zigbee communication device. The communication is one way from WSN to HUB module.

Hub module have 5 functions; data collection, processing, management, interchange, and interface. HUB module uses smartphone has the memories of 16GB (ROM: Read Only Memory) and 2GB (RAM: Random Access Memory) to realize these functions. HUB module collects estimated parameter from WSN. Human body behavior is estimated by data fusion. As the result, HUB module generates the advice. Advice is sent to user through AVHI. Furthermore HUB module sends e-mail to human in remote place through Cloud. Observer cares user by watching user's information. HUB module displays advice on the screen of smart phone in real time and store parameter of data fusion.

AVHI module has two functions. It sends the advice to human as regular interchange and sends the parameter to HUB module as WSN. AVHI is the head mount display with camera like a glass shape. By AVHI, user will be provided advices naturally in terms of display notification. HUB module and AVHI module are connected by Bluetooth communication device. The communication is dual way. One way from AVHI to HUB module is to send parameter as WSN. The other way from HUB module to AVHI is to send advice as interchange.

BAN system is constructed as a distributed and cooperative system. The characteristic of the communication between WSN and HUB module is asynchronous and heterogeneous format. The communication of each WSN is independently by different speeds (30Hz to 1/20 Hz). As examples, in the WSN on ankle, the parameters of walking pitch and impact are estimated by acceleration data in each 20 seconds and are sent to HUB module. In the WSN on waist, the parameters of body inclination and swing are also estimated by acceleration data in each 20 seconds and are sent to HUB module. In the WSN module on shoulder, the parameters of heart rate and SPO2 are sensed by 50Hz and are sent to HUB module. In the WSN on arm, the parameters of skin temperature are sensed by 50Hz and sent to HUB module. These parameters are sent by specific data format from each other. HUB module receives these heterogeneous data from WSN attached on body asynchronously. By data processing function of smart phone in HUB module, the information of physical conditions like body inclination and swing, walking pitch and impact to legs are collected, as well as the information of vital signs are also collected. HUB module prevents data loss and competition of communication by distinguishing the information of heterogeneous format. Almost of the information is unconscious for the user monitored by the system. By referring these information, HUB module produces several types of care advice to the user. By getting the care advice, the user can recognize user's physical conditions, vital signs and improve user's body behavior.

3. ESTIMATION METHOD OF WALKING POSTURE

The walking posture of the user is estimated from 5 parameters. They are body inclination, body swing, gap of landing impact, walking pitch and tendency of walking posture. Fig.4 shows details of body inclination and body swing. Body inclination is gap between center of body in static state and center of body in walking. Body swing also is swing from center of body in static state.Fig.6 shows tendency of walking posture. Estimation methods of them are shown on below processing.

3.1. Body Inclination

The body inclination is calculated by y-axis acceleration of the waist module. Y-axis acceleration is a component in the lateral direction of body. Acceleration data is filtered up to 2Hz to remove the noise. Body inclination is analysed by calculating stored data of 20 seconds. Furthermore, the body inclination is calculated from the average value.

3.2. Body Swing

The body swing is calculated by y-axis acceleration of waist module in about 20 seconds to check the fluctuation of values. The body swing is estimated by the standard deviation of data.

3.3. Gap of landing impact

The land impact is analysed by 3-axis acceleration of ankle module. The analysis uses the synthetic value of 3-axis that is filtered up to 2Hz. The landing impact is estimated from the average value of the data in about 20 seconds. The landing impact is analysed in each ankle module. Ankle modules send the analysis result to the HUB module. The HUB module calculates the difference between both ankle modules. A result is the gap of landing impact.

3.4. Walking pitch

The walking pitch is calculated by 3- axis acceleration of ankle modules. This analysis uses the synthetic value of 3-axies that passes through 5-data SMA (Simple Moving Average). Walking pitch is analysed by counting the number of walking steps in 1024 data. The counting method is used to count local minimum values in 1024 data. In order to count them correctly, two thresholds (value of acceleration and time) are provided. The walking pitch is analysed in each ankle module. Ankle modules send the analysis result to the HUB module. The HUB module determines the lager of two results. The judgment result is the walking pitch of a user.

3.5. Tendency of walking posture

The tendency of walking posture is judged by flow at Fig.5. The analysis uses the sign (plus or minus) of body inclination and gap of landing impact. The tendency is judged by the sign which is produced by the multiplication of two parameters.

(1)TDT(Trunk Distorion Type)

When the direction of the body inclination and received large impact ankle are same side, the tendency type is called Trunk Distortion Type (TDT). Subject in TDT has body inclination in walking. The body inclination causes the landing impact.

(2)TRT(Tread Reaction Type)

When the direction of the body inclination and received large impact ankle are opposite side, the tendency type is called Tread Reaction Type (TRT). Subject in TRT has the landing impact. The walking posture is leaned in the opposite direction by the landing impact. The landing impact causes the body inclination.

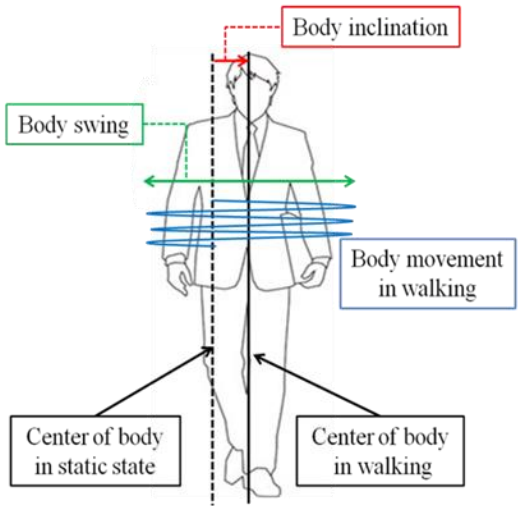

Fig. 4. Definition of body inclination

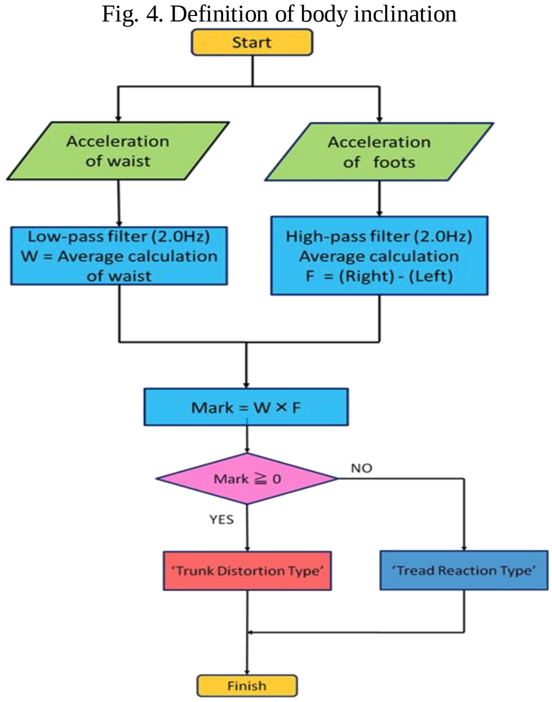

Fig. 5. Flow chart of tendency judgement

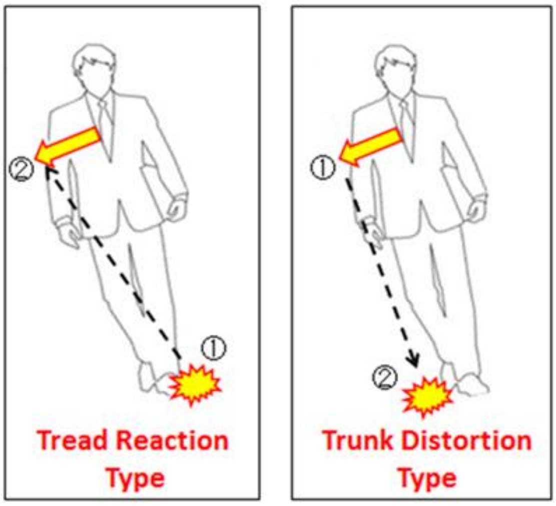

Fig. 6. Tendency of walking posture

4. ESTIMATION OF WALKING POSTURE

4.1. Experiment method

In this experiment, subjects walk without advices for the first 10 minutes. Moreover, subjects walk for the later 10 minutes while receiving advices. By comparing the result of the first half with it of the second half, a usefulness of the feedback function is verified. The experiment consists in the following process.

1. Stay for 20 seconds
2. Walk on a floor for 10 minutes (without advice)
3. Walk on a floor for 10 minutes (with advice)
4. Stay for 20 seconds

Height of subject A is 168cm, weight is 60kg, age is 24.
Height of subject B is 179cm and weight is 60kg, age is 22.
Height of subject C is 166cm and weight is 63kg. age is 22.
Height of subject D is 170cm and weight is 58kg, age is 22

4.2. Advice regulation

Standards of advice are divided into the upper half of a body with the lower half of a body. Advices of the upper half of a body are created by the body inclination and the body swing. In addition, an advice of the lower half of a body is created by the gap of landing impact. These advices are generated by the trend of each parameter. The trend is calculated from the current parameter and the immediately preceding parameter. Table 1 shows advice standards of the upper body. Table 2 shows advice standards of the lower body.

Table1 Advice standards of the upper body

Advice	Previous data of body inclination (PDBI)	Trend of body inclination (TBI)	Trend of body swing (TBS)
Body inclines to right side Body swing is large	PDBI ≧ 0	3 < TBI	5 < TBS
Body inclines to right side		3 < TBI	5 > TBS
Body swing is large		3 ≧ TBI	5 ≦ TBS
Body inclines to left side Body swing is large	PDBI < 0	TBI < -3	5 < TBS
Body inclines to left side		TBI < -3	5 > TBS
Body swing is large		TBI ≧ -3	5 ≦ TBS

Table2 Advice standards of the lower body

Advice	Previous data of gap of landing impact (PDG)	Trend of gap of landing impact (TG)
Right landing impact is very heavy	PDG ≧ 0	30 < TG
Right landing impact is heavy		15 ≦ TG ≦ 30
Left landing impact is very heavy	PDG < 0	TG < -30
Left landing impact is heavy		-30 ≦ TG ≦ -15

4.3. Experimental results

(1) Experimental result of subject_A

Fig.7 shows the experimental result of subject_A. In the figure, the upper left graph shows body inclination, the lower left graph shows body swing, the upper right graph shows gap of landing impact, and the lower right graph shows walking pitch. In all graphs besides walking pitch is plotted with acceleration as the vertical line and time as the horizontal line. In graph of walking pitch is plotted with number of steps as vertical line and the horizontal line is same. The dotted line of each graph shows the timing to start feedback. In addition, various marks often are put on each graph. These marks indicate that BAN system has sent the advice to subject. In four graphs on the top, red mark shows the advice related to right side, therefore blue mark shows the advice related to left side.

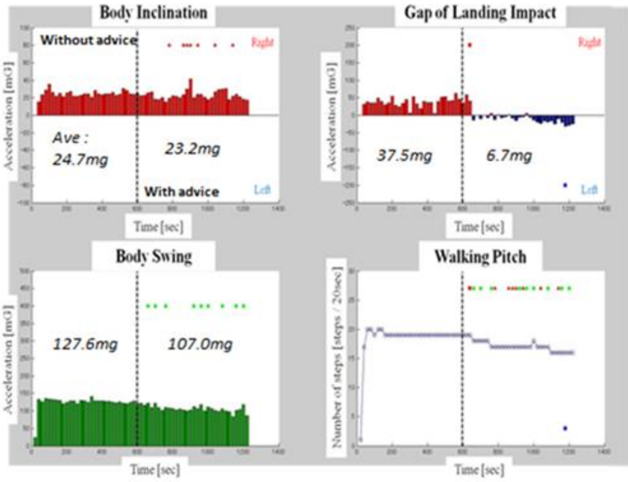

Fig.7 Measurement result of 4 kinds of parameter (subject_A)

Fig.7 shows the experimental result of subject A. subject_A was able to improve three parameters by feedback function. In regards to the gap of landing impact, subject_A was corrected significantly by first advice, and maintained the state until the end of the experiment.

In addition, body swing became gradually smaller in each time that he received the advice.

In contrast, the improvement of body inclination was a little. However, body inclination decreased surely after receiving the advice. This result shows that the feedback function worked to his body inclination. By summarizing all the results, it has proved that the feedback function is useful to subject_ A.

According to the graph of the walking pitch, the number of walking steps in the second half decreased from the first half. Considering their results, lower walking speed is due to be conscious of the advice. The improvement of three parameters was achieved by lowering the walking speed. This experiment has revealed that controlling the walking speed is one of the ways to avoid the deterioration of the walking posture.

It seems that subject_A was conscious to the left after first advice of the body inclination. As a result of its conscience, the landing impact switched from the right landing to the left one and became small value. Therefore consciousness toward advice varied the walking posture of subject_A surely.

(2). Experimental result of subject_B

Fig.8 shows the experimental result of subject_B.

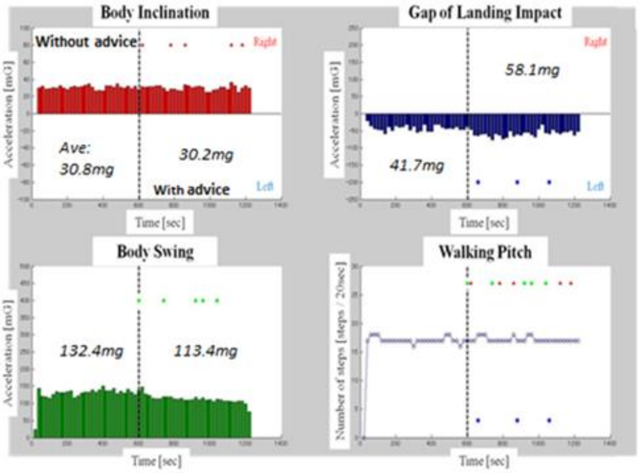

Fig.8 Measurement result of 4 kinds of parameter (subject_B)

Subject_B was greatly improved the body swing by the feedback function. In the first half of the experiment, body swing was unstable. However, body swing became smaller after receiving first advice. Furthermore, body swing eventually became stable at around 110mG.

In contrast, the gap of landing impact of the second half was larger than the first half. The reason for this result was that the landing impact of left ankle became heavier at the beginning of the second half. BAN system sent the advice when the landing impact of his left ankle became heavier. However, subject_B could not correct immediately. However, subject_B gradually corrected the landing impact. Furthermore, the gap of landing impact of subject_B eventually stabilized at around the value of starting to walk.

In regard to the body inclination of subject_B, it did not change much through the whole experiment. However, his body inclination decreased surely after receiving the advice. The feedback function suppressed that his body inclination became large. This shows that the feedback function has worked to the body inclination of subject_B. By summarizing all the results, it has proved that the feedback function is useful to subject_B.

(3). Experimental result of subject_C

Fig.9 shows the experimental result of subject_C.

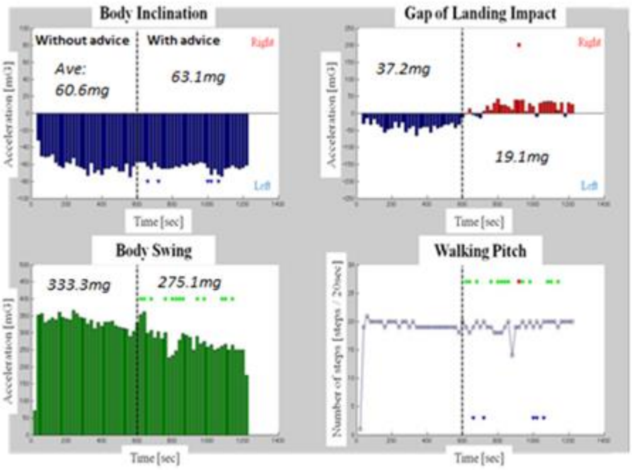

Fig.9 Measurement result of 4 kinds of parameter (subject_C)

According to fig.9, subject C received a lot of advice regarding body swing. Consequently, his body swing of the second half became much smaller than the first half. This result is possible to judge from the average value.

In contrast, his body inclination of the second half was a little larger than the first half. However, his body inclination decreased temporarily after receiving the advice. In other words, the feedback function suppressed that his body inclination became large. This shows that the feedback function has worked to the body inclination of subject_C.

Moreover, the gap of landing impact also became smaller by having the feedback function. However, the advice about the landing impact was hardly sent to the subject_C. Considering this result, the advice about other parameter helped to balance his landing impact. The feedback about the one parameter gives good influence to the other parameters.

Furthermore tendency of subject changes from TDT to TRT. Therefore the feedback function affects the walking posture of subject_C surely.

By summarizing all the results, it has proved that the feedback function is useful to subject_C.

It seems that the subject C was conscious to the right by receiving advice of the body inclination. Subject_C turned too much therefore the landing impact switched from the left landing to the right one. The body inclination decreases each time that he received the advice. The landing impact is also an improvement because of TDT's tendency.

(4). Experimental result of subject_D

Fig.10 shows the experimental result of subject_D.

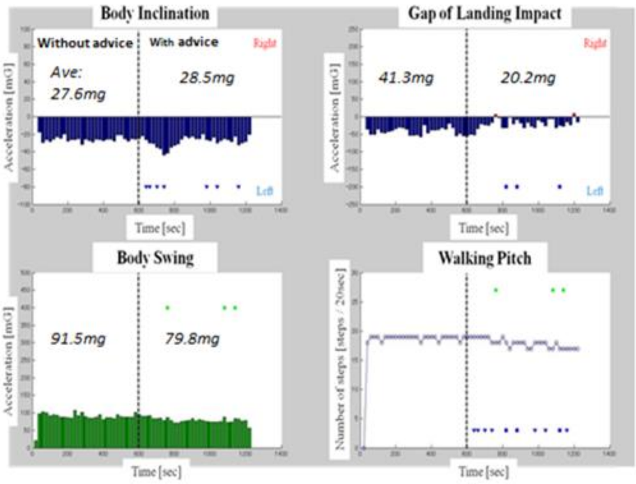

Fig.10 Measurement result of 4 kinds of parameter (subject_D)

The body swing and the landing impact of the second half were smaller than the first half. These results show that the feedback function of BAN system is useful to subject D.

In contrast, his body inclination of the second half was a little larger than the first half. Judging from this result, it is concluded that the feedback has not functioned to his body inclination. However, his body inclination decreased temporarily after receiving the advice. The feedback function suppressed that his body inclination became large. This shows that the feedback function has worked to his body inclination. By summarizing all the results, it has proved that the feedback function is useful to subject_D.

4.4. Discussion

Based on all the experimental results, the utility of the feedback function in BAN system has been shown. However, the effect of the feedback depends on parameters and subjects.

Landing impact of almost every subject is easily controlled by having feedback function. In experiments, three subjects were significantly corrected the landing impact by the first advice. In contrast, subject_B could not correct the landing impact immediately. However, subject_B gradually corrected the landing impact. This result shows that the feedback function has worked surely to his landing impact. In addition, the landing impact was corrected by the slow speed in walking. By summarizing the above explanation, it has been shown that the feedback function of BAN system gives a great effect to the landing impact.

Body swing is also easy to control by using the feedback function. In experiments, all the subjects corrected the body swing by receiving the advice. The common characteristic of most of the subjects was to stabilize the body swing gradually. However, body swing of subject_C decreased steeply after receiving the advice. This is because he has received the advice about the body swing continuously. By summarizing the above explanation, it has been shown that the feedback function of BAN system gradually gives an effect to the body swing.

In contrast to other parameters, body inclination is quite a troublesome to control by using feedback function. The body inclination depends on the body characteristic of the subject by nature. As example, person with a shorter right leg or his right knee is weak inclines to the right. It is possible to judge this tendency from this result. In this case, it is difficult to improve it by advice. However, the body inclination of all the subjects decreased temporarily after receiving the advice. In addition, the body inclination was corrected by using feedback function when BAN system observed the tendency to lead the burden of a body. These results show that BAN system is able to manage the body inclination by having feedback function. The feedback function of BAN system is able to manage all parameters of walking posture.

As a these results, it is shown that the effect of advice depended on subject. It is because the way of improving the waking posture is different from each subject. It is necessary for the subject to change advice to have effect easily. For that reason, it sends the advice of not only the state of the walking posture but also the concrete action. The function of feedback will be able to realize the better walking for the subject.

5. DISCUSSION

The system is the distributed cooperative system. This system can distinguish heterogeneous parameter asynchronously. As the result, the system materialize that it prevents data loss and competition by distinguish parameters. BAN system estimates the walking posture by using four parameters. These parameters are body inclination, body swing, gap of landing impact and walking pitch. In the experiment, BAN system managed user’s walking posture by using feedback function. The experimental results have proved that the feedback function of BAN system is useful to manage user’s walking posture.

6. CONCLUSIONS

BAN is so useful to acquire various dynamic parameters of human activities and vital signs in daily life. As an application, this system estimated user’s walking posture by using these parameters. By feedback function, the user corrects the walking posture consciously. For this reason, BAN system encourages that human improves walking posture autonomously. User can notice user’s body behaviour by feedback function before the body damage. As the result, it is confirmed that this system has cared user’s behavior in real time. Therefore this system would support the improvement of QOL

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