DYNAMIC MEASUREMENT OF BODY SWING IN JOG TRAINING

Ryo Watabe, *Yuki Matsuda, Shigeru Takayama, Yuichi Nakanishi.*

Department of Electrical & Electronic Engineering, Science & Engineering
Ritsumeikan University, BKC, Shiga, JAPAN, re012072@ed.ritsumei.ac.jp

Abstract: To know load unbalance of body is an important concern for us to keep our physical health. The measurement of load unbalance of human body standing at a point is well known. But, on the other hand, it is more important to know the load unbalance in dairy life. This paper describes the system and method to measure load unbalance of human body to left or right side in jogging. The load unbalance is estimated by an inclination angle of body. The inclination angle is calculated by acceleration information from acceleration sensor attached on waist. As the measurement system is constructed as a portable and wearable unit, it is used indoor and outdoor.

Keywords: acceleration sensor; inclination of body; jogging; portable and wearable unit; Body Area Network.

1. INTRODUCTION

Body in jogging is swinging on left-right direction. And, the swing is increased according to time transition. The large body swing becomes the cause of heavy load and strong pain at a hip joint and a knee. So runners need to know the status of the swing of the body while jogging. But, runner doesn't notice an increase in body swing. In addition, it cannot be determined visually. It is necessary to measure and inform the swing of the body in jogging. This paper says about that the acceleration sensor on the waist detect swing of the body in jogging.

2. CONSTRUCTION OF MEASURING DEVICE

Fig. 1 shows construction of BAN (Body Area Network) system. The main function of the system is acquisition, process, management, and storage. This system consists of 4 portions of Shoulder, Wrist, Waist, and Ankle. The interconnection between modules is made by BAN. Data collected by each part of the body is brought together in the module of the waist, and it feeds back to the person who wearing BAN with a voice advice. If he has the health problem, system sends data to his family or doctor using cell phone.

This time, body swing is measured using waist module, and shoulder module. The measuring device is constructed by 3-axis acceleration sensor. Fig. 2 shows the device attached on the waist of human body. Y axis of acceleration is horizontal (right-left) of body. X axis is vertical (up-down). And Z axis is the direction to front-back of body. In this study, the body swing in jog training has been measured by using acceleration data of Y axis. Fig. 3 shows system construction. Acceleration data go to dsPIC33FJ. Audio Module sends advice with a voice. Final data save to Micro SD Card. The body swing in jogging is by the standard deviation of acceleration. The smaller standard deviation is the smaller body swing. Big standard deviation is big body swing. The standard deviation is calculated by the acceleration data for 20 seconds. The smaller body swing is good in jogging. That is, the smaller the standard deviation is good.
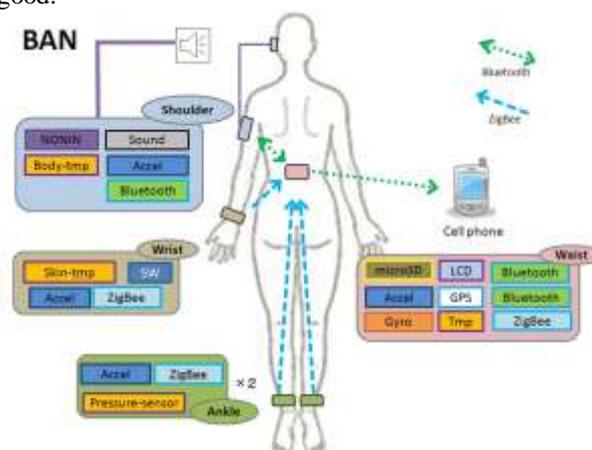

Fig.1 Construct of Body Area Network system.

Table 1 Acceleration sensor spec.

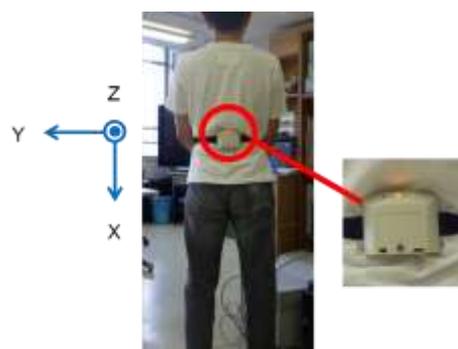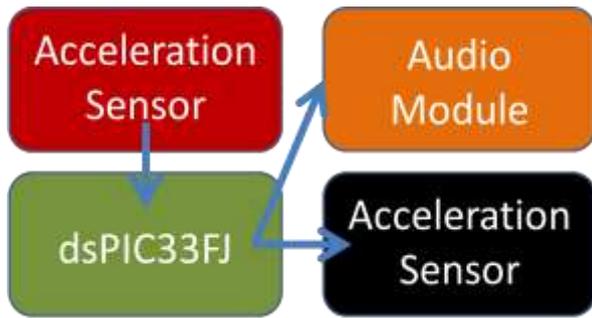| PARAMETERS	VALUE
Range	$\pm 2G$
Sensitivity	660mV/G
0G Offset	1.65V
Power Supply	2.7V to 5.5V

Fig.2 State of mounting.

Fig.3 System construction.

3. EVALUATION OF BODY SWING

3.1 Experimental Method

The subjects jog for 30 minutes, to observe changes in the standard deviation of 30 minutes. This experiment will use the treadmill. Jog speed is 8 km/h. This speed is general jogging pace. The subjects are A, B, C in Table 2. The subject answers the questionnaire of the level of tiredness (5 steps) to every five minutes. "1" means that there is afford to run. "5" means that it is running into limits.

Table 2 Subjects state.

Name	Age	Sex	Height(cm)	Weight(kg)
A	24	Male	170	52
B	23	Male	167	50
C	22	Male	170	68
D	24	Male	172	67
E	21	Male	171	63
F	22	Male	175	75
G	22	Male	170	56
H	21	Male	178	61

Fig.4 Scene of experiment.

3.2 Experimental Result

Figs.5~7 shows standard deviation in 30 minutes. Blue line is the standard deviation (mG). It is clear that an increased standard deviation in 30 minutes. The body swing increases in jogging were observed.

Figs. 8~13 are figures that are cast a spotlight on each 5 minutes (Subject A) to display in detail. Blue line is the standard deviation (mG). Red line is the approximation straight line of standard deviation.

Figs. 8~13 show that the first 5minutes has a large change of the approximation.

Fig.5 Standard deviation in 30 minutes
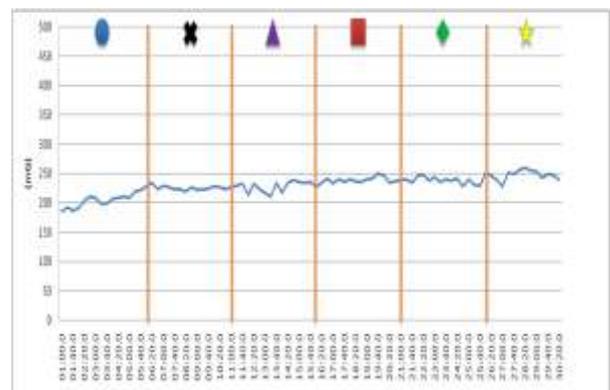(Subject A).

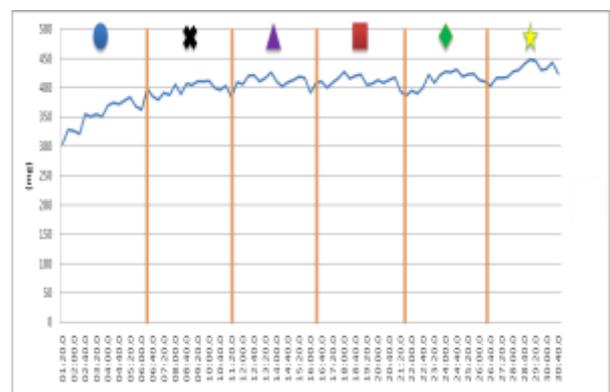Fig.6 Standard deviation in 30 minutes
(Subject B).

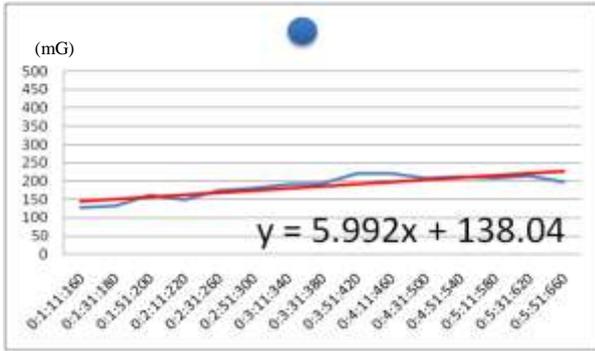Fig.7 Standard deviation in 30 minutes
(Subject C).

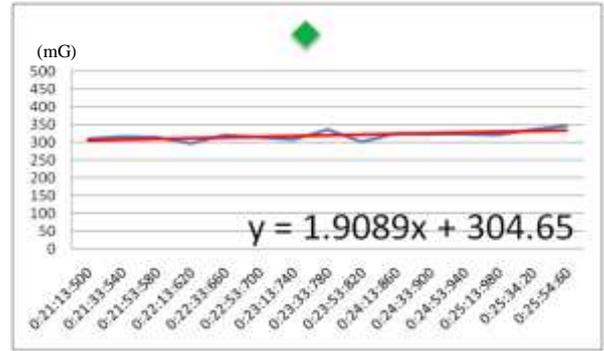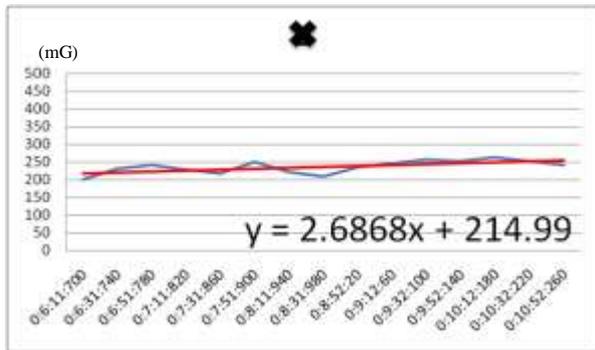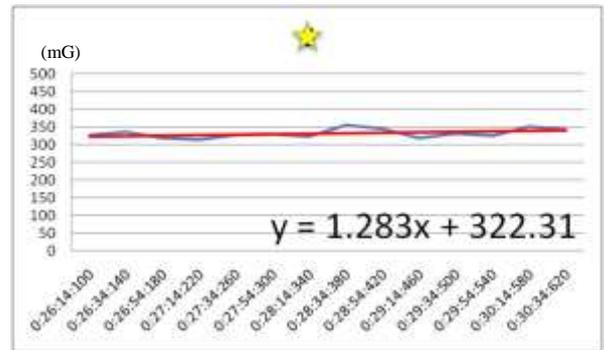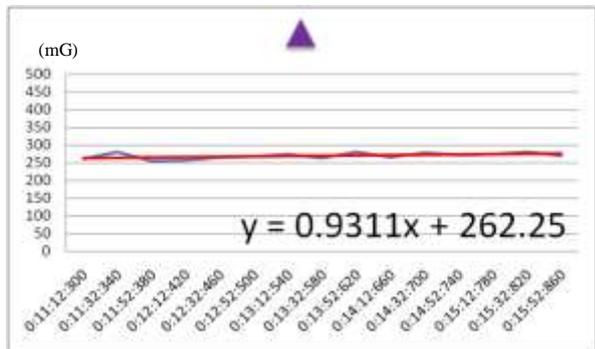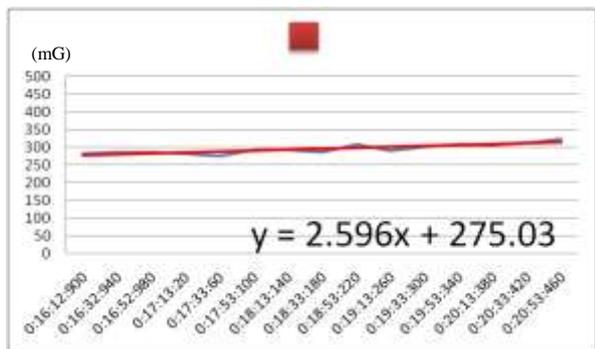Fig.8 Standard deviation in 0-5 minutes
(Subject A).

$$y = 5.992x + 138.04$$

Fig.12 Standard deviation in 20-25 minutes
(Subject A).

$$y = 1.9089x + 304.65$$

Fig.9 Standard deviation in 5-10 minutes
(Subject A)

$$y = 2.6868x + 214.99$$

Fig.13 Standard deviation in 25-30 minutes
(Subject A)

$$y = 1.283x + 322.31$$

Fig.10 Standard deviation in 10-15 minutes
(Subject A).

$$y = 0.9311x + 262.25$$

Compared these values of each section. Figs. 14~19 shows average standard deviation, slope and intercept of the approximation straight line of each 6 subjects. Blue block is the average standard deviation, the level of tiredness. Red line is slope, and green line is intercept of approximation straight line. Yellow triangle on graph is the level of tiredness. This result shows some things. The body swing and the level of tiredness are related. And subject is categorized into three types.
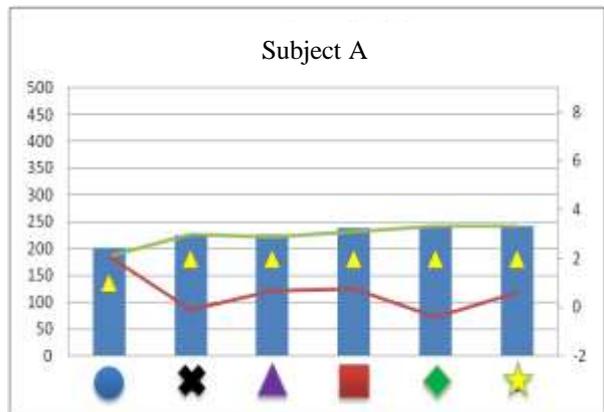

Fig.11 Standard deviation in 15-20 minutes
(Subject A).

$$y = 2.596x + 275.03$$

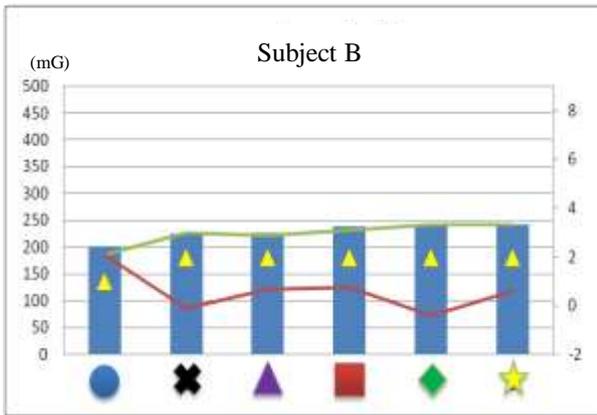Fig.14 Information of standard deviation (Subject A).

Fig.15 Information of standard deviation (Subject B).

Fig.16 Information of standard deviation (Subject C).

Fig.17 Information of standard deviation (Subject D).
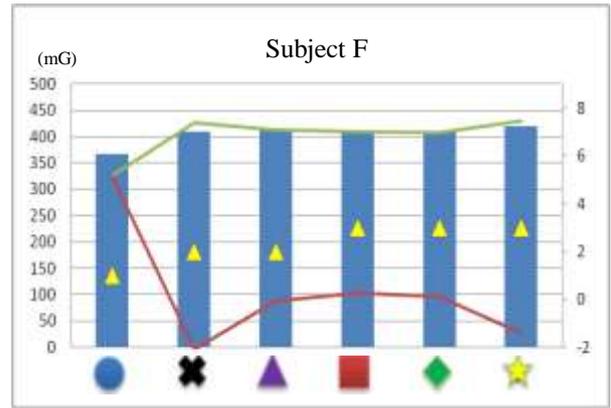

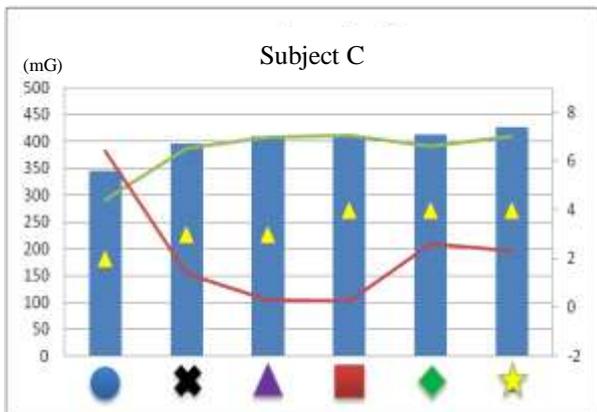Fig.18 Information of standard deviation (Subject E).

Fig.19 Information of standard deviation (Subject F).

Table3 shows details of three types. Subject of type1 has not exercise usually. Subject of type2 and type3 has exercised usually.

Table 3 Subject type.

Type	Type1	Type2	Type3
Subject	A,D	B,E	C,F
Transition of standard deviation	rapidly	stable	stable
Bias of standard deviation	Low to high	low	high

4. RELATION BETWEEN JOGGING SPEED AND BODY SWING

4.1 Experimental Method

The subject is C, G in Table2. This experiment will use the treadmill. The subject jogs at the speed of he's choice. The subject jogs for 4km, to observe changes in the standard deviation of 4km. The subject answers the questionnaire of the level of tiredness (5 steps) to every 1km. "1" means that there is afford to run. "5" means that it is running into limits.

4.2 Experimental Result

Figs.20, 21 shows standard deviation in 4km. Blue line is the standard deviation. Red line is the threshold of advice. Green line shows advice flowed. Light-blue line is speed of jogging. It is clear that a decreased standard deviation by lower speed. The body swing decreases by lower speed in jogging were observed. But standard deviation increases gradually. This is depended on tiredness.
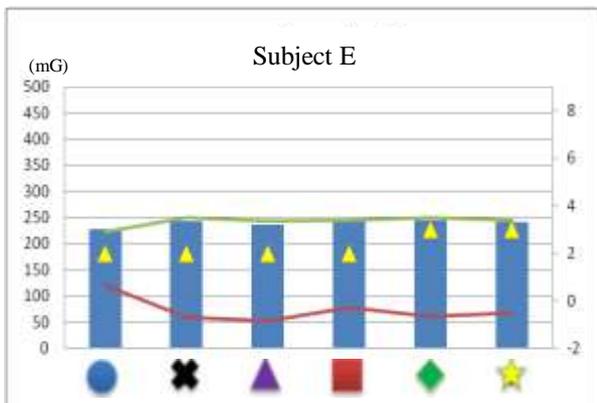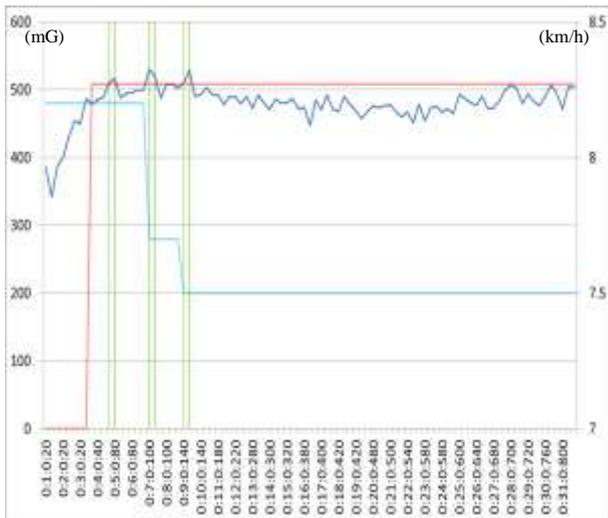
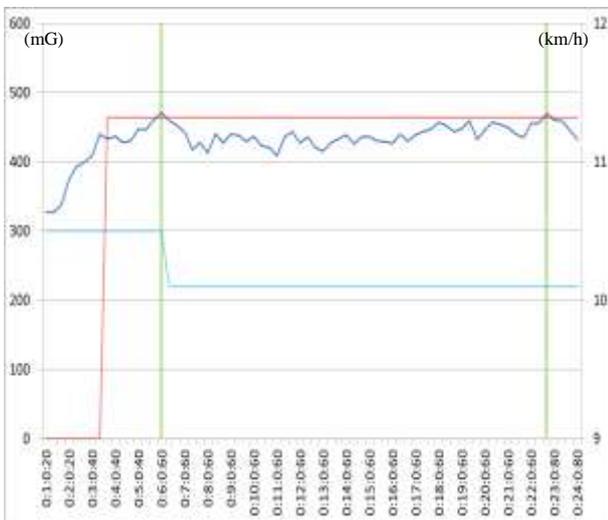Fig.20 Standard deviation in 4 km (Subject C).

Fig.21 Standard deviation in 4 km (Subject G).

5. RELATION BETWEEN BODY SWING AND HEART RATE

5.1 Experimental Method

In this experiment, body swing and heart rate are measured using a waist module and a shoulder module to observe relation between the standard deviation and heart rate. The subject is H in Table2. This experiment will use the treadmill. The subject jogs at the structured speed.

5.2 Experimental Result

Figs.22, 23 shows standard deviation and heart rate in 20 minutes. Blue line shows the standard deviation. Green line is approximate polynomial of the standard deviation. Purple line is heart rate. Yellow line is approximate polynomial of the heart rate. Speed of jogging is 8km/h (in fig.22), and 10km/h (in fig.23).

In fig.22, heart rate increases in the first 5 minutes, and is stabilized about in 150bpm. In fig.23, heart rate increases in the first 7 minutes, and is stabilized about in 160bpm. Compared with heart rate of fig.22, heart rate of fig.23 is high because of speed of jogging.

In fig.22, standard deviation is stabilized around 300mG. Standard deviation of fig.23 increases without being stabilized compared with standard deviation of fig.22. This result shows that standard deviation is able to stabilize to down speed of jogging.
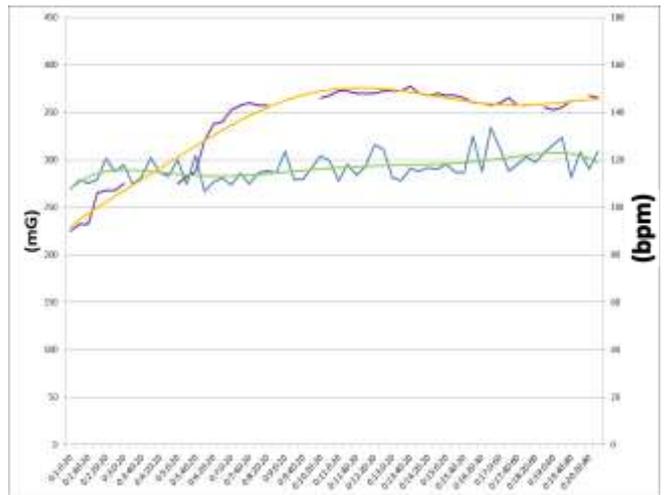

Fig. 22 Relation between body swing and heart rate (Subject H, 8km/h)

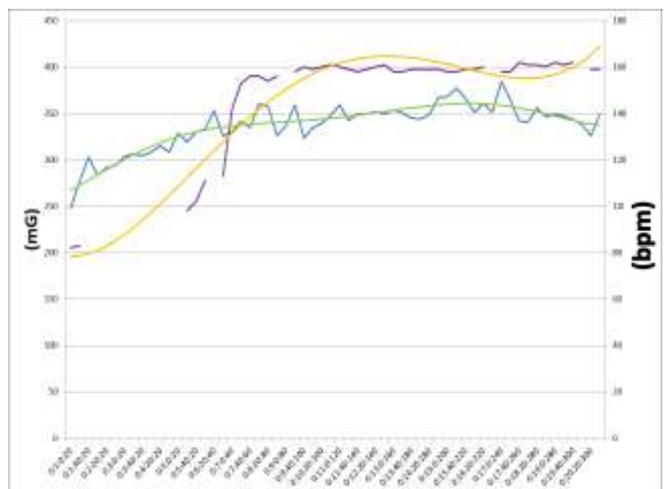Fig. 23 Relation between body swing and heart rate (Subject H, 10km/h)

Exercise in heart rate is110 ~ 150bpm is called aerobic exercise. Aerobic exercise is good for health. Standard deviation should be stabilized by heart rate keep in 110 ~ 150.

6. CONCLUSIONS

Five conclusions were obtained from the experimental result. The body swing increases in jogging were observed. The body swing and the level of tiredness are related. Subjects are categorized into three types. The body swing decreases by lower speed in jogging were observed. Standard deviation should be stabilized by heart rate keep in 110 ~ 150.

Body unbalance in jogging becomes burden to legs, waist and so on. That is serious problem on a viewpoint of physical health. There are some kinds of the body unbalance which can be self-aware or not. Therefore, the system and method to measure the body unbalance objectively are needed. This system can be detected inclination of body by acceleration information. But, method of inspection is ambiguous. In future, we will measure the inclination of body by ever measure machinery. Should be calculated the correlation between that data and the angle data at the acceleration data. Then we need to get the truth of the angle data at the acceleration. Should be made analysis of measurement data in this system, and found a difference for three types. And should be constructed a fine advice system by using standard deviation and heart rate together.

7. REFERENCES

[1]G. Lopez, S. Kawakubo, C. Sugimoto, S. Arimitsu, M. Tsuji, K. Sasaki, H. Hosaka, and K. Itao, "Evaluation Platform for Physiological Information Systems Using Wearable Sensors and Information Technology", Journal of The Horological Institute of Japan, Vol.49, No.193, pp.13-27, March 22, 2005.
[2]P. Celka, R. Vetter, P. Renevey, C. Verjus, V. Neuman, J. Luprano, J-D. Decotignie, and C. Piguet, "Wearable biosensing: signal processing and communication architectures issues", Journal of Telecommunications and Information Technology, pp.90-104, April, 2005.
[3]P. S. Pandian, K. P. Safeer, P. Gupta, D. T. Shakunthala, B. S. Sundersheshu, and V. C. Padaki, "Wireless Sensor Network for Wearable Physiological Monitoring", Journal of Networks, Vol.3, No.5, pp.21-29, May, 2008.
[4]Y. Hiiragi, "Evaluation of Postural Sway Using a Triaxial Accelerometer", Rigakuryoho Kagaku 19(4): 305-309, 2004, Submitted May 10, 2004. Accepted Jul. 8, 2004.
[5]M. Tada, R. Ohmura, M. Okada, F. Naya, H. Noma, T. Toriyama, K. Kogure, "A Method for Measuring and Analyzing Driving Behavior Using 3D-Accelerometers", Information Processing Society of Japan, 2007.
[6]E. Namikata, M. Ohta, S. Ishihara, T. Mizuno, "An Individual Authentication Method With Arm Movements Using a Wrist Watch Loaded With an Accelerator Sensor".
[7]K. Iijima, J. Yanagida, M. Sekine, T. Tamura, "Measurement of Postural Responses in Horizontal Perturbation Using Angular Velocity", Japanese Society for Medical and Biological Engineering 45(4): 285-291, 2007.
[8]K. Oshima, Y. Ishida, S. Konomi, Y. Tobe, "Exploring the Uses of Pressure Sensors and Accelerometers for Footwear-Based Human Probes", FIT2009.
[9]F. Kitamura, "Body Sway Induced by Presentation of Slant Figures –Effects of Displaying Perspective Stimuli-", Equilibrium Res Vol. 58(3): 223-228, 1999.
[10]K. Teramoto, N. Usui, "Effect of Pelvis Adjusting Method on Leg Length Inequality and Center of Gravity of Patients with Hip Joint Disorder", Rigakuryoho Kagaku 11(4): 201-206, 1996.
[11]K. Nishiwaki, S. Kagami, Y. Kuniyoshi, M. Inaba, H. Inoue, "Gyro Sensor based Compensation Method of Hip Joint Deformation for Stable Walking" The Japan Society of Mechanical Engineers No.02-6, 1P1-E05, 2002.
[12]S. Sakurai, M. Sakamoto, R. Nakazawa, M. Kawagoe, K. Kato, "Investigation of the Reproducibility of a 3D Accelerometer-Based Gait Analysis System of the Tibia", Rigakuryoho Kagaku 25(1): 7-12, 2010.
[13]N. Tanaka, S. Sonoda, Y. Muraoka, Y. Tomita, N. Chino, "Reproducibility and Validity of Gait Analysis Using Portable Accelerometer", Jpn J Rehabil Med 33: 549-553, 1996.
[14]Y. Takeuchi, Y. Shimomura, K. Iwanaga, T. Katsuura, "Utility of Dynamic Balance Evaluation of the Elderly by a Small Triaxial Accelerometer", Rigakuryoho Kagaku 22(4): 461-465, 2007.
[15]H. Shinoda, H. Sato, Y. Suzuki, "Evaluation of Gait Stability Based on Variability of Medio-Lateral Motion of the Center of Mass", Rigakuryoho Kagaku 23(1): 55-60, 2008.
[16]H. Kurasawa, Y. Kawahara, H. Morikawa, T. Aoyama, "User Posture and Movement Estimation Based on 3-Axis Acceleration Sensor Position on the User's Body", The Institute of Electronics, Information and Communication Engineers, B-15-8, 2006.
[17]E. Kitahata, A. Kunimine, S. Kenmoku, M. Suzuki, A. Noda, H. Maruyama, "Dynamic Balance Test on a Balance Beam", Rigakuryoho Kagaku 18(2): 83-88, 2003.
[18]R. Hagiwara, D. Karoji, Y. Horie, M. Katsuta, "The characteristic of human chronological order date in a walking cycle".
[19]T. Nakamura, T. Ogawa, K. Kiyokawa, H. Takemura, "Implementation and Evaluation of a User Context Recognition Mechanism for Continuous Wearable Learning Systems", The Institute of Electronics, Information and Communication Engineers.
[20] Y. Matsumura, M.Yamamoto, T. Kitado, H. Nakamura, K. Kidera and S. Fujimoto, "High-Accuracy Physical Activity Monitor Utilizing Three-Axis Accelerometer", MATSUSHITADENKO Technical Report vol. 56 No.2.
[21]N. Oliver and F. Flores-Mangas, "Health Gear: A Real-time Wearable System for Monitoring and Analyzing Physiological Signals", Microsoft Research Technical report MSR-TR-2005-182, Apr, 2006.