Fundamental Study to New Evaluation Method Based on Physical and Psychological Load in Care

Hiroaki Inoue
Tokyo University of Science, Suwa
Chino-city, Japan
jgh12701@ed.suwa.tus.ac.jp

Shunji Shimizu
Tokyo University of Science, Suwa
Chino-city, Japan
shun@rs.suwa.tus.ac.jp

Noboru Takahashi
Tokyo University of Science, Suwa
Chino-city, Japan
srl@ed.suwa.tus.ac.jp

Hiroyuki Nara
Hokkaido University
Sapporo-city, Japan
nara@ssc.ssi.ist.hokudai.ac.jp

Takeshi Tsuruga
Hokkaido Institute of Technology
Sapporo-city, Japan
tsuruga@hit.ac.jp

Fumikazu Miwakeichi
The Institute of Statical Mathematics
Tachikawa-city, Japan
miwake1@ism.ac.jp

Nobuhide Hirai
Jichi Medical University
Shimotsukeshi-city, Japan
nobu@nobu.com

Senichiro Kikuchi
Jichi Medical University
Shimotsukeshi-city, Japan
skikuchi@jichi.ac.jp

Eiju Watanabe
Jichi Medical University
Shimotsukeshi-city, Japan
eiju-ind@umin.ac.jp

Satoshi Kato
Jichi Medical University
Shimotsukeshi-city, Japan
psykato@jichi.ac.jp

***Abstract*—Recently, the aging population has increased in Japan and world-wide countries. As a consequence, a wide variety of welfare devices and systems have been developed. However, the evaluation of welfare systems and devices is limited only to stability, intensity and partial operability. The evaluation of usefulness is insufficient. Therefore, we will attempt to establish a standard to evaluate usefulness objectively and quantitatively on the basis of including non-verbal cognition. In this paper, we measure the load of sitting and standing movements by using EMG (Electoromyogram) and 3D Motion Capture and set a goal to establish an objective evaluation method. We think that establishing an objective evaluation method is necessity to develop useful welfare devices. We examine the possibility of assessing load and fatigue from measuring brain activity by using NIRS (Near Infra-Red Spectroscopy). The idea of universal design is widespread in welfare devices and systems. Measuring requires the verification of all generations. However, our study measured younger subjects as a first step because they had enough physical function. Considering younger subjects as a benchmark is appropriate for creating an evaluation method.**

Keywords- Evaluation; Movement; Exercise; 3D Motion Capture; NIRS; EMG; Care; Welfare Technology; Usefulwelfare device evaluation; Evaluation method.

I. INTRODUCTION

As aging population is increasing in Japan and world-wide countries, welfare systems and devices are rapidly developing, and various devices are manufactured because of this increased popularity. Also, the market of welfare devices and systems is expanding. However, the evaluation method is limited to stability, strength and a part of operability for individual systems or devices. This means that an evaluation methodology for the usefulness of these devices and systems was not established. Therefore, we will attempt to establish a standard to evaluate usefulness objectively and quantitatively on the basis of cognition such as physical load, reduction of fatigue and postural stability. In particular, in considering universality, it is necessary to measure human movement in daily life. Movement was not measured using a particular device, but by routinely-performed movement in daily life.

 ISBN: 978-1-61208-243-1

We examined the possibility of evaluation by measuring physical load due to activities of daily living using 3D Motion Analysis System and EMG. Also, we looked into the possibility of quantitative evaluation of tiredness and load on the basis of brain activity using NIRS. We considered that physical and psychological load are linked to cognition, including non-verbal cognition. In this paper, the purpose of the experiments are to evaluate motion focusing on sitting and standing movements, which are usually done in our life, by using 3D Motion Analysis System, EMG, NIRS. We consider that humans feel physical and psychological load during life motion. We tried to measure the physical load by using 3D Motion Analysis System, EMG. Additionally, we tried to measure non-verbal cognition about psychological load by using NIRS.

Subjects were healthy males in their twenties, because elderly people with various types of disease are inept in quantitative evaluation.

II. EXPERIMENTAL METHODS

A. Evaluation by using 3D Motion Analysis and EMG

We simultaneously measured the 3D position and muscle potential of subjects during tasks by using 3D Motion Analysis System (nac IMAGE TECHNOLOGY Inc. products-MAC3DSYSTEM [1]) and EMG (KISSEI COMTEC Inc. products-MQ16 [2]).

Regarding measuring the 3D position, 8 Infrared cameras were placed around each subject, and 27 makers of the body surface were set on the basis of Helen-Hayes Hospital Marker set (Figure 1). In measuring muscle potential, measurement regions were tibialis anterior muscle, gastrocnemius muscle, quadriceps femoris muscle, hamstring, flexor carpi ulnaris muscle, extensoe carpiulnaris muscle, triceps branchii, latissimus dorsi muscle of the right side of the body because these muscle were deeply associated with standing and sitting movement. Also, wireless measurements were used so that the subject was constrained as little as possible. As sampling frequency, 3D Motion Analysis System was 100Hz, and EMG was 1kHz.

The subjects were three males in their twenties. They were asked to read and sign an informed consent regarding the experiment.

In this experiment, each subject repeated one series of movements, which was to transfer from the chair to seat face of the welfare device (IDEA LIFE CARE Co. Ltd products-NORISUKEsan [3]) and opposite one with alternating between standing and sitting, five times per one measurement. Seating face of welfare device, which was designed to assist transfer movement, was manipulated by a simple method and appeared on the top of chair.

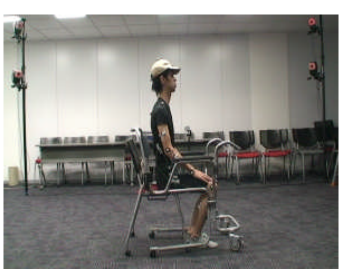

Figure 1. Experimental View of 3D motion Analysis and EMG

Subjects heard a buzzer every second and kept a constant speed of motion to satisfy certain measuring conditions. Also, they transferred from seat face to chair or conversely every 8 seconds with consideration for movement of elderly persons. The operation of the welfare device was performed by an operator other than the subject.

B. Evaluation by using NIRS

We measured brain activity during motion with the purpose of establishing an evaluation method based on generality (Figure 2).

The subjects were six males in their twenties. They were asked to read and sign an informed consent regarding the experiment. The measurement apparatus was NIRS (SHIMADZU CO. Ltd products-FOIRE3000 [4]). The measurement region was at right and left prefrontal cortex.

1) Measuring brain activity during transfer with standing position (task1)

For this measurement, the subjects used a welfare device to perform transferring to a standing position. For this measurement, each subject sat on seating face of the welfare device appeared on the top of chair after raising the hip until kneeling position. Also, each subject performed the inverse motion of transferring from seating face to the chair. The time design was rest (5 seconds), task (10 seconds), and rest (5 seconds). This time design was repeated 30 times. The rest time was used to stabilize the brain activity.

2) Measuring brain activity during transfer with half-crouching position (task2)

For this measurement, the subjects used a welfare device to perform transferring to a half-crouch position. For this measurement, the subjects sat on seating face of welfare device appeared on the top of chair after raising hip until kneeling position. Also, the subject performed inverse transfer from seating face to chair.Time design was rest (5 seconds), task (10 seconds) and rest (5 seconds). This time design was repeated 30 times.

In the experiments of task1 and task2, the operation of the welfare device was performed by an operator other than the subject. Before these measurements, the subjects adjusted to transferring using the welfare device.

3) Measuring brain activity during keeping a half-crouch position (task3).

The subjects performed two tasks in this measurement. During task3-1, each subject sat on the seating face of the welfare device with eyes open. During task3-2, they kept a half-crouch position.

Figure 2. Experimental View of NIRS

 ISBN: 978-1-61208-243-1

The subjects alternated task3-1 and task3-2. Also, the subjects took resting time between the two types of motion with their eyes closed. The time design was: rest (5 seconds), task3-1 (10 seconds), rest (5 seconds), task3-2 (10 seconds) and rest (5 seconds). This time design was repeated 15 times.

III. EXPERIMENTAL RESULTS

A. Evaluation by using 3D Motion Analysis and EMG

Figure 3 shows the result of transferring which was measured by 3D motion analysis and EMG. In Figure 3, the middle trochanter is the height of the midpoint between right and left trochanter from the floor. The trunk angle is the forward slope of the trunk. Also, following terms are rectifying voltage wave for each eight muscles, which are Tibialis anterior muscle, Astrocnemius muscle, Quadriceps femoris muscle, Hamstring, Triceps brachii muscle, Etensor carpi ulnaris muscle, Flexor carpi ulnaris muscle and Latissimus dorsi muscle.

Next, analysis was performed by extracting the muscle potential during standing and sitting movements from the measured result with reference to middle trochanter and trunk angle and calculating the value of integral during movement. Table 1 shows the ratio of the value integral with the welfare device to the one without the device. Also, we compared the moving distance of median point between using the welfare device and not. Table 2 shows the comparison results in a manner similar to Table 1.

B. Evaluation by using NIRS

As a common result for all subjects, oxy-Hb tended to increase during the task and to decrease in resting state. Therefore, it was thought that a change of hemoglobin density due to task was measured. Figure 6 shows the trend of the channel in which a significant difference was shown. Analysis was performed via one-sample t-test [5,6,7,8,9] by a method similar to previous researches [5,6,7,8,9]. In this analysis, it was necessary to remove other than change of blood flow due to fatigue. So, our method was mainly focused on resting state to compare with the 1st trial and other trials of brain activity. In task1 1 and 2, each of sample data for analysis was 4 seconds after the task (Figure 4). In task 3, the sample data was 4 seconds during task (Figure 5).

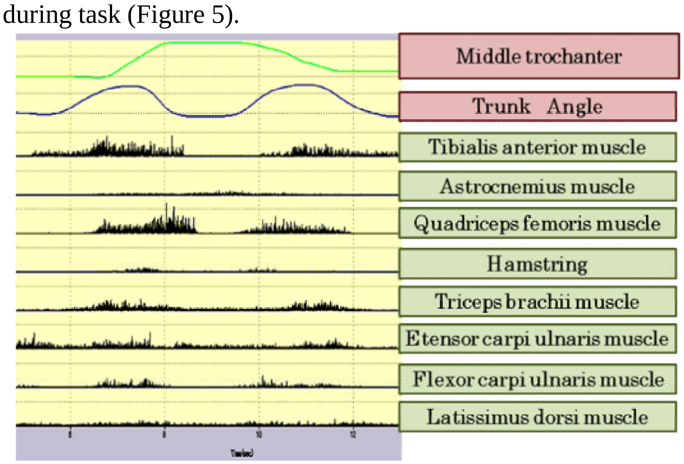

Figure 3. Result of 3D Motion Analysis and EMG

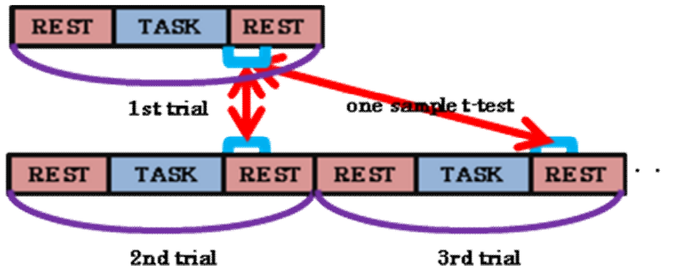

Figure 4. T-test of sample data of task1 and 2

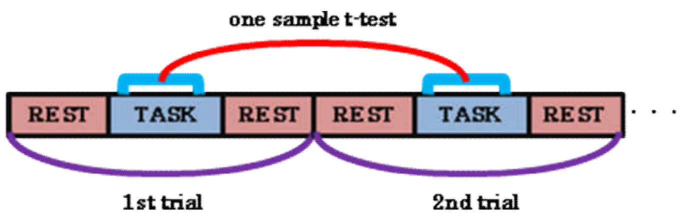

Figure 5. T-test of sample data of task3

TABLE I. COMPARISON OF INTEGRAL EMG

muscle	region	Subject1	Subject2	Subject3
Standing	Tibialis anterior muscle	0.37	0.49	0.64
	Astrocnemius muscle	0.83	0.78	0.97
	Quadriceps femoris muscle	0.66	0.36	0.81
	Hamstring	1.90	0.50	1.07
	Triceps brachii muscle	1.07	3.34	1.01
	Etensor carpi ulnaris muscle	1.08	1.31	0.96
	Flexor carpi ulnaris muscle	1.07	0.89	0.85
	Lattissimus dorsi muscle	0.98	0.87	1.20
Sitting	Tibialis anterior muscle	0.50	0.59	0.80
	Astrocnemius muscle	1.01	0.92	0.94
	Quadriceps femoris muscle	0.49	0.57	0.85
	Hamstring	2.16	1.60	0.96
	Triceps brachii muscle	0.89	0.96	1.07
	Etensor carpi ulnaris muscle	0.79	0.89	0.86
	Flexor carpi ulnaris muscle	0.79	0.86	0.95
	Lattissimus dorsi muscle	1.16	1.18	0.93

TABLE II. COMPARISON OF CHANGE IN MEDIAL POINT

	Subject1	Subject2	Subject3
Sitting	0.89	1.03	0.90
Standing	1.00	0.84	1.08

 ISBN: 978-1-61208-243-1

In the t-test of the same task, we performed t-test with first time trial and other trial which was from second times to thirty times, and examined relationship of the number of trials and significant differences.

In task 1, a significant difference could be found from the about 10th trials. Figure 9 shows the region confirmed significant difference. In task 2, significant difference could be found from the about 10th trials too. Figure 10 shows the region confirmed significant difference.

Next, we performed t-test with the case of standing position (task 1) and half-crouch position (task 2). In this analysis, a significant difference could be found at prefrontal area (14ch, 17ch, 28ch and 32ch). Figure 11 shows a region confirmed significantly different.

Also, two types of motions which were sitting and keeping a half-crouching position were repeated alternatively in task 3. At first, we performed t-test using 4 seconds during the first trial and 4 seconds during other trials, which were from second to fifteenth in same position. Regarding the result analysis using sample data during sitting position and half-crouching position, there were significant differences at prefrontal area. Figure 12 confirms the significant difference.

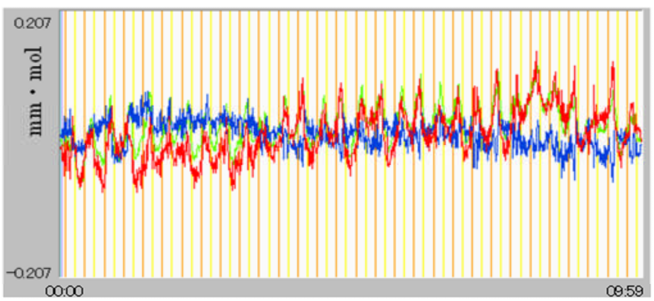

Figure 6. Measuring Result of Task1

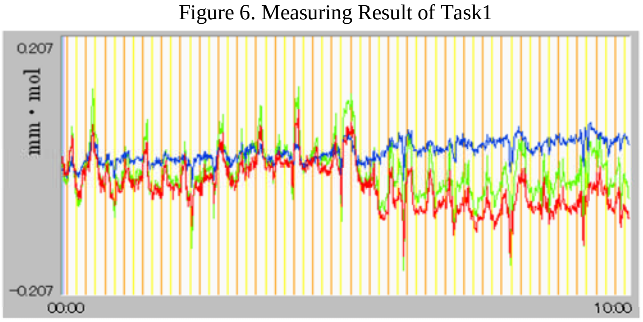

Figure 7. Measuring Result of Task2

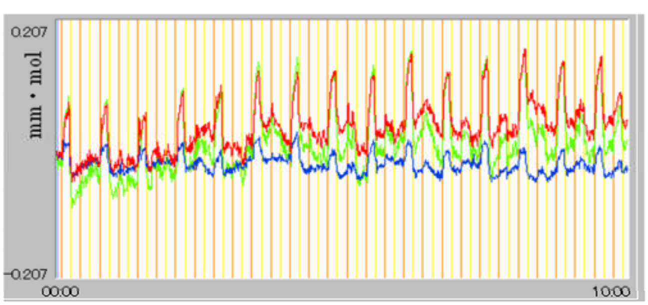

Figure 8. Measuring Result of Task3

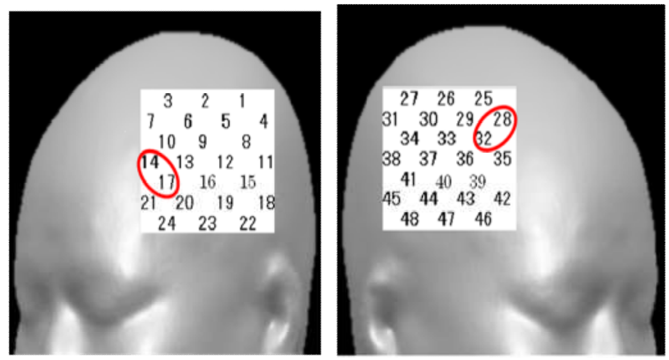

Figure 9. Significant Difference of task1

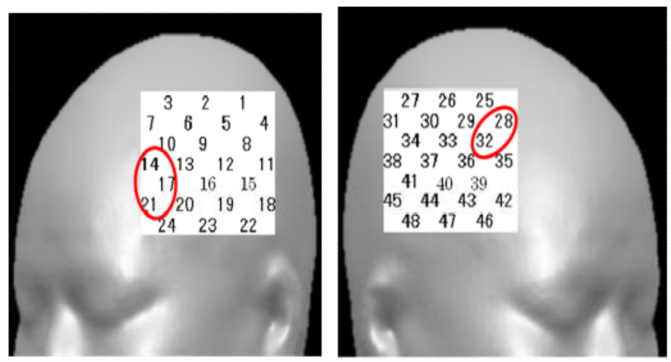

Figure 10. Significant difference of task2

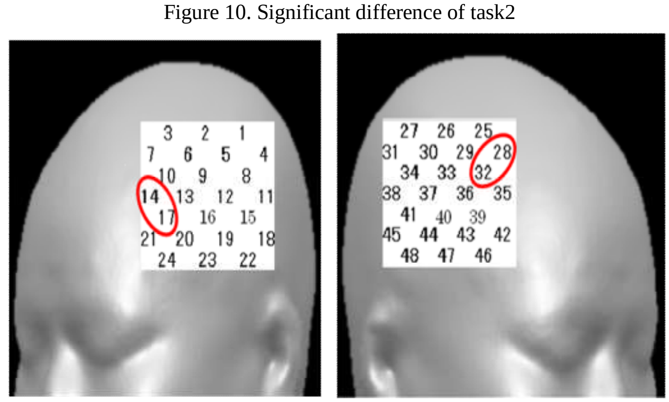

Figure 11. Significant Difference of task 1 and 2

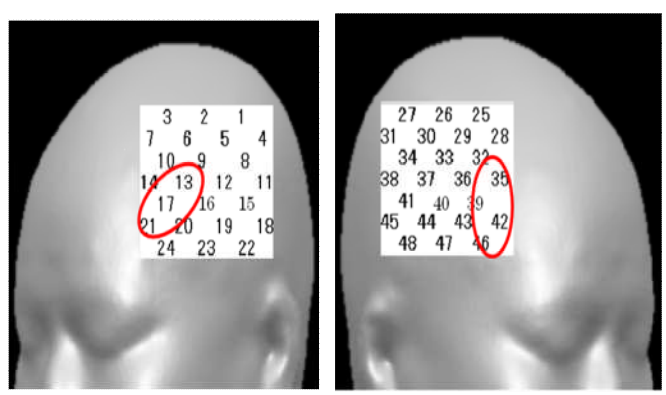

Figure 12. Significant Difference in sitting position

IV. DISCUSSION

1) Evaluation by using 3D Motion Analysis and EMG

From the analysis of the result, it was shown that the value of the integral decreased by using assistive apparatus for transfer. Especially, there was a remarkable decrease in the value of the integral at tibialis anterior muscle, quadriceps femoris muscle. On the other hand, we have shown a minor decrease in one at upper limb and muscles of the back. Also, the moving distance of barycentric position was decreased by the use of the welfare device.

This result was thought to be due to the difference in height between chair and seating face of welfare device. Therefore, it was thought that the use of assistive apparatus is useful to lighten the burden on lower limbs. Thus, it's contemplated that muscle load during standing and sitting movements was decreased and reduced centroid fluctuation to lower the possibility of turnover.

Even if the subjects performed daily movements of standing and sitting with the use of the assistive equipment, we have shown that the integral of muscle potential and distance of centroid change was decreased. Therefore, we proved that there is the possibility of evaluation of daily performance except for movement with the welfare device.

2) Evaluation by using NIRS

In this experiment, we tried to measure quantitatively the physical and psychological strain on the basis of brain activity. Also, we think that brain activity discloses human cognitive including non-verbal. As a result, it was shown that there were differences in brain activity due to the number of trials and postural. At this time, analysis was performed via one-sample t-test using sample of brain activity in resting state, during task, or after task. Hence, the analysis method was to remove disturbance such as body motion and angular variation of neck to the best extent possible although there was the possibility to measure skin blood flow. Therefore, the strain due to tasks was quantitatively measured by recognizing the significant differences.

Also, in previous research, a decrease in the brain activity was reported around #10, 11 [10], as the result of measuring brain activity during Advanced Trial Making Test using PET [11]. Therefore, this result came out in support of previous research.

Of course, it is necessary to increasethe number of subjects at the present stage. In addition, there are problems associated with the experiment, the number of subjects, the method and the measured region. However, in terms of being recognized significant differences at brain activity due to movement, it was thought to show useful result in evaluating quantitatively daily movements.

V. CONCLUSION AND FUTURE WORK

In this experiment, our purpose was to quantitatively evaluate the physical load with focus on standing and sitting movements which are part of usual daily movements, using 3D motion analysis system and EMG.

As the result, it was shown that the integral of lower-limb muscle, such as tibialis anterior muscle and gastrocremius muscle, significantly decreased with the use of the welfare device.

Also, it was reported that there is a positive correlation between anteversion angle of body trunk and movement duration in previous research [12]. But, our experiment method was to estimate the possibility of falling in rising from a sitting position by calculating moving distance of median point. It was confirmed that the possibility of falling was decreased by using the device.

Next, we tried to measure physical and psychological load quantitatively on the basis of brain activity. There were significant differences due to the number of trials, holding position. In this experiment, the analysis method was to remove disturbance such as body motion and angular variation of neck to the extent possible by using the measurement result in resting state as sample. This has been useful in evaluating quantitatively the load due to movement task by being recognized difference in brain activity caused by number of trials, substance of task and holding position.

The main purpose in this study was to evaluate physical load and fatigue quantitatively. We tried to evaluate the change of muscle load due to the difference of motion by simultaneously measuring with 3D motion analysis System and EMG quantitatively.

However, the evaluation of psychological load was necessary, too. In terms of using the welfare device, prolonged use must be taken into account. In this case, it is important to consider not only physical load but also psychological load due to prolonged use from the standpoint of developing the welfare device and keeping up surviving bodily function.

Also, in previous research, separation between physical and psychological loads has been performed. But, our view is that there is a correlation between physical and psychological loads. For this reason, we tried to measure psychological load including physical one based on brain activity to quantitatively evaluate both loads.

For the future, our aim is to establish a method of discussing the usefulness of welfare devices by evaluating the load involved in other daily movements with increasing number of subjects.

ACKNOWLEDGMENT

This research was supported as follows.There dimensional motion analysis and commodious room were provided by nac Image Techonogy Inc. EMG and analysis software were provided from KISSEI COMTEC. NIRS was provided by SHIMADZU COPPORATION. Developing welfare device was provided by IDEA SYSTEM CO., LTD. We are deeply grateful to them.

This study contributes to become the basis for one of theme of s-innovation program in Japan Science and Technology Agency which was named “Development Fatigue-reduction Technology for Social Contribution of Aged Person and Establishment System for Evaluation.

REFERENCES

[1] Y. Shinoda, “Considertion of feature extraction based on center of gravity for Nihon Buyo dancer using motion capture system,” SICE Annual Confference 2011, Tokyo Japan, pp. 1874-1878.

[2] Y. Yamaguchi, A. Ishikawa, and Y.Ito, “Development of Biosignal Integration Analysis System for Human Brain Function and Behavior,” Organization for Human Brain Mapping 2012, China.

[3] H.Inoue, S. Shimizu, N. Takahashi, H.Nara, and T. Tsuruga “Fundamental Study for Evaluation of the Effect due to Exercise Load” , Assistive Technology, Bio Medical Engineering and Life Support 2011, Japan.

[4] E. Watanabe, Y. Yamashita, Y. Ito, and H. Koizumi, "Non-invasive functional mapping with multi-channel near infra-red spectroscopic topography in humans," Heurosci Lett 1996, Feb 16, 205(1), 41-4.

[5] N. Takahashi, S. Shimizu, Y. Hirata, H. Nara, F. Miwakeichi, N. Hirai, S. Kikuchi, E. Watanabe, and S. Kato, "Fundamental Study for a New Assistive System during Car Driving," Proc. of International Conferrence on Robotics and Biomimetics, DVD-ROM, 2010, Tenjin, China.

[6] N. Takahashi, S. Shimizu, Y. Hirata, H. Nara, H. Inoue, N. Hirai, S. Kikuchi, E. Watanabe, and S. Kato, "Basic study of Analysis of Human Brain Activities during Car Driving," the 14th International Conferrence on Human-Computer Interaction, 2011, USA.

[7] S. Shimizu, N. Takahashi, H. Nara, H. Inoue, and Y. Hirata, "Fundamental Study for Human Brain Activity Based on the Spatial Cognitive Task," the 2011 Internatinal Conference on Brain Informatics-BI 2011, China.

[8] S. Shimizu, N. Takahashi, H. Nara, H. Inoue, and Y. Hirata, "Basic Study for Human Brain Activity Based on the Spatial Cognitive Task," The Third International Conference on Advanced Cognitive Techonologies and Applications, 2011, Italy.

[9] S. Shimizu, N. Takahashi, H. Inoue, H. Nara, F. Miwakeichi, N. Hirai, S. Kikuchi, E. Watanabe, and S. Kato, "Basic Study for a New Assitive System Based on Brain Activity associated with Spatial Perception Task during Car driving," Proc. International Conferrence on Robotics and Biomimetics, 2011, Thailand.

[10] Y. Watanabe,"Molecular/neural mechanisms of fatigue, and the way to overcome fatigue," Folia Pharmacological Japonica, vol. 129, pp. 94-98, 2007.

[11] H. Kuratsune, K. Yamaguti, G. Lindh, B. Evengard, G. Hagberg, K.Matsumura, M. Iwase, H. Onoe, M. Takahashi, T. Machii, Y.Kanakura, T. Kitani, B. Langstrom, and Y. Watanage,"Brain Regions Involved in Fatigue Sensation: Reduced Acetylcarnitine Uptake in to the Brain," Neuroimage, vol. 17, pp. 1256-1265, November 2001.

[12] K. Maruta,"The influence of Seat Angle on Forward Trunk Inclination During Sit-to-Stand," Jounal of Japanese Physical Therapy Association, vol. 31, No.1, pp. 21-28, 2004.