2C5-IOS-1a-2

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

Hiroaki Inoue[*1] Shunji Shimizu[*1]

Hiroyuki Nara[*2] Takeshi Tsuruga[*3]

Fumikazu Miwakeichi[*4] Nobuhide Hirai[*5]

Senichiro Kikuchi[*5] Eiju Watanabe[*5]

Satoshi Kato[*5]

[*1] Tokyo University of Science, SUWA [*2] Hokkaido University

[*3] Hokkaido Institute of Techonology [*4] The Institute of Statistical Mathematics

[*5] Jichi Medical University

Recently, Japan (also world-wide countries) has become aged society, and a wide variety welfare device and system have been developed. But evaluation of welfare system and device are limited only stability, intensity and partial operability. So, evaluation of usefulness is insufficient. Evaluation of usefulness is necessity to consider about interaction of human and welfare device. In this paper, we measure load of sitting and standing movement to use EMG (Electoromyogram) and 3D Motion Capture and set a goal to establish objective evaluation method. We think that establishing objective evaluation method is necessity to develop useful welfare device. We examined possibility of assessing load and fatigue from measuring brain activity to use NIRS (Near Infra-Red Spectroscopy). We think that measuring load and fatigue is very important for developing user-friendly welfare device. Idea of universal design is widespread in welfare device and system. Measuring require verification of all generations. But, we performed to measure younger subjects as a first step.

1. Introduction

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

So, we examined the possibility of evaluation by measuring physical load due to activities of daily living with 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. Also, we consider that physical and psychological load are linked to cognition including non-verbal cognition. In this paper, the purpose of experiments are to evaluate motion focusing on sitting and standing movement, which is usually done in our life by using 3D Motion Analysis System, EMG, NIRS. We consider that human feel physical and psychological load during life motion. We tried to measure 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 twenties, because the elderly person who has various types of disease is inept in quantitative evaluation.

2. Experimental Method

2.1 Evaluation by using 3D Motion Analysis and EMG

We simultaneously measured 3D position and muscle potential of subject during task by using 3D Motion Analysis System (nac IMAGE TECHNOLOGY Inc. products- MAC3DSYSTEM [Shinoda 2011]) and EMG (KISSEI COMTEC Inc. products- MQ16).

Regarding to measuring 3D position, 8 Infrared cameras were placed around subject, and 27 makers of the body surface were set on the basis of Helen-Hayes Hospital Marker set (Figure 1).

Contact:Hiroaki Inoue, Tokyo University of Science, SUWA, 5000-1,toyohira,chino-city,Nagano,Japa , +81266731201 , +81266731207, jgh12701@ed.suwa.tus.ac.jp

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 measurement was used so that subject was constrained as little as possible.As sampling frequency, 3D Motion Analysis System was 100Hz, and EMG was 1 kHz.

Subjects were three males aged twenties. They were asked to read and sign an informed consent regarding the experiment.

In this experiment, subject repeated one series of movement, which was to transfer from chair to seat face of welfare device (IDEA LIFE CARE Co. Ltd products-NORISUKEsan [Inoue 2011]) and opposite one with alternating between standing and sitting, at five times per one measurement. Seating face of welfare device, which was designed to assist transfer movement, was manipulated by simple method and appeared on the top of chair.

Subjects were heard buzzer every one second and kept a constant motion of speed 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. Operation of welfare device was performed by the operator other than subject.

2.2 Evaluation by using NIRS

We measured brain activity during motion with the purpose of establishing evaluation method based on generality (Figure 1).

Subjects were six males aged twenties. They were asked to read and sign an informed consent regarding the experiment. Measurement apparatus was NIRS (SHIMADZU CO. Ltd products-FOIRE3000 [Watanabe 1996]). Measurement region was at right and left prefrontal cortex.

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

At this measurement, the subjects used welfare device to perform transferring in a standing position. In this measurement, subject sat on seating face of welfare device appeared on the top of chair after raising hip until kneeling position. Also, subject performed inverse transferring 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. Rest time is to stabilize the brain activity.

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

At the measurement, the subjects used welfare device to perform transferring in a half-crouch position. In 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 experiments of task1 and task2, operation of welfare device was performed by operator other than subject. Before this measuring, subjects adjusted to transferring by use of welfare device.

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

3) The subjects performed two tasks at this measurement. During task3-1, subject sat on seating face of welfare device with eyes open. During task3-2, they kept a half-crouch position. Subjects alternated task3-1 and task3-2. Also, subjects took resting time between two types of motion with eyes close. Therefore 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.

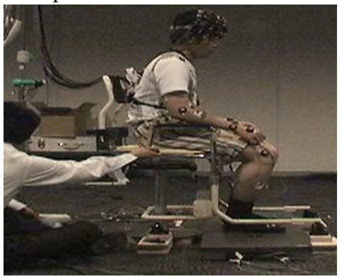

Figure 1. Experimental View of NIRS

3. Experimental Result

3.1 Evaluation by using 3D Motion Analysis and EMG

Figure 2 shows result of transferring which was measured by 3D motion analysis and EMG. In Figure 2, middle trochanter is the height of midpoint between right and left trochanter from the floor. Trunk angle is the forward slope of trunk. Also, following terms are arectifying 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 muscle potential during standing and sitting movement from measuring result with reference to middle trochanter and trunk angle and calculating value of integral during movement. Table 1 shows the ratio of value integral with welfare device to one without device. Also, we compared moving distance of median point between using welfare device and not. Table 2 shows the comparison results in a manner similar to Table 1.

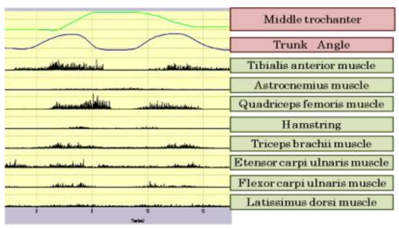

Figure 2. Result of 3D Motion Analysis and EMG

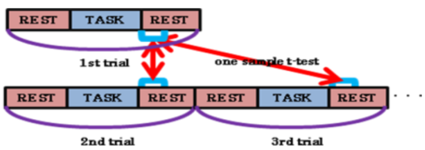

Figure 3. T-test of sample data of task1 and 2

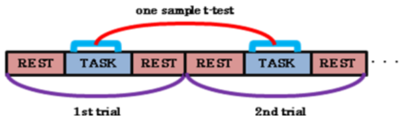

Figure 4. T-test of sample data of task3

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

3.2 Evaluation by using NIRS

As common result of all subjects, oxy-Hb tended to increase during task and to decrease in resting state. Therefore, it was thought that change of hemoglobin density due to task was measured. Fig. 5 shows trend of the channel in which significant different was shown. Analysis was performed via one-sample t-test [Takahashi 2010, Takahashi 2011, Shimizu 2011, Shimizu 2011] 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 (Fig. 3). In task 3, sample data was 4 seconds during task. (Fig. 4)

4. Discussion

4.1 Evaluation by using 3D Motion Analysis and EMG

From analysis result, it was shown that value of integral was decreased by using assistive apparatus for transfer. Especially, there was remarkable decrease in value of integral at tibialis anterior muscle, quadriceps femoris muscle. On the other hand, it was shown to be minor decrease in one at upper limb and muscles of the back. Also, moving distance of barycentric position was decreased by the use of welfare device. On the ground of this result, it was thought to be due to 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 burden on lower limb. Thus, it's contemplated that muscle load during standing and sitting movement was decreased and reduced centroid fluctuation to lower the possibility of turnover. Even if subjects performed daily movements of standing and sitting with the use of assistive equipment, it was shown that the integral of muscle potential and distance of centroid change was decreased. Therefore, it was proved that there is the possibility of evaluation of daily performance except for movement with welfare device.

4.2 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 disclose human cognitive including non-verbal. As a result, it was shown that there were differences at brain activity due to number of trials and postural. In this time, analysis was performed via one-sample t-test using sample of brain activity in resting state during task or after task. Hence, analysis method was to remove disturbance such as body motion and angular variation of neck to the extent possible although there was the possibility to measure skin blood flow. Therefore, it was thought that strain due to tasks was quantitatively measured by being recognized significant differences. Also, in previous research, it was reported to decrease in activity in the brain around #10, 11 [Watanabe 2007], as the result of measuring brain activity during Advanced Trial Making Test using PET [Kuratsune 2001] . Therefore, this result came out in support of previous research in no small part. Of course, it is necessary to increase number of subject at the present stage. In addition, there are problems associated with experiment, number of subject, method and 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.

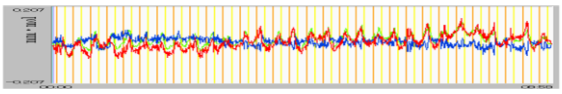

Figure 5. Measuring Result of Task1

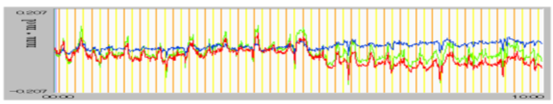

Figure 6. Measuring Result of Task2

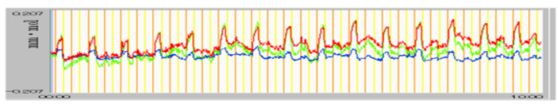

Figure 7. Measuring Result of Task3

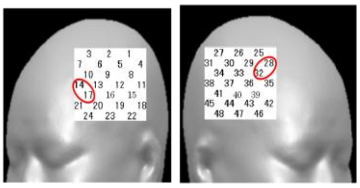

Figure 8. Signififant Difference of task1

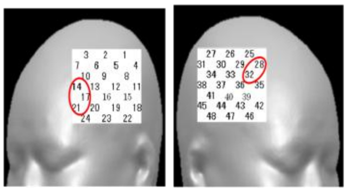

Figure 9. Significant difference of task2

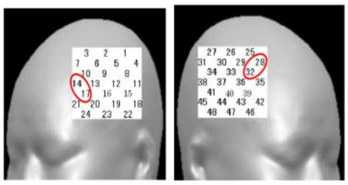

Figure 10. Significant Difference of task 1 and 2

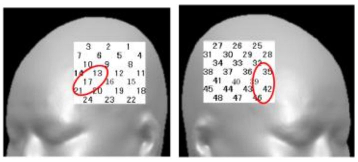

Figure 11. Significant Difference in sitting position

5. Discussion

In this experiment, our purpose was to evaluate quantitatively physical load with focusing on standing and sitting movement which was part of 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 by the use of welfare device.

Also, it was reported that there is a positive correlation between anteversion angle of body trunk and movement duration in previous research [Maruta 2004] . But, our experiment method was to estimate the possibility of falling in rising from a sitting position by calculating moving distance of median point. And, it was confirmed that the possibility of falling was decreased by using device.

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

Main purpose in this study is to evaluate physical load and fatigue quantitatively. So, we tried to evaluate change of muscle load due to difference of motion by simultaneous measuring with 3D motion analysis System and EMG quantitatively.

However, evaluation of psychological load is necessary, too. In terms of using 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 standpoint of developing welfare device and keeping up surviving bodily function.

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

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

References

[Shinoda 2011] 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.

[Inoue 2011] H.Inoue, S. Shimizu, "Fundamental Study for Evaluation of the Effect due to Exercise Load" , Assistive Technology, Bio Medical Engineering and Life Support 2011, Japan.

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

[Takahashi 2010] N. Takahashi, S. Shimizu, "Fundamental Study for a New Assistive System during Car Driving," Proc. of International Conferrence on Robotics and Biomimetics, DVD-ROM, 2010, Tenjin, China.

[Takahashi 2011] N. Takahashi, S. Shimizu, "Basic study of Analysis of Human Brain Activities during Car Driving," the 14th International Conference on Human-Computer Interaction, 2011, USA.

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

[Shimizu2011] S. Shimizu, N. Takahashi, "Basic Study for Human Brain Activity Based on the Spatial Cognitive Task," The Third International Conference on Advanced Cognitive Techonologies and Applications, 2011, Italy.

[Shimizu 2011] S. Shimizu, N. Takahashi,"Basic Study for a New Assitive System Based on Brain Activity associated with Spatial Perception Task during Car driving," Proc. International Conference on Robotics and Biomimetics, 2011, Thailand.

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

[Kuratsune 2001] 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.

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