A Study on Fatigue Reduction of Driver by Changing Back Support Position During Long Time Driving

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Abstract. Our main study theme is to reduce fatigue of driver during long time driving. In order to reduce fatigue of drivers during long time driving, we focused on a method of using back support mechanisms to change the posture of the driver. We predicted that fatigue level of driver would change in accordance with the change of back support position. Furthermore, we evaluated the muscle activity change when the support position changed. By examining the correlation between the evaluated data, we expected that the driver’s optimum support position would be found out. As a result of conducting driving and subjective assessment, it was found that there was a difference in fatigue reduction effect on the change of the driver’s back support position. When the driver’s fatigue level was low, muscle activity was low.

1. Introduction
In recent years, automobiles are required to improve not only efficiency and safety but also comfort during driving. In order to improve comfort, it is necessary to reduce driver fatigue in long time driving. The cause of physical fatigue during long time driving is poor blood circulation by maintaining the same posture for a long time. Fatigue accumulates in the muscles of the lumbar and buttocks due to this poor blood circulation. Various researches are being conducted to lessen fatigue accumulation. For example, there are studies that verify the reducing effect of driving fatigue increase rate by massage effect [1, 2, 3]. However, the conventional research did not change the driving posture during driving. It is said to relieve fatigue feeling by movement of the body, such as changing driver's posture and re-sitting. Therefore, we considered that changing the driving posture using the seat mechanism is effective for fatigue reduction. As a previous research in our laboratory, we found that fatigue can be reduced by periodically using the lumbar support built into the driver's seat [4, 5, 6]. Furthermore, we are studying way to improve the fatigue reduction effect of the driver.

In this paper, we aimed to verify the fatigue reduction effect of the driver during long time driving when the support position of the back support mechanism was changed. Based on the results, we examined the optimum supporting position for reduce fatigue. Driving simulator was used for fatigue evaluation. Fatigue evaluation was performed by muscle fatigue evaluation based on finger plethysmogram and blood lactate level increase amount and subjective evaluation based on survey. In addition, we measured the driver's muscle activity when the back support position was changed and discussed the relationship with fatigue.
2. Methodology

2.1 Purpose and Procedure

2.1.1 Experimental purpose
We considered that accumulation of fatigue of driver during long time driving will vary depending on the driver's back support position. In this case, we predicted the difference of the driver's back muscle activity when the back support position was different. If we can clarify the relationship between the fatigue evaluation results and the muscle activity measurement results, it might be a way to find the best position for the driver. So, this study examines the relationship from two experiments. First, we evaluate the driver's seating fatigue using objective and subjective evaluation during long time driving. Second, we measured the muscle activity of the driver's back muscle at each support position. This measurement was carried out separately from fatigue evaluation.

2.1.2 Specification of automobile seat
The automobile seat used in this study has a support device that supports the driver's back. The air cell support shown in figure 1 was used for the back support mechanism. The amount of protrusion of the air cell can be changed by the number of times the pump is pushed. We determine the height of the support position based on planned Hip Point (SRP). The amount of protrusion of the air cell can be changed by the number of times the pump is pushed. As shown in figure 2, two positions of 120 mm above the SRP(B120) and 150 mm above the SRP(B150) were set as the support positions.

2.1.3 Structure of experiment equipment
In this paper, we evaluate the lessening effect of driving fatigue using the air cell support fitted in the seat. The evaluation experiment is conducted using the driving simulator (DS) shown in figure 3. DS consists of steering, accelerator, brake, seat and 40inch monitor. We experimented using GranTurismo SPORT of PlayStation 4, and we used a Nurburgring North course with many curves to prevent chronic operation due to long time driving. Volkswagen Golf was selected for the experimental vehicle. It is similar to the car that the subject usually drives. We used BACS Advance to measure finger plethysmogram. It is laid out the elbow rest at the left side of the seat. It measures finger plethysmogram by using the infrared absorption characteristics of hemoglobin. The sampling time is five msec. For muscle activity measurement, EMG (electromyography) measurement system (EMG amplifier: SX 230 - 1000, measuring system: K800 type) manufactured by Biometrics, and respiratory sensor (DL - 230) manufactured by S & ME company was used. Lactate-pro 2 ™ LT-1730 manufactured by ARKLEY Co., Ltd. was used for measurement of blood lactate levels.
2.2 Fatigue evaluation

2.2.1 Experimental conditions
In this study, we evaluate the driver's seating fatigue during long time driving using biological information. Biological information is easily affected by daily life. Subjects tried to make daily life (breakfast, lunch, sleeping, getting up) and experimental start times as similar as possible. Also, finger plethysmogram is affected by the experimental environment around the subjects such as temperature and humidity. Air conditioning management was conducted so that the experimental environment could be maintained. We conducted the experiment at least every other day to prevent fatigue accumulation of subjects by daily experiments. The subject are two males in their twenties. The experimental time was ninety minutes. The air cell is operated by the operator. For this reason, the driver does not operate the air cell device. Also, the operate pattern of the air cell device does not use the air cell device for fifteen minutes after starting the experiment based on our previous research results. Operating of the air cell device was made after fifteen minutes from the start of the experiment. As shown in figure 2, two positions B120 and B150 were set as the support positions and the fatigue reduction effect in each support pattern was verified. There are three experimental patterns as follows. The first pattern is not to actuate the air cell. The second pattern is to actuate it at B120 every fifteen minutes. The third pattern is to actuate it at B150 every fifteen minutes. We conducted five times experiments for each pattern.

2.2.2 Fatigue evaluation method
In this study, we evaluate the driver's seating fatigue during long time driving by objective evaluation and subjective evaluation. In the objective evaluation, we measure two biological information. The one is finger plethysmogram. Another is blood lactate level. We use the analysis method of finger plethysmogram to derive pulse wave fatigue curves [7]. Finger plethysmogram is sensitive to body motion. Therefore, when measuring, we indicated to steer with just my right hand while leaving my left arm on the armrest (figure 4). The evaluation using blood lactate level was conducted by defining the difference between lactate level before and after driving as the increased amount [8]. We have drew blood with attention to infection. We conducted subjective questionnaire assessments on three parts of the body: buttocks, lumbar and back. Evaluate the fatigue of each part body on a self-evaluated basis every five minutes. As shown in figure 5, the fatigue level at the start of the experiment is set to one. If the subject feels that fatigue has increased in each part of the body compared to 5 minutes ago, the fatigue level is increased by 1 point. If the fatigue does not change, the score also does not change. Evaluation was carried out using the final fatigue value after ninety minutes.

(This study is approved by the Mie University of Engineering Ethics Committee.)
2.3 Muscle activity evaluation

2.3.1 Experimental conditions
When the back support position was changed, it was predicted that the muscle activity of the driver's back muscle was changing, and the muscle activity change of the driver's back muscle at each support position was measured. Also, since it is the purpose of confirming the change of the muscle activity due to the support position change, it is necessary to avoid fatigue of the subject affecting the measurement result. In addition, it is necessary to suppress variations in the state of subjects in each measurement. In order to match the condition of the subject as closely as possible, we requested the subject to sit for three minutes. After sitting, the muscle activity was measured for ten seconds while the air cell device was not operated. Thereafter, measurement was carried out for ten seconds in a state where the air cell device was operated at each support position. After completion of the measurement, the subject was kept standing for three minutes so that there was no influence of seated fatigue on the next measurement. This was regarded as one cycle, and changes in muscle activity at each support position were measured. The support device was operated by the operator in the same way as the fatigue evaluation experiment. The measurement is a state in which the support device is not operated, B120, B150. Measurement order is random. We conducted five times experiments for each pattern.

2.3.2 Muscle activity evaluation method
In this research, muscle activity in the state of static seating when maintaining posture is the object to be measured. Since muscle activity at this time is very small, it becomes minute value as myoelectric value. From preliminary experimental results, it was found that the muscle activity in the static seating is susceptible to the influence of minute body motion by respiration, and the variation is large. Therefore, in order to suppress variations in measured values, respiration timing during myoelectric measurement was synchronized. For measurement, a respiratory sensor (DL - 230) manufactured by S & ME company was used. In addition, the muscles to be measured were the Longissimus thoracis, iliocostalis thoracis, iliocostalis lumborum, and Multifidus, which are said to be used in posture keeping. As shown in figure 6, the position of the electrode is the position recommended by the SENIAM project (total of five position (Longissimus thoracis: two places, iliocostalis thoracis: one place, Iliocostalis lumborum: one place, Multifidus: one place)) [9]. After treatment of the subject's body surface, muscle activity was measured at a sampling frequency of 1 kHz. Integrated myoelectric method (IEMG) was used for the evaluation of muscle activity [10]. The muscle activity amount was normalized by calculating the change ratio, and comparison was made.
3. Result and Discussion

3.1 Results of fatigue evaluation

3.1.1 Results of pulse wave muscle fatigue curve

Figure 7 shows the pulse wave muscle fatigue curve for each experimental pattern. The results represent the average value of 5 times. The vertical axis represents the fatigue value of the subjects, and the horizontal axis represents time [min]. In these figures, the red line shows the Pattern 1, the blue line shows the Pattern 2, and the green line shows the Pattern 3. Figure 8 represents the final fatigue value after ninety minutes. The vertical axis represents the final fatigue value of the subjects, and the horizontal axis represents experimental pattern. In the figure, the red bar denotes the Pattern 1, the blue bar denotes the Pattern 2, and the green bar denotes the Pattern 3. The error bars indicate the standard deviations. A significant difference test by multiple comparison is performed to evaluate the significant difference of these results. Bonferroni’s method was used for the multiple comparison. The marks of (*) and (**) indicate the significant of 5% and 1%, respectively.

As shown in the results of subject A in figure 8, a significant difference was obtained in pattern 2 and pattern 3 compared to pattern 1. From this, the fatigue lessening effect was confirmed in Pattern 2 and Pattern 3. However, there was no difference in the effect of lessening fatigue between two patterns. On the other hand, as shown in the results of subject B in figure 8, the subject B did not obtain the fatigue lessening effect in the pattern 3 compared to the pattern 1. However, pattern 2 obtained a significant difference tendency compared to pattern 1. From this, the tendency to lessening fatigue was confirmed.

Figure 6: EMG amplifier position

Figure 7: Pulse wave muscle fatigue curves
3.1.2 Results of increase amount of blood lactate level
Figure 9 shows the blood lactate level increase amount for each pattern. The results represent the average value of 5 times. The vertical axis represents the increase amount of the blood lactate level, and the horizontal axis represents each experimental pattern. The red, blue and green bars represent the average values of the blood lactate level increase in Pattern 1, Pattern 2 and, Pattern 3, respectively. The error bars indicate the standard deviations. A significant difference test by multiple comparison is performed to evaluate the significant difference of these results. Bonferroni's method was used for the multiple comparison. The marks of (*) and (**) indicate the significant of 5% and 1%, respectively.

As shown in the results of Subject A in figure 9, a significant difference was obtained in pattern 2 and pattern 3 compared to pattern 1. From this, the fatigue lessening effect was confirmed in Pattern 2 and Pattern 3. However, there was no difference in the effect of lessening fatigue between two patterns. On the other hand, as shown in the results of subject B in the figure 9, the subject B did not obtain the fatigue lessening effect in the pattern 3 compared to the pattern 1. However, pattern 2 obtained a significant difference tendency compared to pattern 1. From this, the tendency to lessening fatigue was confirmed.

3.1.3 Results of subjective fatigue evaluation
Figure 10 shows the final value of each body part fatigue obtained by the subjective questionnaire assessments. The results represent the average value of 5 times. The vertical axis represents the fatigue value, and the horizontal axis represents each part body. The red bar represents average of the fatigue value of the Pattern 1, the blue bar represents the one of the Pattern 2, and the green bar represents the one of the Pattern 3. The error bars indicate the standard deviations. A significant difference test by multiple comparison is performed to evaluate the significant difference of these result. Bonferroni's
method was used for the multiple comparison. The marks of (*) and (**) indicate the significant of 5% and 1%, respectively.

As shown in the results of Subject A in figure 10, in the buttocks, a significant difference was obtained in pattern 2 and pattern 3 compared to pattern 1. In the back, a significant difference was obtained in pattern 3 compared to pattern 1. From this, the fatigue lessening effect was confirmed in Pattern 2 and Pattern 3. On the other hand, as shown in the results of subject B in the figure 10, in the lumbar, a significant difference was obtained in pattern 2 compared to pattern 1. In the back, a significant difference was obtained in pattern 2 and pattern 3 compared to pattern 1. From this, the fatigue lessening effect was confirmed in Pattern 2 and Pattern 3.

![Subjective evaluation results](image)

**Figure 10**: Subjective evaluation results

### 3.2 Muscle activity evaluation results

The muscle activity amount was derived by the method in the subsection 2.3.2. Measurement of the muscle activity was performed five times for each support position. The result of averaging the rate of change of the muscle activity amount for each support position is represented in figure 11. The vertical axis represents muscle activity ratio, and the horizontal axis represents experimental patterns. The error bars indicate the standard deviations. A significant difference test by multiple comparison is performed to evaluate the significant difference of these results. Bonferroni’s method was used for the multiple comparison. The marks of (*) and (**) indicate the significant of 5% and 1%, respectively.

As shown in the results of Subject A in figure 11, a significant difference was obtained in B120 and B150 support compared to no use. From this, it was confirmed that the muscle activity of B150 support pattern and B120 support pattern was lower than that when the support was not used. However, there was no difference in muscle activity amount in B150 support pattern and B120 support pattern. On the other hand, as shown in the results of Subject B in figure 11, the subject B did not obtain the lessening muscle activity in the B150 compared to no use. However, B120 obtained a significant difference compared to no use. From this, it was found that subject B had a difference in muscle activity amount depending on the support position.

As a result of fatigue evaluation using the biological information (pulse wave muscle fatigue curve and blood lactic level) in subject A, fatigue lessening effect was confirmed in patterns 2 and 3 as compared with pattern 1. From the subjective evaluation results, it was confirmed that the feeling of fatigue was reduced in the buttocks in the pattern 2 and in the buttocks and the back part in the pattern 3, as compared with the pattern 1. We consider that the most effective support position of subject A is pattern 3(B150) from these results. On the other hand, as a result of fatigue evaluation using the biological information in the subject B, fatigue reduction effect was confirmed in pattern 2 as compared with the pattern 1. From the subjective evaluation results, it was confirmed that the feeling of fatigue was reduced in Pattern 2 at the lumbar region and back part compared to Pattern 1.
From these results, we consider that the most effective support position of subject B is pattern 2(B120). In addition, we investigated which position of each subject's body was supported for reducing the fatigue. As a result, it was found that fatigue reduction effect was obtained when both test subjects were supported near the third lumbar vertebrae. From this, we found a possibility that there is a correlation between the support position against the body and the fatigue alleviating effect. In addition, reduction of the muscle activity amount could be confirmed in the support position where fatigue reduction effect was obtained in both subjects. From this result, we found a possibility that there is a correlation between the muscle activity amount and fatigue reduction.

4. Conclusion
In this paper, we verified the fatigue reduction effect during long time operation for each driver when the support position of the back support mechanism was changed. In addition, we measured the muscle activity change of the back muscles of the driver when the back support position was changed, and examined the correlation with fatigue. As a result, we found a possibility that there is a correlation between the support position against the human body and the fatigue reduction effect. In other words, it was found that posture with less muscle activity on subject's back is effective for reducing fatigue. From this, it is considered that the back support position is an important parameter for reducing fatigue. For future work, we investigate the muscle activity used in posture maintenance in more detail and derive the optimal support position for reducing fatigue accumulation in each driver.

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