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Differences in Facial Muscle Movements Affected by Respiratory Status in Children with Severe Motor and Intellectual Disabilities during Sputum Suction

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ABSTRACT

The current study aimed to identify facial muscle movements that can be indicators of stress in children with severe motor and intellectual disabilities（SMID）who presented with subtle changes in facial expressions. This research focused on the analysis of cases in which sputum aspiration was required in children with SMID. In total, four children aged 3-11 years who presented with Oshima class 1 SMID were examined. Multiple regression analysis was conducted using the variable incremental method with heart rate as an index. Results showed that items such as eyes closed, lips part and outer brow raiser were common explanatory variables among the participants. The degree of effect of the three items, which can be related to the presence or absence of tracheostomy, differed.

Keywords: Children with SMID（severe motor and intellectual disabilities）, Multiple regression analysis, Pulse rate, Action Unit, Sputum suction

Ⅰ. Introduction

Children with severe motor and intellectual disabilities（SMID）present with severe intellectual and physical disabilities caused by brain damage attributed to conditions such as hypoxia and encephalitis before and after birth［1］. Therefore, these children experience difficulties in expression through words and actions and present with subtle changes in facial expressions. Therefore, it is challenging to understand the pain and needs of children with SMID.

During the process of human growth and development, it is difficult to express pain and needs verbally. In such cases, the FLACC pain scale［2］, which is a scoring system based on facial expressions, crying and body movements, can be used. In addition, previous research has evaluated heart rate changes［3］, pain using a salivary amylase activity monitor［4］and the correlation between movement and heart rate measured on EKG using sensors attached to the head, trunk and pelvis［5］. However, previously, qualitative research on the reactions of children with SMID was commonly performed using questionnaires and by conducting interviews with family members and professionals［6］. The interpretation of changes in facial expressions and muscle tension differs based on the recipient's interest［7］. Therefore, the risk of being influenced by experience and subjectivity cannot be disregarded. In addition, the facial expression analysis software is used to infer emotions in some cases. However, as it was developed overseas, its direct application on evaluating emotions among Japanese is challenging［8］. Moreover, these systems were not developed for children with SMID. Hence, there are issues with the reliability of its analysis results.

In recent years, data in the healthcare field have been collected using ICT devices, and various biological details in daily life scenarios have been visualised to maintain the health of people. Using large amounts of data acquired using various sensors and artificial intelligence (hereinafter referred to as AI) [9], we can discover characteristics and create new values to establish a society that is independent of age and disability. Hence, a person must first specify the features of the data to focus on and learn.

Therefore, the ICT equipment was used to understand breath sounds, minor changes in facial expressions, and trunk movements, which had been previously understood by cautiously observing the daily life situations of children with SMID [10]. Therefore, the characteristics of time-series data are evaluated to develop a system that can be used to reduce the burden on children with SMID and their families and caregivers [11, 12].

The facial muscle movements of one child with SMID who could determine the presence or absence of stress were analysed in three situations (sputum suction, transfer to a wheelchair and mother's absence) using heart rate as an index [13]. Results showed that the common facial muscle movement in the three situations was eyes closed. Moreover, outer brow raiser could be a feature during sputum suctioning, which is highly stressful. In this case, multiple regression analysis was performed using heart rate as the objective variable to validate facial muscle movements that explain the stress caused by sputum aspiration. This result was almost similar to that of the explanatory variables extracted via logistic regression analysis, which were classified into binary levels of pleasant and unpleasant based on the opinions of caregivers and professionals [14].

Therefore, this research aimed to validate the facial muscle movements that can explain the stress caused by sputum aspiration via multiple regression analysis using heart rate as the objective variable in four cases in which changes in facial expressions were challenging to assess. Results showed the commonalities and specificities.

Ⅱ. Objective

The current study aimed to identify common changes in facial muscle movements during stressful situations by collecting data before and after sputum aspiration in four children with SMID who did not clearly present with changes in facial expressions.

Ⅲ. Methods

1. Recruitment of research collaborators

The current study was approved by the research ethics review committee of the affiliated institution (approval numbers: 2019034 and 2019045) and was performed using the consent of the facility. We distributed an explanatory note, a cooperation consent form, and a self-addressed stamped envelope to the caregivers of patients with SMID (Oshima's classification 1-4) who visited the research cooperation facility. Then, the caregivers were explained about the essential items. Next, research participants were recruited.

2. Data collection period

The data collected period lasted from November 2019 to the end of February 2020.

3. Data collection methods [15]

Before collecting data on patients with SMID, we confirmed the physical condition of patients with SMID and points to keep in mind with their families. Next, an interview about their experiences in raising children was performed. After participating in training, health care programmes and child development support activities in research cooperation facilities and understanding the characteristics of patients with SMID, data were collected while paying attention to safety. In addition, interviews with nursing care personnel and families and assessments of patients with SMID were conducted with the support

of medical specialists. Simultaneously, methods that are suitable for assessing the individuality of patients with SMID were examined.

Information on heart rate was recorded every second using a pulse oximeter Listox 2 model 3150BLE (hereinafter referred to as the pulse oximeter). The facial muscle movement was captured with a web camera and analysed with Face Reader 8. Next, 20 items in the facial muscle movement data were used as numerical values. This analysis software can detect 500 facial points and capture minute changes in facial muscles. Therefore, it can detect facial muscle movements and blood flow that are invisible to humans. The facial muscle movement was digitised within a range of 0-1, with 1 indicating the maximum intensity. Breath sounds were collected using an electronic stethoscope before and after sputum suction and during postural changes during sleep to ensure not to disturb the sleep of patients with SMID. Auscultation was performed by placing sensors on the left and right sides of the anterior chest and the left and right interscapular regions of the back. Lung sounds during breathing were recorded for approximately 1 min. Data were compared with the frequency spectra subjected to a fast Fourier transform. In addition, all sensing devices were connected to the same computer and synchronised by setting the time. After the data were analysed, they were output as comma-separated value data.

4. Analysis method

Based on the results of a previous study [13], multiple regression analysis was performed using the Statistical Package for the Social Sciences software version 26 (IBM Inc.) using the variable incremental method with heart rate as the objective variable. The significance level was set at 5%.

5. Ethical considerations

Patients with SMID presented with complications such as respiratory depression associated with increased muscle tone caused by unfamiliar stimuli, seizure induction and associated respiratory depression or respiratory disorders. Therefore, infectious diseases could lead to exacerbation of respiratory disorders and life-threatening crises. In addition, patients with SMID had linguistic communication disorders, and they could not complain of poor physical condition. Therefore, we paid attention to the changes in their physical conditions and facial expressions and attended trainings, health care programmes for daily life or child development support activities in various facilities in advance after obtaining consent from the family. To understand the characteristics of patients with SMID, safety was ensured during data collection. In addition, we examined the methods suitable for assessing the individuality of patients with SMID via the hearing of specialists and families and the observation of patients with SMID, with support from paediatric cranial nerve specialists. At the stage of request for study collaboration, we provided a written and verbal explanation about the purpose of the study; guaranteed free participation and withdrawal, which does not lead to any disadvantage; and ensure that data anonymity will be maintained and a method of publication of results before obtaining consent from the subjects.

Ⅳ. Results

1. Overview of the participants

This study included four children aged 3-11 years who presented with Oshima class 1 SMID. In case 1, an 11-year-old boy underwent tracheostomy. In case 2, a 5-year-old girl did not undergo tracheostomy. In case 3, an 11-year-old girl had tracheostomy. In case 4, a 3-year-old girl did not undergo tracheostomy. Both caregivers and professionals performed sputum suction, which is painful, in children with SMID. Although the suction procedure was painful, the procedure made it easier.

2. Multiple regression analysis results

To explore changes in facial expressions that explain stress caused by sputum retention, multiple regression analysis was performed using the variable

incremental method, with heart rate as the objective variable and action unit as the explanatory variable.

The items and standardised coefficients (β) that make up the regression equation in case 1 were eyes closed (–0.63), outer brow raiser (–0.30), jaw drop (0.17), lips part (–0.10), mouth stretch (–0.06) and lid tightener (–0.06). These six items explained approximately 74% of the heart rate changes (Table 1).

The items and standardised coefficients (β) that make up the regression equation in case 2 were eyes closed (–0.58), lips part (–0.25), outer brow raiser (0.19), jaw drop (0.13), lip tightener (0.11) and lip corner depressor (0.04). These six items explained approximately 62% of the heart rate changes (Table 2).

The items and standardised coefficients (β) that make up the regression equation in case 3 were eyes closed (–0.48), lip corner puller (0.33), outer brow raiser (0.20), lips part (–0.20), lip pucker (0.09), lid tightener (0.09) and inner brow raiser (–0.08). These seven items explained approximately 38% of the heart rate changes (Table 3).

The items and standardised coefficients (β) that make up the regression equation in case 4 were eyes closed (–0.74), lips part (0.36), jaw drop (–0.14), lip tightener (–0.13), inner brow raiser (–0.12), lip corner depressor (–0.09), outer brow raiser (0.08) and lip pressor (–0.05). These eight items explained approximately 73% of the heart rate changes (Table 4).

Table 1 Multiple regression analysis results in case 1 n=492

Action Unit (AU)	*B*	*β*	*p*	*95%CI*		*VIF*
				lower	*upper*	
(constant)	130.51		0.00 **	127.65	133.37	
Eyes Closed	-88.60	-0.63	0.00 **	-96.01	-81.19	1.35
Outer Brow Raiser	-295.07	-0.30	0.00 **	-349.16	-240.97	1.47
Jaw Drop	170.83	0.17	0.00 **	123.13	218.54	1.09
Lips Part	-16.78	-0.10	0.00 **	-25.39	-8.18	1.25
Mouth Stretch	-14.89	-0.06	0.01 **	-26.09	-3.69	1.10
Lid Tightener	-54.76	-0.06	0.02 *	-98.96	-10.55	1.07

Adjusted R2:0.74

forward, dependent variables Heart rate (The heart rate here is the pulse rate measured by a pulse oximeter.)

*p<0.05. **p<0.01. n(The number of data) . VIF (Variance inflation factor)

Table 2 Multiple regression analysis results in case 2 n=1564

Action Unit (AU)	*B*	*β*	*p*	*95%CI*		*VIF*
				lower	*upper*	
(constant)	141.58		0.00 **	139.78	143.37	
Eyes Closed	-53.57	-0.58	0.00 **	-57.17	-49.96	1.58
Lips Part	-44.98	-0.24	0.00 **	-51.38	-38.57	1.25
Outer Brow Raiser	66.23	0.19	0.00 **	54.54	77.93	1.17
Jaw Drop	17.38	0.13	0.00 **	11.88	22.89	1.72
Lip Tightener	71.49	0.11	0.00 **	49.86	93.11	1.04
Lip Corner Depressor	126.76	0.04	0.01 **	37.43	216.10	1.01

Adjusted R2:0.62

forward, dependent variables Heart rate (The heart rate here is the pulse rate measured by a pulse oximeter.)

*p<0.05. **p<0.01. n(The number of data) . VIF (Variance inflation factor)

Table 3 Multiple regression analysis results in case 3 n=734

Action Unit (AU)	*B*	*β*	*p*	*95%CI*		*VIF*
				lower	*upper*	
(constant)	117.52		0.00 **	115.90	119.13	
Eyes Closed	-14.95	-0.48	0.00 **	-16.83	-13.08	1.09
Lip Corner Puller	49.96	0.33	0.00 **	41.21	58.70	1.05
Outer Brow Raiser	-55.61	-0.20	0.00 **	-73.04	-38.18	1.24
Lips Part	-4.57	-0.09	0.00 **	-7.64	-1.51	1.10
Lip Pucker	129.80	0.09	0.00 **	46.89	212.71	1.01
Lid Tightener	37.29	0.09	0.00 **	12.84	61.74	1.17
Inner Brow Raiser	-37.87	-0.08	0.02 *	-69.60	-6.13	1.28

Adjusted R2:0.38
forward, dependent variables Heart rate (The heart rate here is the pulse rate measured by a pulse oximeter.)
*p<0.05. **p<0.01. n(The number of data) . VIF (Variance inflation factor)

Table 4 Multiple regression analysis results in case 4 n=1816

Action Unit (AU)	*B*	*β*	*p*	*95%CI*		*VIF*
				lower	*upper*	
(constant)	106.76		0.00 **	105.65	107.86	
Eyes Closed	-33.00	-0.74	0.00 **	-34.17	-31.82	1.22
Lips Part	38.14	0.36	0.00 **	34.78	41.51	1.75
Jaw Drop	-51.48	-0.14	0.00 **	-63.44	-39.52	1.74
Lip Tightener	-116.59	-0.13	0.00 **	-138.16	-95.02	1.01
Inner Brow Raiser	-96.70	-0.12	0.00 **	-118.85	-74.55	1.30
Lip Corner Depressor	-165.34	-0.09	0.00 **	-209.84	-120.83	1.06
Outer Brow Raiser	354.09	0.08	0.00 **	219.23	488.95	1.68
Lip Pressor	-2346.30	-0.05	0.00 **	-3893.16	-799.44	1.65

Adjusted R2:0.73
forward, dependent variables Heart rate (The heart rate here is the pulse rate measured by a pulse oximeter.)
*p<0.05. **p<0.01. n(The number of data) . VIF (Variance inflation factor)

Ⅴ. Discussion

This study focused on and analysed the suction situations of four children with SMID. Families who care for children with SMID rely on changes that they notice in their daily interactions for decision-making. Moreover, they could sense and respond to their child's discomfort or changes in physical condition. However, they are not confident in their judgements based on what they observe, and it is challenging to verbalise them in order to obtain sympathy from others. Therefore, the authors focused on situations in which children with SMID were aspirating sputum. The current study aimed to specifically understand the commonalities and specificity of reactions in stressful situations by analysing data on facial muscle movements.

1. Common points during sputum aspiration among the patients

In this study, multiple regression analysis using heart rate as the objective variable was performed to understand the stress status based on the facial muscle movements of children with SMID. The following items were extracted as common variables based on the four items: eyes closed, outer brow raiser and lips part. As there are sayings such as 'the eyes speak as much as the mouth' and 'the eyes speak', movement around the eyes

and eyelids was discovered. Based on these three items, facial muscle movements during stress might be caused by sputum aspiration.

2. Differences in facial muscle movements during sputum suction in four cases

In all four cases, eyes closed was considered as the first facial muscle movement that had a high impact on stress. However, the facial muscle movements that were the second most affected differed. In cases 1 and 3, it was outer brow raiser. In cases 2 and 4, it was lips part. The movements could be caused tracheostomy in cases 1 and 3 and sputum aspiration from the oral or nasal cavity in cases 2 and 4. Furthermore, the item lip tightener was extracted in cases 2 and 4. However, the degree of influence was low. This is believed to be attributed to stress associated with intraoral suction. This result is consistent with that of an analysis of oral care in children who do not like brushing their teeth [16]. Therefore, differences in the location where stress is directly experienced also affect the extracted explanatory variables.

3. Need for data in stable situations

In four cases in this study, there were differences in the accuracy of the multiple regression equation between heart rate and facial muscle movements. In particular, in case 3, the accuracy of the multiple regression equation was 36%, which was considerably lower than that in the other three cases. This could be attributed to the fact that the patient in case 3 had experience in sputum suctioning during range of motion exercises for the limbs and data could not be collected in a normal calm situation. In the other three cases, this was believed to be caused by performing multiple regression analysis with combined data before and after suctioning, such as during calm sleep. Hence, the accuracy of the multiple regression equation will increase by adding and analysing data in normal, calm situations.

4. Future tasks

This study included four children with Oshima class 1 SMID, and analysis was conducted by focusing on suction scenarios based on the observed data. Because this result only involved facial muscles that appear during the stressful conditions such as sputum suction, it is challenging to generalise changes in facial muscle movements during stress based on the results of this study alone. Therefore, in the future, we will continue to analyse situations other than sputum aspiration and to examine not only the degree of stress and the unpleasantness that causes stress but also pleasurable situations. We also believe that it is necessary to create a children's SMID database by determining commonalities and specificities, with consideration of differences caused by factors such as the presence or absence of disabilities, disease severity, age, and sex.

Ⅵ. Conclusion

This study focused on and analysed the observational data of children with severe mental and physical disabilities who experienced sputum aspiration. Results showed three common facial muscle movements that changed during stress, which were as follows: outer brow raiser, lips part and eyes closed. Among them, outer brow raiser could be used as an indicator of the degree of stress. Moreover, it was possible to extract data visualising the degree of stress even with slight differences in the parts of the body that receive stress could. Finally, the accuracy of the model could be improved by adding and analysing data from normal and calm situations.

Conflict of interest

There are no conflicts of interest to disclose regarding this article.

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