

Case Study

# Seating arrangements for children with insufficient head control: lessons from trials using the i2i head & neck positioning & support system

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**Abstract.** [Purpose] An insufficient head control is the most troublesome condition for children with impaired mobility who require optimal seating. [Subjects and Methods] We report on the clinical trial of the newly developed i2i head & neck positioning & support system called i2i for locomotively disabled children with periventricular leukomalacia (PVL). [Results] Two major advantages of the i2i were observed in the trial. The first was its favorable effect on the alignment of the spine to prevent scoliosis and to provide stable breathing and optimal seating, which resulted in improvement of the children's activities of daily living (ADL). The second was its direct application of force to the head rather than indirectly to the pelvis in a conventional seat arrangement. The conventional way of head support is based on stabilization of the trunk which is based on stabilization of the pelvis by some seating arrangement. [Conclusion] The trial of the i2i device demonstrated its usefulness in helping PVL children with insufficient head control develop their abilities while preventing secondary disability.

**Key words:** Periventricular leukomalacia, Disabled children, Seating

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## INTRODUCTION

Among clinical cases requiring seating arrangements, we see a number of periventricular leukomalacia (PVL) children with insufficient head control. PVL is often accompanied with symptoms such as respiratory dysfunction, and visuoperceptual dysfunction. Therefore we need to take into account the alignment of the head and the spine as well as their supporting devices. Here we introduce our seating arrangement using by a i2i Head & Neck Positioning & Support System called i2i (Fig. 1) for PVL cases with insufficient head control, and report on the efficacy of the i2i.

This is a non-profit study and all the published photographs are used with the permission of the subjects.

## PURPOSE

The aim of this study was to investigate the effect of the i2i.

## SUBJECTS

Case 1: 6-year-old male

Diagnosis: PVL, symmetrical tonic neck reflex (STNR) (+), with tracheotomy and gastric fistula.

Condition: Various physical stimuli predispose to a collapsed posture. In the seated position, his neck pushes against his tracheostomy tube and disturbs his breathing (Fig. 2).

Case 2: 9-year-old male

Diagnosis: PVL.

Condition: He has difficulty maintaining the cervical position and requires effort to look at persons or things for any length of time; while doing so upper extremity mobility decreases. During operation of his electric wheelchair, he often inadvertently leans on the wheelchair tray to maintain his posture (Fig. 3).

## METHODS

We compared the sitting posture of the i2i head support with the Panda head support.

For Case 1, we measured four segment lines in the frontal plane<sup>1)</sup>, respiratory function, and the Cobb angle on an X-ray for the evaluation of scoliosis.

For Case 2, powered wheelchair (PWC) driving competence was measured using the Powered Mobility Program (PMP) test<sup>2)</sup> (Fig. 6).

## i2i

i2i is a product of the Stealth Corporation.

The unique integrated form of the i2i connects the head, neck and shoulders and forms a support similar to that of an exoskeleton. Unlike many collar-type devices, the i2i is not positioned low on the neck leaving the upper neck and head

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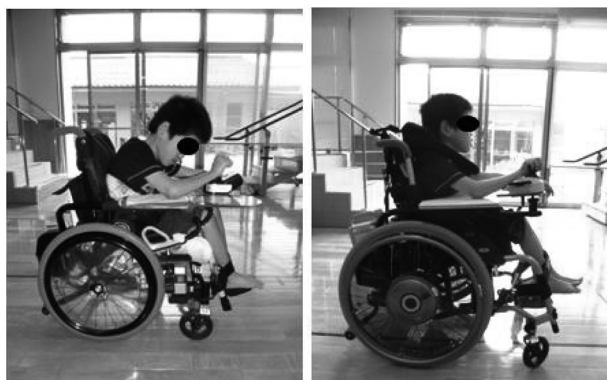
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**Fig. 1.** i2i Head & neck positioning & support system  
Stealth product's i2i medium head and neck support system anterior arms act as an anchor for the chin. It provides an anterior thoracic boundary and creates a channel to direct ex-tensor tone into a mid-line position. The i2i body is made of iron and it is coated with a special urethane foam.



**Fig. 2.** Before and after use of i2i



**Fig. 3.** A case with the i2i head support attached to a powered wheelchair

unsupported. The anterior arms of the i2i act as an anchor for the chin prompt, provide an anterior thoracic boundary, and create a channel to direct extensor tone into a mid-line position. The lateral component promotes the mid-line head position and offers cervical support while maintaining range of motion (ROM). As the client begins to extend the neck, their head is guided into a more neutral position.

#### ISO16840-1

In the ISO16840-1 standard, which took effect in 2006, measurement rules of the seated posture are defined. The standard provides a different way of measuring seated posture using body segment angles.

The measurement divides the body into segments and identifies body landmarks on each segment, connects landmarks with lines, and measures the orientation of the body segment line with respect to the perpendicular. All angles are measured positive in the clockwise direction from 0 to 360 degree.

The landmark provisions of the measurements have seven locations in the frontal plane, ten locations in the sagittal plane, and six locations in the transverse plane. The number of body segment lines connecting them is 15, and there are six lines in the frontal plane, six lines in the sagittal plane, and three lines in the transverse plane<sup>1)</sup>.

Generally, Subjects are measured in the sitting position with a seating system on a chair or in a wheelchair. A provision is also made for measurements without a seating system. Therefore, ISO16840-1 has a three-dimensional coordinate system corresponding to each of the three conditions: "wheelchair", "seating systems", and "human body".

#### PMP Test

The PMP test comprises 34 tasks, categorized into 3 parts: basic mobility skills, integration of basic skills in a structured environment, and integration of basic skills in an unstructured environment<sup>2)</sup>. The PMP test was modified for indoor operation referring to a previous report by Bottos<sup>3)</sup>. The subject only drove in an indoor area to performing 20 tasks in this modified test. The indoor PMP was scored on a 100-point scale was used for the assessment. A score of 4 points, defined as "verbal cueing only", was regarded as independent indoor driving in the task. Therefore, we used a tentative criterion, that a subject with a total of 80 points or more could drive PWC safely only in an indoor setting.

#### Measurement

##### Segment lines

Rysis<sup>4)</sup> is 2-dimensional image analysis software for quantitative seated posture measurement following the ISO16840-1 standard<sup>1)</sup>. We compared the angle of each body segment lines between the i2i and the Panda head support on photographic images.

We compared each body segment line with the subjects in the i2i head support and the other head support sitting posture under each of three conditions: tilt 0 degree, tilt 15 degree, tilt 30 degree.

First we used the continuous shooting function of a digital camera to capture 10 frames in the sitting posture. Next, we measured each body segment lines using Rysis software, and

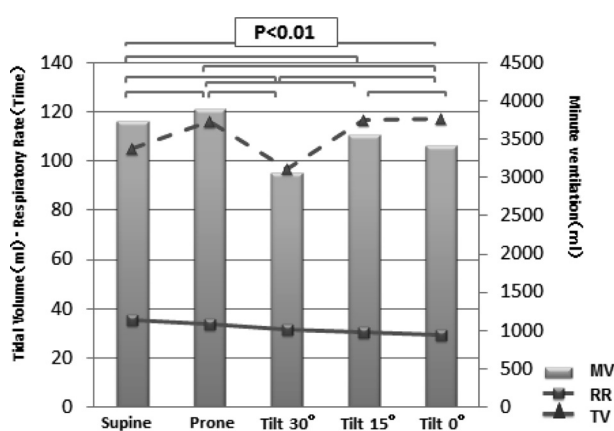
**Table 1.** Angles between the four major body segment lines and the frontal plane at various back support tilts

|                 | Pelvic line | Sternum line | Neck line   | Head line |
|-----------------|-------------|--------------|-------------|-----------|
| Panda 0 degree  | 9.4±4.1**   | 9.6±6.1      | 64.7±25.5** | 29.4±16.5 |
| i2i 0 degree    | 3.0±2.3**   | 10.2±3.3     | 11.0±3.2**  | 17.2±8.8  |
| Panda 15 degree | 15.1±7.1    | 6.3±4.0      | 29.6±13.9   | 21.5±5.8  |
| i2i 15 degree   | 6.0±3.4     | 9.1±2.9      | 22.1±12.1   | 20.4±6.1  |
| Panda 30 degree | 4.2±2.7**   | 10.8±6.7     | 40.1±5.6**  | 15.6±9.9  |
| i2i 30 degree   | 11.1±4.6**  | 3.2±3.2      | 21.6±8.4**  | 21.2±4.1  |

Tabled by the Rysis seat rank posture measurement software (Mean ±SD).

Panda: Panda seating system (R82), i2i: wheelchair+i2i Head Support

Spearman's rank correlation coefficient and the Kruskal-Wallis test were performed using SPSS ver. 18.0 and a significance level of 5%, \*p<0.05, \*\*p<0.01.

**Fig. 4.** Respiratory function at various postures (measured by a spirometer)

Statistical analyses in this study were performed using SPSS ver. 18.0 and a significance level of less than 5%.

MV: minute volume, RR: respiratory rate, TV: tidal volume

calculated the arithmetic mean lean of each segment lines from the standard position.

The four body segment lines were the frontal head line (line perpendicular to the line passing between the right and left eye corners), frontal neck line (line passing through the upper and lower neck points: approximately base of nose to suprasternal notch), frontal sternum line (line passing through the upper sternal notch and the lower sternal notch), and frontal pelvic line [line perpendicular to the line passing through the right anterior superior iliac spine (ASIS) and left ASIS, passing through the ASIS midpoint]<sup>1)</sup>.

### Respiratory function

We compared respiratory function in five positions: the supine position, prone position, tilt 0degree, tilt 15 degree, and tilt 30 degree.

We measured the respiratory rate and minute ventilation using the A Hall scale Wright respirometer (IMI Corporation) 35 times, and calculated the mean tidal volume.

**Fig. 5.** Cobb angles before and after the use of i2i device

## RESULTS

Angles between the four major body segment lines in the frontal plane are shown in Table 1<sup>1)</sup>.

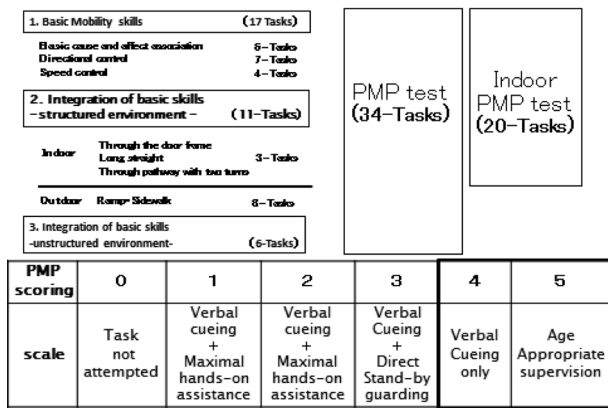
Significant difference were found between the i2i and the Panda head support in the degree of lean of the neck line and pelvic line at the tilt angles of 0 degree and 30 degree, (p<0.01).

As the tilt angle decreased, the degree of lean of the body segment lines with respect to the neck and pelvic lines increased significantly (p<0.05) when using the Panda head support, whereas with the i2i they decreased significantly (p<0.01).

After examining all the data of the i2i and the Panda head supports, only when using the i2i did we find a meaningful correlation between the pelvic and neck body segment lines (r=0.69).

The respiratory function evaluation analysis found significant differences between respiratory rates in each posture (p<0.01) (Fig. 4).

Scoliosis was compared using the Cobb angle measured on X-rays (Fig. 5). For Case 1, the conventional support



**Fig. 6.** Powered mobility program test (PMP)

method to stabilize the head needed a rearward tilt of the back support. It is notable that the i2i device stabilizes the neck itself and provides an upright posture on the wheelchair, even for a tracheostomized patient who needs to avoid anterior flexion of the neck. Furthermore, the posture ensured sufficient thoracic inflation, which would prevent atelectasis of the lung.

For Case 2, after providing a wheelchair seating position which prevented scoliosis, and a stable breathing state had been achieved, his respiratory activity increased.

The powered wheelchair operation ability of Case 2, limited to indoor operation of PMP Test (Fig. 6)<sup>2)</sup>, was a PMP score of 94/100 on the first day of due using the i2i, and it improved to 97/100 when using the i2i on the second day.

**LIMITATIONS**

The i2i multiple axis structure lacks flexibility and damage can be caused if more than just the weight of the user’s head is applied. Also only trained personnel can adjust the i2i. The position of the arm rests may restrict upper limb mobility depending on the user’s body size.

**DISCUSSION**

Two major advantages of the i2i were observed in the trial. First it has a favorable effect on the alignment of the

spine, preventing scoliosis and providing optimal seating and stable breathing<sup>5, 6)</sup>, which improved the subjects’ ADL<sup>7)</sup>.

Second, direct force is applied to the head rather than indirect force applied to the pelvis as in the conventional seat arrangement. The conventional method of head stabilization<sup>8)</sup> is based on stabilization of the trunk which is based on stabilization of the pelvis by some seat arrangement. However, there are several disadvantages of this conventional, indirect head stabilizing method.

The i2i was developed to avoid provocation of primitive reflexes, often seen in the children with PVL, which spoil the optimal posture, and also to address the relatively bigger head of children<sup>9)</sup> which may also decrease stability.

A seating arrangement providing both trunk and head optimal positioning seems necessary for children with PVL. We observed improved swallowing function as well as improved ADL of the upper extremity resulting in reduced nursing care burden for the study subjects using the i2i.

In this study, the i2i device demonstrated its usefulness in helping the PVL children with insufficient head control develop their abilities while preventing secondary disability.

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