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New Ideas of Treatment for Cerebral Palsy I Capital Flexion of the Neck: The Key Link in Prematurity Treatment

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Abstract: In a human, the head and spine work together in any kind of posture and movement. Any movement starts from the head through neck flexion and specifically capital flexion. Capital flexion initiates the straightening of the cervical spine which causes the connection of the head on the C1-C2 suboccipital part to the thoracic and lumbar parts. With this, the spine starts to move and postural tone increases. Without construction of the neck or alteration of the axis, as seen with cases of prematurity, postural tone becomes low. Typical features of children with prematurity include low postural tone, altered axis of the head and neck which generates incorrect or ineffective vestibular information and poor cortical movement caused by poor development of capital flexion. Therefore, the most important aspect to consider is the lack of capital flexion causing the absence of some initiation of movements of the spine which leads to further weakness of the neck and trunk.

Key Words: Eyes, capital flexion, neck, postural tone, axis, spine movement.

1. Introduction

During the last two decades medical professionals face new types of children including those with cerebral palsy due to prematurity.

According to reports, prematurity now represents 40-50% of children with cerebral palsy [1]; 6% has birth weight lower than 1,500 g or 1,000 g [2]; and 11% is from short gestational age lower than 28 weeks [3]. In addition, research from Korea which reportedly presents a statistically realistic set of data due to a big number of respondents (i.e. 700 respondent mothers), relates that 53% of prematurity cases have cerebral palsy [4].

Among the cases of children with cerebral palsy from prematurity, findings show that the damage to the brain is around the lateral ventricle [5]. This group shows a different picture as children with cerebral palsy, as previously reported, obtained damage on the cortex. As such, with respect to the degree of spasticity, premature cases are noted to have moderate or lower than moderate levels.

Both spastic quadriplegia and diplegia cases caused by damaged on the cortex show strong typical hypertonic pattern with poor head control while present premature cases show low tone on the proximal part while hypertonus exists on the distal parts of the body. The quantity and quality of their movements are different as they are seen with better head control, level of cognition, and speech, which are all necessary for development of functional movement. Many of those affected are able to sit and walk although these may develop slowly.

Clinical picture of older cases of spastic diplegia from prematurity include inability to assume upright posture and difficulty in staying still in sitting or standing. As they walk, neck and trunk sway either with or without a certain degree of hypertonus on the feet. These findings are brought about by low tone of the neck and trunk (Figure 1).

One way of assessing the postural tone of the child can be done by asking him to come to the sitting

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Fig. 1 Walking of Child with Spastic Diplegia.

position from supine. A child with prematurity cannot flex and raise their head completely. This can be described as weak neck, or weak muscle tone of the neck. This weak neck consequently contributes to the low tone on the trunk. Most of them will prefer to go into prone first; then, come to sitting using extension pattern instead of using neck flexion. Therefore, it is evident that the limited frequency of using neck flexion may lead to missing some components in relation to normal human movement.

Human movement, in any situation, is governed by the person's ability to modulate postural tone in order to sustain head upright against the base of support. His repertoire of movement depends on alignment and balanced activation of the intrinsic muscles of the neck especially those used for capital flexion. Capital Flexion initiates increase postural tone by connecting the whole cervical spine to thoracic and lumbar with lowered ribcage and posteriorly tilted pelvis, respectively. Constructing the neck's C1-C2 suboccipital component or getting capital flexion straightens the whole cervical spine which makes the whole spine move consequently. Capital Flexion increases neck muscle tone and together with spinal movement, postural tone as a general also increases.

Another way Capital flexion increase postural tone is by serving as the axis (midline) of vestibular system. With neck in the middle, this means eyes are also in the midline and oriented together with the inner ear to get all the vestibular information needed to increase postural tone and perform any kind of movement against gravity.

To illustrate this, let us use rising from the bed as an example. When lying down, postural tone is mostly low. As soon as the head comes to midline with sent information of the vestibular system to eyes and inner ear regarding the environment and situation, capital flexion initiates increase in postural tone. Simultaneously, capital flexion straightens and moves the cervical spine as a whole and connects it to thoracic spine as ribcage lowers down and to lumbar spine as pelvis posteriorly tilted. Further increase in the position of the head to a more upright position then orientes the child's vestibular information and the muscles of the trunk to increase activation of the postural tone as to support and sustain the head on its axis against the base of support available.

All muscles of the body works towards maintaining the head aligned at any posture or in any movement contexts with just the right modulation of tone of individual muscles. However, when the neck axis is compromised which is often seen in cases with prematurity as hyperextension, the role of the capital flexion will not be maximized. There is unequal activation of the muscles of the neck causing immobility of the spine and poor orientation in vestibular system, thus low postural tone becomes evident.

Therefore, in order to cope with the need to move, maintain the head up and increase the postural tone, a child with prematurity compensates by using an atypical pattern.

Considering these ideas, we can surmise that a child with prematurity who moves with low tone and with an atypical manner is brought about by weakness or poor development of the neck especially capital flexion. Thus, the presence of weak neck causing low tone of the trunk or low postural tone, in general, should not be taken for granted. Vestibular information (as neural component) and spinal movement (as non-neural component) to effectively increase postural tone should be well assessed and managed. As medical professionals, strategies to promote correct patterns of movement with modulated postural tone should be included when treating children with prematurity.

The skills and repertoire of movement of the child with prematurity also deviate from typical ones due to missed events during the latter part of gestation. Events inside the womb that should have been experienced must be given importance as bases to explain the missed components of development. Promoting missed experiences, especially capital flexion which serve as reference or key to stronger and more fluid human movement repertoire, should be done in cases with prematurity.

When analyzing the clinical picture of children with prematurity, the following important and common difficulties are expected:

(1) With or without issues related to low arousal level

(2) Poor eye movement with weak facial muscles

(3) Weak neck and poor Capital Flexion

(4) Poor spinal movement or immobile spine

(5) Low tone on trunk or low postural tone of the body with hypertonus on distal parts of the body

(6) Poor body scheme

To understand the difficulties of children with prematurity, it is vital to clinically assess the components of their movements, compare it to normal human movement, and link these observations to events missed in the latter part of gestation.

This paper will, therefore, describe important factors in fetal development commonly missed by children with prematurity, especially capital flexion as a key reference to normal human movement, and foundations of normal movement including relationship of vestibular information, postural tone, axis and cortical level of movements. At the latter part, ideas of treatment which can help in filling in the gaps and in making a child's movement as close to normal as possible will be described.

2. Fetal Development: Development in and Importance of the Flexed Posture

2.1 Movements of Flexion

At the fetal stage, flexor components fully develop. The physical changes in the developing fetus happen while experiencing flexed posture in a very limited space. This gives the whole body a chance for connective movement from head to feet through passive elongation, making the initial development of capital flexion as a key feature and basis of normal human movement possible.

At around 28-34 weeks of gestational age, all parts of the body move into flexion within an axis [6]. As the fetus becomes more confined and as he assumes a more flexed posture, the neck goes into deeper capital flexion (Figure 2).

As such, when the fetus moves with flexed neck and spine, movement of the legs towards flexion with posteriorly tilted pelvis is also reinforced. This manner of moving all the parts of the body in the same direction can also be described as mass pattern of movements. Kicking at this stage develops muscles of the lower proximals, hips and ankles, and joint structures such as the acetabulum, ligaments, and joint capsule. This state of the neck is actually similar to chin tuck in adults when power and speed can be

Fig. 2 Flexed Posture.

produced by increasing neck stability (i.e. when throwing or kicking a ball farther in sports activities).

This important posture activates isolated muscles on the body and contributes to a stronger and more concentrated co-activation of the neck and trunk. This is comparable to isometric exercises of the target muscles. At this stage, then, primarily assists in building up neck and proximal muscles in preparation for head and trunk movements against gravity after birth.

Since the neck and trunk are naturally flexed, all segments of the spine from cervical to lumbar, simultaneously move into flexion. Flexion also makes the shoulders and scapulae go down and forward. Because of this, the fetus can easily bring his hands to mouth and suck his fingers. This helps the fetus perceive the existence of his hand. Moreover, as he pushes with his hands against the wall of the uterus, he could learn that his hand is connected to the elbow and that the elbow is connected to the shoulder. This experience is very important in the development of body scheme and the perceptual process, in general. When outside the womb, this idea of the hand will be further supported by vision. The use of the forearm and hand for support and play will then develop consequently.

At 36 to 40 weeks, the fetus prepares for delivery by turning and changing his head's position towards the mother's cervix. This posture gives the fetus information about change in direction as he tries to relate this with his body. As such, the development of body scheme is further enhanced.

Alongside the development of capital flexion of the neck comes the development of the neural network of the body. Connectively moving in a fully flexed posture prepares the child for movement against gravity. Immediately upon birth, various movements that may go along and/or through physiologic flexion are noted until a more stable head control is developed.

2.2 Neck Dynamic Stability

Inside the womb, the infant's movements such as sucking, swallowing, breathing, turning the head in various directions, pushing the arms and kicking the legs against the uterine wall while in the flexed posture all reinforce development of the muscles of the neck and trunk, especially capital flexion. The recoil of all the movements of the fetus against the wall of the uterus while in fully flexed and elongated neck sends signal to the intrinsic muscles of the neck, thus strengthening the development of capital flexion. As mentioned above, these activities not only cause development of each utilized muscle fiber but also promote connective neck and proximal co-activation through isometric contractions.

All of the infant's flexor movements seen in the womb continue to develop with physiological flexion after birth. These movements are essential for the development of head movement and stability in space. However, with the absence of the rigorous development of the flexor components in the womb, as in cases of prematurity, the development of neck stability is hampered given the lack of passive capital flexion.

As previously mentioned, muscles located around the neck are the most important muscle groups necessary for postural control. This is because the neck muscles, although smaller and shorter than other muscles of the body, contain the highest density of muscle spindles [7].

The neck modulates postural tone to enable the infant to move against gravity after birth. Neck muscles work in collaboration with the neural network that mediates various reflexes (vestibulospinal, vestibulocollic, and vestibulo-ocular reflexes) to ensure good alignment of the head and trunk, and to facilitate appropriate adjustments as one moves. Vestibular inputs from the head, eyes, and postural muscles are integrated with the information from the stable neck, maintaining all parts of the body in the same axis with regards to the position of the head. Therefore, if the neck is unstable and out of axis, insufficient postural tone will be generated. This causes inactivity of the truncal muscles which is one of the main problems associated with prematurity [8]. Thus, neck dynamic stability is essential not just for maintaining head in space but also as a basis for postural control.

It is logical, therefore, to state that the most important feature of the fetal stage is the development of neck stability.

2.3 Development of Breathing Pattern, Oromotor Control, and Oculomotor Skills

When in the flexed posture during the fetal stage, the fetus sucks his hand, swallows amniotic fluid, and practices breathing. These activities, which are all vital functions, are easily done in flexed posture. In this posture, contraction and relaxation of the face muscles are practiced with sucking and swallowing. The flexed posture also reinforces increase in negative pressure. It is easier to close the mouth while in the flexed position which makes nasal breathing easier and deeper: amniotic fluid can then go into deeper lung structures [9]. These facilitate the development of the structure of the lungs and diaphragm; thus, enhancing pulmonary function.

After birth, the infant continues to develop his breathing pattern with the development of the abdominal muscles. At 5 to 6 months, with the emergence of the Landau pattern, the breathing pattern of the infant shifts from abdominal breathing to thoracic breathing [10]. This change is very much related to the development and shaping of the shoulder girdle, rib cage, lower trunk and abdominal muscles.

While the baby practices breathing in midline (axis) and as he uses his mouth, oculomotor control also develops simultaneously [10]. Neck maintained in midline and in flexed position allows for the development of oculomotor muscles. Conversely, all these activities which involve the development of oral movements, eye movements, and breathing help develop neck dynamic stability. As such, these also contribute to the development of stable and connected head and trunk movement.

Activity of the facial, oral and oculomotor muscles plays an important role in facilitating adaptation to different stimuli, increasing level of arousal and promoting motivation to move especially at the beginning of anti-gravity movement. As such, prematurity not only compromises the activity of the aforementioned muscle and movement developments but also affects emotional and sensory adaptation, cognition, and arousal level.

2.4 Counterbalance of Extensor Activity

Movements in the flexed posture continue until 2 months after birth. When the leg is extended it flexes back like a spring. This is the recoil phenomenon, a mechanism that prevents too much extension after birth [10]. At this stage, human beings have a tendency to move following the direction of gravity with extension and the recoil phenomenon counterbalances too much extension. With increased development of neck stability and its connection to the trunk, co-contraction of the flexor and extensor group matures and stabilizes further; thus, promoting the use of more dynamic movement.

2.5 Emotional Stability / Psychological Stability

In the flexed posture, the fetus moves to midline in mass flexor pattern. This posture develops as a protective response and can be related to promoting security for emotional stability and survival in response to various sensory stimulation from the environment such as visual, auditory, olfactory, and movement.

2.6 Self-regulation

After 20 weeks in the mother’s uterus, the fetus recognizes many different sounds: his mother’s biological rhythms, as well as his mother’s daily routine—sleeping, eating, toileting, and other activities. This helps the fetus recognize his mother and learn from environmental cues (e.g. day, night) which are some of the bases for socio-emotional and cognitive development. This also serves as the foundation for the development of attachment or relationship between the mother and the baby [11].

Thus, cases with prematurity often experience difficulty recognizing and adapting to changes in the environment given the shorter length of time in the womb.

3. Foundations of Normal Movement

To understand the problems of children in terms of movement, medical professionals have to recognize the importance of postural axis (midline) in relation to how postural tone should be modulated based on vestibular information and cortical level of movement.

3.1 Vestibular Information

The vestibular neural network contributes to providing information about the location of the head and body in order to maintain the same line from top to bottom with regard to any displacement.

Modulation of the degree of postural tone happens with fast activation of certain muscle groups supporting the head and body in a given posture or movement. Sensory receptors from the vestibular apparatus located in the inner ear send vestibular information or feedback to the vestibular nuclei. The vestibular nuclei functions for two different reflex systems [12].

The lateral vestibular nucleus (LVN) projects down to the ipsilateral cervical and lumbar levels of the spinal cord where they excite antigravity motor neurons that control slow extensor muscle fibers for antigravity posture. The very fast conducting lateral vestibulospinal tract travels through the ventromedial white matter of the cord explaining its preferential access to the axial and proximal limb musculature and intermediate zone circuits which determine postural support. Thus, it is responsible for labyrinthine righting reflexes involving the limbs. The medial vestibular nucleus (MVN), on the other hand, sends bilateral and partly inhibitory projections to the neck motor neurons and intermediary circuits in the upper cervical cord. Thus, it subserves vestibulocollic reflexes for maintaining head stability.

Projections from the vestibular nuclei contribute to sensory information about head movement and position relative to gravity, gaze stabilization (control of eye movement when the head moves), postural adjustments, autonomic functions, and consciousness [12].

In normal development, as the central nervous system (CNS) matures, specifically the vestibular system, the child becomes driven to move to higher positions. Consequently, as the head goes in space from the ground, the vestibular system activates muscles of the body to maintain the head in space in a much higher location. This describes modulation of postural tone with regard to head position which essentially happens with the integration the neural network of sensory and motor channels for the execution of body movements.

A special contributory function of vestibular system to human movement is to provide an idea of a central line from the head, as the keystone, to bottom. As guided by the vestibular system, all parts of the brain contribute to directing human movements in maintaining the head in the same line with the body, and in adjusting the line of the body as related to the displacement of the head. All neural systems and the postural muscles involved activate independently in an interrelated manner to recover displacements automatically. A person in sitting position, for example, moves his legs freely without activating all muscles to take weight. But with attempts to go to standing, the displacement of the head forward produces vestibular information that may send signals to the muscles of the legs to keep the weight on the feet and support the head and the body while maintaining the axis. Therefore, humans are able to stand from sitting with adequate vestibular information from the head. This includes integration of information from the head, eyes, and neck. In other words, if the head is not located at the middle or it shows altered vestibular system, the sequence of movements for standing up will be atypical.

Thus, the apparatus most responsible for providing information of the head's location in relation to the axis (midline) and for activating parts of the body to preserve this axis is the vestibular system.

In human movement, the head moves in various directions (forward, backward, lateral elongation and rotation) in order to watch something. This act of watching generates adequate postural tone and activates special muscle groups in the body in relation to the location of the head.

For instance, when a person rests on a sofa, his head is flexed and his body leans backward, making all muscles of the body relaxed; thus, lowering his total postural tone. Generally, in this situation, humans sit on the sacrum. But when he intends to do something, which is mostly triggered by watching, the head goes to a higher position and the pelvis automatically goes upright. This movement is generated by the gluteus maximus with the pelvis acting as the base of support. The back muscle extensors will then work to extend the body and maintain the axis of the head against the pelvis. The gluteus maximus, however, can only do its work as the initiator of the sequence of movements and as the axis keeper for upright sitting if the head location is correct. If, in any case, the axis of the head and the pelvis is altered, there will be consequent alteration of the vestibular information. Gluteal muscles will be incapable of responding to change; thus, the child assumes sacral sitting.

In the same way, cases of premature diplegia with hyperextended neck and with poor ability to watch can be observed with a different pattern of standing up. They start to move with hyperextended neck and proximal, followed by anteriorly tilted pelvis and hyperextended, adducted, internally rotated legs. This is referred to as altered vestibular system in extension.

In summary, the location and movements of the head in any posture, in relation to vestibular information, activate specific group of muscles to immediately maintain the head in space. Similarly, as the trunk or the pelvis rotates, the head rotates immediately to maintain the axis from head to bottom which illustrates how the body changes direction in relation to the initiating part. A person's head which stays in extension to watch something at or above eye-level will lead to the activation of extensor groups of muscles rather than flexors.

3.2 Postural Tone

Postural tone is an automatic mechanism for dynamic activation of body muscles to maintain the head at the middle in the context of any posture or movement.

In standing, people generally activate 100% of their postural tone to maintain the head position in midline. Soldiers who are standing at attention generate about 120% activation of postural tone through capital flexion (chin tuck) and connective activation of the proximal muscles. (An accurate score cannot be given and the percentage mentioned is only an assumption and illustration of the varied quality of postural tone.) Postures that do not require any kind of movement, such as lying down in bed, generates little postural tone. At rest, as when dreaming or in REM (rapid eye movement) a state of about 10% of postural tone is activated. Upon initial transition to an awakened state while opening eyes (which signals all body parts to orient towards the midline), 20% of postural tone starts to work. As the person starts to raise his head to go to sitting, postural tone further increases until the person assumes upright sitting and standing, where the postural tone generated is at 100%.

A child who has yet to develop the brain and muscle bulk will use different mechanisms to increase tone compared to an adult.

In normal development, postural tone of the infant is initially low until the vestibular neural network develops. Sensory channels especially vision and auditory peak in development during the latter part of the 1st stage of normal development. Vision and vestibular apparatus in the inner ear help in orientation and exploration of the environment, thus vestibular information becomes clearer. This vestibular neural network urges the child to keep pace with the surrounding and be encouraged to lift the head against gravity. As they learn to bring the head up, postural tone starts to increase and develop, like in rolling over and prone on elbows. The infant simultaneously learns to bring his center of gravity higher and move or keep his head in that position by adjusting the postural tone relative to the position. This is the neural part of increasing the postural tone.

Non-neural factor of increasing postural tone, on the other hand is capital flexion as axis of construction of the spine and development of the muscles of the neck and trunk. C1-C2 suboccipital component of the neck should be constructed, especially to cases with prematurity so as to connect spinal movement and proximal muscles activation. Capital flexion serves as the axis of the whole cervical spine from which spinal movement starts to happen. As capital flexion develops together with more established vestibular information, postural tone starts to increase.

Thus a poorly constructed neck drives the neck and trunk to low tone and weakness due to poor axis of the neck for vestibular information and spinal movement. A good postural tone in sitting, for example, includes two columns formed by the upper trapezius muscles implying a symmetrical activation of both sides of the neck and proximal muscles. Disappearance of or a smaller bulk of the column on one side is caused by poor connective movement of the neck and trunk muscles secondary to poor capital flexion and disconnected spinal movement. Similarly, if the eye and face muscles are weak meaning there is no strong axis of the head, neck muscle activation and postural tone of the body will not increase as well.

As such, modulation of postural tone happens in relation to the head location relative to construction of capital flexion for vestibular information and spinal movement, movement against gravity, and base of support. To sum up, both neural and non-neural factors for increasing postural tone depend on development of Capital Flexion.

However, because all the neural network and muscles are fully developed in a typical adult, postural tone automatically increases as related to voluntary movement of the hands, feet, or any specific part of the body even when lying down.

Modulation of postural tone in any kind of posture and movement involves use of base of support. Postural tone increases in relation to head location over a stable base of support, whether in sitting, standing, or walking. When the base of support is not stable and strong as noted when the muscles surrounding the base of support have changed due to dislocations, subluxations and contractures, postural tone will also not be properly increased and sustained. The presence of limited or smaller bases of stability will confuse the body in terms of alignment and the supposed concomitant increase in postural tone.

3.3 Axis (Midline)

Basically, there is a clear but imaginary line at the middle of the human body from head to feet. The position of the midline at the center of the head and body is between the two eyes. This invisible line is oriented and adjusted relative to the displacement of the head and body based on the vestibular information. But it is important to note that based on the anatomical position, the axis (midline) does not only exist at the center of the body or trunk but also in each extremity.

When axis of an extremity is altered or displaced, the body moves along the same line of displacement immediately. And when the body is moved away from the midline, the head goes in the same line as the body.

According to Norkin [13], maximal active force of a muscle can be generated when it is at its resting length which can be achieved when the joint is in its accurate alignment. Thus, complete activation of the involved parts of the body and generally the overall postural tone will not happen if there is an altered axis (midline).

In the case of premature children with CP, they usually show a hyperextended neck such that there is shortness or limitation of movement at the C1-C2 suboccipital component. If these segments of the neck are extremely shortened and fixed for a long time, the C7 spinous process at the back disappears. Muscle tone activation of the sternocleidomastoid and upper trapezius muscles will weaken or cause disappearance of the anterior or posterior side of the neck. Thus, when capital flexion of the neck does not occur, the construction of head and whole spine connection will not happen. Usual presentation of hyperextended neck causes altered axis or altered vestibular system. This position drives the eye to move to an upward location and the mouth to an open posture.

3.4 Cortical Level of Movement

Volitional movement is related to the neurological process that requires intention, judgement, and processing. Axis (midline) and postural tone are bases for human movement but there is a need to match these not only to the functional level of movement but also to the functions of the brain.

Cortical level of movement refers to purposeful movement in the context of a functional activity like rolling over, sitting, standing, and walking. This type of movement increases the neural activity of the neocortex. It utilizes and requires motivation to perform in a specific functional level.

Compared to cortical level, the subcortical level of movement focuses on postural control and more automatic types of movement while providing and preserving the correct axis of the body, and while activating the right quality of postural tone.

Important activities to increase cortical level of movement are engagement in watching, grasping and manipulation of hands, and foot movement as related to function.

4. Basic Knowledge for Treatment

4.1 The Neck

4.1.1 Capital Flexion

The head moves dynamically for watching and directing any kind of movement. Capital flexion refers to straightening of C1, C2 cervical spine to get appropriate extension of whole cervical. It later connects to thoracic spine, and thereafter, to the lumbar level of the spine. Thus, we may name it as construction of the whole spine through capital flexion.

The C1, C2 suboccipital component is quite mobile just like a compass and is involved in all kinds of human postures and movements. The spine, when moved with capital flexion, serves as the axis or stability point to where the distal parts of the body depend its quality of movement. Thus, if the spine is twisted and immobile, all kinds of movements of the arms and hands will be difficult because of the changed axis of the bone structure as well as the changed direction of all muscles. Therapists should recognize this general concept related to spinal movement and apply this in children with prematurity or Cerebral Palsy.

Capital flexion is a small movement of the C1-C2 suboccipital component. This is generated by small muscles such as the longitudinal oblique, superior & inferior longus colli from the anterior part of the neck. There is also activity of the rectus capitis anterior, posterior major, rectus capitis lateralis during activation of capital flexion. The extension, flexion, lateral elongation or rotation of the neck requires a clear initial movement. This movement refers to capital flexion which is the primary movement of the neck relative to the construction of the cervical spine to the head.

When analyzing the case of premature children with poor or no flexor movements, take specific consideration of this principle: if capital flexion does not get initiated, neck flexion cannot be executed because the cervical spine does not get completely flexed. Complete sequence of neck flexion includes the eyes going downward, mouth closing with deeper capital flexion and then finally the neck goes to flexion.

Downward movement of the ocular muscles and closing of mouth are packaged together as initiators of active capital flexion of the neck. When there are many problems related to the movements of ocular muscles or the eyes are fixed and located high in relation to the Frontalis and Masseter, there will be consequent difficulty in closing the mouth. There will be poor deep nasal breathing experience. Premature cases, though, may present with poor movement of eyes and facial muscles as related to low arousal level and missed flexion experience.

Comparing the development of the neck during the fetal stage which is more passive and isometric because of the given elongation from physiologic flexion, neck construction during the first stage of normal development is more active. The mass pattern decreases as physiologic flexion decreases and specific components of capital flexion develop against gravity one at a time. At around 3-4 months [14] as active capital flexion develops, spinal connection between head and cervical spine is established, consequently, connecting all parts of the spine more precisely.

4.1.2 Connective Movement of the Spine

Capital flexion facilitates the construction of all parts or levels of the spine from its connection to the head. It is the primary connective movement of the head to the cervical spine. At the beginning of neck flexion, capital flexion illustrates the articulation or connection of the head and the cervical spine by generating or activating tone of certain parts of muscle groups. If capital flexion does not occur before neck flexion, it is clearly disconnected to other levels of the spine. Poor connective activation of the cervical spine movement with capital flexion cannot provide signals to switch on the flexor group of muscles because of limited vestibular information related to location of the head.

Similarly, capital flexion activation maximizes cervical extension, which eventually moves with the thoracic spine as well as the lumbar spine. A strong neck extension includes capital flexion as initial movement. This demonstrates that connective movement of the spine from top to bottom occurs with any kind of movement of the neck.

If only cervical spine moves without connection to thoracic spine, i.e. capital flexion of the neck does not occur, it will be similar to moving the head of a doll without movement of the body. There is also no connective movement from the head and trunk causing low postural tone as what happens to cases of prematurity with neck in hyperextension or poor construction of capital flexion. Their spine remains immobile and stiff evident in all movement patterns. In normal human movement, when the head flexes with executed capital flexion, the thoracic spine connectively goes to flexion generating some small downward movements of the clavicle and ribcage. Therefore, the absence or limitation of active capital flexion in the majority of children with CP results in the higher location of the rib cage. Consequently, the shoulder joints and arms become fixed.

Poor movement of the spine causes weak activation of the trunk as well as difficulties of arm and hand, and leg and foot movements. The movement of thoracic spine contributes to movement of the arm and hand. When the arm goes forward, there should be smooth movement of the scapula and the shoulder joint. But the lack of rotation from the cervical to thoracic spine prevents dissociated scapular movement, which leads to insufficient construction of the shoulder joint. Poor construction, on the other hand, impedes the full range of motion of the humerus on the glenoid fossa. Thus, children with no connective movement show poor scapular dissociation causing their arms to move together.

Along the same line of rationalization, limitation in the mobility of the lumbar spine limits the variable movements of the leg and foot since dynamic pelvic movements, i.e. 3-dimensional pelvic movement, are also limited. The pelvis executes complex and multi-directional movements with the extension and rotation of the lumbar spine onto the both hip joint. If poor extension of lumbar spine is present, 3-dimensional pelvic movements will also be difficult.

All these movements of the spine are the bases for arm and foot movement but if the spine is not connected from the cervical spine level, all parts of the spine will be fixed and immobile.

Capital flexion is the starting point of all movements of the spine and all dynamic activation of body musculature. That is the reason why poor neck muscle activation leads to poor movement of the spine which then contributes to weak muscles, low tone of the body, especially, proximal part of the body.

When all kinds of spinal movement are limited, all parts of the trunk muscles do not work; thus, driving the body to low tone, especially with the weakness of flexor muscle groups in premature cases. Consequently, these children show typical low tone on the trunk.

4.1.3 Muscle Tone of the Neck

To further illustrate how flexible and adaptable the postural control of a child should be, let us consider this example. Sport players such as wrestlers or weightlifters, show remarkable thickness of neck muscles compared with other individuals. They execute power and speed from arm and leg use but a strong neck provides stability for movement of extremities. Chin tuck results from increased exertion of the neck.

The muscle tone of the neck is affected both by low tone or hypertonus of the body. If the child shows low muscle tone of the neck or weakness, the therapist must build up muscles with capital flexion to increase muscle tone of the neck. In contrast, if the child shows hypertonus on the body along with the neck, the therapist must decrease or release the muscle tone of the neck. A strong neural signal contracts the muscles of neck and body continuously.

Severe hypertonus is always accompanied by altered vestibular information from the eye and face muscles due to muscular changes. Thus, the most important aspect to consider before increasing tone of the specific parts of the neck is the modulation of the hypertonus of the body requiring restoration of the midline (axis) and reduction of strong muscle tone of the eye and face.

4.1.4 Problems of Children with Spastic Diplegia

In children with spastic diplegia, neck flexion with the absence of capital flexion limits the activity of the flexor muscles of the neck as well as the trunk. Because of the alteration of the structure of the cervical spine in children with hyperextended neck, the cervical muscles cannot function optimally, most especially the sternocleidomastoid (SCM) muscles, upper trapezius and deep neck muscles, which work for straightening of the neck. Over time, further shortness of other muscles, such as the trapezius and deep capital extensor muscles should be expected. This means that the neck is incapable of becoming a strong axis and information center for providing signals regarding the position and direction of the head.

Disappearance of or noticeable weakness of one or both sides/heads of the sternocleidomastoid muscles may probably be seen. Poor extension and capital flexion of the neck also lead to poor activation of both upper Trapezius muscles seen at the back of the neck, below the base of the skull. Weakness of one side of the neck (i.e. one side of the upper Trapezius muscles), which can be seen as the neck collapsing towards one side, leads to low tone on one side of the proximal. This presentation is commonly seen not just in hemiplegia but also in diplegia cases with unequal activity of both sides. Generally, in hemiplegia cases, they show low proximal tone and less movements on more affected side because of hypertonus, poor body scheme or noted infrequent or limited weight bearing on the more affected side.

When a child with CP shows hyperextended neck, a corollary to this is the presence of an altered vestibular system which leads to activation of purely extensor muscle groups. This should be a primary consideration of the therapist. There is a need to change the axis in order to neutralize the vestibular system of the neck and head which is necessary to activate the appropriate muscles on the body.

In human movement, rotation or displacement of the head to one side activates the muscles of the same side. This is mainly based on the vestibular information from the head and neck. Thus, the location of the head must be taken into special consideration. In order to activate the more affected side, the therapist should consider changing the location of the head and then, encourage watching on the more affected side.

The presence of weak capital flexion could be a logical sign of weakness or disappearance of muscle activity of one side. Capital flexion is the basis of muscle tone of the neck which in turn is the basis of postural tone of the body; thus, capital flexion modulates the muscle tone not just of the neck but also the whole body. To facilitate clear description of the location of the neck, 3 terminologies can be used: out of axis, on axis, and in capital flexion (which is also termed as chin tuck).

4.1.5 Cerebral Palsy

In case of CP children with severe brain damage such as spastic quadriplegia or dystonic athetosis, they typically show a hypertonic pattern from head to feet. Although some are not born prematurely, management through capital flexion construction for postural tone and spinal movement should be applied. They present with asymmetric posturing such as head rotation with the trunk, arm/s, pelvis, and legs rotated to one side as well. The location of the head is totally changed so the resultant altered vestibular system and the difficulty in executing capital flexion are expected. The spine is immobile as well. The therapist should change all the wrong information being received and mobilize the spine in order to make the right movement and modulate postural tone appropriately; otherwise, it will be difficult to change their movements and make these as close to normal as possible.

Another important reason for the problems seen in children with cerebral palsy is instability of the base of support. Whether the child maintain a posture or do a movement, base of support helps in initiating the increase and modulating the postural tone. The base of support refers to the point where the body and the neck align with each other so as to maintain the axis (midline). Without a stable base of support, activation of the neck muscles especially the posterior column will not be observed.

In hemiplegia cases, for example, because of the tendency to lean on one side and not use equal bases of support in sitting or standing, the activity of both sides of the back and neck muscles are not be equal. The presence of contractures on the ankles or pelvis, in the case of hemiplegia or diplegia, may also contribute to the inability of the child to maximally use the stated structures for support. Activation of postural tone is, therefore, not maximized and sustained.

4.2 The Eyes

4.2.1 Vestibular System of the Eyes

One of the basic roles of the eyes is to be the point of reference for neutral vestibular system of the head in relation to body. This refers to the position where both eyes are exactly in midline (axis) in relation to the head. The most functional and voluntary type of movement of eyes is watching.

When human beings wake up (without any movement), the two eyes align at the middle, in the same line as the head and even up to the bottom. In the presence of any displacement of the head or any other part, the eyes do automatic and appropriate movements to maintain the eyes at the middle. When the head is moved from side to side, the eyes follow the same midline as the head. But when watching starts, both eyes are kept in midline even though the head is moved in various directions or when the body is swaying. This is called the Vestibulo-ocular Reflex (VOR).

The VOR is a reflexive eye movement that stabilizes images on the retina during abrupt and brief head movement. The eyes move in the opposite direction of the head movement. For example, when the head moves to the right, the eyes reflexively do a left side movement. This is in response to the neural input from the vestibular system of the inner ear. This response is seen for head movements going up and down, left and right, and tilting to the right and left; all of which give input to the ocular muscles in response to sustain visual stability.

Other types of eye movements are saccades, smooth pursuit, and optokinetic, all of which function to direct the eyes on target and keep it there: watching. Saccades happen when scanning the environment and when discerning what to watch by moving the eyes from one point to another. Smooth pursuit, on the other hand, keeps the eyes on a moving target by calculating the speed of the target and moving the eyes at the same time. It is easy to follow a moving object in a constant speed but with disturbance or increase in speed, saccadic jerks happen to keep up. The combination of smooth pursuit and saccadic eye movements is called optokinetic reflex. It is responsible for keeping the target stationary with continuous head movements like rotation and translation [12].

All of the eye movements are important to consider and check when analyzing the vestibular system function in relation to movement.

4.2.2 The Muscles of Eye

There are six muscles of the eye which control its movements: the lateral rectus, the medial rectus, the inferior rectus, the superior rectus, the inferior oblique, and the superior oblique. When the muscles exert different tensions, a torque is exerted on the globe-like structure that causes it to turn, in almost pure rotation, with only about one millimeter of translation. Thus, in essence, the eye rotates around a single point at the center of the eye.

All ocular muscles react very fast to any displacement, similar to the activation of the muscles of the body when balance reactions are triggered. Grading of the movement of the eyes is also noted as necessitated by watching. The eyes are composed of small and short muscles that are basically higher in density of muscle spindles compared to other muscles of the body. As such, it is possible for the eyes to contribute to the vestibular network by stabilizing the eye in relation to head movement.

The muscles of the eyes may not develop because of limited watching or because of blindness and problems related to the visual system such as sensitivity to light. Imbalance of movements of the eyes, as seen with strabismus, may also cause delay in ocular muscle development. These may lead to “fixed” eyes which in turn, causes fixed neck and can be an evidence of typical hypertonic pattern of movement.

4.2.3 Capital Flexion with Eye Movement

When analyzing eye movement in relation to neck movement, particularly capital flexion, the flexor muscles of the proximal and the neck are the ones primarily firing. To initiate and follow through capital flexion, downward movement of the eyes should be noted with simultaneous closing of the mouth which then straightens the neck. These are “packaged” or set of movements that are mostly automatic except when there is a specific context or purpose for a part of the movement. Limitation in downward gaze produces a consequent weakness or difficulty in performing capital flexion and therefore, the precise activation of flexor movements will not be present.

Capital flexion does not only occur automatically when the neck starts to move flexion but also when it moves towards extension. This may then be instrumental in the construction of the neck in relation to the spine. When capital flexion is weak or absent as the person moves the neck towards flexion or extension, proximal muscles do not get activated completely thus, contributing to confusion about which muscles need to fire.

When the child is unable to move the eyes down or close the mouth completely, weakness of the neck (i.e. inability to do capital flexion) logically presents with general low tone of the body.

4.3 The Face Muscles

When the eyes move in various directions, the Frontalis muscles automatically and simultaneously move with these. This direct relationship is notable when you try to move the eyes with or without movement of the Frontalis. For example, in the case of a child with choreoathetosis who has low tone of the face and the body as well, there is weak movement of the eyebrows, generally.

Weakness of the Masseter muscles also contributes to weak capital flexion. This set of muscles is used while moving towards the end range of capital flexion in order to produce speed and power when the tone of the face muscles is normal. For example, when a person pulls or lifts excessively heavy things or when initiating transition movements from supine posture, we observe how these face muscles contract strongly with closed mouth.

5. Deep Considerations for Treatment

As soon as possible, activate capital flexion. The right axis of the neck will be achieved with enough movement of the C1-C2 component, along with greater mobility of the eyes and face muscles.

Ocular muscles should then be dissociated from the neck to produce accurate responses as related to the vestibulo-ocular reflex. Facial muscles should be active as well by facilitating eyes down and closed mouth.

Adjustment of the cervical spine curvature. Aside from recovering the C1-C2 component to elongate the structures surrounding this, the lower part of the cervical (C7) should have more prominent spinous process. Its appearance means good alignment of the cervical spine curvature.

Connecting the spinal movement from cervical to thoracic and to lumbar parts. Through mobilization of the spine with promotion of one side elongation, flexion, extension, and rotation, there will be a more mobile spine which allows for connective movement. Capital flexion should act as the key point or reference about the movements of the lower parts of the spine move and how these should follow through. The inability to connect the spine with correct Capital flexion will limit the activity of the trunk; thus, causing it to go into low tone.

Facilitating a deeper Capital flexion. This should be done by building up muscles of the eyes, face and neck while facilitating a deeper and more elongated neck. A stronger capital flexion done with neck flexion is evident with the activity of the Sternocleidomastoid muscles on each side of the neck. This should, then, aid in extension of the neck where the Upper Trapezius muscle is activated and clearly visible.

Activation of the flexor component of the body. In supine, full flexion of the body includes capital flexion, neck flexion, and trunk flexion with pelvic posterior tilting.

Mobilization of the thoracic and lumbar spines. Facilitating thoracic spine rotation and activating the muscles surrounding it, will generate a descent of the ribcage and produce a wider range of scapular movement. Lumbar spine extension and rotation, on the other hand, will aid in three dimensional (3-D) movement of the pelvis as well as activation of the lower parts of the proximal.

Facilitate hand use. This should be done by recovering the right axis of the arms while moving the glenoid head on the fossa. Shoulder joint construction should be done to facilitate more forward hand movements. However, there will be smoother and more consistent glenohumeral/scapulohumeral rhythm after connectively mobilizing the shoulder joint with the scapula while making sure that there is enough spinal mobility.

Increase voluntary activation of the feet. Promoting use of the feet as a base of support will improve activation of postural tone in standing and walking. Mobility of the ankles and toes also increases connection of the flexor components; thus, gaining axis should be done through adjustment of the location of the muscles of the legs and mobilization of the calcaneal bone.

Promote Base of Support. A good base of support serves as the foundation of postural tone modulation in a stable posture or during movement execution. Because of poor development of the size of the pelvic bone and gluteal muscles as a consequence of frequent sacral sitting in children with cerebral palsy, moving the pelvis upright while weight bearing on ischial tuberosities should be promoted. Therapists may also fill in the gap by using towel or cushion to promote a more upright pelvis.

Promoting foot as base of support, on the other hand, should include realignment of the axis of the legs and ankles. If the foot is altered or collapsed on the medial side, muscles of the legs, intrinsic muscles of the feet, gastrocnemius, ankle dorsiflexors and toe muscles should be made active to prevent further lowering of postural tone. The priority of treatment is to activate voluntary movement of the foot in order to contribute not only to reducing hypertonus but also in increasing body scheme of the foot.

5.1 The use of Neck Brace or Pad on Calcaneal Bone

Since the recovery of capital flexion of the neck and building up of the muscle tone of the neck take time, it is quite necessary to provide a support that will serve as a transient external stable source of vestibular information and axis (midline) of the neck as they move. Thus, the idea of a temporary neck brace (see picture 3) is quite useful for them until they develop good neck dynamic stability. This brace is tiny and thin relative to the size of the neck and is made out of hard sponge and reinforced by steel wires. This may be in the form of sponge taken from electronic boxes, which are easy to cut and pliable enough. This will then be wrapped by a handkerchief or any cloth with ends that can be easily tied together.

Fig. 3 Child wearing Neck Brace.

In instance when the calcaneal bone is already small or the axis of the foot is collapsed; it is difficult to increase postural tone dynamically even with the use of an ankle foot orthosis (AFO). Use of pad will aid the calcaneus to maximally function as base of support. There will be an increase in postural tone when the affected foot becomes more stable in standing or walking. Therefore, the therapist should check the size and height of the calcaneal bone and put a special material (similar to a hard foam) to fill in the difference in size and height of the calcaneal bone.

5.2 Early Treatment for Prematurity in a Neonatal Intensive Care Unit

Providing treatment as soon as possible is important in reducing huge gaps in the development of premature children in comparison with full term infants.

5.2.1 Reinforcing the Flexed Posture

In NICU treatment, the therapist should hold the infant in flexed posture to produce capital flexion with deep elongation of the neck muscles. Also, the eyes are facilitated to go to neutral or downward gaze while elongating the whole back with pelvis posteriorly tilted.

This is actually describing the flexor "package" of the head and neck: deep capital flexion, eyes down, closed mouth, and finally, neck flexion with flexed trunk and posteriorly tilted pelvis. The following may be done to facilitate this flexed posture:

(1) Activate facial muscles with closed mouth, particularly, the frontalis and masseter. This can affect not just the movements of eye ball and mouth but also increase the level of alertness.

(2) While lowering the eyes (from the forehead) and closing the mouth with capital flexion, mobilize the pelvis to initiate co-activation of the proximal muscles with the neck muscles. This will, in effect, facilitate nasal and deeper breathing which will increase the tone of the proximal muscles as well.

(3) If full capital flexion cannot be done either passively or actively, mobilize the C1-2 segments to adjust the alignment of the neck and activate the vestibular network through the neck. There may also be a need to put the jaw going to the direction of the spine (i.e. chin tuck) in order to further activate neck flexion. Adjust the curve of cervical spine (e.g. decrease hyperlordosis) to make capital flexion possible.

(4) To activate the vestibular system, the therapist puts the infant in a supine posture where the legs are flexed towards his chest, putting the center of gravity nearer the neck. This will simulate the vestibular sensation that the fetus may experience during the last trimester, when full flexion of the fetus is maximized and the head turns towards the cervix of the mother.

(5) Facilitate hand to mouth play in the infant like sucking of fingers while holding the cheeks together to increase body scheme of the hand.

(6) Put both legs at the middle and then, mobilize the foot to enhance the activation of ankle dorsiflexion. Then, co-activation of the proximal with the foot needs to be facilitated. This set of activities contributes to increasing body scheme of the foot.

5.2.2 Sensory Adaptation

(1) Tactile system. The therapist may provide tactile sensation (e.g. gentle massage) on the whole body of the infant to help him calm down and to increase adaptation of the tactile receptors in the skin given the system's immature development.

(2) Vestibular system. The therapist holds the infant firmly near the adult's body, then moves from side to side or up and down in a rhythmical manner (i.e. similar to the movement sensation being received by the infant while inside the uterus) in order to facilitate adaptation to being moved. A full term fetus will have 40 weeks to adapt to being moved while inside the womb so a premature infant may cry easily and frequently because of poor development of the vestibular system and the limited experience of this sensation.

(3) Mobilization of the joint. Although mobilization is passive movement, it is a necessary preparation especially when the child's arms, hand, legs, or feet are already very stiff and fixed. The therapist should mobilize these affected parts to prevent the development of contractures.

(4) Establishment of emotional attachment and relationship between the mother and the infant. Utilize Kangaroo care. This promotes emotional security and a sense of connection to the mother.

6. Conclusions

With the right interpretation of the clinical picture of prematurity and the identification of elements based on comparison between normal and atypical patterns of movement, the therapist may be able to set the correct treatment priorities.

Early activation of capital flexion and building up of neck should be the priority of treatment, as guided by principles of basic human movement, rather than just focusing on guidance of functional movements such as rolling over, sitting, and walking.

References

[1] Ferrari, F., Cioni, G., Einspieler, C., Roversi, M., Bos, A. F., Paolicelli, P. B., and Prechtl, H. F. 2002. "Cramped Synchronized General Movements in Preterm Infants as an Early Marker for Cerebral Palsy." *Arch Pediatr Adolesc. Med. 156* (5): 460-7. doi:10.1001/archpedi.156.5.460.

[2] Oskoui, M., Couthino, F., Dykeman, J., Jette, N., and Pringsheim, T. 2013. "An update on the prevalence of cerebral palsy: a systematic review and meta-analysis." *Developmental Medicine and Child Neurology*. doi: DOI: 10.1111/dmcn.12080.

[3] Poets, C. F., Wallwiener, D., and Vetter, K. 2012. "Risks Associated With Delivering Infants 2 to 6 Weeks Before Term—a Review of Recent Data." *Deutsches Ärzteblatt International* 721-6. doi:10.3238/arztebl.2012.0721.

[4] Hong, J. 2014. From the normal development Cerebral Palsy Ideas (3rd ed.). Seoul, Korea: Koonja Publishing Inc.

[5] Englander, Z. A., Pizoli, C. E., Batrachenko, A., Sun, J., Worley, G., Mikati, M., and Song, A. W. 2013. "Diffuse reduction of white matter connectivity in cerebral palsy with specific vulnerability of long range fiber tracts." *Neuro Image: Clinical 2*. doi: 10.1016/j.nicl.2013.03.006.

[6] O'Rahilly, R., Muller, F., and Meyer, D. B. 1980. "The human vertebral column at the end of the embryonic period proper. 1. The column as a whole." *Journal of Anatomy* 565-75. Retrieved January 18, 2017, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1233253/.

[7] Gordon, J., and Ghez, C. 1991. Muscles receptors and spinal reflexes: the stretch reflex. In Kandel E., Schwartz J.H., Jessell T.M., eds. Principles of neuroscience, 2nd ed. New York: Elsevier.

[8] Groot, L. 2000. "Posture and motility in preterm infants." *Developmental Medicine & Child Neurology* 42 (1): 65-8. doi:111/j.1469-8749.2000.tb00028.x.

[9] Shatz, A., Arensburg, B., Hiss, J., and Ostfeld, E. 1994. Cervical posture and nasal breathing in infancy. [Abstract]. Acta Anat (Basel). Retrieved January 18, 2017, from https://www.ncbi.nlm.nih.gov/pubmed/8036875#.

[10] Alexander, R., Boehme, R., and Cupps, B. 1993. *Normal Development of Functional Motor Skills: The First Year of Life*. Tucson, Arizona: Therapy Skill Builders.

[11] Nilsson, Lennart. 1990. A Child is Born. New York: Dell Publishing.

[12] Kandel, E. R., Schwartz, J. H., Jessell, T. M., Siegelbaum, S. A., and Hudspeth, A. J. 2013. *Principles of Neural Science* (5th ed.). New York: McGraw-Hill Companies, Inc.

[13] Norkin, C. C., and Levangie, P. K. 1992. Joint Structure and Function: A Comprehensive Analysis (2nd ed.). United States of America: F. A. Davis Company.

[14] Hislop, H. J., and Montgomery, J. 2008. *Muscle Testing Techniques of Manual Examination* (8th ed.). Singapore: Elsevier.