Original articles

Relationship between postural cephalic pattern and speech intelligibility

Asociación entre el patrón postural cefálico y la inteligibilidad articulatoria del habla

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ABSTRACT

Purpose: the objective of this study was to establish an associative factor that connects the morphology of the skull - cervical system with the articulatory intelligibility level of speech in young subjects.

Methods: cross-sectional study. It considered a sample of 42 university students from a universe of 140, both male and female, without morbid background and of an age range in between 18 and 21 years. Evaluated aspects: a) articulatory intelligibility by the diadochokinetic periodic variation coefficient, b) traditional static postural parameters using the photogrammetric method and c) cephalic postural pattern by lateral cephalometric radiograph

Results: 36 subjects with adequate intelligibility and 6 having altered intelligibility where cervical antero-posterior skull rotation variable showed statistically noteworthy differences (p = 0,009) in between the group with normal intelligibility compared to the group with impaired intelligibility. The linear regression analysis showed that subjects with posterior rotation of head on neck show more variability in the syllabic emission of speech diadochokinetic performance (Sq r lineal = 0,128).

Conclusion: it is established that cephalic position with subsequent posterior rotation of the head on the neck is associated with loss of speech intelligibility in the sample studied.

Keywords: Articulation Disorders; Speech; Posture; Head; Neck

RESUMEN

Objetivo: el propósito de este estudio fue establecer un factor asociativo que relacione la morfología del sistema cráneo - cervical con el nivel de inteligibilidad articulatoria del habla en sujetos jóvenes.

Métodos: estudio transversal, consideró una muestra de 42 jóvenes universitarios de un universo de 140, ambos sexos, sin antecedentes mórbidos y con un rango de edad entre 18 y 21 años. Se evalúo: a) inteligibilidad articulatoria mediante el coeficiente de variación periódica diadococinética, b) parámetros posturales estáticos tradicionales mediante método fotogramétrico y c) patrón postural cefálico mediante radiografía cefalométrica lateral.

Resultados: se encontraron 36 sujetos con inteligibilidad adecuada y 6 alterada, donde la variable rotación cráneo cervical antero-posterior presentó diferencias estadísticamente significativas (p= 0,009) entre el grupo con inteligibilidad normal respecto al grupo con inteligibilidad alterada. El análisis de regresión lineal evidenció que sujetos que presentan rotación posterior de cabeza sobre cuello presentan mayor variabilidad en la emisión silábica del rendimiento diadocinético del habla (Sq r lineal = 0,128).

Conclusión: se establece que la postura cefálica con presencia de rotación posterior de la cabeza sobre el cuello se asocia a la pérdida de inteligibilidad del habla en la muestra estudiada.

Palabras clave: Trastornos de la Articulación; Habla; Postura; Cabeza; Cuello

INTRODUCTION

The biomechanical study of the human body is defined as one great morpho-functional unit where each biokinetic link is intrinsically connected to other subunits. Cephalic posture has been traditionally studied because of the biomechanical relationship existing between the cervical spine, head, and dento-facial structures[1]. Therefore, if one of these segments is compromised, and very often undiagnosed, changes could be triggered in other structures responsible for vital human functions, such as mastication, deglutition, respiration, and speech articulation[2,3].

Cephalic posture has been defined as a particularly important factor in the morphological diagnosis of skeletal, articulatory, and myofunctional discrepancies[4]. Updated reports on the topic have established a consensus that a good cranio-cervical posture can positively influence the individual's speech production[5]. Nacci et al.[6] studied proprioceptive postural behavior in subjects with voice alterations, and they concluded that increased proprioceptive awareness through speech and kinesic therapy directly affect oral production.

Other studies have demonstrated that cephalic posture directly influences the diameter of the pharyngeal airway[7], generates changes in cervical muscle tension[8], and can affect respiratory support and voice quality[5]; a correlation has been reported between the cranio-cervical posture pattern and the abovementioned factors. Cuccia and Caradonna[3] were able to conclude that dentofacial alterations can modify cephalic posture and demonstrate that nasal obstruction induces anomalous head extension, which represents a functional adaptation that facilitates oral respiration.

Rocabado[9] proposes a teleradiography method to objectively assess cephalic posture in anteroposterior and vertical direction using cephalometric measurements on a sagittal plane to define three parameters: a) hyoid position (hyoid triangle), b) anteroposterior cranio-cervical rotation, and c) suboccipital space cervical 0–cervical 1 (C0-C1); the influence of these parameters is emphasized in the harmony of dentofacial structures involving respiration, speech, voice, deglutition, and the limited clinical relevance given to the orthostatic stability of the skull on the cervical spine[4].

Ferrand[10] conceptualizes speech as a complex motor activity by which oral, laryngeal, and respiratory structures produce sound patterns, whose production can be influenced by a good postural alignment and permanent self-correction and proprioception of the body scheme[8]. García de Paula et al.[11] point out that the cranio-cervical postural relationship would condition the existence of the odonto-stomatological equilibrium necessary for successful and intelligible speech production.

In this context, Pahkala and Qvarnström[12] conducted an interdisciplinary study in a population of 287 children and young adults; they were able to establish a correlation between cranio-cervical-mandibular dysfunctions and the presence of functional dyslalia. Likewise, Anegawa et al.[7] demonstrated that the cervical spine position with respect to the head is directly associated with a change in the muscle tension chains related to oral motor skills, which could alter speech and deglutition. In summary, evidence establishes that alterations of the cranio-cervical postural pattern can represent a risk factor for developing odonto-stomatological system disorders, which in turn provoke alterations of any of the five basic motor processes of speech, such as respiration, phonation, resonance, prosody, and articulation[13].

The present study attempts to understand if there is a relationship between the morphology of the cranio-cervical system and speech articulation, particularly at the intelligibility level measured by diadochokinetic (DDK) speech performance in young university subjects with no relevant morbid history. This population is considered to be high risk for exhibiting bad habits or postural defects resulting from factors such as a sedentary lifestyle, misuse of backpacks or bags, and excessive use of mobile devices, and laptops[14,15]. Staes et al.[5] mention that there are few studies that provide information about cranio-cervical postural descriptor parameters in a young and apparently healthy university population. Most available research studies on this topic establish relationships between postural disorders and voice dysfunctions, not to mention the influence that cephalic posture can cause on correct speech production.

METHODS

This cross-sectional study selected a sample of 42 subjects, from a total of 140, of both sexes between the ages of 18 and 21 who belonged to the Speech and Language Therapy and Physical Education programs of the Universidad del Bío-Bío. This study was authorized by the Ethics Committee of the Universidad del Bío-Bío and all the participants signed an informed consent under the Protocol/Code DIUBB 1229213R.

We included subjects with no history of musculoskeletal deformities of the locomotor system, no speech and language disorders, no history of neurological impairment, or who would have received physiotherapy, speech therapy, or orthodontic treatment during this period. Subjects who did not complete the planned measurements of the study were excluded. The research study involved three stages:

The first stage considered speech intelligibility level assessment by the diadochokinetic periodic variation coefficient (cpv) of speech measured as a percentage (normal DDK cpv: 6.006 % ± 1.118 %). A sample of 113 subjects was obtained from an eligible population of 140 students (1-α/2= .95, e= 0.041, and $P_{estimated}$= 0.50).

The procedure was carried out in the Speech and Language Therapy Laboratory of the Universidad del Bío-Bío by a speech and language therapist experienced in this area. Three acoustic registers were conducted per subject, and each register repeatedly emitted the syllable "pa" for 8 s. Registers were entered into the Motor Speech Profile software, and an automatic method for measuring the degree of regularity (or percentage of variability) of syllable emission was then applied. Results were automatically compared with the pattern of normality generated by the software (normal DDK cpv: 6.006%±1.118%) where values greater than or equal to 7.124% were considered an anomalous variation. A unidirectional Shure SM58 microphone, speech digitalization CSL4500 KayPENTAX hardware, and Motor Speech Profile KayPENTAX software were used to obtain these registers.

In the second stage, traditional postural descriptor parameters were characterized: a) Plantar footprint, b) Lumbo-pelvic equilibrium, c) Torso cervical segment, d) Torso lumbar segment, e) Rachis equilibrium, and f) Head equilibrium. This was also applied to a sample of 113 subjects from an eligible population of 140 students (1-α/2= 0.95, e= .041, and $P_{estimated}$= 0.50).

The procedure was carried out by a professional kinesiologist specialized in posture biomechanics in the Biomechanics and Motor Control Laboratory of the Universidad del Bío-Bío. The assessment technique is the bipodal photogrammetric postural analysis protocol described by the Universidade de São Paulo, Brazil[16]. The following equipment was used: Panasonic DMC-FZ40PU-K camera, tripod, body reflective spherical markers, Arquimed symmetrograph, as well as the tpsDig2 photogrammetric analysis program (angular and linear scalar measurements) (Figure 1).

Finally, plantar footprint analysis was performed with a podoscope and the Hernández Corvo protocol.

The third stage included cephalometric analysis of 45 subjects willing to undergo the radiological study. The procedure was performed in the DentoAnalisis Radiology Center in Chillán, Chile. A total of 42 subjects were evaluated (1-α/2= 0.95, 1-β= 0.80, and $r_{estimated\ minimum}$= .43). The other subjects did not complete the study. The parameters referred to in this sample were analyzed according to the protocol described by Rocabado with the following main descriptors: a) hyoid position, b) anteroposterior cranio-cervical rotation, and c) suboccipital distance C0-C1; units of measurement were degrees and centimeters (Figures 2 and 3).
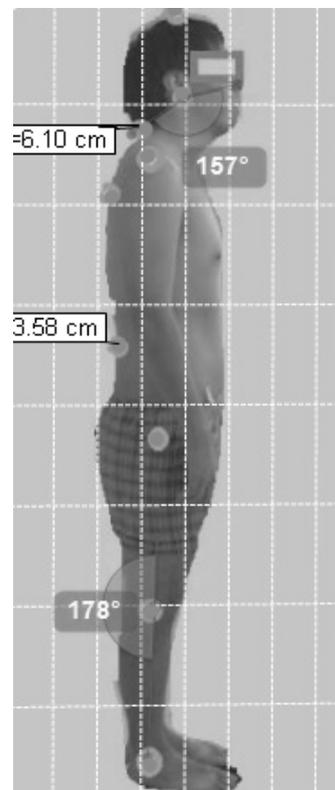

Figure 1. Photogrammetric method according to Ferreira et al.[16] used to describe the static postural variables. Markers, lines, quadrants, and angles generated with the tpsDig2 photogrammetric analysis program are highlighted.

The final sample of 42 subjects was analyzed at the speech intelligibility level (dividing subjects with normal and altered DDK); arithmetic means were calculated for the anatomic postural characteristics for both groups and these results were compared by Student's t-test. Finally, diadochokinetic speech performance scores were correlated with the postural variables by linear regressions. The significance level was α= 0.05.

Figure 2. Lateral cephalometry (X-ray). All the X-rays were taken with the X-ray tube positioned at 165 cm from the film, and the midsagittal plane of the subject's head was 15 cm from the film. X-rays were taken under the following conditions: subject in sitting position, natural head position (external reference: horizon), jaw occlusion, and tongue in rest position.
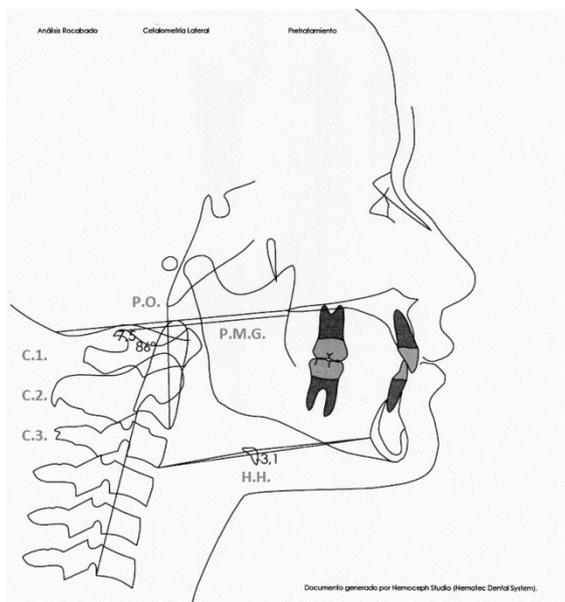
Legend: PO =odontoid plane; PMG = McGregor plane; HH =hyoid bone
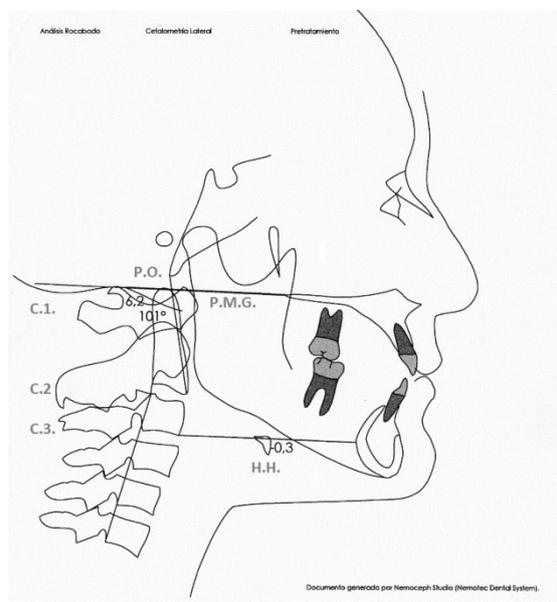
Figure 3. Rocobado cephalometric analysis: (A) Subject with cranio-cervical posture equilibrium, posteroinferior angle formed by McGregor plane and odontoid plane, normal (101°); (B) Subject with posterior head-neck rotation (extension) and related posteroinferior angle reduction (86°).

RESULTS

A sample of 42 subjects (27 women and 15 men) was analyzed; of the total, 36 exhibited appropriate speech intelligibility (normal DDK performance) and 6 altered speech intelligibility (altered DDK performance). The anteroposterior cranio-cervical rotation revealed statistically significant differences with a mean of 102.0° in the normal DDK group and 94.0° in the altered DDK group (p= 0.009) (Table 1).

When comparing arithmetic means of the postural characteristics of subjects with normal versus altered speech intelligibility in the women's subgroup (n=27), the plantar footprint (p= 0.013), lumbo-pelvic equilibrium (p= 0.038), anteroposterior cranial rotation (p= 0.047), and suboccipital distance C0-C1 (p= 0.049) variables exhibited statistically significant differences. In the case of the men's subgroup, no significant differences were found in any of the analyzed postural variables (Table 2).

Table 1. Comparison of measurements of anatomical and postural characteristics according to speech intelligibility (DDK performance)

Postural characteristics	Normal DDK (n=36)	Altered DDK (n=6)	p-value
Plantar footprint (%)	65.00 ± 14.00	56.50 ± 7.00	0.129 *
Lumbo-pelvic equilibrium (cm)	3.20 ± 2.00	3.35 ± 2.10	0.820 *
Torso cervical (cm)	6.39 ± 1.94	6.13 ± 1.21	0.756 **
Torso lumbar (cm)	5.00 ± 2.00	5.70 ± 1.00	0.459 *
Rachis equilibrium (cm)	0.40 ± 0.80	0.30 ± 1.20	0.739 *
Head equilibrium (cm)	4.90 ± 2.30	5.10 ± 2.60	0.766 *
AP cranio-cervical rotation (°)	102.00 ± 8.00	94.00 ± 10.00	0.009 *
Hyoid position (cm)	1.06 ± 1.51	1.14 ± 1.76	0.539 *
Suboccipital distance C0-C1 (cm)	1.09 ± 0.31	0.86 ± 0.19	0.063 **

*; Mann-Whitney U test (data does not belong to a normal distribution, previously evaluated by Shapiro-Wilk test)
** ; Student's t-test (normal data distribution evaluated by Shapiro-Wilk test)

Legend:
Plantar footprint (%) = relationship between plantar forefoot and isthmus.
Lumbo-pelvic equilibrium (cm) = relationship between pelvis and lumbar lordosis.
Torso cervical (cm) = linear measurement of cervical lordosis segment..
Torso lumbar (cm) =linear measurement of lumbar lordosis segment,
Rachis equilibrium (cm) =separation of spinous processes of the vertebral column with respect to the gravity line.
Head equilibrium (cm) = linear measurement between the head segment and the gravity line.
Anteroposterior (AP) cranio-cervical rotation (°) =angular relationship between the head position and the direction of the cervical spine.
Hyoid position (cm) = relationship between hyoid bone and direction of cervical spine.
Suboccipital distance C0-C1 (cm) =separation distance between the occiput and first cervical vertebra (atlas).

The linear regression analysis demonstrated that the anteroposterior cranio-cervical rotation was statistically associated with speech intelligibility in such a way that subjects with posterior head-neck rotation showed a higher percentage of variability in syllable emission of diadochokinetic speech performance (Table 3 and Figure 4).

Table 2. Comparison of means of anatomical and postural characteristics in women according to speech intelligibility (DDK performance)

Postural characteristics	Normal DDK (n=22)	Altered DDK (n=5)	p-value
Plantar footprint (%)	69.00 ± 15.00	56.00 ± 8.00	0.013 *
Lumbo-pelvic equilibrium (cm)	4.18 ± 1.55	3.20 ± 0.63	0.038 **
Torso cervical (cm)	6.66 ± 1.85	6.16 ± 1.35	0.575 **
Torso lumbar (cm)	5.50 ± 2.00	6.00 ± 1.00	1.000 *
Rachis equilibrium (cm)	0.00 ± 0.90	0.00 ± 1.10	0.976 *
Head equilibrium (cm)	4.90 ± 4.10	5.50 ± 3.50	0.786 *
AP cranio-cervical rotation (°)	101.00 ± 6.00	91.00 ± 10.00	0.047 *
Hyoid position(cm)	0.74 ± 1.19	1.05 ± 1.63	0.880 *
Suboccipital distance C0-C1 (cm)	0.98 ± 0.66	0.92 ± 0.50	0.049 **

*; Mann-Whitney U test (data does not belong to a normal distribution, previously evaluated by Shapiro-Wilk test)
** ; Student's t-test (normal data distribution evaluated by Shapiro-Wilk test)

Legend:
Plantar footprint (%) = relationship between plantar forefoot and isthmus.
Lumbo-pelvic equilibrium (cm) = relationship between pelvis and lumbar lordosis.
Torso cervical (cm) = linear measurement of cervical lordosis segment.
Torso lumbar (cm) =linear measurement of lumbar lordosis segment.
Rachis equilibrium (cm) = separation of spinous processes of the vertebral column with respect to the gravity line.
Head equilibrium (cm) = linear measurement between the head segment and the line of gravity.
Anteroposterior (AP) cranio-cervical rotation (°) =angular relationship between the head position and the direction of the cervical spine.
Hyoid position (cm) = relationship between hyoid bone and direction of cervical spine.
Suboccipital distance C0-C1 (cm) =separation distance between the occiput and first cervical vertebra (atlas).

Table 3. Linear regression between the cranio-cervical posture, which is statistically significant, and the speech intelligibility level (DDK performance) (n=42)

Variables	Beta coefficient	Typical error	Wald	gl	Sig.	OR
AP cranio-cervical rotation (°)	-0.176	0.075	5.568	1	0.018	0.839
Constant	15.403	7.143	4.650	1	0.031	

Legend:
Anteroposterior (AP) cranio-cervical rotation (°) =angular relationship between the head position and the direction of the cervical spine.
Constant= alpha value of the regression line.
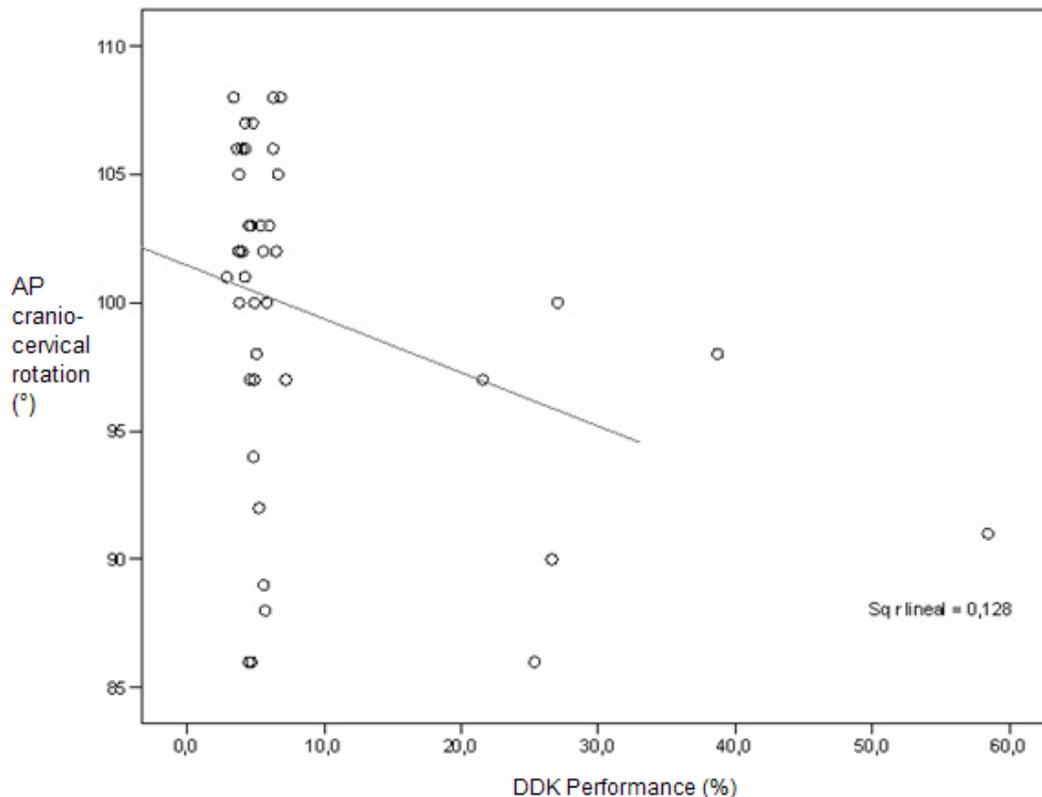
Legend:
Anteroposterior (AP) cranio-cervical rotation (°) =angular relationship between the head position and the direction of the cervical spine.
DDK Performance (%) = diadochokinetic periodic variation coefficient of speech.

Figure 4. The dispersion graph represents an inversely proportional tendency between DDK performance and the anteroposterior cranio-cervical rotation, that is, a smaller head-neck rotation angle increases the diadochokinetic periodic variation coefficient of speech (DDK).

DISCUSSION

Different studies point out the importance of the cranio-cervical relationship and the modification of odonto-stomatological functions[3,5,6] given that postural equilibrium can be defined as an important factor that describes the human physical and mental condition where controlled and balanced willingness allows preserving body structures and minimizing the risk of deformation or progressive dysfunction; this willingness is a descriptor of biomechanical efficiency to deal with the environment[17]. The present study revealed that a group of young subjects with no relevant morbid history can exhibit slight speech intelligibility alterations as a result of postural dysfunctions at the head-cervical level, particularly because of the presence of posterior head-neck rotation.

The reviewed literature states that an imbalanced head-cervical posture does not allow either efficient or synchronized muscular work, which eventually modifies the morphology and functionality of the musculoskeletal system[7]; this affects the mobility of the intrinsic-extrinsic tongue, perioral, masseter, and orbicularis musculature necessary for well-articulated and intelligible phoneme production. Discacciati de Lértora et al.[1] also point out a relationship between cranio-facial morphology, cephalic posture, and functions such as respiration, deglutition, speech, and voice; these alterations could be explained by posture problems from childhood that were not promptly corrected[18] and became more noticeable in adolescence because of poor posture habits. Noll et al.[19] provide an example of this in their study about the prevalence of these bad habits in youth, concluding that only 15.1% adopt a correct posture when writing and 21.5% sit properly at the computer.

In addition, Avantika et al.[14] studied a group of young and healthy subjects with no diagnosed posture or speech disorders, but who were considered to be at high risk because they exhibited inappropriate daily habits by carrying heavy backpacks equivalent to 10% to 20% of their body weight, which conditions

significant changes in postural behavior and the gravitational position of the center of body mass causing anterior translation of the head, shoulders, and upper back region. Straker et al.[15] pointed out the postural impact of the height of the computer screen and desk design in 36 young adult subjects of both sexes; they concluded that a higher screen results in less head and neck flexing, lower elevation and protrusion of the scapula, and less shoulder flexing and abduction. We believe that both these studies show very well the reality of the studied sample and the results that were obtained given that these university students carry weight and dedicate most of their time in front of a computer every day; a number of them exhibit undiagnosed postural alterations.

More specifically, the study results indicate contrasts in the cephalic postural pattern at the anteroposterior cranio-cervical rotation level because there was a statistically significant difference for this variable between youth with good speech intelligibility compared to those with altered intelligibility (p= 0.009). This difference can be explained by the study by Wilson and Frederick[20], which points out that defined body postures, such as cervical hyperlordosis and thoracic kyphosis, are associated with an anomalous head rotation, thus generating an increased distance from the hyoid bone to the mandibular symphysis. As a consequence, exaggerated tension of the supra- and infrahyoid muscles in the dorsocaudal direction is produced, which promotes an increase in tongue muscle tension that leads to imprecise and slurred speech articulation.

A comparative analysis of the women's group with good speech intelligibility and low speech intelligibility led to statistically significant differences for the plantar footprint posture variables (p= 0.013) and lumbo-pelvic equilibrium (p= 0.038). On this point, Kendall et al.[21] point out that persons that exhibit sway back posture are characterized by a marked anterior pelvic translation (lumbar imbalance) and increased thoracic kyphosis, which leads to functional inefficiency of the anterolateral abdomen and diaphragm musculature, thus affecting the respiratory function and intelligible speech production. All these posture parameters can be explained because the magnitude of lumbar lordosis has been traditionally considered as being higher in women than men; mean differentiation values have even been established [2°- 5°][22]. This could be associated with a compensatory cervical hyperlordosis as a response to the arthrokinematic rachis equilibrium; however, it is now possible to clarify that lumbar

hyperlordosis in women is more apparent than real because it is mainly conditioned by the high muscle and gluteal fat mass on the hip[23].

In this same group, it was established that the anteroposterior cranio-cervical rotation and suboccipital distance C0-C1 variables equally showed statistically significant differences between women with good intelligibility and those with low intelligibility (p= 0.047 and p= 0.049, respectively). We believe that when there is a reduction of the posteroinferior angle formed by the McGregor and odontoid planes for the anteroposterior cranio-cervical rotation variable, a compensatory cervical hyperlordosis associated with an increased distance from the hyoid bone to the mandibular symphysis would be generated. An exaggerated tension of the supra- and infrahyoid muscles and a decrease in the suboccipital distance between C0 – C1[24] would be added to this. As a result of these imbalances, we hypothesize that a loss of equilibrium of the extrinsic tongue muscles, which limits their mobility and causes a loss of articulatory accuracy of post-dental, alveolar, and palatal phonemes.

The anteroposterior cranio-cervical rotation variable was determined by the linear regression test and was statistically associated with speech intelligibility. Thus, the studied sample showed that the posterior head-neck rotation affects speech intelligibility. This result was similar to the finding published by Kooijman et al.[25], who evaluated 25 teachers and reported a relationship between hypertrophy of the laryngeal extrinsic muscles, postural deviations, and vocal dysfunction; the muscles most affected by hypertension were the sternocleidomastoid and geniohyoid muscles, which are associated with cranio-cervical postural changes and hyoid elevation; this demonstrates that a correct and upright posture influences adequate articulation. In addition, Carneiro and Teles[26] investigated the influence of different body postures in voice production based on a sample of 25 subjects of both sexes who exhibited three postures: (A) orthostatic upright posture, (B) forward head posture associated with marked cervical extension, and (C) posture with increased kyphosis associated with forward head posture. Results showed that voice characteristics, such as pitch, resonance, and voice quality, were statistically better in the upright position without the anomalous head-neck rotation. Miller et al.[27] investigated the relationship between the images from cephalometric magnetic resonance imaging (MRI), the muscle function of the stomatognathic system during speech production, and voice;

they were able to verify the existence of correlations between cranio-facial bones, cervical vertebrae, size of respiratory tract, and the position of the hyoid bone, larynx, epiglottis, uvula, and jaw.

When comparing the means between subjects with good and low speech intelligibility with the rest of the described postural variables, no significant differences were found for the results obtained in the present study. This can be explained by the presence of compensatory postural responses that are mainly defined in a one-dimensional plane, as mentioned by Rodríguez et al.[28], who point out that global postural re-education methods try to establish an equilibrium between muscle chains mainly arranged in a single plane (anteroposterior direction), favoring the agonist-synergist functional relationship between static muscle chains. It is therefore necessary to mention the intrinsic characteristics of the sample: young, healthy university subjects; these characteristics provided them with more awareness and proprioception of the body scheme, cephalic postural pattern, and speech articulation whereby they possibly compensated imbalances when being assessed.

CONCLUSION

The present study establishes evidence to suggest that the cephalic postural pattern measured by the degree of anteroposterior head-neck rotation is associated with the speech intelligibility level of young, healthy university students exhibiting poor posture habits. This also demonstrates that postural alterations not only have a repercussion on the phonatory system, as extensively exposed in the literature, but also at the speech articulation level. We consider that this report can be of interest to approach speech therapy from the point of view of oral motor skills and esthetics, especially associated with the therapeutic approach of rehabilitating or restructuring at the oral muscle level, considering the growing number of adult users looking to enhance their oral articulatory skills for their professional or artistic development.

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