Radiographic Head and Neck Positional Changes in Response to Oculomotor Muscles Tonic Modification Using Low-powered Prismatic Lenses

NCT ID not yet assigned

Reviewed in 22.Nov.2025

PhD Project Intent

Doctoral Programme of the Lisbon Academic Medical Centre (CAML)

1. Applicant's Name:
João Luís Gomes Lopes Alves da Silva

2. Project Title:
Active Cervicocephalic Mobility in Postural Deficiency Syndrome and its Response to Treatment with Supero-External Base Prismatic Lenses

3. Supervisor
3.1 **Name:** Pedro Manuel Gonçalves Silva Fernandes
3.2 **Institution:** Faculty of Medicine, University of Lisbon
3.3 **Curriculum Vitae:** Document highlighting publications in the scientific field of the proposed thesis, attached to the application documents.
3.4 **Supervisor's Opinion:** Document attached to the application file.

4. Co-Supervisors

4.1 **Name:** Ivo da Piedade Álvares Furtado
4.2 **Institution:** Faculty of Life Sciences, University of Madeira
4.3 **Curriculum Vitae:** Document highlighting publications in the scientific field of the proposed thesis, attached to the application documents.
4.4 **Supervisor's Opinion:** Document attached to the application file.

4.5 **Name:** Fábio Miguel Vasconcelos Trindade
4.6 **Institution:** Faculty of Life Sciences, University of Madeira
4.7 **Curriculum Vitae:** Document highlighting publications in the scientific field of the proposed thesis, attached to the application documents.
4.8 **Supervisor's Opinion:** Document attached to the application file.

5. Institutions of Execution:
Faculty of Life Sciences, University of Madeira
Faculty of Medicine, University of Lisbon
Posturmed Clinic
CUF Descobertas Hospital

7. Summary

The relationship between ocular and vertebral motor activity is very close and was already evident at the foundational moments of neuroscience. When the English physiologist Charles Scott Sherrington (awarded the Nobel Prize in Physiology or Medicine in 1932[1]) published his major work *The Integrative Action of the Nervous System*—in which he also coined the term *proprioception*—he demonstrated the independence of retinal images in both cerebral hemispheres and their correlation with a common ocular motor pathway, thereby achieving a single image perception (Sherrington, 1906). Sherrington clearly stated that this motor relationship is not exclusive to the ocular muscles but also involves the head and the entire body: "[...] the taxis of the lateral movements of the two eyeballs transfer thought each eyeball from its own actual sagittal plane to the median sagittal plane of the head; and this latter corresponds in the resting position with the sagittal median plane of the animal as a whole."

Half a century after Sherrington's studies, the French ophthalmologist Jean Benard Baron published his science thesis *Muscles moteurs oculaires, attitude et comportement locomoteur des vertébrés* (Baron, 1955). He described several experiments on the proprioceptivity of ocular motor muscles in rodents and fish. Through surgical manipulation of these muscles, he managed to modify the animals' locomotor patterns: by surgically displacing the position of the eyeballs up to four dioptres via partial scleral tenotomies, the animals changed their swimming or walking pattern in accordance with the induced deviation.

To clarify the cause of the postural deviation, Baron performed the same experiment with blinded animals—obtaining "absolutely identical" results—and with enucleated animals, which showed no postural deviation. Based on these data, he concluded:

- A deviation of the ocular motor muscles of less than 4° provokes a particular attitude that varies with the nature of the deviation.
- This attitude generates a specific motor behaviour.

[1] https://www.nobelprize.org/prizes/medicine/1932/sherrington

- These attitudes and behaviours do not depend on vision but solely on the ocular motor and paravertebral muscles.
- In cases of deviation exceeding 4°, the attitude depends on the position of the paravertebral muscles.

In 1979, the Portuguese physiatrist Henrique Martins da Cunha defined the *Postural Deficiency Syndrome* (PDS). He interpreted PDS as a proprioceptive dysfunction: in these patients, the sensory information required to construct a biomechanical schema—originating from multiple sources (cutaneous, tendinous, muscular, articular, visual, and labyrinthine)—becomes discordant, resulting in a sensory conflict that distorts the biomechanical schema and overloads the postural regulation mechanisms. From the outset, he identified this syndrome as a deviation from the ideal biomechanical scheme, producing a complex clinical picture variably affecting the musculoskeletal, stato-acoustic, and visual proprioceptive systems (Martins da Cunha, 1979, 1987).

The notion of good posture depends on an optimal mechanical relationship among body parts, which varies across bodily attitudes over the days and throughout an individual's life. The American Academy of Orthopaedic Surgeons (AAOS, 1947) defined posture as the state of muscular and skeletal balance that protects the body structures from injury or progressive deformity. Given the important anatomical variations of individual vertebral curvatures, it is not possible to establish an ideal vertebral dynamic, only to assess variations in vertebral statics that maintain the centre of gravity balanced over the plantar support area. This equilibrium situation was defined as the "cone of stability" by Jean Dubousset (1994). Several authors have defined different vertebral morphotypes and the positional and angular limits necessary to maintain vertebral stability within good posture (Le Huec & Hasegawa, 2016; Mac-Thiong et al., 2010; Roussouly et al., 2003; Roussouly & Pinheiro-Franco, 2011; Vaz et al., 2002).

Treatment of PDS offers several options: correction of the "simple deviation from the ideal biomechanical scheme" (Martins da Cunha, 1979) can be achieved through various sensory modalities. The physiotherapeutic treatment proposed by Martins da Cunha consisted of postural correction through positioning and breathing exercises (1987). Other modalities include proprioceptive manipulation using dental orthoses (Marino & Quercia, 2021) or insoles (Quercia et al., 2007). The use of the proprioceptive pathway of ocular motor muscles for PDS treatment began in the late 1970s, when Martins da Cunha requested support from the Ophthalmology Department of Hospital de Santa Maria to investigate gaze deviations he regularly identified in his patients: detecting convergence abnormalities became one of the diagnostic criteria for PDS (Martins da Cunha, 1979, 1987). This finding was later interpreted as an alteration in the proprioceptivity of the oculocephalic muscles (Alves da Silva, 1987; Alves da Silva & Alves da Silva, 2019; Gagey, 1987; Martins da Cunha & Alves da Silva, 1986a; Roll & Roll, 1987; Roll et al., 1991). The collaboration between these two departments enabled the development of a PDS treatment centred on postural reprogramming and the use of external or supero-external base prisms (Alves da Silva & Alves da Silva, 2019).

Over the last century, extensive scientific work has clarified the close relationship between periocular and cervical muscles—phylogenetic, ontogenetic, anatomical, and functional. Their common origin in the paraxial mesoderm (Pourquié, 2011; Schoenwolf, 2021) is expressed, despite the singularity of craniofacial development, in a clear anatomofunctional correlation of the motor and sensory nuclear columns of the cervical spinal cord and brainstem (Joyce et al., 2021; Vishram, 2021). This functional relationship is so well recognised that its absence constitutes part of the criteria for brain death (Harvard Medical School, 1968).

Objective of the Project

The aim of this project is to clarify the relationship between PDS and asymmetry in active and static axial mobility through an observational study, as well as to assess the axial postural effect of prismatic treatment in these patients through four studies.

8. Technical Description

8.1 Literature Review

Search Criteria

A preliminary search was conducted in the databases PubMed, LILACS, Cochrane Library, and SciELO using the following criteria: “postural deficiency syndrome”, “syndrome de déficience posturale”, “Martins da Cunha”, and combinations of at least two of the following terms: *proprioceptive*, *proprioception*, *eye*, *eyes*, *neck*, *spine*, *impairment*, *impairments*, *deficit*, and *deficits*.

From these searches, 256 original titles were identified. After reviewing the abstracts, 12 scientific articles related to Postural Deficiency Syndrome (PDS) were selected. Cross-referencing citations from these articles and evaluating their bibliographies yielded an additional 17 relevant articles. Out of the total of 29 identified, 23 complete articles were obtained.

Axial postural changes are part of the description of Postural Deficiency Syndrome (Martins da Cunha, 1979). The author described as a typical PDS pattern an increase in both cervical and lumbar lordotic curvatures (Martins da Cunha, 1974, 1983).

The scientific studies collected on axial postural changes in PDS focus primarily on the neurophysiological mechanisms of postural control and the correlation between axial posture and oculomotricity (Berthoz, 1987; Buisseret, 1987; Gagey, 1987; Martins da Cunha & Alves da Silva, 1986b).

Although changes in the amplitude of spinal physiological curves in PDS have been described since the first publications, they have never been quantified—clinically or radiographically—in subsequent studies, nor has the effect of treatment on these curves been measured.

The evaluation of these postural changes in PDS patients is mentioned in several studies, often referring to their alteration following treatment; however, none of these are prospective or randomized, nor do they clearly specify the vertebral parameters before and after treatment. All identified articles in this literature review were retrospective, non-randomized, and lacked a clear definition of pre- and post-treatment outcomes. No studies using conventional radiography in the evaluation of PDS patients were found.

8.2 Objectives

Research Question
Can the use of supero-external base prisms alter axial mobility in patients with Postural Deficiency Syndrome?

Working Hypotheses

The use of supero-external base prisms in patients with PDS modifies their vertebral mobility.

Active axial mobility in patients with PDS:

- Is asymmetric and quantifiable;
- Represents a proprioceptive dysfunction;
- Can be treated with supero-external base prisms.

Main Objectives

This work aims to:

- Demonstrate the axial postural repercussions of using supero-external base prisms in patients with PDS.
- Confirm the effectiveness of treating these clinical manifestations using supero-external base prisms.

Secondary Objectives

1. Quantify the asymmetry of cervical mobility in PDS patients.
2. Correlate this asymmetry with other signs and symptoms characteristic of PDS.

8.3 Research Plan, Methods, and Task Description

Materials and Methods

Participant Selection

Inclusion Criteria

The studies aim to include patients who meet the defined diagnostic criteria for *Postural Deficiency Syndrome (PDS)*.

We consider the original diagnostic criteria proposed by Martins da Cunha and apply the classification of Alves da Silva (Alves da Silva & Alves da Silva, 2019; Martins da Cunha, 1987).

The following table presents the characteristic signs and symptoms of PDS as defined by Martins da Cunha:

Annexe

Signes fonctionnels du syndrome de déficience posturale (SDP) (Martins Da Cunha H. (1979)). *Syndrome de déficience posturale,* "Actualités en rééducation fonctionnelle et réadaptation", 4^e^ série (Éd. *L. Simon),* Mallon, Paris.

TABLEAU I

Signes fonctionnels du syndrome de déficience posturale (SDP). Signes cardinaux.

Signes	Manifestations cliniques
Douleur	Céphalée, douleur rétro-oculaire, thoracique ou abdominale, arthralgie, rachialgie.
Déséquilibre	Nausée, étourdissement, vertige, chutes inexplicables.
Signes ophtalmologiques ..	Asthénopie, vision trouble, diplopie, scotomes directionnels, métatopsia.
Signes de nature proprioceptive	Dysmétrie, somatoagnosie, erreurs d'appréciation du schéma corporel.

TABLEAU II

Signes cardinaux.

Signes	Manifestations cliniques
Articulaires	Syndrome de l'articulation temporo-mandibulaire, torticolis, lumbago, périarthrites, entorses.
Neuro-musculaires .	Parésies, défaut de contrôle moteur des extrémités.
Neuro-vasculaires ..	Paresthésies des extrémités, phénomène de Raynaud.
Cardio-circulatoires .	Tachycardie, lipothymie.
Respiratoires	Dyspnée, fatigue.
ORL	Bourdonnements, surdité.
Psychiques	Dysléxie, dysgraphie, agoraphobie, défaut d'orientation, défaut de localisation spatiale et droite-gauche. Défaut de concentration, pertes de mémoire, asthénie, anxiété, dépression.

We also include his own description of the physical examination characteristics of these patients:

"Patients with PDS present a characteristic body attitude, with rotation of the head, trunk, and one of the lower limbs—usually the right—around a vertical axis in a clockwise direction. This incomplete rotation results in a typical posture, characterised by a particular gaze direction, facial asymmetry, asymmetry of the trunk and upper limbs, accentuated physiological spinal curvatures, and a scoliotic attitude with lumbar muscle hypertonia and clearly asymmetric plantar support (fig. 1)."

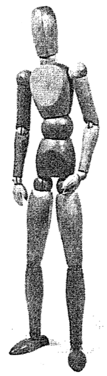

FIG. 1. — *Attitude habituelle du malade porteur du syndrome de déficience posturale (S.D.P.)*

The classification used in this study corresponds to Table 1 from the most recent publication by Alves da Silva & Alves da Silva (2019).

To establish the diagnosis of PDS, the following criteria are required:

- Presence of at least **two cardinal signs** defined by Martins da Cunha.
- Presence of **asymmetric plantar support**, as described by Martins da Cunha.
- Presence of **asymmetry of head rotation and extension**, as described by Martins da Cunha.
- Presence of **directional pseudo-scotomas** on synoptophore testing.

The selection of these criteria is based on the inclusion of key clinical features defined as central by the original author, associated with signs considered essential for proper classification, as expressed in the first three columns of the referenced table.

Table 1. Diagnostic classification of PDS and treatment protocol with active prisms.

Plantar stance	Head extension	Head Rotation	Synoptophore	Prismatic lenses
Mixed	**Pure**			
Divergent feet, side of preferential stance may shift	Head exam is concordant: Limitation of rotation and head tilt in extension on the same side "farther and shorter" to the same side		Pseudoscotomas for symmetrical angles of version	2 Prisms of asymmetrical power RE 125° LE 55° Higher powered prism on the side of head limitation
Mixed	**Pure right**			
Divergent feet, plantar stance may shift but with preference for **right side**	Limitation of rotation and head tilt in extension to the right		20°/20° or 30°/30°	**RE- 3Δ 125°** LE- 2Δ 55°
Mixed	**Pure left**			
Divergent feet, plantar stance may shift but with preference for **left side**	Limitation of rotation and head tilt in extension to the **left**		20°/20° or 30°/30°	RE- 2Δ 125° **LE- 3Δ 55°**
Mixed	→		**Predominant**	
Divergent feet, side of preferential stance more clearly defined	Head exam is not concordant: Limitation of rotation for one side and head tilt in extension to the other side		Pseudoscotomas are asymmetrical occur in higher angle of version to the side of preferential plantar stance	1 Prism RE 125° or LE 55° Prism on the side of higher angle of version and preferential plantar stance
Mixed			**Predominant right**	
Divergent feet, plantar stance with preference for **right side**	Head exam is not concordant		**20 ° dextroversion** 30 ° levoversion	**RE 125°** 2Δ or 3Δ
Mixed			**Predominant left**	
Divergent feet, plantar stance with preference for **left side**	Head exam is not concordant: Limitation of rotation for one side and head tilt in extension to the other side		20 ° dextroversion **30 ° levoversion**	**LE 55°** 2Δ or 3Δ
Pure				
Clear lateral preference in plantar stance, stance foot in sagittal position	Head exam is not concordant: Limitation of rotation for one side and head tilt in extension to the other side		Pseudoscotoma only to one side of version the opposite side of plantar stance	1 **horizontal prism** RE 180° LE 0° Prism on the side of plantar stance, On the opposite side of pseudoscotoma
Pure			**Right**	
Right plantar stance **Right foot** is sagittal	Head exam is not concordant		**20 ° levoversion**	**RE 180°** 2Δ or 3Δ
Pure			**Left**	
Left plantar stance **Left foot** is sagittal	Head exam is not concordant		**20 ° dextroversion**	**LE 0°** 2Δ or 3Δ

Exclusion Criteria

The following exclusion criteria will apply:

- Corrected visual acuity below 8/10 in either eye.
- Strabismus.
- Nystagmus.

- Glaucoma.
- History of ophthalmic or vestibular surgery.
- Use of medication affecting binocular vision, accommodation, or balance.
- Ocular or central nervous system lesion reducing visual field.
- Vestibular or otological disease affecting inner ear function.
- Known neurological or muscular disorder interfering with postural control or gait (e.g., Parkinson's disease, Charcot–Marie–Tooth, stroke, etc.).
- Previous PDS treatment within the last year.

Study Design

The research will be divided into three phases, comprising a total of **four distinct studies**. The study presented here corresponds to Study 3, as stated in the following summary table:

Table 3 – Summary of Proposed Studies

Description	Type	Duration
Phase 1 – Population Characterisation		
Study 1 Prospective Assessment of the Baseline Characteristics of Patients with SDP	Observational	1 year
Phase 2 – Short-Term Outcomes Clinical Evaluation of Short-Term Prismatic Treatment for SDP		
Study 2	Prospective Randomized Trial Against Regular Lenses	6 months
Study 3	Prospective (non-randomised)	6 months
Phase 3 – Medium-Term Evaluation of SDP Treatment Outcomes		
Study 4	Prospective randomised vs regular lenses	9 months

All studies follow the principles of the **Declaration of Helsinki** (World Medical Association, 2013) and will be submitted for approval by the **Ethics Committee of the University of Lisbon**.

Any additional costs arising from these studies will be fully covered by the candidate.

The proposed studies aim to assess a set of PDS parameters at different stages and in response to treatment. For the current study, these parameters are defined in **Table 2** below.

Table 2. Parameterisation of Recorded Variables

Description	**Measurement Unit**	**Reference**
Radiographic Parameters		
Cervical lordosis, thoracic kyphosis, and lumbar lordosis	degrees	2
Global and cervical (C2–C7) vertical spinal alignment	millimeters	2
Inclination of C0, C1, and C2	degrees	2
Pelvic incidence, pelvic tilt, and sacral slope	degrees	2
Head inclination and rotation	degrees	2
Clavicular angle and radiographic shoulder height	degrees & millimeters	2
Pelvic obliquity	degrees	2
Hip rotation	degrees	2

The methodology for measurement and recording of these parameters (Table 2) is detailed in **Annex 1**. A summary table of the proposed studies is presented at the end of this section.

Evaluation of the Short-Term Prismatic Effect on Spinal Static Posture

This study aims to assess the short-term prismatic effect on the spinal static posture of patients with PDS, using radiographic evaluation before and after the application of the appropriate prisms.

The radiographic study is conducted using the EOS very low-dose biplanar scanning system. This system, which has been duly validated and calibrated for the European population, provides exceptional precision for angular measurements and is capable of obtaining the aforementioned records in any patient position due to its three-dimensional assessment capability of the vertebral column (Le Huec & Hasegawa, 2016). The EOS system performs these acquisitions using radiation doses significantly lower than conventional digital radiography, with exposure levels 5 to 20 times lower. In total, the proposed study results in an expected exposure of less than 3 μSv, approximately half the average daily exposure to natural background radiation (Hui et al., 2016).

The measured angles follow the criteria defined in the Radiographic Measurement Manual published by the Spinal Deformity Study Group (Group & O'Brien, 2005).

Participant Recruitment

Participants will be recruited from patients referred to the specialist consultation at a private clinic in Lisbon (Posturmed Clinic).
All adult consecutive patients fulfilling PDS diagnostic criteria will be invited.
Written informed consent will be required.

The aim is to recruit an initial sample of 12 patients for this study (Julious, 2005). Using this initial sample as a pilot study, we will seek to compare the results between the two paired observations (before and after treatment) to calculate the sample size required to determine the number of participants needed to detect differences in the parameters chosen as primary outcomes (see below – statistical processing of the data).

The study will have a maximum duration of 1 year after the sample size calculation ending earlier if the planned sample size is reached beforehand.

Methodology

The study comprises of three assessment moments:

1. **Initial assessment** – follows the procedures already defined previously ffor diagnosis and treatment prescription, carried out by the ophthalmologist.

   Participants will undergo an ophthalmological consultation by a specialist experienced in strabology and posturology to confirm inclusion/exclusion criteria.
   In cases that meet these criteria, it is proposed that all parameters Table 2 be recorded for the purposes of the study.

   In this phase of the study, the ophthalmologic examination, diagnosis, and treatment prescription will be performed by an ophthalmologist. The candidate will attend this appointment as an observer, only performing the formalities associated with the study.

   The ophthalmological evaluation, diagnosis, and treatment will be performed by Dr Orlando Alves da Silva, Chief Ophthalmologist and former Head of the Strabismus Unit, Hospital de Santa Maria / Lisbon University Hospital Centre (1977–2005).

2. **Pre-treatment radiographic assessment** – after the prescribed lenses have been prescribed but before their use, this assessment consists of performing the examination with the patient standing in their natural posture.

3. **Radiographic assessment after 15 minutes of treatment** – fifteen minutes after the patient begins wearing the prescribed glasses with the evaluated visual correction (if not emmetropic) and the supero-external or external base prisms, according to the established prescription criteria for the diagnosed PDS subtype, the radiographic assessment and the measurements described in the previous point are repeated.

   The EOS system's proprietary software allows for the measurement of all parameters defined as clinical outcomes, namely:

- *in profile view*
    - Sagittal plane
    - Cervical lordosis
    - Thoracic kyphosis
    - Lumbar lordosis
    - Global spinal vertical alignment
    - Cervical vertical alignment (C2–C7)
    - Inclination of C0, C1, and C2
    - Pelvic incidence
    - Pelvic tilt
    - Sacral slope
- *in frontal view*
    - Head tilt and rotation
    - Shoulder tilt and height (clavicular angle and radiographic shoulder height)
    - Pelvic obliquity
    - Hip rotation

Statistical Analysis

The sample size calculation for the study will follow the following assumptions:

1. Estimating an expected outcome. In this study, given the absence of robust data in the published literature, it is proposed to include a pilot group of 12 patients to provide a basis for estimation. By analysing this group using analysis of variance, it is possible—provided that a normal distribution is confirmed—to determine the sample size required to achieve the desired alpha level. The following baseline parameters are defined for this calculation:
    - statistical power of 0.8;
    - α of 0.05;
    - dropout rate of 0%.

2. Defining a clinically significant value for the outcomes. As no sufficiently reliable values exist in the published literature from which to objectively determine clinically meaningful differences, the following thresholds were selected, each well above the known limits of measurement error:

- clinically significant difference in pelvic tilt: 3 degrees;
- clinically significant difference in C0 inclination: 3 degrees;
- clinically significant difference in cervical spinal vertical alignment: 2 mm.

The analysis of the final results of the study will be carried out, for continuous variables, using analysis of variance (ANOVA) and mean comparison tests—Student's t-test for paired variables or, if normality is not confirmed using the Shapiro–Wilk test, the Wilcoxon test.

8.5 Bibliographic References

Alves da Silva, O. (1987). *Scotométrie directionnelle et corrections prismatiques dans le syndrome de déficience posturale.* Agressologie: Revue Internationale De Physio-Biologie Et De Pharmacologie Appliquées Aux Effets De L'agression, 28(9), 945–946.
Alves da Silva, O., & Alves da Silva, T. (2019). *The Eye and Proprioception.* Vision Development and Rehabilitation, 5(2), 130–146.
American Academy of Orthopaedic Surgeons. (1947). *Posture and its Relationship to Orthopaedic Disabilities: A Report of the Posture Committee.* AAOS.
Baron, J. (1955). *Muscles moteurs oculaires, attitude et comportement locomoteur des vertébrés.* Thèse de Sciences, Université de Paris.
Berthoz, A. (1987). *Regard et posture: Influence de la direction du regard sur le contrôle de la posture.* Agressologie, 28(9), 893–895.
Buisseret, P. (1987). *Développement du système visuel et proprioception d'origine extraoculaire et cervicale.* Agressologie, 28(9), 913–916.
Dubousset, J. (1994). *Three-dimensional analysis of the scoliotic deformity.* In S. L. Weinstein (Ed.), *Pediatric Spine: Principles and Practice* (pp. 479–483). Raven Press.
Gagey, P. M. (1987). *L'oculomotricité comme endo-entrée du système postural.* Agressologie, 28(9), 899–903.
Group, S. D. S., & O'Brien, M. F. (2005). *Radiographic Measurement Manual.*

Medtronic Sofamor Danek.
Harvard Medical School. (1968). *A Definition of Irreversible Coma: Report of the Ad Hoc Committee …* JAMA, 205(6), 337–340. https://doi.org/10.1001/jama.1968.03140320031009
Hui et al. (2016). *Radiation dose of digital radiography (DR) versus micro-dose x-ray (EOS)… Scoliosis and Spinal Disorders,* 11, 46. https://doi.org/10.1186/s13013-016-0106-7
Joyce, C., Le, P. H., & Peterson, D. C. (2021). *Neuroanatomy, Cranial Nerve III (Oculomotor).* In *StatPearls.* StatPearls Publishing.
Julious, S. A. (2005). *Sample size of 12 per group rule of thumb for a pilot study. Pharmaceutical Statistics,* 4(4), 287–291.
Le Huec, J. C., & Hasegawa, K. (2016). *Normative values for the spine shape parameters using 3D standing analysis… European Spine Journal,* 25(11), 3630–3637.
Mac-Thiong, J.-M., Roussouly, P., Berthonnaud, E., & Guigui, P. (2010). *Sagittal parameters of global spinal balance… Spine,* 35(22), E1193–E1198.
Marino, A., & Quercia, P. (2021). *Stimulations trigéminales bipolaires: Vers une orthodontie neuro-sensorielle …*
Martins da Cunha, H. (1974–1987). Multiple works on Postural Deficiency Syndrome as cited in text.
Pourquié, O. (2011). *Segmentation of the vertebrate spine: From clock to scoliosis. Cell,* 145(5), 650–663.
Quercia et al. (2007). *Étude de l'impact du contrôle postural associé au port de verres prismatiques… J. Fr. d'Ophtalmologie,* 30, 380–389.
Roll & Roll (1987). *La proprioception extra-oculaire comme élément de référence posturale…* Agressologie, 28(9), 905–912.
Tavares, C. S. F. da S. (2013). *Tradução e adaptação do questionário Convergence Insufficiency Symptom Survey (CISS)…* Master's Thesis, Univ. Beira Interior.
Tukey, J. W. (1977). *Exploratory Data Analysis.* Addison-Wesley.
Vaz et al. (2002). *Sagittal morphology and equilibrium of pelvis and spine. European Spine Journal,* 11(1), 80–87.
Vishram, S. (2021). *Textbook of Clinical Neuroanatomy* (4th ed.). Elsevier.
World Medical Association. (2013). *Declaration of Helsinki. JAMA,* 310(20), 2191–2194.

Annex 1 – Parameterization and Measurement Methodology

Ref.	**Description**	**Measurement**	**Specifications**
Musculoskeletal Parameters			
1a	Head-rotation asymmetry	cm and degrees, menton-acromion distance, protractor reading	Patient performs maximal active rotation avoiding trunk motion.
1b	Head-extension asymmetry	cm, tragus-trapezius vertical distance	Measured during maximal active head extension.
1c	Head tilt (neutral)	degrees	Digital AP photograph; interpupillary or midsagittal line angle.
1d	Head tilt (extension)	degrees	Same as 1c during maximal active extension.
1e	Head extension	degrees	Digital right-profile photo, tragus–subnasal line inclination.
1f	Foot orientation (natural)	degrees	Measured with protractor in comfortable stance.
1g	Perceived foot orientation (corrected)	degrees	Patient indicates direction of each foot with hands while blind to feet position.
Radiographic Parameters			
2	All measured via EOS software per *Radiographic Measurement Manual* (Group & O'Brien, 2005).		
Ophthalmological Parameters			
3a	Refraction study	Spherical/cylindrical power and axis for each eye; prism power/axis; near-addition in dioptres	Recorded per standard optical prescription norms.
3b	Interpupillary distance	mm at 40 cm	

3c	Directional pseudo-scotomas	degrees, dextro- and levoversion	Using Clement-Clarke synoptophore (slides G3 & G4).
Oculomotor-coordination Parameters (PDS)			
4a	Hand–eye test	± (> 1 cm error = positive)	According to Alves da Silva & Alves da Silva (2019).
4b	Near point of convergence	cm to fusion break	RAF rule, 1 cm/s approach, pinpoint target.
4c	Near point of asthenopia	cm to onset of effort	Measured immediately after 4b.
4d	Convergence Insufficiency Symptom Survey – V15	total score	Portuguese-validated version (Tavares 2013).
4e	PDS subclassification	diagnostic record	According to Alves da Silva & Alves da Silva (2019).