Consensus paper on postural dysfunction: recommendations for prevention, diagnosis and therapy

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Good fundamentals of posture and balance are essential for the efficient performance of both simple daily tasks and more complex movement patterns. In particular, postural balance is the ability to keep the body in equilibrium and to regain balance after the shift of body segments: postural control mechanisms of integration of the visual, vestibular and foot afferential channels contribute to this. This document provides recommendations based on scientific evidence, clinical practice, and consensus between experts concerning the prevention, diagnosis, and treatment of postural dysfunction at the three stages of life as the developmental age, adult age, and old age > 65 years and follows the "National Guidelines on Classification and Measuring of Posture and its Dysfunctions" per the Italian Ministry of Health (December 2017). The paper answers four main questions: i) "Which measures can be adopted to prevent postural dysfunctions?" ii) "What can we do in order to make a correct diagnosis of postural

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dysfunction?" iii) "What are the correct treatment programs for postural dysfunctions?" iv) Which professional competencies and experiences are useful for preventing, diagnosing and treating postural dysfunctions? By the Consensus of the Experts and the scientific evidence, emerge that the approach to postural dysfunctions requires a multidisciplinary and interdisciplinary team. Furthermore, rehabilitation treatment interventions must be specific to the age groups that have been indicated, to consider the integration of the main systems and subsystems of postural control that change with age.

Key words: posture; rehabilitation; exercise; balance; scoliosis; foot; elderly; child

The implementation of appropriate responses and adjustments before and during every movement helps ensure correct postural balance. Anticipatory or compensatory adjustments are appropriate responses to sensory stimuli that are collected primarily by cutaneous receptors and foot receptors, as well as vestibular and musculoarticular proprioceptors (1). Posture can be therefore considered a "multiple-entry" structured system. Somatosensory and vestibular data are transmitted to the cerebellum and cerebral cortex by proprioceptors; specifically, muscular and articular proprioceptors carry information concerning muscle tension and the biomechanical condition of the body, which are critical for selecting the temporal and vectorial properties of mechanical postural responses (2).

As Brosel S. et al. studied (in "The Vestibular System and Ageing", Subcell Biochem 2019), the vestibular system contains the proprioceptors of the saccule and utricle, which supply data on gravity, whereas the receptors of the cristae ampullaris in the semicircular ducts show the speed of head rotation. This information is important for maintaining balance on unstable surfaces and during head movements. The mechano-receptors of the foot sole are some of the most important cutaneous receptors. The 104 foot sole mechanoreceptors are activated following vibrating or stretching pressure on the foot sole (3, 4).

The data that contribute to maintaining balance in the upright position in the static and dynamic state spread from foot sole mechano-receptors to the central nervous system. Stimulation of the primary areas that support the foot activates adaptive postural adjustments. The resulting responses consist of a body incline in the opposite direction of the stimulated area, "faking" a disequilibrium condition. As Buldt AK et al. (in "The relationship between foot posture and plantar pressure during walking in adults: A systematic review", Gait Posture 2018) explained, the information that is conveyed by foot sole mechano-receptors contributes to the awareness of body posture due to the illusory perception of declivity that is induced by tactile pulse trains on the foot sole of a blindfolded person. This hypothesis is supported by the decrease of afferent data as a consequence of the heat reduction in the foot sole due to anesthesia or weariness of the sole muscles which is associated with increasing postural oscillations.

Photoreceptors are involved in the stabilization of posture, as evidenced by the increasing postural instability that results from the reduction in visual activity. Visual stimuli give information about proximity and distance. Sight reduces postural oscillations when the subject is in the upright position, the clinical relevance of which increases in the elderly and in pathological conditions that effect a decline in visual activity (5, 6).

Two core matters are often discussed by studies on postural control with regard to visual problems: the role of the central and peripheral visual fields and that of optical flow i.e., the apparent movement of the elements in a visual area. The central visual field correlates with the focal view, whereas the peripheral visual field is linked to the "overall" view. The former is important for discerning the outline of physical properties, and the latter processes the spatial elements of the surrounding area.

Postural responses differ, depending on the selective provision of visual stimuli in the central or peripheral visual field. Vectorial responses depend on the orientation of the head or the sight in relation to visual stimuli when they are created in the peripheral visual field. These responses are essential for keeping postural stability, whereas if the stimuli are

directed to the middle of the visual field, suggesting the significance of the peripheral visual field in the visual control of posture, it is possible to notice more important postural oscillations. Visual flow determines postural oscillations and, consequently, stabilizing adjustments. According to recent studies, visual flow improves postural responses if both the central stimulation and stimulation of the peripheral visual field are present simultaneously.

In conclusion, we assert that visual data provide cognitive dynamic models in advance concerning potentially destabilizing situations and contribute to orienting the subject in the surrounding area. The central nervous system, through cortical, brain stem, and spinal circuits, controls posture and its adjustments.

With regard to cortical circuits in primates and humans, at the level of the cerebral cortex and, especially, the temporoparietal junction, an area of fundamental importance for the control of posture has been detected. This area harbors multisensory integration processes (somatosensory, vestibular, visual, occlusal, and temporomandibular) that spawn internal models of position of the various parts of the body and the vertical axis in relation to the orientation of the body. These models are fundamental for the organization of the anticipatory responses of the supplementary and presupplementary motor areas, which are conveyed to the spinal cord through the direct pyramidal tract. Contextually, the direct and crossed pyramidal tracts convey movements.

Brain stem circuits integrate sensory data from peripheral areas with movements and cerebellar modulation, originating compensatory responses that are used for maintaining correct posture. These compensatory responses are transmitted to the spinal cord through the extrapyramidal tracts - the reticulospinal, vestibulospinal, and tectospinal tracts. At the level of the cerebral trunk, the trigeminal nerve appears to condition the reticular formation by monitoring all nervous structures along its sensory nucleus (from the superior midbrain colliculi to the first cervical segments of the spinal marrow). This oversight derives from sensory responses that result from the proprioception of the masticatory system, including deglutition.

It must be taken into consideration that the control of posture is a complex mechanism that is activated during most activities that are carried out by a human being over his entire lifetime and this system has great adaptability. This adjustment can occur in the short term i.e., a period of continuous change in conditions of the surrounding environment and during age-related body modifications. These adjustments appear to be exclusively somatic; however, according to recent studies, important connections between the cerebellum and limbic system prove that the nature of these phenomena are also visceral and emotional. We can therefore assert that in the soma, posture represents the manifestation of the sensorimotor and visceral motility of the central nervous system in relation to phylogenetic and ontogenetic aspects.

Purpose of the Consensus

This document provides recommendations on the basis of scientific evidence, clinical practice, and consensus between experts concerning the prevention, diagnosis, and treatment of postural dysfunction at various stages of life developmental age, adult age, and old age > 65 years and follows the "National Guidelines on Classification and Measuring of Posture and its Dysfunctions" per the Italian Ministry of Health (December 2017).

Subjects

Addressees of this document are, in particular, pediatricians, general practitioners, geriatricians, orthopedists, physiatrists, sports doctors, rheumatologists, ophthalmologists, otolaryngologists, odontologists, audiologists, phoniatrics, coroners, occupational doctors, and health care professionals, as well as professionals who are not involved in health care: PhDs in sport sciences, parents, educators, particularly regarding the recommendations for developmental ages (youth and adolescence); and caregivers for every age.

MATERIALS AND METHODS

Bibliographic research

It was considered appropriate to pose clinical questions

that required answers based on evidence pertaining to the most recent literature to compose this document. Some keywords match with these questions per the MeSH (Medical Subject Headings) criteria.

Question 1: "Which measures can be adopted in order to prevent postural dysfunctions?" Related MeSH terms: amblyopia, refractive status, orthoptic defects, strabismus, convergence insufficiency, ocular motility, low vision, erected posture, scoliosis, postural stability, low back pain, physiotherapeutic strategies, flatfoot, plantar foot pain, vascular disease, vascular remodeling, musculoskeletal asymmetries, preventive and adapted motor activity, obesity and quality of life.

Question 2: "What can we do in order to make a correct diagnosis of postural dysfunction?" Related MeSH terms: malocclusions, postural assessment, postural balance (PB), postural clinical evaluation, vestibulo-ocular reflexes, visual field defect, retina diseases, optical coherence tomography, orthoptic evaluation,ophthalmic evaluation, cycloplegia.

Question 3: "What are the correct treatment programs for postural dysfunctions?" Related MeSH terms: rehabilitation, postural re-education, visual rehabilitation, correction of strabismus, refractive error surgery, refractory error correction, asymmetry, orthopedic treatment, scoliosis, Global Postural Reeducation (GPR).

Inclusion criteria: scientific work published between January 1, 2008 and December 31, 2017 was taken into consideration, based on the following research limitations: age from 0 to 65 years; species: human; article type: clinical trial, clinical trial form I to IV, controlled clinical trials, randomized controlled trials; and language: English. The following electronic databases were used: Medline, Embase, Scopus, Google-Scholar, Lilacs, Scielo.

The seven group coordinators autonomously selected every title/abstract and searched for the "full text." Every working group was assigned pertinent publications that were later recorded using a specific form. At least 2 members autonomously evaluated each work. In case of a lack of evidence, the indications above are reported as if based on the consensus of the experts (Tables I and II).

General postural recommendations

Question: "Which procedures can be implemented in order to prevent postural dysfunctions?" Good posture (or neutral spine) refers to the «three natural curves that are present in a healthy spine." Looking directly at the front or back of the body, the 33 vertebrae in the spinal column should appear completely vertical. From a side view, the neck (C1-C7) is bent inward, the thoracic (upper back)

Table I. *Levels of evidence*

I	Evidence obtained by meta-analysis of multiple studies, well outlined and controlled; randomized trials with few false positive and false negative errors (high power).
II	Evidence obtained by at least 1 well-outlined experimental study; randomized trials with many false positive and false negative errors (low power).
III	Evidence obtained by well-outlined semiexperimental studies and non-randomized studies, controlled by a single group, before/after comparison, cohort studies, or case-control sequence.
IV	Evidence obtained by well-outlined studies, non-experimental, such as comparative and descriptive studies on correlation and case studies.
V	Evidence obtained by case report, clinical examples, and experts' points of view.

region (T1-T12) bends outward, and the lumbar (lower back) region (L1-L5) bends inward. The sacrum (tailbone area) (S1-S5 fused) and coccyx (on average, 4 fused) rest between the pelvic bones. A neutral pelvis indicates that the anterior superior iliac spines and pubic symphysis fall in the same vertical line. In contrast, poor posture results from certain muscles tightening up or shortening while others lengthen and become weak, which often occurs due to one's daily activities. There are various factors that influence posture, including occupational activities and biomechanical factors, such as force and repetition. Consequently, postural dysfunction should be prevented throughout life, promoting:

- The adoption of a varied and balanced diet (B)
- The maintenance of an optimal body weight in relation to body mass index (BMI) and waist circumference (B)
- A healthy diet and lifestyle and regular athletic activities that are tailored to individual characteristics (A)
- Good posture, both static and dynamic, during everyday life (B)
- Scrupulous monitoring to preventively identify potential postural dysfunction and diseases that cause it. This monitoring shall first be carried out by the general practitioner (GP) and pediatrician, as well as a specialist (orthopedy and traumatology, physical medicine and rehabilitation, sports medicine, rheumatology, ophthalmology, otorhinolaryngology, odontology, audiology, phoniatrics, geriatrics, forensic medicine, occupational medicine).

Greater circulation of postural evaluation could allow specialists to implement prevention measures, particularly during developmental age (A). An examination of postural assessment can help to identify postural dysfunction in its early stages and implementing the appropriate treatment and most commonly recommended rehabilitation program, if needed. The postural assessment requires a multidisciplinary approach that involves the general practitioner, pediatrician, specialist (physiatrist, orthopedist, otorhinolaryngologist, audiologist, ophthalmologist), and odontologist (consensus of the experts), depending on age and type of case.

Preventive screening examinations that identify postural dysfunction are highly recommended. There is also evidence in favor of the efficacy of treatments, especially conservative ones. Adolescent idiopathic scoliosis is a suitable example: its preventive identification allows to implement adequate conservative therapy to halt the evolution of the pathology and avoid incorrect postures (B).

Postural assessment should be performed with

Table II. *Strength of recommendations (degree)*

A	The implementation of a particular process or diagnostic test is highly recommended. This level suggests a particular recommendation that is supported by scientific evidence of good quality, even if it is not necessarily of type I or II.
B	Doubts about this peculiar process and its recommendation, but its implementation shall be carefully taken into consideration.
C	There is a significant uncertainty in favor of or against the recommendation.
D	The implementation of the procedure is not recommended.
E	The implementation of the procedure is highly advised against.

Strength of Recommendations, Methodological Manual, "How to produce, divulgate and update recommendations for clinical practice", May 2002, National Institute of Health (NIH)

a thorough global clinical examination to exclude complications of another nature, verifying whether the position of the body is in line (in axes) with the ideal position. Taking into consideration the indications in the "National Guidelines on Classification and Measuring of Posture and its Dysfunctions", the global postural assessment should be carried out through (B):

- A complete collection of anamnestic data
- An examination of postural attitude static and dynamic
- An assessment of how the sole of the foot lies on the surface (static and dynamic)
- An evaluation of the masticatory system
- An analysis of potential anomalies that localize to one or more body regions, including vascular alterations
- An analysis of the oculomotor and visual systems
- An analysis of the function of the rachis, cingulum (pelvis and shoulders), and main fulcrum of upper and lower limbs (joint mobility, strength tests, global and segmental muscle length)

In addition to cervical lordosis, dorsal kyphosis, lumbar lordosis, the position of the head, the horizontality of the line of sight, the position of the pelvis (anterior or posterior pelvis tilt), and the position of the knees should be examined on a sagittal plane.

On a coronal plane, it is important to examine: the lines of symmetry in relation to ocular alignment and, thus, the rotation and the inclination of the head in relation to the reference plane; the symmetry of the clavicles; the symmetry of waist "triangles;" the alignment of the anterior superior iliac spine (ASIS); the alignment of the lower limbs; and the potential heterometry of the lower and upper limbs. If there is heterometry, it must be distinguished from functional heterometry through specific clinical and instrument-based examinations. On a rear view of the coronal plane, it is important to evaluate the lines of symmetry of the auricles, head, shoulders, shoulder blades, and axillary creases and the alignment of the posterior superior iliac spine, gluteal creases, lower limbs, and, in particular, the popliteal fosses and malleolus.

A complete, correct, and accurate postural evaluation should include such tests as (C): maneuvers for convergence of the feet; ocular vestibular evoked myogenic potentials (o-VEMPs) and cervical vestibular evoked myogenic potentials (c-VEMPs); march-in-place test; Fukuda stepping test; thumb test; Finkelstein test (thumb test); Nahmani test; Romberg test; head rotation test; video-head impulse test; functional-head impulse test and Meersseman test.

It is recommended that the gap between the coronal plane of the bi-pupillary plane, the coronal plane of the bi-acromial breadth, and that of the iliac crests (C) be verified using specific tools, such as inclinometers and spirit level analyzers. Concerning the sagittal plane, it is recommended that the Frankfurt Plane and Barrè Vertical Axis, per Stagnarà, be used as references, allowing to analyze the following parameters: distance occiput plumb line, fléche cervicale, dorsal plane, fléche lombaire, and gluteal plane (B). When necessary, integration of the evaluation of posture with optoelectronic photogrammetric systems (opto-kinematic evaluation) is recommended to quantitate, analyze, and ease the interpretation of the anthropometric results in the three planes of space — static and dynamic. Also, (B) static and dynamic stabilometry is useful for the evaluation of the oscillations of the mass center in the support polygon(CoM and CoP), under gravity pressure, and in the postural dynamic test (PDT).

Similarly, radiation-free diagnostics of the spinal column with gait and running analysis, raster stereoscopic spinal column measurements, foot pressure analysis, and electromyography of the muscles (also in the static and dynamic condition) have gained prominence in the modern evaluation of posture. Ultimately, clinical experience is a fundamental aspect of the evaluation of correct posture.

Recommendations during developmental age

In developmental age, any postural dysfunction must be preventively individuated, as it could portend problems with psychosomatic development (B). Developmental age is an existential period that is fundamental for postural adjustments, because optimal physical development, with correct static and dynamic posture is essential for a healthy and efficient body, beginning with the musculoskeletal system (by Calvo-Muñoz I et al. in "Preventive physiotherapy interventions for back care in children and adolescents: a meta-analysis." BMC Musculoskelet Disord, 2012). To this end, the pediatrician is a fundamental reference for the evaluation of posture. The other medical experts above can also be references, collaborating with the pediatrician to implement the correct, complete diagnostic-therapeutic pathway (by Hegde AM et al. in "Prevalence of vision defects in a school based population with malocclusion" Int J Dent Med Res 2015 and by Holden S et al. in Sex Differences in Landing Biomechanics and Postural Stability During

Adolescence: A Systematic Review with Meta-Analyses. Sports Med, 2016).

To avoid permanent postural dysfunction, every subject must be monitored from birth until the end of the skeletal growth and the developmental process, at least once a year, with particular attention paid at

Table III. *Conditions to identify and evaluate in developmental age*

Birth - 1 year	- plagiocephaly - craniosynostosis and asymmetries - characteristics of ocular motility and anatomical integrity of eyes - characteristics of the auditory system - congenital muscular torticollis (twisted neck) - axial asymmetries - muscle hypotonia of the frontal and posterior planes - persistence of primitive reflexes - late manifestation (appearance) of parachute reflexes - hip dysplasia - curved knee - clubfoot, talipes valgus deformity, metatarsus adductus - characteristics and properties of the acquisition of motor skills - hearing
1-3 years	- characteristics and properties of motor skills - characteristics and properties of ambulation (on tiptoes, axis deviation of the lower limbs, potential asymmetries in static and dynamics) - analysis of the anatomical integrity of the eyes, potential refractive errors, ocular motility, convergence, strabismus, and nystagmus - evaluation of mouth breathing and bad habits - evaluation of auditory function - craniofacial vascular malformations - control of hearing performance
3-8 years	- mild spinal asymmetries - characteristics and properties of ambulation (on tiptoes, axis deviation of the lower limbs, potential asymmetries in static and dynamics) - analysis of the anatomical integrity of the eyes (potential refractive errors, amblyopia, low vision, congenital disorders, retinal diseases and disorders of the optic nerve, functional alterations of extraocular muscles) - convergence insufficiency, strabismus, and nystagmus - speech - auditory and vestibular function - nasal respiratory function - vascular malformations - maxillary malformations - dysfunctional tongue deglutition - hearing
8-14 years	- anatomical integrity of the eyes (e.g. potential refractive errors, amblyopia, low vision, congenital disorders, retinal diseases and disorders of the optic nerve, functional alterations of extraocular muscles, convergence insufficiency, strabismus, and nystagmus - auditory and vestibular function - nasal respiratory function and night snoring - mild spinal asymmetries - functional and structural disorders of the lower limbs - limb vascular malformations - scarring - potential lymphoedema - characteristics and properties of ambulation (on tiptoes, axis deviation of the lower limbs, potential asymmetries in static and dynamics) - full-body muscle rigidity - integrity of masticatory and swallowing functions - hearing

approximately 6 months of age. In the case of one or more types of dysfunction (e.g., a specific disease: somatic, vestibular, visual, masticatory), the pediatrician should refer the patient to the best expert and verify the outcomes of the specific interventions once or twice yearly (Experts Consensus) (Tables III and IV).

To prevent or limit positional plagiocephaly, it is necessary to provide precise indications that limit

Table IV. *Main prevention measures to avoid postural dysfunction in developmental age*

Early diagnosis and treatment of - musculoskeletal disorders - disorders of the visual system - alterations in vestibular and auditory areas - dysfunction of deglutition and the masticatory system **Promotion of** - an appropriate and supervised physical activity; - an adequate sport activity; - a varied and balanced diet; - balanced head movements in order to avoid deformations and/or rigid positions of the head; - the physiological development of the psychomotor learning in the developmental - age (crawling, prone rolling, straightening). For safety reasons, carriage devices - shall be used for a limited lapse of time **Avoiding** enlarging the hole of the teat and reduce the use of the baby bottle from the 2nd year of the baby
Reduction/limit of asymmetrical loads on the spine (eg, lowering the weight of a backpack and wearing it in a correct and symmetric manner).
Promotion of exercises for the normalization of muscle and myofascial tone in the case of hypotonia and myofascial muscle rigidity.
Correction of dysmorphia, foot dysfunction, and suprasegmental disorders using adequate foot proprioceptive orthoses and implementing rehabilitation programs and pathways per a specialist.

potential problems due to pre- and perinatal plagiocephaly, particularly in subjects aged from 0 to 4 months. It is important to prevent infants from keeping their head on only one side while they are sleeping and not to limit the movement of the muscles of the neck when they are awake. It is preferable to ensure that the infant sleeps in the supine position.

Attention must be paid to the substitution of the maternal breast, especially from age 2 years: prolonged and inappropriate use of a dummy should be disincentivized, whereas an "anatomical" and not "dropped" pacifier should be preferred to effect proper tongue placement. In fact, it is necessary to place the tip against the hard palate (behind the upper front teeth), facilitating phonation and speech, deglutition, breathing, and head movements. It is good practice not to enlarge the hole of the teat to feed a baby more quickly. Furthermore, the administration of solid foods should be incentivized at the appropriate time, as it favors proper development of the maxillary teeth. In the case of persistent tongue dysfunction after the absence of use of a dummy and baby bottle, the expert should make an evaluation. It is not good practice to precociously bring an infant to orthostatic and ambulation, because that negatively affects myofascial and musculoskeletal systems (which have not formed completely yet) and the building of the infant's "step diagram".

Prolonged use of playpens and the use of walkers and other aids are discouraged as they tend to impede the important phase of crawling and promote incorrect habits, such as staying on the tiptoes or developing asymmetric motricity while learning how to stay upright. It is fundamental that an infant who is learning how to stay upright not be given excessive help, favoring the crawling phase. Barefoot ambulation, preferably on non-smooth surfaces, stimulates proprioceptive results and postural balance, promoting a correct "motor and sensory diagram."

Particular attention must be paid to potential alterations in the vestibular and visual systems, especially with regard to the function of oculomotor muscles, which could provoke significant asymmetries in muscle tension bilaterally. Localized deficits modify the natural order of muscle tone between gravity and antigravity muscles. A direct consequence is the incorrect assessment of the position of the body. The vestibular system positively affects the skeletal muscles of the body, maintains balance (decreasing the loss of balance and the risk of falling), and controls movements.

Furthermore, the indirect effects of vestibular deficits on cognitive processes in relation to the near peri-personal space must be considered. The lack of vestibular data often requires the difficult substitution with visual proprioceptive or other types of signals to keep balance, posture, and sight. This replacement decreases attention, limits concentration, and can negatively affect mental processes, compromising other activities, such as multi-tasking, the elaboration of sequences, and the transfer of attention. In these situations, children may encounter difficulties in organizing more than one piece of data and, in particular, in integrating new information while keeping other and previous elements in memory.

Vestibular dysfunction can cause low scholastic results as it provokes oculomotor dysfunction, followed by unavoidable repercussions on reading skills and growing cognitive efforts to maintain balance, which causes emotional disorders. Vestibular and visual disorders have a significant role in determining postural dysfunctions of the head, altering the perception of the subjective visual vertical. Concurrently, dysfunctions of posture, the head, or the masticatory system can affect craniocaudal deficits, with consequent extensive adaptation of the vestibular and visual systems. An eye-muscle imbalance generally alters the perception of one's surroundings. The postural control system can compensate for this anomaly through rotations and slope of the shoulders and pelvis: at the postural level, a visual adjustment affects the underlying structures and muscle chains, and vice versa. When a sensory conflict initially exists, such as from vision, the stomatognathic system, plantar afferences, it can lead to lower motor control and induce asymmetrical postural tone. This asymmetry has the particularity of being labile and organized and should be distinguished from anatomical and behavioral asymmetries, which cannot change immediately.

Matheron E. et al. recommended (in "Impact of a 1-diopter vertical prism on binocular alignment on head rotation: a pilot investigation." Front Neurol, 2016) that for an individual with abnormal position of the head or other types of postural alteration, an eye examination, orthoptic examination, and vestibular evaluation be carried out during the third year of age and no later than the fifth year, to exclude the presence of visual and vestibular system diseases. An adjustment of the visual system by altering the position of the optical axis can determine a loss in parallelism of the eyes, which can lead to heterophoria

and heterotropia. Moreover, a dental examination is suggested to evaluate the harmony of deciduous teeth and maxillary alignment as a potential cause of irregular head positions and non-symmetrical dislocation of the mandibular condyles at the level of the temporal bones. These examinations should be performed to exclude defects in the visual, vestibular, and stomatognathic systems. A low-dose cone beam — only if necessary and diriment — can be implemented for tridimensional diagnosis of the facial bones and cervical segment by age years of 9 (expert consensus). As Korbmacher H et al. studied (in "Correlations between anomalies of the dentition and pathologies of the locomotor system - a literature review. J Orofac Orthop, 2004), it is necessary to monitor the transition of deciduous into permanent teeth, evaluating errors and malocclusions that can occur during this period. Nasal breathing should also be evaluated to permit harmonic growth of the maxillary bases. Informed parental consent is essential for every X-ray examination. The exposure parameters for cone beam CT units for patients in developmental age should be reduced in relation to those for adult patients (C).

Recommendations in adult age

In adult age, posture must be evaluated to identify potential—and asymptomatic—dysfunctions, because preventive interventions and treatments can avoid pathological conditions from arising. It is important to discourage a sedentary lifestyle, whereas moderate and constant physical activity made appropriate for every individual should be promoted to maintain a balanced body weight (B) (Table V).

During everyday activities and in the workplace (use of personal computer, weight lifting, etc.), it is important to maintain proper ergonomics and modify the posture induced from the activity to avoid having an excessively fixed posture for prolonged times. Myofascial, osteoarticular, and muscle stretching exercises are useful in cases of full body inflexibility. For excessive and prolonged upright standing, adequate footwear is recommended to ensure proper biomechanical function of the foot. Shoes should have comfortable heels, cushioned footbeds, stable heel seat linings, and an anatomical and receptive insole. In critical phases, such as pregnancy and menopause, women should pay more attention to monitoring their posture to avoid an imbalance in the sagittal plane with increasing lumbar lordosis during pregnancy and greater dorsal kyphosis during menopause.

In adult age, potential vestibular disorders can often

Table V. *Main preventive actions to avoid postural dysfunctions in adult age (B)*

Preventive interception and treatment for diseases of the: - musculoskeletal system - visual system - auditory and vestibular system - masticatory system
Promotion of: - appropriate and supervised physical activity - sport activities - a varied and balanced diet - global postural reeducation (GPR) methods
Correction of foot and suprasegmental disorders and dysmorphia through adequate proprioceptive foot orthoses and rehabilitation pathways prescribed by an expert.
Correction of body dysmorphic and paramorphic disorders using specific rehabilitation techniques.

be accompanied by extreme symptoms of vertigo. The expert usually focuses on easily controllable symptoms (thanks to the instinctive recovery led by the central system) instead of permanent damage to the vestibular system, which leads to pathology, necessitating careful evaluation and classification. Stochastic vibration therapy could be considered as a rehabilitative approach to create undirected proprioceptive input into the vestibular system.

It is necessary to control masticatory function to avoid the loss of vertical dimensions of the dental arches, which can cause abnormal anteposition of the head. Missing teeth should be replaced with a prosthesis that can avoid improper positioning of the mandible, which can induce adaptation and deviation of the head on the frontal and sagittal plane.

Recommendations age over 65 years

It is also useful to evaluate posture in healthy persons aged over 65 years and with specific symptoms that do not match the pathologies that are outlined by specific diagnostic exams to differentiate potential dysfunctions (C) (7) (Table VI). In this age range, during everyday life, it is necessary to maintain ergonomics and good tone of the myofascial system and muscle chains (by Borel L. et al. in "Posture and cognition in the elderly: interaction and contribution to the rehabilitation strategies." Neurophysiol Clin, 2014). Preventing falls, supported by a re-evaluation and possible readjustment to everyday life framework, is particularly important if signs of altered posture manifest. This phenomenon correlates with a fragile balance, which is common among individuals aged 65 years and over and

Table VI. *Main preventive actions to avoid postural dysfunction at age > 65 years (C)*

Preventive interventions and treatments for: - diseases of the musculoskeletal system - diseases of the visual system - alterations in the auditory and vestibular systems - alterations in the cognitive and psycho-limbic system - loss of proper masticatory function
Promotion of: - appropriate and supervised physical activity - a varied and balanced diet - global postural re-education (GPR) methods and proprioceptive exercises aimed at improving balance and reducing falls
Reduction and limitation of asymmetrical loads on the spine
Correction of postural dysmorphia and paramorphia using specific rehabilitation techniques and, if necessary, specific orthoses that are prescribed by an expert
Correction of foot and suprasegmental disorders and dysmorphia through adequate rehabilitation with proprioceptive foot orthoses prescribed by an expert **Correction** of masticatory function with the replacement of missing teeth that maintain the correct vertical dimension of the dental arches to support the head on the cervical region and promote correct alignment of the cephalic region Mobile prosthetics shall be kept in the mouth during the night to avoid problems with the position of muscle chains.

is intensified by a lack of vestibular function. In particular, the vestibulo-ocular reflex, which can be deficient due to physiological reasons, negatively affects visual activity during movement, eliciting greater cognitive effort, which is not used for other tasks, such as memory and paying attention. This condition worsens in the presence of a permanent vestibular disorder, favoring falls and direct consequences (traumatisms, fractures, disabilities, loss of safety, anxiety of falling again, reduction of motor activity, depression, social isolation). A reduction in visual activity and perception of moving in an environment, especially in this age group, correlates strictly with decreased ability to control balance. Thus, it is important to use adequate footwear and perhaps foot orthoses that are personalized to the anatomical morphology of the feet, deformities (physiological and typical for this age), and the dynamics of the step. Furthermore, postural rehabilitation pathways (with stretching and muscle-strengthening exercises in aquatic or terrestrial microgravity-based environments (8) and cognitive training exercises are especially useful, as they are more effective in preventing postural imbalance. Each activity should be practiced under "safe conditions." (by Pietrangelo T. et al. in " Effects of local vibrations on skeletal muscle trophism in elderly people: mechanical, cellular, and molecular events." Int J Mol Med, 2009 and Saggini R. et al. in " Efficacy of two micro-gravitational protocols to treat chronic low back pain associated with discal lesions: a randomized controlled trial. Eura Medicophys, 2004).

Losses in weight and postural stability might be related to a loss in normal masticatory function i.e., partial edentulism, especially in the molar region, or total edentulism or to the use of a dated prosthesis with a consequent loss in vertical dimension. This occlusal error generates a sensory deficit of the trigeminal nerve, which interacts with the reticular formation of the cerebral trunk, necessitating maintenance of the masticatory system.

WHICH PATHWAYS SHOULD BE UNDERTAKEN TO CORRECTLY DIAGNOSE POSTURAL DYSFUNCTION?

As Nagymáté et al. (in "Reliability analysis of a sensitive and independent stabilometry parameter set. PLoS One, 2018) underlined, postural evaluation (measurement of postural arrows and symmetry, evaluation of balancing) represents the reference procedure for diagnosing postural dysfunction. Also, Petró and colleagues (in "Devices and tasks involved in the objective assessment of standing dynamic balancing. A systematic literature review. PLoS One .2017) reported that, if necessary, the expert should administer more examinations using specific tools (A).

In daily clinical routine, it is good practice to avoid using complex and expensive methods, except when recommended or prescribed by the expert. If necessary, a radiological investigation should be conducted in orthostasis (on graph paper in two projections) of the rachis, with adequate justification. In developmental age, the patient should not undergo standard radiography more than once a year, and if regular checkups are required, a non-invasive optoelectronic instrument should be used. Considering the correlation between posture and the vestibular, visual, odonatological, and somatosensory systems, as discussed, in the case of suspected dysfunction, it is good practice to refer the patient to an expert for in-depth clinical and instrumental analysis (B).

What Are The Clinical Pathways To Undertake For Postural Dysfunction?

Clinical and rehabilitative pathways in children and adolescents

In children and adolescents, motor disorders manifest through postural dysfunction in most cases. Thus, experts recommend global postural re-education (GPR) to recreate the correct synergy between sensory and somatic output, with a readjustment of posture and optimized motor coordination (A).

Ophthalmologists recommend the best achievable correction of ametropia, convergence insufficiency, strabismus, and other pathologies, for which the optimal treatment should be selected. Treatments can be medical and surgical or a simple prescription for corrective lenses. Certain disorders could require rehabilitation techniques.

In children and adolescents, foot sole disorders (flat feet, hollow foot, and pes valgus) and ambulation diseases (on tiptoes or in hyperpronation) can be related to specific postural disorders of the lower

limb, rachis, and pelvis. They can also be the cause, a compensatory response, or a consequence as Saftari LN et al. suggested (in "Ageing vision and falls: a review." J Physiol Anthropol, 2018).

There is no evidence in favor of treatment of the asymptomatic foot, for which clinical monitoring is suggested. To treat the asymptomatic foot, orthopedics and physiatrists recommend rehabilitative therapies and the use of proprioceptive foot orthoses (C). Surgery should be chosen only for specific cases with persistent pain and ambulation diseases, only when suggested by the orthopedic specialist (B). Stretching and muscle-strengthening and proprioceptive exercises (barefoot and with shoes and foot orthoses) are recommended during the rehabilitative therapy. There is no specific evidence on the proper window for treatment with orthoses (it is possible to start at 3 years of age, if suggested by the expert) or on the best model of foot orthoses (C).

Substantial heterometry of the lower limbs (over 5 millimeters) requires periodic evaluation of postural balance (expert consensus). For the compensation of heterometry, experts suggest the use of foot orthoses with adequate correction of the dysmetria. This correction can be clinical and optoelectronic to evaluate the "step dynamic." An individualized treatment plan is recommended to increase the symmetry of static and dynamic posture (C).

In the case of structural dysfunction of the body, e.g., of the rachis (Cobb angle larger than 25° or smaller, during puberty, with confirmed development and presence of hunchback), experts recommend (A) (10):

- individual global rehabilitation to rebalance muscle tone
- increased elasticity and tone of myofascial lines (expert consensus)
- exercises to improve static and dynamic proprioceptive function in aquatic or terrestrial microgravity-based environments
- conservative treatments with an orthopedic corset (A)

There is no scientific evidence of the efficacy of one corset rather than another (expert consensus). The type of corset depends on age and the type of scoliotic curve. A corset is recommended only in global rehabilitation, individualized through: specific muscle- and myofascial chain-stretching exercises, exercises for rebalance of muscle tone of the trunk, proprioceptive exercises, and exercises for self-correcting posture (B).

Stretching exercises are advised in cases of scoliosis that include the pelvis, whereas proprioceptive exercises are suggested for scoliosis that exclude it. Because it is a global developmental disease, treatments should always be personalized, prescribed, and periodically verified (6-8-12 months) by experts and an orthopedist or physiatrist, and should stabilize the correct posture. Health care professionals who are involved in the project must have specific competencies in the treatment of postural dysfunctions and scoliosis. In the case of non-structural dysfunctions, experts recommend: exercises that rebalance muscle tone, specific muscle- and myofascial chain-stretching exercises, exercises for proprioception of the trunk in aquatic or terrestrial microgravity-based environments, and exercises for self-correction of posture during ordinary activities (C). For this purpose, experts advocate therapeutic protocols to optimize posture, re-establishing the space alignment of the body using global postural re-education techniques involving muscle and myofascial chains.

Monitoring the proper change from deciduous to permanent teeth, it is important to pay attention to masticatory function to ensure correct alignment of the head and body, representing the cephalic portion of the scale of static and dynamic balance of the column. The new dental structure is complete between 12 and 14 years of age and should ensure proper masticatory movements of the mandible in relation to the balance of the temporomandibular and atlanto-occipital joints.

To achieve correct alignment of the body, for example, for ensuring optimal reactivation of the postural tone system, experts recommend individualized rehabilitation programs with repetitive training. These rehabilitation approaches emphasize the afferent input and improve movements as a complex function. For this purpose, motor exercises in terrestrial micro-gravity-based environments with three-dimensional body alignment and exercises for functional re-education of the tongue appear to be

useful. These exercises introduce mechanical and proprioceptive changes to the body. The exercise in a micro-gravity-based environment maintains the induced postural optimization, which becomes automatic in relation to the execution of motor exercises (C). Instructions for ergonomics and correct postural hygiene are recommended.

Non-performance-based activities and non-competitive sports are highly recommended. In the literature, there are no univocal data concerning competitive and non-competitive sports with asymmetrical requests; motor activities and sports that require a "global effort" and that respect the morpho-functional characteristics of every individual are useful and recommended (B).

Clinical and rehabilitative pathways in adulthood

In adulthood, postural dysfunction often originates pain symptomatology, carried by the spatial and functional subsystems of the body: craniomandibular, stern-scapulohumeral (acromioclavicular, sternoclavicular, and scapulohumeral joints), pelvic girdle, and foot-ankle complex, related to the lower limb. These functional and spatial entities are connected by the relay subsystem of the spinal column and interact through the myofascial-bone and nervous subsystems. It is therefore necessary to identify the system that compensates for the postural dysfunction through a clinical examination — for implementing rehabilitation programs to recreate postural homeostasis and, in particular, for re-establishing the alignment of the body in space and the flexibility of the posterior, anterior, and crossed myofascial chains. For adults, a diagnosis of postural dysfunction necessitates re-programming with postural optimization (C) (expert consensus).

According to the literature (by Zhang C. et al. in "Efficacy of splint therapy for the management of temporomandibular disorders: a meta-analysis. Oncotarget, 2016 and by Di Pancrazio L. et al. in "Combined rehabilitation program for postural instability in progressive supranuclear palsy. Neuro Rehabilitation, 2013), every patient who is affected by acute, subacute, and chronic unilateral or bilateral vestibulopathy should undergo vestibular rehabilitation. As Sulway S. et al. suggested (in "Advances in Vestibular Rehabilitation." Adv Otorhinolaryngol, 2019) with regard to vestibular rehabilitation, experts recommend motor exercises that recover deficits in function, based on neurophysiological mechanisms according to the principles of addiction, adjustment, and sensory and behavior substitution, for functional recovery of vestibular lesions. Exercises for gaze stabilization (stimulating visual information), correct posture of the tongue, soma, and the body itself (stimulating proprioception), and balance (stimulating vestibular information) are recommended rehabilitative approaches.

Sensory recalibration is an important aspect of vestibular rehabilitation. Repetitive exercises that are guided through head movements that provoke vertigo are useful for examining the progressive reduction in vertigo symptomatology, based on the principle of addiction, according to "vestibular habituation training". The therapeutic approach should be multidisciplinary and include periodic assessments of the objectives of the rehabilitation program. The information above is also recommended for disorders of the visual system.

These exercises aim to re-created the correct synergy between sensory and somatic output, readjusting posture and optimizing motor coordination to better manage the asymmetrical adjustments to locomotion. Exercises that increase static and dynamic proprioception are recommended as Ferreira GE. et al. studied (in "Global Postural Reeducation for patients with musculoskeletal conditions: a systematic review of randomized controlled trials." Braz J Phys Ther, 2016). Experts recommend viscoelastic foot orthoses with support function and viscoelastic proprioceptive foot orthoses, which can be adaptive or compensative. According to the literature, lumbar supports should be used only in the case of acute pain and for short periods (C).

Attention must be paid to a loss in masticatory function due to the parafunctional activity of bruxism, which uses the dental arches to unload psychical and emotional tension. The unconscious tensing of the masticatory muscles activates the alarm system of the reticular system, increasing the muscle tone of the axis. The resulting abrasion of teeth causes

a loss in the vertical dimension and the alignment of the head on the body, causing migraines, cervical dysfunction, and rigidity of the bilateral clavicular subsystems. Hypertonia of the masticatory and hyoid muscles is transmitted to the anterior myofascial chains, causing anterior flexion of the body, with lumbar hypertonia to maintain static balance.

Clinical and rehabilitative pathways in the elderly

In elderly subjects, postural dysfunction is often associated with certain diseases of the nervous and musculoskeletal systems. In the elderly, a postural disease frequently correlates with specific pathologies of the neuro-musculoskeletal system, thus, it is highly recommended that the postural disease be monitored and treated, even when it is an adaptive and non-symptomatic compensation, consistent with the concepts of preventing disability and falls (C). In elderly patients, evaluation and counseling with regard to the adoption of simple precautions to ease postural stability and reduce the risk of falling (e.g., wearing closed instead of open footwear) are recommended (8), also through adaptation of the domestic environment such as shower support bars and removal of carpets (11) (C). Exercise programs are efficient in the elderly only if they are personalized and specific for problems, which should be evaluated and monitored over time, such as hyposthenia, balance and agility disorders, visual deficits, internal pathologies, and pathologies that are related to pharmacological therapies. Furthermore, polyneuropathy and other nervous disorders are common in the elderly, for which a clinical neurological examination and supplementation with vitamins B6 and B12, folic acid, and vitamin D are recommended, because there are huge deficits in this population, which can cause polyneuropathy. This condition then promotes gait and posture insecurity and the tendency to fall. Painful dysfunction of a subsystem has been suggested to be controlled, normalizing the homeostasis of the patient. A multidisciplinary postural program can ensure a specific approach for the system and its correlative for the various subsystems. The priority for a specialistic direction and for the treatment show up in this mechanism (expert consensus).

Safe and low-impact aerobics rehabilitation programs that are easy to execute are recommended, with exercises that strengthen the extensor muscles of the rachis (to prevent and correct dorsal hyper kyphosis) and lower limbs, control static and dynamic balance, and increase the elasticity of the muscle kinetic chains and myofascial system. For this purpose, motor exercises with three-dimensional alignment of the body performed in a terrestrial microgravity-based environment are useful (expert consensus). Once the rehabilitation program is completed, individuals with stable clinical conditions can benefit from adapted physical activities (APAs), preferably supervised by a specialist in motor sciences with significant experience and competencies in posturology. APAs are not part of health services and aim toward regeneration after rehabilitation, contrasting hypomobility and promoting a better lifestyle (expert consensus).

Viscoelastic foot orthoses with adaptive or compensative proprioceptive and supportive purposes are also highly recommended for the elderly (C). Lumbar corsets, anti-gravity or for lumbar support, can be used for pain with obvious postural asthenia (C). The discussion concerning diseases of the visual system is also valid for the elderly. Nevertheless, it is important to take into consideration the limited efficacy of certain therapeutic options, given the reduced recovery due to minor "plasticity" and the potential presence of comorbidities in the visual system (expert consensus). An elderly patient is often edentulous and uses a removable total or partial dental prosthesis, which should be placed properly to balance the maxillary loss due to osteoporosis. Correct positioning of the prosthesis allows to obtain the correct vertical dimension of the dental arches, which is necessary for supporting the head on the body, thus avoiding frequent displacement of the cervical thoracic portion. The improvement in the position of the head assists the visual and vestibular functions, decreasing the feeling of static and dynamic instability.

Which professional competencies and experiences are useful for preventing, diagnosing and treating postural dysfunctions?

The diagnosis of postural dysfunction is a medical

act (B). The prevention of postural dysfunctions includes experts of various age ranges who implement an interdisciplinary approach (expert consensus). When the postural dysfunction requires the intervention of a specialist, implementation of a treatment according to the functional prognosis with short-, medium-, and long-term objectives and programs for specific competencies may be necessary (expert consensus). A specialist in physical medicine and rehabilitation (PM&R) can arrange an *ad personam* therapeutic and rehabilitative program for postural dysfunctions. The team comprises health care professionals who act according to current regulations for their professional profile (B) (12). Among non-health care professions, graduates in motor sciences can contribute through APAs (expert consensus).

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