Vertigo Rehabilitation Protocols

Dario Carlo Alpini
Antonio Cesarani
Guido Brugnoni

Springer

Vertigo Rehabilitation Protocols

Dario Carlo Alpini • Antonio Cesarani
Guido Brugnoni

Vertigo Rehabilitation Protocols

Springer

Dario Carlo Alpini
"Don Carlo Gnocchi" Foundation
Milano
Italy

Guido Brugnoni
Istituto Auxologico Italiano
Milano
Italy

Antonio Cesarani
UOC Audiologia Dip. Scienze Cliniche e Comunità
Università degli Studi di Milano
Milano
Italy

ISBN 978-3-319-05481-0 ISBN 978-3-319-05482-7 (eBook)
DOI 10.1007/978-3-319-05482-7
Springer Cham Heidelberg New York Dordrecht London

Library of Congress Control Number: 2014940284

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Foreword

In the last years, rehabilitation gained more and more interest in the medical field at least in the industrialized world. On one hand, clinical and epidemiological evidences highlight the importance of rehabilitation as a complimentary, but indispensable, part of the therapeutic pathway, on the other hand rehabilitation per se is the main therapeutic approach to chronic diseases.

Although drugs and surgery are first directed toward the resolution of a lesion or a dysfunction, they themselves may become source of lesion or dysfunction. Rehabilitation is not able to solve a lesion but it is always directed to restore a dysfunction and avoid a handicap.

Rehabilitation, per se or as a part of a wider therapeutic project, is aimed to return a patient to her/his own living and working environment. In other words, rehabilitation is mainly aimed to reduce the social impact, and thus at the end the social costs of a disease, an accident, a trauma, etc.

At the beginning, the goal of rehabilitation was the recovery of the motor functions but, progressively, it became a more and more complex medical discipline directed to restore every function of the human being, motor, psychological or cognitive.

Due to the complexity of the action field of rehabilitation and its "social" ultimate goal, sometimes rehabilitation resembles more a restoration art than a medical science. (About this argument see "don Carlo Gnocchi's *Restoration of the Human Person*, Milan, 1946.)

Furthermore, some diseases or disturbances may be not healed but only managed. Rehabilitation is frequently the most complete and less expensive approach to management of chronic disorders.

Equilibrium disturbances are becoming more and more frequent in the western industrialized countries, maybe due to particular aspects of the modern life with substantial changes in the life rhythm and feeding, or the modification of the epidemiology or the increase of degenerative diseases and viral infections, and last but not least, the increase in the average age of life.

Rarely equilibrium disturbances are dangerous to life but always they are annoying and expensive, both due to various investigations frequently employed to formulate a diagnosis and the loss of working days due to the resolution of the problem.

The authors of these book dedicated their last 25 years to study the vestibular system and to refine their approach to patient in order to optimize both the diagnostic pathway and, especially, the therapeutic approach. In their experience, the functional diagnosis and rehabilitation are the cornerstones of a daily cost-effective work.

The functional approach to equilibrium disturbances falls in the field of the so-called neuro-otology, a sort of super specialty which starts from otolaryngology to reach neurology passing through general medicine, ophthalmology, orthopedics, endocrinology, virology and physical medicine.

A valid rehabilitation is effective and efficient, that is to say that it is able to obtain the best and lasting functional result in the most time- and cost-saving way.

Along the chapters of this book the authors lead the reader to the management of the most frequent equilibrium disturbances, from the acute viral vestibular neuritis to elderly unsteadiness, through cervicogenic vertigo, quite a distinctive vertigo of the PC and tablet age, always keeping in mind the rehab key words, *effectiveness* and *efficiency*: simple life style advices and complex exercises are blended to obtain the best and lasting therapeutic result.

We can state that the authors approach vertigo dizziness and unsteadiness more along the pathway of the fuzzy logic than the evidence based guidelines, but always leaning on solid neurophysiological basis.

We are grateful to the authors that decided to share their experience, due to successes and failures, including tradition and innovation, guidelines and common sense, always directed to *restore* the unbalanced human being.

Prof. Pasquale Ferrante
Ordinary Professor of Microbiology
and Clinical Microbiology,
University of Milan,
Milan, Italy

Adjunct Visiting Professor,
Department of Neuroscience,
Temple University,
Philadelphia, PA, USA

Scientific Director Clinical Institute
“Città Studi” Milan,
Milan, Italy

Preface

Vertigo is one of the most frequently experienced physical disturbances and is probably also the most interdisciplinary symptom. As Thomas Brandt highlighted in his book "*Vertigo. Its Multisensory Syndromes*" [1], understanding vertigo may be approached through taking into account how vision, hearing, and proprioception interact with vestibular cues and result in the distinct dynamic balance of human beings. As detailed in chapter 1, human balance is unique along the evolutionary scale. Human bipedalism-based balance is a continuous challenge against gravity. Life, in general, is a challenge for every kind of living being. However, bipedalism-based balance presents both a challenge and opportunities for humans to change their habitat, their interaction with the environment, and their interaction with other humans. Humans have the possibility of changing the rules of gravity, changing the rules of life; they are able to walk, run, jump, and swim, and they may also become able to skate, fly, and more. Modern life demonstrates how humans are able to change the rules of the game of life, combining challenges and opportunities. The problem of vertigo arises from how the vestibular system adapts to the opportunities of modern life.

Inner ear vestibular organs and the subcortical vestibular system developed to control the balance of the dinosaurs approximately 400 million years ago. With similar vestibular systems, *Homo sapiens* had a span of only 150,000 years to adapt to managing the balance of a complex multisegmental body that was continuously moving and continuously close to falling. In only the past 100 years, modern *Homo sapiens*, who often live in a high-velocity world, have had to adapt to managing the balancing required by modern life while still using the same vestibular system. Vertigo reminds *Homo* s*apiens* that gravity exists, that the body has structural limits, and that sometimes we overwhelm the rules of life, exceeding the rules of our biology and overpowering our natural limits. It seems that vertigo says to us, "Hey, you are on the Earth, you can't fly, you can't live so fast, you need rest, you can't change more quickly than your vestibular system can adapt to your lifestyle!"

Thus, vertigo is a part of the experience of modern human life for the majority of our lives. Children enjoy playing in vertigo-provoking manners, such as playing ring-around-the-rosy or on the seesaw; many adults enjoy carousels and rollercoasters and many adults enjoy challenging gravity, experiencing an exciting adrenergic vertigo. Vertigo as pleasure or vertigo as suffering is always with us, reminding us that we are dino-sapiens, living here and now. Because of this role, vertigo may deeply impact a patient's life. Vertigo patients deeply suffer because they have become a restricted *Homo sapiens*, frequently no longer *erectus* and sometimes a bit less *sapiens*.

The purpose of vestibular rehabilitation is to restore an adequate relationship between the patient and the Earth, even if it is through a damaged vestibular system. Since the 1940s, when Cawthorne and Cooksey first proposed vestibular rehabilitation, the recommended physical exercises have not changed significantly, whereas the scientific approach to vertigo has changed and is a "work in progress." For this reason, the foreword is devoted to a virologist and the first chapter to the adaptation of the vestibular system to bipedalism-based human balance, the subsequent chapters on vestibular disorders begin with considering the patient as a complex biomechanical and biological system interacting with a specific disease, and each rehabilitation protocol ends with specific suggestions regarding the mutual impact of disease and lifestyle.

Reference

1. Brandt T. Vertigo: its multisensory syndromes. Springer, London (1991 first edition, 1999, second edition)

Milan, Italy — Dario Carlo Alpini
Milan, Italy — Antonio Cesarani
Milan, Italy — Guido Brugnoni
February 2014

Contents

Part I

Human Balance and Rehab

From Bipedalism to the Vestibulo-vertebral Unit

1

1.1 Introduction

Vertigo and dizziness are symptoms very common in the population. The self-reported prevalence among the working population is 20 % [1] and increases with age [2, 3]. The symptoms are often reported to be severe enough to constitute a handicap for daily activities [1, 2, 4, 5]. Moreover, with a frequency of close to 2 %, dizziness ranges among the most common reasons for consulting a primary care physician. Nearly 45 % of outpatients with dizziness are seen and treated by general practitioners or family physicians [6].

Dizziness as a nonspecific symptom can be caused by a variety of disorders. These include peripheral vestibular disorders (e.g. benign paroxysmal positional vertigo, BPPV), central vestibular disorders (e.g. Wallenberg's syndrome), cardiovascular disorders (e.g. orthostatic arterial hypotension), ocular disorders (e.g. double vision due to ocular motor nerve palsy), somatosensory disorders (e.g. polyneuropathy) and others [7].

Vertigo and dizziness are also frequently associated with other common diseases and conditions, such as migraine [8], motion sickness [9], faints [10] and anxiety [11, 12].

In epidemiologic studies, vertigo and dizziness have a prevalence ranging from 5 to 10 %; according to different age classes, they are particularly common over 40 years of age; they are the first reason for a medical visit in patients over 65 years [13].

In women, the symptoms are more frequent than in men in most age groups except for ≥70 years. The prevalence is similar across the various age groups except that in women, acute vertigo is lower for the age group 40–49 years [14].

Although there are some specific drugs for the treatment of these symptoms and specific treatment for the major part of the causes of vertigo and dizziness, rehabilitation seems to be the most effective tool for the therapy of vertigo and dizziness. The so-called vestibular rehabilitation (VR) is a special rehabilitation of motion intolerance and imbalance problem based on the head, body and coordinated eye exercises.

D.C. Alpini et al., *Vertigo Rehabilitation Protocols*,
DOI 10.1007/978-3-319-05482-7_1, © Springer International Publishing Switzerland 2014

In the mid-1940s, an English otolaryngologist, Sir Terence Cawthorne, observed that some patients who experienced dizziness did better or recovered sooner when performing rapid head movements. In cooperation with a physiotherapist, Mr. Cooksey, he developed a regimen of exercises which, with some modifications, are nowadays still used. The Cawthorne–Cooksey protocol is based on the concepts of habituation and sensory substitution. These concepts are not sufficient to explain the therapeutic effects of vestibular rehabilitation.

Vertigo and dizziness are conscious symptoms, and the disturbances are not disequilibrium or nystagmus but the *consciousness* of disequilibrium and nystagmus. Thus, rehabilitation must not only be pointed to the resolution of objective disorder, but it must be aimed to the resolution of subjective consciousness of the disorder itself, too.

Such a particular kind of treatment needs a particular theoretical basis. This is the reason why we structured our method of rehabilitation on a particular model of the vestibular system.

The first consideration that moved us to propose a personal model was the need of thinking about a clear and satisfactory definition of equilibrium.

According to Massion [15], equilibrium control is correlated to postural control. Postural control is a behaviour that involves "the maintenance of the alignment of body posture and the adoption of an appropriate vertical relationship between body segments to counteract the forces of gravity and allows the maintenance of upright stance". According to Norrè [16], balance function "consists of a sensorimotor complex. The goal of this function is: stabilization of the visual field and maintenance of the erect standing position".

Both these two important concepts don't explain, in our opinion, the ultimate goal of this sensorimotor complex. Why is stabilization of the visual field or maintenance of the upright stance necessary? Why does balance "work in a subconscious way, and in normal conditions why is 'well-feeling' present rather than a detailed perception of every change"?

The sensorimotor complex that controls balance that we can name equilibrium system is aimed to allow the animal man to be a *man*, that is to say, interacting into the environment, communicating with the environment and learning from the environment itself. *Into*, *with and from* are the keys to understand the reason why the human vestibular system is so complicated and equilibrium is so important for animals, in general, and for man, in particular. *Into*, *with and from* are the practical keys of the exercises we will propose in this book.

During evolution human beings conquered an upright posture that allowed, progressively, the *Homo erectus* to become *habilis* and then *sapiens*. The conquering of the upright stance represents a specific step into evolution, and the upright stance is the base of bipedalism. Anthropological studies [17, 18] identified bipedalism as the specific sign of evolution from primates to *Homo* which required both anatomical adaptations, specifically the atlo-occipital junction and the lumbosacral joint, and neurophysiological adaptations, specifically the head-to-trunk dynamic stabilization during movement. In this condition the vestibular system had to evolve to satisfy the needs of *Homo erectus* and, according to Skoyles [17], is the vestibular evolution that allowed specific cognitive evolution of mankind.

Humans are in fact biologically novel in several respects including language, dexterity and complex culture. One trait which tends to get overlooked is bipedality. This is perhaps because two legged locomotion is biologically common. However, the manner in which humans stand, walk and run only occurs in our own species.

The human body is arranged vertically such that the head, trunk, legs and feet and their links in the neck, spine, pelvis, knees and ankles dynamically balance together to form an upright "antigravity pole". Since these segments and their points of articulation are not fixed, and the downward force of gravity never stops, the erect body exists always an inch or two away from falling. There is no locomotive use of holds, as with other primates. That the body is constantly upright is due to the unending skeletal–muscular adjustment of posture (in the manner of a Segway scooter or iBOT wheelchair). The habitual stance of no other animal has this total dependence upon the maintenance of vertical balance.

Bipedalism, as a descriptive term for the use of two legs for standing and locomotion, can be applied to a variety of animals. These include, as an occasional method of locomotion, primates (such as macaques, chimpanzees, bonobos, gorillas), birds (in general and as a specialization in flightless ones such as penguins, ostriches and emus) and extinct reptiles (*Tyrannosaurus rex*).

Humans are habitual and obligate bipeds that engage in a wide and diverse variety of erect locomotion (walking, running, skipping, jumping and dancing) and, apart from a brief period in infancy, normally (unlike all other primates) do not engage in any form of quadrupedalism. Other obligate bipedal mammals such as kangaroos exist, but they hop rather than walk or run. Humans use their upper limbs exclusively for non-locomotion such as manipulation, clubbing, carrying, throwing and arm gestures. In contrast, the upper and lower limbs of nonhuman primates engage regularly both in locomotion and non-locomotion.

Given the central role of the balance faculty in human biped standing and locomotion, it might be expected that it could be impaired during development. The impairment of this faculty would, however, not underlie all individuals with balance problems since balance can also be affected by dysfunction to sensory input or the motor coordination needed to make balance adjustments. Only one developmental condition exists that can be directly attributed to the central impairment of the balance abilities needed for bipedalism: the very rare autosomal recessive balance disorder of disequilibrium syndrome [19].

As noted above, there is a close link between cerebral cortical processing abilities including those in the frontal cortex and balance. Between *australopithecine species* and *H. erectus*, there was a marked increase in brain size particularly of the cerebral cortex. Such an increase would have provided increased numbers of cortical circuits with which to model the anticipation needed to control erect balance. Only with *H. erectus* did balance become sufficiently competent to allow for endurance running [20]. Together this argues that a radical enhancement of erect balance competences occurred between the *australopithecine* and *Homo species*.

On the basis of the over-mentioned considerations, it is clear that the importance of the interaction of the vestibular system with the vertebral apparatus is to allow

Homo to become *erectus*, to explore the environment, to interact *with* the environment and to learn *from* the environment. For this reason, we think it is important to begin our book showing the so-called vestibulo-vertebral unit.

1.2 The Vestibulo-vertebral Unit

The importance of the head as reference in dynamic control of balance is supported by evidence that the head itself supports three types of sensors: the vestibular system, which is sensitive to both gravity forces and the head, itself, accelerations; vision which is able to stabilize the head and the body with respect to the external space; and the neck muscle proprioceptive input which conveys the position of the head with respect to the trunk providing an "error signal" to the central vestibular system in order to optimize vestibulospinal control.

The head stabilized in space serves as a reference frame for the postural organization of the rest the body. In fact, while vertical alignment and centre of pressure displacement control during quiet standing are strictly important in postural control, head stability is important for balance in dynamic conditions like walking [21]. Static and dynamic head stabilization is obtained through proper tonic and phasic contraction of the cervical muscles. Due to spine biomechanics, also dorsal and paravertebral muscles contribute to head stabilization in space.

In this way, it is possible to define the cooperation between vestibular cues and vertebral muscle activity as a functional unity, that is to say, the vestibulo-vertebral unit.

Because head stabilization occurs during different tasks and conditions, some investigators speculate that motor system utilizes a top–down control schema. The top–down schema corrects head displacements preventing upward transmission of movements from the trunk so that the head remains stable in the space providing an inertial guidance system [22]. The stabilization of the head is thought to improve the interpretation of vestibular input for balance. In fact, head stabilization reduces the inertial acceleration on the otolithic membrane and semicircular canals, improving the estimation of gravitational acceleration and providing a stable gravitational reference. Head stabilization also decreases the retinal slip of the image of the world, and, specifically, the decrease of retinal slip allows a more accurate visual control of the environment. Head control is not directly influenced by input from sensorial systems; rather the complex high order of sensory mechanisms combines inputs forming frames of reference; so each sensory cue has a value of reference against which the changes of signal are interpreted. Finally frames of reference of each cue are used to create body schema that is defined as "a combined standard against which all subsequent changes of posture are measured".

The internal representation of body schema allows the CNS to represent body geometry, body kinetics and the attitude of the body with respect to gravity.

The importance of different body parts in the definitions of body schema relies on the specific characteristic of each segment itself. For example, the feet inform the position and attitude of support surface and the forces that are exerted by the support surface on the body; the importance of the trunk in the representation of body schema is justified by the fact that the trunk is the segment with bigger mass; a primary role of the head in body schema is justified by the fact that visual and labyrinthine systems are located in the head and inform on the position of the line of gravity and the horizontal; moreover inputs from neck proprioceptors control the relationship between the trunk and head.

This process leads to a better evaluation of the movement of the body segments with respect to the segment of reference and the position of the subjects with respect to the external world.

Vestibular function depends also on the blood supply and venous drainage. The vascular inner ear system is regulated by the sympathetic and parasympathetic cervical system. In this way, the so-called vestibulo-vertebral functional unit of the vascular and autonomic cervico-cephalic systems has to be taken into account.

1.3 Head Stabilization Control

1.3.1 Vestibular Reflexes

During each movement of the head and/or body, it is necessary that the image of the perceived surrounding has to remain on the same place on the retina [23]. Thus, the image of the perceived part of the environment must change in a very quick way. During head movement, the eye has to make movements relative to the skull in such a way as to guarantee immobilization of the image projection on the retina. If there is a "retinal sip", the vision is blurred; the surrounding is perceived as moving around. As a result, during head movement the required eye movement has to be "compensatory", in order to cancel the effect of the head movement. Such eye movement is executed in a reflexive manner, without conscious intervention, and it is called vestibulo-ocular reflex (VOR).

The achievement of correct erect standing position, both in static and in dynamic conditions, requires continuous adaptation of counterreaction of the antigravity muscles to the gravity force, in order to stabilize head position and to maintain the erect position itself. Maintaining upright position of the body is acquired via a continual to-and-fro movement of the centre of gravity (CoG) around the point of mass equilibrium. This movement is called "postural sway". It is achieved in a reflexive manner by means of the so-called vestibulospinal reflexes (VSR). The control of correct head position is possible through the activation of the neck muscles by means of a part of the VSR (the so-called vestibulo-collic reflex, VCR) and the cervical reflexes.

1.3.2 Cervical Proprioception

The receptors of the cervical region play a separate and particular role and constitute what can be considered as a "secondary labyrinth" [23]. In a clinical context, attention has been devoted to the neck with respect to a possible origin of vertigo, the so-called cervical vertigo. Furthermore its role in the posture of the head and the body seems undeniable. The cervical region with its structures intervenes in the elaboration of balance reflexes. Neck–body reflexes as well as cervical influences upon eye position have been described. The task of neck proprioceptors is to inform the centres about movement or change of position of the head, as this concerns a differential movement between the head and trunk. This is the fundamental difference from the vestibular system which is sensitive to head movements relative to space. Both sensory systems provide specific and proper information, thus complementing one another.

Peripheral proprioceptors of the muscles and the joints have a feedback control on the vestibular nuclei through spino-vestibular pathways. Neuromuscular spindles and Golgi receptors are dynamometers, and they are particularly sensitive to variations in muscle length and tension. Joint receptors, Ruffini and Golgi bodies, give information regarding the position of a joint and its movement. The portion of the neck including the first three vertebrae is particularly involved during the major part of everyday head movements. The paravertebral muscles of this region are very rich in proprioceptors. They are especially concentrated in the splenius capitis, the rectus capitis major, the longissimus capitis and the semispinalis capitis. These muscles compose the deep plane of the nuchal muscles. The splenius is just more superficial. They act in the extension homolateral bending and rotation of the head. During head movements they discharge to the vestibular nuclei.

The direct projection from the first three cervical roots to the inferior vestibular nucleus has been described and the convergence of the cervical and labyrinth inputs on vestibular nuclei has been showed. Convergence regards especially inputs from the horizontal semicircular canal: the electrical stimulation of the vestibular nerve induces action potentials in the contralateral abducens nerve. This response is increased when also neck roots are simultaneously stimulated. Thus, facilitatory convergences of proprioceptive inputs from C2–C3 receptors on the medial vestibular nucleus of the opposite side and an inhibition on the ipsilateral muscles have been demonstrated. The latency between electrical stimulation of the dorsal cervical roots and vestibular nucleus response is only 2 ms; thus direct projections from neck to vestibular nuclei have been hypothesized. Proprioceptive nuchal afferents on the Schwalbe nucleus have been demonstrated, and it has been shown that neurons in the dorso-caudal portion of the Deiters nucleus receive tonic cervical inputs, while the neurons in the rostro-ventralis portion receive especially otolithic inputs. Roller nucleus and the accessory group Y receive ipsilateral projections from the cervical muscles, and cerebellar projections on the nodulus and the flocculus have been demonstrated, and projections on the cerebellar anterior lobus have been described.

Proprioceptive convergences in 80 % of the neurons in the suprasylvian parietal cortical vestibular area have been demonstrated and sensitive inputs run through IA and IIA fibres that rise along the spinal cord and through the spino-reticular and spino-cerebellar fasciculus that seem to send direct projections to the vestibular nuclei.

From cervical proprioceptors arise the cervicospinal reflexes (CSR): bending the neck and turning the head relative to the body evoke reflexes in the limb muscles either in decerebrate cats or in human beings.