The methodology of adapted physical activities for older persons

CHAPTER V

The methodology of adapted physical activities for older persons

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V.1 Methodological framework and educational information

The recommendations are based on studies lasting 6-12 months in which healthy older persons participated to various programs of aerobic activity. The increase in VO2max is directly related to frequency, intensity and duration, as well as to individual genetic characteristics.

The classification of the intensity of aerobic exercise can be based on the increase produced in heart rate, compared to the maximum heart rate (MHR = Maximum Heart Rate, calculated by the formula 220-age in years), or on the threshold of perceived exertion as expressed by the Borg scale.

The Borg scale, owes its name to Dr. Gunnar Borg in the fifties introduces the concept of perceived exertion, by developing two scales, the RPE (Ratings of Perceived Exertion) and CR10 (Category-Ratio anchored at The Number 10). The RPE scale is considered easier to administer and score.

The RPE is used to evaluate the subjective perception of stress in relation to the same amount of effort, with 15 possible scores (from 6 to 20). The Borg score corresponds ideally to heart rate during physical effort: the lowest value of scale (6) corresponds ideally to 60 beats per minute, while the highest value (20) corresponds to a heart rate of 200 beats per minute.

The Borg scale is a simple and safe method to assess the perception of stress. For example, you can stop a test when the subject feels a particular effort.

In order for the Borg scale to be reliable, the amount of perceived exertion corresponding to each score must be clearly explained to the person that shall be tested. The opinion given by the subject should be as objective and honest as possible without over-estimate or underestimate the effort.

The table I.V. correlates heart rate with the Borg scale, for instance a score of 16 corresponds to 85% of maximum heart rate, that in turn corresponds to the anaerobic threshold.

An even more simple and practical method is to maintain the ability to converse with the training partner (if present) or talking loudly during training; the loss of such an ability during a physical effort has been correlated with the beginning of lactate accumulation (the threshold of blood lactate accumulation, corresponds to the concentration of lactate of 4 mmol / L and should correspond to a level 11 on the Borg scale RPE).

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The intensity of effort can be expressed in METs (multiples of the equivalent energy costs borne by the basal metabolic rate), calculated through dedicated tables. Compared to previous recommendations, it is now accepted that the benefits of training can be obtained, for sedentary people, even starting with an intensity of 55% MHR, corresponding to 40% VO2 max.

The recommended intensity of exercise is between 55 and 90% MHR or healthy adults, while elderly persons are advised to stay below 75-80% MHR (11-13 RPE), and to decrease intensity if they realize they are no more able to talk without effort during the training sessions. Sedentary, smoking elderly people must start at lower intensity.

The total workload (kcal) for each training session is the product of the intensity for the duration of the session: although the relationship is not fully elucidated, it is possible to think that we can modulate the initial activity in untrained subjects by reducing increasing the intensity and increasing the duration; the recommended duration, for an intensity between 55% and 80% MHR, ranges between 20' and 60'. The increase in VO2max increases with increasing frequency of sessions to reach a plateau above 3 sessions per week.

SCALA RPE DI BORG		
6	nessuno sforzo	20%
7	estremamente leggero	30%
8		40%
9	molto leggero	50%
10		55%
11	leggero	60%
12		65%
13	un po' pesante	70%
14		75%
15	pesante	80%
16		85%
17	molto pesante	90%
18		95%
19	estremamente pesante	100%
20	massimo sforzo	esaurimento

Tab.I.V

Regarding the training mode, any aerobic activity involving large muscles, rhythmic and maintained over time, produces the benefits of aerobic conditioning (walking, cycling, skiing, swimming, aerobic dance). Running is not recommended for excessive impact that follows the phase of impact after the flight phase, on the foot, ankle, patella (for the internal rotation of the lower leg pulling inward and the quadriceps pulling outward result in a higher pressure applied to the patella against the lateral condyle of the femur), hip and lower back.

Football, ice hockey, skating and skiing are all sports that tend to put a high stress on the knee joint. The latter in particular, is associated to a high risk of knee injury, especially anterior cruciate ligament tear, that, in turn, increases the risk of damage to the meniscus.

Those who report knee problems should avoid or cautiously practice high impact activities, including dances that involve jumping, preferring instead swimming, cycling, rowing. In short, all those activities that involve strength training and aerobic energy expenditure reducing joint overload.

The effects of aerobic workout conducted according to the ACSM recommendations are as follows:

- Increase of 10-15% VO2max (starts from the first week);
- Increase of lactate threshold by 10-20%;
- Increased of hypoglycemic action of insulin;
- Improvement of muscle oxidative capacity;
- Stimulation of fat oxidation;
- Promotion of cardiovascular fitness and weight control (linked to the diet).

Aerobic exercise is recommended for diabetes, hypertension, obesity, osteoporosis, osteoarthritis (low impact exercise).

With regard to the maintenance of effects, a significant loss of aerobic benefit is evident after two weeks of the suspension of training, with a return to baseline levels of aerobic capacity by eight months at most.

V.2 Limits and recommended sport activities for the elderly: the example of cycling

As the prevalence of hip and knee OA is age-associated, the use of the bicycle is a highly recommended physical activity for the elderly, as the impact on weight bearing joints is reduced and the potential to increase mobility as well as self-confidence. According to the ACSM recommendations, it is advisable to start gradually, with an intensity of 60% MHR, for 30-40 minutes per session, and to remember heating before and cooling after the ride.

To avoid pain in the buttocks and knees, it is very important to adjust the height and size of the saddle. Further it must be considered that if the seat is too wide, we end up swaying from side to side; so, there may be more friction and thus more pelvic problems. More than an adequate padding, it is important to distribute the weight evenly, and to avoid overloading the buttocks. Attention must also be paid to regulate the height of the seat. A saddle set too low implies an excessive withdrawal of the legs, too high stresses the knee.

The mechanical efficiency of cycling is high, averaging 40%, about three times that of racing and eight times that of swimming. This implies a low energy expenditure per distance travelled (long distance covered at low cost); to obtain a significant energy expenditure (for example, within a program of losing body weight) is necessary to travel much greater distances than in swimming or running. The air resistance in relation to driving speed is higher on average than in running, especially in windy conditions, which may be against or in favour to the rider. The aerodynamics of the bicycle is mostly important but a role is also played by the friction between the body surface and the air (for this reason professional cyclists shave or wear low-friction sportswear).

Cycling is a predominantly aerobic exercise that selectively engages the lower limbs, although in the competition the anaerobic component is also involved (20% or more in energy expenditure).

In the workout of the cyclist a variety of factors should be considered:

- Strength and leg muscle power (proportional to the cross section of the muscle and the lever arm in pushing on the pedal);
- Agility (economy and efficiency of athletic gesture);
- Aerobic capacity;
- Resistance to muscle fatigue;
- Ratio length of body / limbs: the cyclist is usually slender, only pure sprinter can be sturdy;
- Ratio length thigh / leg: the thigh is a pushing that works mainly on strength, and the leg as a rotation lever that works mainly on the rotation speed.

The work in cycling may involve strength, agility and endurance.

The muscles involved in cycling (stage push / pull phase) are:

1. Rectus femoris
2. Large medial and lateral
3. Sartorius
4. Tensor fascia lata
5. Hamstring
6. Gracilis
7. Tibialis anterior
8. Soleus
9. Gastrocnemius

In regular cyclists, it is important to assess the position of the foot on the pedal (metatarsal support), and to verify the seat position forward and height to be appropriately adjusted, to avoid overloading the knee and ankle.

The position of the foot pedal must be level of the metatarsal, as, if the first metatarsal head is too advanced, the mobility of the ankle joint during cycling is reduced, and the Achilles tendon, patellar tendon and quadriceps may be stressed.

The saddle should be adjusted so that at the end of the boost phase the leg is fully extended, but slightly bent, with a thigh-leg angle of 25 °-30 °, because a lower angle (lower limb fully extended) would lead to excessive stress on the knee in extension and would be disadvantageous from a mechanical standpoint, conversely a greater angle would apply too much stress on the patello-femural joint and the patellar tendon.

The position of the seat must be such that the subject is seated properly support the foot on the pedal with the crank horizontal and the vertical line from the front and back of the patella (knee-axis crank), respectively, falling back and forth at the heart of the pedal but within the support area of the foot on the pedal; if this line crosses the patella, or it falls too backward, the knee will work in a mechanically disadvantageous condition and at greater risk of injury .

The knee joint is the most stressed in cycling, most at risk of overload injury if the knee in malaligned (varus or valgus). In these cases, it may be considered a correction of the support of the foot to reduce the asimmetric strain of the medial compartment. As to the spine, a higher risk of low back pain in cyclists has not been shown, but athletes have an increased risk of neck pain because of the hyperextension of the neck in racing.

It is also essential to assess the shape and padding of the saddle, to prevent compression of the pudendal nerve on the ischial tuberosity, and even clothing (breathable, hypoallergenic) are important to reduce the risk of ischiatic compression and saddle sores; finally, the position the wrist on the handlebars should avoid hyperextension compression and irritation of the nervous structures, particularly at the ulnar canal.

Riding a bike or ride on the cycle ergometer is a useful activity for fitness and health, even in people who can not run or walk, as it happens in diseases of the foot; the cycle ergometer implies less risk of injury compared to biking. In addition, with the subject sitting on the saddle, the weight-bearing joints and the lumbar spine are in partial discharge, and can work with a reduced risk of overloading. Bicycling is recommended in early osteoarthritis of the hip and knee; it is also recommended as an aerobic training in hypertension and in ischemic heart disease, diabetes, and it can be useful as a calory burning exercise to lose weight, especially for those who have difficulties walking or swimming. It is not particularly recommended for back pain and road cycling is not recommended for those who have balance, eye or ear problems; cross country cycling and mountain bike is not recommended to persons with poor health or unfit.

Each session must be accompanied by heating and cool-down. Compared to the cycle ergometer, the energy cots of cycling are more complex to calculate, as the type of terrain, slope and weather conditions may play a role; however, on average it can be said that the energy cost of cycling at the same average distance travelled amounts to 1/3-1/4 that of running; thus, to burn the same amount of calories, it is necessary to bike a 3-4 times greater distance compared to running. Generally, you start with three times a week; for the first sessions it is useful to ride at least 1500-3000 m; at a later stage, the same distance should be covered at a speed that will produce an increase in heart rate up to 40% MHR. In the subsequent sessions the distance should be progressively increased, increasing progressively training intensity (heart rate), frequency and duration of sessions. A distance of about 8-10 km in 45-60', 3 times a week is generally considerate an adequate schedule for maintaining training benefits in terms of fitness and as a preparation for more demanding programs.

V.3 Training strength and flexibility in the elderly

In very old persons (aged 80 or more), the main objective of training is to develop and maintain muscle strength needed for self-sufficiency. A thorough training is essential to learn the proper and safe exercises. Before training however, it is important to check risk factors (see the questionnaires, Chapter III), and to avoid exercise in the presence of any alarm bell.

For strength training the use of machines with programmable ROM is generally safer than free weights.

The training should include all major muscle groups (abdominal, often released and providing content to the viscera, back, chest, hip flexors and extensors). The effects of strength training is specific, being confined to the body part trained.

The strength and muscular endurance increase with exercise, following the principle of progressive overload, and the total volume of work for each muscle group is dependent on the load, the number of repetitions and of series within the session.

The initial charge can not be less than 30% 1RM and should gradually increase, it is generally not recommended to exceed 80% 1RM for the risk of musculoskeletal injuries. As with aerobic exercise, within the range of workout intensity, lower values would be effective and recommended for sedentary or unfit persons, while individuals who are already trained and fit should reach values in the highest stage of the spectrum.

Strength training is stimulated by increasing exercise intensity (external load), resistance training by increasing repetitions.

The recommended number of repetitions is 8-12, for a power exercise 6-8 repetitions with a higher load.

At least one series per session is recommended for every major muscle group, the set of muscles that help determine a specific movement in a specific articulation (for instance: flexor of the elbow); in fact, doubling the number of series the benefit is very small. This suggests that the quality (intensity) and not the total amount of work the most important factor for the development of strength in sedentary persons. Indeed, all studies conclude that for the first 3-4 months of strength training for elderly untrained persons, programs based on single series are as effective as multi-series programs. In addition, the time required to complete a program based on individual series is one and a half times less than that required for a multi-series program. It is also possible to combine muscle groups with exercises that engage more than one set, for example:-dorsal arms, shoulders, buttocks, thighs, chest, abdomen, legs.

The total duration of a session must be at least 20'-25 ', while the optimal frequency varies depending on the muscle group. Indeed, not all muscle groups in fact have the same optimal frequency of training: chest, arms and legs should be trained by 3 or more workouts per week, while lumbar and other small muscles of the trunk respond optimally to even lower frequencies (1-2 per week). The American College of Sports Medicine recommends a minimum of 2 times per week for all muscle groups, with at least 48 hours of rest between sessions. The recommended type of exercises is dynamic, rhythmic, at slow to moderate speed, involving all the joint ROM, with particular attention during the eccentric contraction, which is associated with higher risk of injury.

The effects of strength conducted according to the ACSM recommendations are as follows:

- Increase in mass and muscle strength (on average 25-30% in 6 months - in very weak persons up to > 100%);
- Increased resistance to muscle fatigue (endurance);
- Increased muscle power, more if you exercise at high intensity;
- Increased bone strength;
- Increase in VO2max (much less than with aerobic workout);
- Improvement in glucose tolerance (to a lesser extent than aerobic workout).

The strength training is especially recommended in sarcopenia, the loss of muscle mass that occurs with aging, and in osteoporosis.

Since the suspension of training, maintenance of the effects is short: there is an initial loss within 1-2 weeks, which is completed within a few months.

For flexibility we mean the ability to perform large-scale movements within the limits of joint and muscle tendon, depending on individual elasticity and joint mobility.

The older you are, the longer it will take to develop the desired level of flexibility. The main reason we become less flexible aging is the result of some changes related mainly to a different degree of hydration and reduction of physical activity, things that both increase the rigidity of the connective tissue fibres. The other changes induced by aging that impact negatively on flexibility are represented by a larger amount of calcium deposits, and the replacement of muscle fibres with collagen fibres and adipocytes.

Stretching, the main mode of flexibility training, became popular from the States in Europe and Italy in the early 80s. The workout implies literally stretching the muscles through specific exercises, simple or complex. For several decades it has become part of any program of sports training, both for power sports and for endurance sports, before, during and after the performance.

Recently, however, some contradictory scientific evidence on stretching and dynamic ballistic exercises is emerging, especially concerning strength and power disciplines, while there is no negative feedback at the time on resistance, disciplines that require a considerable range of motion such as dance or martial arts. Some authors explain the negative effect of stretching on the performance of power (when it is executed before heating), attributing this phenomenon to the term "creeping" as so: during a year of extensive and prolonged stretching the muscle lengthens and this has the muscle fibres in alignment, although they usually have an oblique orientation and this accounts for the gain in elongation, but is accompanied by a decreased ability to store elastic energy.

According to Gummerson, flexibility (he uses the term mobility) is affected by internal and external factors.

Internal influences:

- Type of joint (some joints are not flexible)
- Internal resistance within a joint
- Bony structures which limit movement
- Elasticity of muscle tissue (muscle tissue marked from a previous injury is not very elastic)
- Elasticity of tendons and ligaments (ligaments do not stretch much and tendons should not stretch at all)
- Elasticity of the skin (skin actually has some degree of elasticity, but not much)
- Capacity of a muscle to relax and contract to meet the increased range of motion
- Temperature of the joint and associated tissues (joints and muscles offer better flexibility at body temperatures that are 1 to 2 degrees above normal).

External influences

- The temperature of the place where you train (a higher temperature contributes most to increase flexibility)
- The time of day (most people are more flexible in the afternoon than the morning, peaking from about 2:30 to 4 pm)
- The stage of the recovery process of a joint (or muscle) after injury (injured joints and muscles usually offer a lesser degree of flexibility than healthy ones)
- Age (before adolescence we are universally more flexible than as adults)
- Gender (females are generally more flexible than males)
- The individual capacity to perform a particular exercise (we learn by practice)
- Individual commitment to achieve the flexibility
- Restrictions on clothing or tools.

It is possible that the muscles of a joint to become too flexible; in this case the joint is given less support by the muscles around it, and too much flexibility can be detrimental as well as too little flexibility is not enough because both increase the risk of injury .

Once a muscle has reached its maximum length, trying to stretch the muscle further only stretches the ligaments and tendons providing excessive stress on them. The ligaments, if stretched more than 6% of their normal length, are torn; the tendons stretch only minimally and excessive stretching greatly increases their risk of injury.

The exercises for increasing flexibility represented by:

1. Active mobilizing exercises throughout the Range of Motion (ROM); these exercises should be slow and progressive;
2. PNF (Proprioceptive Neuromuscular Facilitation), a method of alternating isometric contraction drected againt the reisistance offered by the physiotherapist and stretching of the same muscle group; PNF is very effective, but requires a skilled operator to assist the person in the exercise. A modified technique called PNF can be performed alone or with a partner: expected contraction-relaxation exercises or stretching assisted (6''contractino against resistance, 30'' assisted stretching);

3. static stretching, easy to do and effective.

The ACSM recommendations for stretching advice a slow mode, a duration of 10''-30'' stretching the muscle group as far as to cause a slight discomfort (not pain!). The maximum gain in ROM can be obtained with 4 repetitions, then there is a plateau. All the major muscle-tendon groups (chain front and rear legs, shoulder girdle) must be stretched every training session, the minimum frequency of 2-3 sessions per week. The effects of stretching in accordance with the ACSM recommendations are as follows:

- Improvement of joint ROM and function;
- Improvement of muscular performance;
- Prevention of skeletal muscle type traumatic injuries.

As we have seen, the actual effectiveness of stretching before a session to improve the performance reviews is still controversial, while the long-term beneficial effect of stretching properly made with regard to flexibility and its impact on motor activity are not under question. The ACSM recommendations for physical activity to promote fitness in healthy elderly are given in Table II.V.

	AT	**ST**	**M**
Frequency Number of sessions per week	3-5	2	3-4
Intensity	55-80% MHR (=40-85%VO_2 max)	1 series, 8-12 repetitions for each of 8-10 main muscle groups; load: 30% 1RM - 80% 1RM	4 repetitions for all main maucle groups, stretch up to slight discomfort. (no pain)
Duration (minutes)	**20-60′**	**20-60′**	**5-15′**
Progression	Progressive increase of intensity and technical difficulty of the exercises		
Adjiustments	Progression of conditioning must e individualized		
Maintainance	If intensity is maintained and frequency or duration of sessions are decreased up to 2/3, VO_2 max is maintained up to 15 weeks and strength to 12 weeks		
Detraining	Deconditioning starts within 2 weeks from interrupting training and is completed by 10 weeks-8 months. Those who have trained for a long time seem to maintain benefits longer.		

Tab. II.V. AT = aerobic training; ST = strength training; M = Mobility/flexibility training.

V.4 Didactics technologies for the elderly: virtual environment role in balance training *Paola Aiello*

Recently, the importance ascribed by medicine, by the rehabilitation and psychological fields to all the tools which create virtual environments, make us consider the latter ones important aids to improve deficits in the elderly.

Technological literature distinguishes three kinds of VR: immersive, half-immersive and not-immersive, which can be carried out through many kinds of instruments having many different functions (Morganti & Riva, 2006).

Anyway, they all carry out, albeit in different ways, a new kind of man-computer interaction (Steuer 1992, Ellis 1996), involving not only the use of hands or of language but every single action of the person, which becomes a useful information for the Central Nervous System (CNS) which can remodulate, consciously or unconsciously, the action according to the received input.

The sensory-perceptive and motor involvement that takes place in virtual environments, makes the use of these technologies appropriate to the recovery, through training, of some functions affected by the aging. One of them that very often appears to be involved in the degenerative process, typical of the elderly, is the control of the balance making falls undesirable scenarios significantly affecting the individual's quality of life.

The control of the balance is the result of the integration of stimuli generated by the sensory organs like the view, the labyrinths of the inner ear and the sensory organs of the conscious and unconscious proprioceptive system and afferent to the central nervous system; it produces a motor response as a result of a complex process of rapid and selective integration.

"The visual cues provide information about the position and motion of the head with respect to the surrounding and based on information in the visual surrounding, a reference for verticality. The main role of the proprioceptive and somatosensory system is to provide a relationship between the body segments with respect to one another (limb position) and to sense the distributed tactile input stimuli at the neural level respectively. The vestibular system (located in the inner ear) keeps tabs on the motion and position of the head in space. It consists of otolithorgans, which detect the linear acceleration and gravity, and three semicircular canals, which detect the angular acceleration of head "(Virk et al., 2006).

How the nervous system takes cognitive decisions about the balance has been for long time an area of interest of neurophysiopathology that have helped to highlight how the deficit of the balance may be at the basis of peripheral lesions with impairment of sensory stimuli or central nervous system.

In the absence of one or more cues, or when the input from one of the sensors is skewed, the CNS "adapts" to the new environment and gives less weight to the conflicting inputs (Virk et al.,2006); if this process of adaptation of the CNS can be also observed in the presence of some specific focal cerebral and cerebellar disease conditions and in degenerative cortical or subcortical diseases that frequently involve the CNS, in common degenerative processes that are typical of old age, (such as cortical atrophy, the myelin degeneration of chronic vascular ways with consequent degenerative changes of the connection fibers of white matter ...), the CNS ceases to be accurate. This is obviously worsened when there is also a disease process that affects the central nervous system and/or sensory organs.

Numerous studies have investigated the integration of sensory inputs on the process of adaptation implemented by the CNS ,verifying as well that in the absence of signals from the above mentioned systems, the CNS reformulate the weight and the integration of the available inputs.

In fact for effective balance control, it is necessary for the sensory inputs to work in a set of feedback loops so that, integration and feedback forms the key issues in any model that explains the strategies of CNS for balance.

To treat patients with deficit connected to degenerative processes that affect the correct functioning of the systems involved in balance, typical of ageing, researchers often suggest physical exercises, even if, not surprisingly, Virtual Reality (VR) is being evaluated for the recovery and training of the functions connected to balance (Virk, et al., 2006).

Various experiments have been performed with patients with a history of falls or exposed to the risk of falls. They have showed positive results about the effectiveness of the training using interactive, immersive and non-immersive, interfaces in CNS reweighting of the inputs and in giving less weight to the faulty or the conflicting inputs (Hayashi et al.,1998).

Older adults rely more on visual information to maintain their balance or to recover their balance even if there is a clear trend toward the reduction of head movements in elderly.

In this regard, some experimentation have shown that visual information that conflicts with the others arising from other sensory channels can have a rapid and profound effect on postural responses. (Vidal et al., 1982; Kreshner et al., 2004).

The influence of moving visual fields on postural stability seems to depend largely on the characteristics of the visual environments as well as from support surfaces, including the size of the base of support, its rigidity or compliance (Streepey et al., 2006).

A central recalibration process, within the limits imposed by the physiology of the organism, exists to produce appropriate responses even in the presence of sensory conflicts, i.e. when visual perception of the environment is discordant with proprioceptive information gathered from the support surface.

The decline in the integrity of many postural regulating systems, associated with ageing, may in fact be balanced by training strategies for the acquisition of selective sensory-motor of conflicting stimuli. Virtual reality providing conflicting stimuli as often they are realized in real contexts, in particular, appears to be a valuable teaching tool for training the capacity of the CNS of the elderly to select relevant information and resolve sensory conflicts that may undermine the postural stability.

A recent study has shown in fact that repeated exposure to contrasting stimuli through VR technology improves the ability of balance control in elderly subjects, through sensoty-motor integration with the constraints imposed by the environment and the ability to postural adaption.

It has been specifically elicited, through training in VR, cognitive processes ranging from correctly perceiving and interpreting information from different body sensors (somatosensory, vestibular and visual) planning and coordinating the effectors appropriately to produce the desired movement.

Learning new motor strategies or entraining them is, in this case, promoted in virtual environments from the changes in contextual stimuli, from alterations in the physical demands, problem solving, and random presentation of practice motor tasks demands imposed by the body, with consequent enpowerment of the involved subject (Winstein, 1991).

In this sense, the virtual reality for its reproducibility features of the real world provides an ideal environment to understand the strategies implemented by the CNS functional to maintain the balance using all the above mentioned techniques and making possible, in the meanwhile, the differentiation of the behavior of different sensory stimuli.

In these virtual environments, the simultaneous effects of various sensory modalities and the resulting associated or separated neural responses can be investigated and as evidenced by Keshner and colleagues, the postural responses can be evaluated through the deliberate manipulation of visual, vestibular and somatosensory stimuli.

International literature on this topic therefore suggests a possible use of virtual reality in the manipulation of feedback, particularly visual, to produce conflicts between visual, vestibular and somatosensory information thus acting as a mechanism of sensory-motor training of the different systems involved in balance control.

One of the principles that underpin the scientific *rationale* to support the efficacy of these technologies lies in the widely acknowledged role of the feedback in the control of movement and balance as well as of the repetition and motivation that are the key concepts of training programs and rehabilitation in the motor field. These elements appear to be deeply interrelated because the repetition of an executive pattern is necessarily accompanied with an increase in the success of actions that is registered by the central nervous system according to the information gathered from the senses (eg. vision, proprioception ....). The repetition, however, requires motivation that aims to make more bearable the extensive practice period.

In this regard, it is probable that the VR is a powerful tool for the development and the integration of all elements that are involved in the rehabilitation and training programs also aimed at the elderly. It can not be underestimated that the awareness of their deficit leads to a state of anxiety and / or depression that not only may cause a worsening of the deficit itself but may generate demotivation, slowing down the time of a possible recovery of vicariant and compensative functions.

In particular, in a virtual environment, feedback and / or knowledge of results which is acquired in real time following a trial, or block of trials, derives from the "*sense of presence*" that is realized when one has the feeling of being immersed in a real life situation, even if simulated, and the perceptual illusion of non mediation made by the technological medium (Lombard & Ditton, 1997). Interaction in VR generates, in particular, the plausibility of a causal relationship between perception and action to support what Gibson (1977) defines affordances that is a call to action on the basis of the acting opportunities offered by the reality; the "action" is controlled and planned in response to environmental conditions, needs, motivations and planned objectives.

It is therefore to identify a leading role to virtual reality in research, training and rehabilitation with, therefore, investigative, training and clinical functions also with regard to the difficulties and diseases that affect the quality of life of elderly individuals.

As heuristic tools, the successful integration of virtual reality into multiple aspects of medicine, psychology, and rehabilitation has demonstrated the potential for the technology to present opportunities to conduct safe, ecologically valid experimentations while maintaining experimental control over stimulus delivery and measure-ment through a deliberate manipulation of the variables that are assumed to be involved in the examined processes.

In the field of rehabilitation and training, these tools help to standardize the measurements, individualize treatment or training protocol, graduating, documenting, and above all creating motivating contexts and situations in which the elderly can recover through the success of her/his own actions and the gradual improvements, the self-efficacy and the internal locus of control undermined by aging.

V.5 The educational use of stabilometric platforms for the realization of physical activity for the elderly

Stefano Di Tore

The technological progress and the general improvement of the social conditions, together with the new discoveries of the medical science, lead to a general increase of the average age of life, especially in the Western Countries.

Hence, the main issue about the improvement of the lifestyle in the elderly is becoming more and more important in every field, from psychology to medicine, from sociology to the motor science, etc.

Therefore, how to help older persons in saving their independence is becoming a great issue both from a social and a medical point of view.

In view of this, the analysis of posture has certainly an important role, since it can help to prevent troubles of balance, falls and, generally, other pathologies linked to the balance which can lead to the loss of one's own motor abilities and of the independence of the elderly.

The word "posture" is generally used in the medical and motor science fields to indicate the position of the body in the space and in relation to the outer world. The science which studies it is called Posturology. It studies the causes of the troubles of balance responsible for many diseases affecting the musculoskeletal system, such as scoliosis, spinal pains, balance disorder, etc.

To achieve this goal the Posturology uses tests to measure specific factors useful to understand and study the posture of the subjects.

The Stabilometry is one of these factors and it is particularly important for this article. It is a test that can evaluate and measure the balance, through precise instruments that meet international standards of construction, sensitivity and calibration.

Before introducing the practical clinical applications of this analysis, it is useful to illustrate what systems are responsible for the postural attitude, how the bioengineering tools at our disposal work and how they consider the phenomenon of posture from a biomechanical point of view.

All this in order to better understand the level of reliability of this analysis and how the data, provided by the technologies discussed herein, can be interpreted.

It is also worth noting that in this article we will discuss only the possible applications of the analysis of quiet stance taken through force platforms.

The postural system

The upright position, typical of the human race, is maintained through continual adjustments of the posture of the body, carried through a continuous stabilization process implemented by muscles and osteoarticular system. The upright posture implies continuous postural adjustments to compensate for strength, both internal and external, which modifies the balance of the subject. The body, left to itself, would be inevitably destined to collapse to the ground, yet this does not happen. This is due to the fact that the human body has got a system which can set its own balance finely and effectively.

To describe the stability of the upright posture of the human body, it is useful to point out that the projection of the body gravity vector generally stands inside a surface smaller than a cm^2, an area smaller than 1% of the base of support that is available and compatible with the upright balance.

Therefore the body can assure a wide margin of safety to maintain its upright posture. The loss of the balance naturally causes falls which, on their turn, may cause serious injuries; so here's the importance of a system that preserves and maintains the balance.

The range of parameters, which allows this system to maintain an upright posture without collapsing to the ground, is a study on which particularly focuses the scientific interest. They search and analyse the standards that allow to note the warning signs of the normal antigravity function, even in small changes of the posture, and the standards which allow prevention and suitable treatments for a correct posture.

The analysis of the process and the factors which determines the upright posture is called posturography. It observes and measures the occurred stabilization against gravity and any disruptive agents, whether internal or external to the body.

The balance

The maintenance of the upright posture and the balance in human beings is mainly the result of a continuous cooperation of three systems:

- The sensory system
- The central nervous system
- The muscle and bones-joints actuators

Any change of one or more of these systems may cause the loss of a postural stability.

The human being can control the motor responses through the activity of his brain in order to maintain the balance and avoid dangerous falls. The brain interprets and integrates the information from the senses during the continuous changes of the posture due to the movement.

Even the cerebellum plays an important role in the regulation of movements, especially with regard to the synergy between agonist and antagonist muscles.

In the elderly, the balance gradually deteriorates, and this influences the gait that worsens considerably (shuffled, uncertain, arrhythmic steps, etc). The deterioration of the balance in older people is mainly due to senile deterioration of the sense organs and the locomotor system.

The causes, which can arouse a change of the balance in the elderly, can be summed as follows:

1. Decrease of the speed of the rapid postural reflexes or alteration of the efficiency of nerve antigravity pathways.
2. Osteoarticular diseases
3. Cardiovascular diseases
4. Cerebrovascular diseases
5. Neurological diseases
6. Taking drugs that interfere with nerve reflectivity
7. Diseases of the labyrinth
8. Visual disorders
9. Hormonal Disorders
10. Anemia
11. Infectious diseases

Specific tools, as the force platform, can provide objective measurements of the change of some factors which are essential to preserve the balance, as the wideness of the COP oscillation, or the pressure distribution.

Before introducing the possible uses of this analysis, it is useful to show some important concepts underlying the functioning of the technologies on which it is based.

The functioning factors of the postural system from a mechanical point of view.

To better understand the functioning of the technologies which allow this kind of analysis it is necessary first to understand the mechanical process that regulates the maintenance of the upright posture, and to this end, it is necessary to introduce some important factors.

Although there are studies on the movements that each part of the body makes to allow the body to maintain an upright posture, such as the studies on the movements of the head and those on the relationship between the movements of the trunk and head, usually, in practice, only fluctuations in the body’s center of gravity are examined, assuming that "the primary purpose of a control strategy of an upright posture is to keep the center of gravity within the perimeter of support, within an area small enough to ensure some margin of safety."

Hence, the following two variables become essential:

- *The center of mass* (**COM**), i.e. the centroid of the body segments that make up the body, "whose position determines the lever arm of the force of gravity compared to the joints and the sign of the corresponding destabilizing moment".
- *The center of pressure* (**COP**), i.e. the centroid of the pressures applied on each point of the surface of the foot in contact with the ground.

It is the application point of the resultant of the forces exchanged between the foot and the ground (ground reaction force), whose position determines the lever arm of the external force of reaction as to the joints and the sign of the corresponding reagent time.

In other words, the COP is the center of gravity of the ground reaction forces applied on each point of the surface of the foot in contact with the base.

To sum up, we can state that the COM, reflecting the real movements of the body segments, and the COP, reflecting the action of the muscular forces, are the two key variables of the postural control.

The biomechanical model, which is applied to the analysis of an upright posture at rest, can indeed be illustrated with a simple inverted pendulum hinged at the ankle, with a single degree of freedom in the sagittal level.

Inside this model, the COM, the COP and their relationships are the main factors to analyse.

Tools and Technologies

With regard to the experimental analysis of the postural control, there are many tools that the bioengineering proposed. Anyway, the force platforms are the first group of technologies that imposed itself in this kind of analysis.

Generally, the only external forces studied with regard to the posture are those due to the gravity.

The tools which study these kinds of forces are those based on Newton's Law, which states that for every action there is always an equal and opposite reaction. During the evaluation of the posture of a person at rest, the body exerts a force on the ground and the ground reacts with a force of equal intensity but opposite direction. Noting the force with which the soil responds, it is therefore possible to calculate the force applied on it by the body.

On this principle it is based the functioning of the instruments for the analysis of the external forces acting on the body, such as the force platforms, which are the key factors for an analysis of the posture.

The force platforms allow to record some important aspects of a posture at rest. Generally, they have sensors which survey the pressure, rejecting the third dimension, which is not particularly important in this case, and reducing the analysis of the posture to a bidimensional problem.

Traditionally, the two coordinates of the COP (middle-lateral, anterior-posterior) are the parameters which are detected and studied. Almost all the other indicators used to study the posture through the force platforms can be traced back to these two parameters.

The detection of the coordinates of the COP over the time allows the analysis of the time trend of its position, which can be done through two types of representation standardized by the International Society of Posturography: the Statokinesigram (or Ball) and the Stabilometry.

- The Statokinesigram is the bidimensional layout of the path of the center of pressure on an horizontal support surface.
- The Stabilometry is the graph of the coordinates of the center of pressure over the time.

These indicators allow to visualize and to quantify the instant speeds of the COP, i.e. the frequency of the oscillations.

The area of confidence is another parameter that is often studied.

The confidence ellipse is defined as the ellipse that, with the 95% of probability, contains the center of the points of the sway. The surface of the confidence ellipse is expressed in mm^2, it allows to calculate the wideness of the sway and thus to highlight the patient's energy expenditure to maintain an orthostatic position. In a normal situation it is less than 1 cm^2, anyway the posture is highly subjective and, therefore, the only area of the ellipse cannot prove the existence of any disease.

The length of the ball and the average speed are not important measure to calculate the patient's energy expenditure.

With regard to the COM, there have been proposed many models of evaluation based only on data got from the force platforms. They range from the application of filters to eliminate high frequencies (lowpass-filter) of the COP, to eliminate the rapid oscillations of the same, to the integration of horizontal elements of the reaction force. However, none of these methods provides an accurate analysis of the COM and the mathematical models to calculate it only through the force platforms are still under development and validation.

For these reasons the study of the COM, although this is an essential parameter for a thorough examination of posture, did not spread very far in this kind of analysis, and numerous models deal with the problem through the assimilation of the COM projection on the ground with the position of the COP.

Clinical Applicactions

The risk of falling increases dramatically as far as the age raises, so that almost a third of people whose age is more than 65 years lives the unpleasant experience of falling once a year.

Of course, the posture and the equilibrium can be influenced by several factors and the analysis of the changes of the COP and the COM can be related to different diseases.

Currently, many studies in the clinical field are using the techniques of the static posturography and force platforms to analyze the effect of the aging on the postural control and on the balance.

Era and Haeikkinen made a study which seems to prove that the postural sways stay within certain established parameters till the age of 30, then they progressively increase with the age.

Instead, other studies are intended to identify in the oscillations a clear predictive sign of the increase of the risk of falling in the elderly.

Nowadays the main applications of the surveys conducted through force platforms in the clinical and the rehabilitation fields cover illnesses such as diabetes, Parkinson's disease, deficits related to sight and hearing and many other diseases that can affect the normal maintenance of the postural equilibrium.

The diabetic foot, for example, has an uneven distribution of pressure, and this contributes to create serious problems such as foot ulceration.

An analysis of the distribution of the pressure on people with such diseases is particularly useful for the production of footwear designed to balance the abnormal distribution of pressure and so avoid serious consequences.

Other studies have focused on the pharmacological and surgical treatments in relation to postural oscillations.

Particularly, in the case of patients with Parkinson's disease, postural changes were noted after several treatments, such as levodopa (DOPA) and electrical stimulation of the basal ganglia.

The COP area, which is larger than the mean in people with Parkinson's disease who did not have undergone treatments, increased further after the administration of levodopa, while the electrical stimulation of the basal ganglia seems to produce a stabilizing effect on posture, bringing the area of the COP to the average levels.

Other studies of the implications and changes in postural balance have been done on elderly subjects in relation to the physiological conditions of the visual apparatus such as presbyopia, myopia, and in general all the pathologies that involve a decrease of the sight.

These studies have shown that the changes of the balance due to the age and to the sight lead to strategies to control the step while walking.

However, the results of these studies have also shown that these natural strategies to balance the body while walking reduce the instability but do not increase the safety margins of walking.

It seems clear that a careful analysis of these factors could help to prevent the deterioration of the balance in the elderly through appropriate remedial training means or through physical activities specifically designed for the type of deficit of the subject.

The analysis of the static posture, made only through force platforms, provides important clues about maintaining the balance of a subject.

As shown, a careful exam of the posture would require a careful analysis of even the COM, which often cannot be detected, unless loosely, through the only force platforms.

Despite this lack, the COP sways and the standard parameters provided by this type of tools may help to understand the posture of patients and provide a valuable aid to plan effective remedies.

The balance may in fact be re-educated or trained with exercises specifically studied and carefully graded according to the difficulties. These could be aimed at restoring, as far as possible, the values of the COP within the mean, or they could be directed at increasing the safety margins necessary to maintain an upright posture.

In this way, it would be possible to decrease the risk of falls in older people thus avoiding the attendant risks, such as loss of their own motor skills.