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FROM THE ITALIAN CHAMPIONSHIP TO THE PARALYMPIC PODIUM: ELABORATION OF A NOVEL APPROACH OF DRY-LAND TRAINING IN ÈLITE SWIMMERS WITH DISABILITY

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- **Cavaggioni L**., Ongaro L., Alberti G. "*Respirazione e stabilità: un approccio innovativo di "core training".* Strength & Conditioning. Per una scienza del movimento dell'uomo. ISSN 2281-3772. – 3:9 (july), 2014, pp. 41-46
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ABSTRACT

The present Ph D. thesis describes the longitudinal evolution of the physical, postural and functional parameters of three top-level Paralympic swimmers (classes S9-SB8-SM9, S7-SB6-SM7, S5-SB4-SM5) during two years of training promoting a novel approach of “dry land” training based on quality of movement. It is divided into three sections.

PART I: in according to available literature, it is described the importance to shift the focus from a movement expressed in *quantity* (the parameters evaluated are basically related on the athlete’s fitness level) to a movement *quality* which means a more economic, efficient, biomechanically correct motion and their related assessments procedures. The foundations of human movement patterns are posture and breathing.

PART II: two studies, based on aspects that have been an important part to the Paralympic swimmer’s training method, are exposed.

The aim of the *first* research was to evaluate the difference between traditional core training and the abdominal training corrected by diaphragmatic breathing pattern on abdominal fitness, quality of movement and pulmonary function during 4 weeks of training, in two groups (N=32; 29±3 years): the Experimental Group performed abdominal exercises characterized on muscular chain stretching accompanied by a diaphragmatic breathing pattern with vocal sound emission, conversely Traditional Group performed traditional core exercises like crunches or isometric planks.
The purpose of the *second* study is to show a different modality of strength training without external devices which effects are similar to those obtained with Blood Flow Restriction Resistance Training. This method is characterized by the modulation of muscle action velocity using moderate intensities (low loads) and slow speed without pause between repetitions nor between phases.
PART III: The aim is to show the longitudinal evolution three èlite Paralympic swimmers during two years of training.

Methods: related to their disability each subject underwent a specific dry-land training comprising a diaphragmatic breathing technique, aimed to improve their body alignment, mobility and trunk stabilization, as well as a slow-velocity resistance training aimed to improve their muscle strength. They were tested for functional movement by using FMS™

tests, a morphological analysis to describe their body posture, a MARM evaluation for the breathing patterns and the strength measured by vertical jump test with the infrared device Optojump. All data were collected over two years, from the Paralympic games in London in August 2012 to the IPC European Championship in Eindhoven in August 2014.

Results: all swimmers improved both the single and the composite scores of the FMS^{TM} assessment, indicating the achievement of a better postural control. They ameliorate their body alignment reaching a better balance between thoracic and diaphragmatic breathing pattern. The male athlete, also increased his strength parameters showing a +14% from December 2012 to August 2013 and an additional 2.6% from August 2013 to August 2014. All athletes won medals (silver and bronze ones) in the major international competitions, especially the male athlete won two bronze medals in London 2012, ended up five gold medals in Eindhoven 2014.

Conclusion: These results show that a two-year specific dry-land training comprising body balance, breathing, and slow-velocity resistance training is capable of enhancing the functional, postural and strength performance of three top-level Paralympic swimmers. We conclude that such a gentle approach of training contributed to improved performance in world-class competitions, thus enabling them to reach consistently the highest step of the podium.

Keywords: Paralympic swimming; posture; breathing; strength; quality of movement; body balance

PART I

Background: the "quality" of movement over the "quantity".

During these three years of Ph.D. academic education I developed very interesting research topics; these themes involve the breathing function, the postural control and neuromuscular mechanisms related to strength development, both with athletes and common people.

I could study in deep these arguments thanks to the supervision of many experts like Professors G. Alberti, L. Ongaro, A. Caumo, E. Arcelli, P. Bellotti and R. Bianchi who have built their professionalism "on field".

On the other hand, in the context of èlite sport performance level, also strength and conditioning coaches like Mark Verstegen, Vern Gambetta, Pierre Paganini, Michael Boyle, Eric Cressey and Al Vermeil emphasize the concept of quality of movement(17,45,72,157,174).

Therefore, thanks to the Italian Swimming Paralympic Federation Coach Massimilano Tosin, I met a group of Paralympic athletes with lots of humanity who are subjects of my Ph.D. thesis.

They could reach lots of success winning medals in the major international competitions, thanks to their strength, determination and talent.

During these three years, I experimented a different "dry land" training approach based on aspects that, at first sight, could not be considered important in order to ameliorate performances but, in truth, they are the foundation of human movement.

The *first key point* of the methodology that I adopted with Paralympic athletes is based on two principles; the first one is the *Evidence Based Coaching,* the process whose purpose is to increase sport performances based on the selection of peer rewieved scientific articles using an experimental design setting, hypothesis formulation, analysis and verification of results.

In opposition to this principle, there is the *Belief-based Coaching* which is subjective, biased, unstructured, mostly lacking in accountability and also includes pseudo-scientific coaching.

The *second key point* is the fact that it is impossible not to consider the aspects related to the quality of movement, rather than quantity: first of all, we need a system to help us gauge movement quality before we gauge movement quantity (41).

In this regard there is a fashion born in 2007 in USA in Silicon Valley (for many people it becomes almost a philosophy of life) the so-called “Quantified Self”, i.e. the desire to quantify the various human activities, that has become very popular.
The need to measure what a man does, grew up many technological tools such as bracelets that measure steps taken, stairs climbed or descended in the course of a day, sensors inside of tennis shoes to record calories burned, devices for measuring blood pressure, heart rate, etc.

A large number of parameters is recorded in real time by sophisticated applications within electronic instruments such as, for example, mobile phones that store data with the objective of improving performances.

For many years, coaches, physical trainers and rehabilitation professionals have often performed testing evaluations by measuring conditioning parameters related to the fitness level of performance or specific skills assessments in order to plan their training programs.

The most studied parameters could be measured through units like inches, kilograms, watts, degrees, m/s, seconds, beat / min, accumulation of LA-, etc arising from conditional skills such as strength, power, speed, endurance, anaerobic power, etc.

This quantitative approach about the functional evaluation of motor skills does not consider a fundamental aspect: the *quality of movement*.

This aspect in Sport Science is also crucial for performance and should be carefully investigated: these types of tools have a fundamental problem related to the high operating costs, and also a certain difficulty in obtaining validation by the scientific community : nowadays the analysis of the movement is referred to micro electronics which obtained a great development (36,56,140,144).

The movement efficiency is an essential parameter, because allows the body to move economically, biomechanically correctly without muscle imbalances or compensatory motions.

An example would be a person who has an above average score on the number of push-ups performed during a test but is performing them very inefficiently by compensating and initiating the movement without lumbar spine control.

Compare this person to an individual who scores the same number of push-ups, but performs them very efficiently without using compensatory movements.
These two individuals would be considered “on average” without noting their individual movement inefficiencies, but if major deficiencies in their functional movement patterns are noted, their performance could not be judged as equal: these two individuals would have differences in functional mobility and stability.

Fitness tests are important to obtain baseline quantitative information about the level of aerobic or anaerobic fitness in order to make recommendations and establish training objectives. The recommendations are generally based on standardized normative values, which may not be relative to the individual’s specific needs.

In many cases, performance tests provide objective information that fails to evaluate the efficiency by which individuals perform certain movements.

There is a predominance of quantitative measurement of an athlete’s skill (how fast he runs, how much is his jumping elevation, etc), but there is little information about the qualitative aspects related to the efficiency of the movement patterns (how he runs, how he jumps, how he moves, etc).

It is also important to know that common fundamental aspects of human movement occur similarly throughout many athletic activities (figure 1) (in a more complex way because they are the sum with technical skills).

Coaches must realize that, in order to train or rehab individuals for a wide variety of activities, such a screen of fundamental movements is imperative.

it is important to measure the efficiency and the quality of execution of functional and postural aspects of a person, because they are the foundation of human movement.

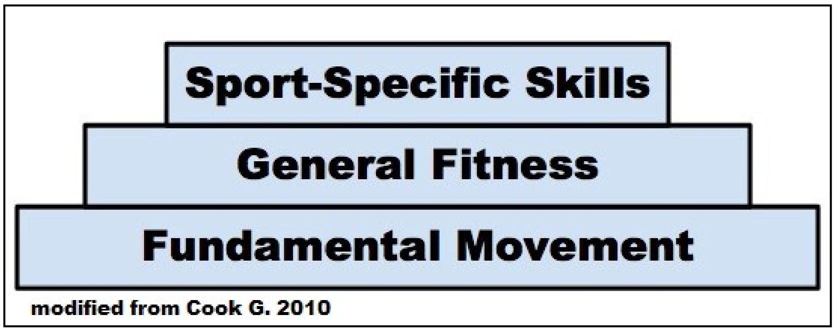

Figure 1: Gray Cook's Performance Pyramid: from fundamental human patterns to sport specific skills development (modified from (41).

Therefore it's essential to try to shift the focus, firstly on aspects related to "how" a person performs a motion (the *"quality"*) and only later to measure and program a volume training workout based on the *"quantity".*

The purpose is to quantify the functional deficits related to a correct efficiency of movement (quality) through tests which are practical, simple, low cost, reliable with a scientific validity.

So, before we try to obtain measurable information about the quality of execution of basic motor patterns (which are the foundation of each movement), and later to investigate other quantitative sport-performance parameters about the athlete's fitness level (strength, power , Vo2max, lactate accumulation, etc.).

1.1 Human motor behaviour: postural control and breathing aspects

Movement, motor skill coordination and breathing are very sophisticated aspects which involve the human in his integrity.

The human body is considered as a whole composed of anatomical ‘‘segments’’, including muscular forces ‘‘internal’’ or “external” to the mechanical system. They are the result of a combination of muscle torques and ground reactions (15) divided in two abilities: the ability to execute the voluntary movement to mobilize the focal segments and the ability to manage the perturbation to balance associated with the forthcoming movement.

Initial studies of Bouisset S.e Zattara M. in 1987 (16) demonstrated that postural control and motor command is the result and cooperation between ‘‘focal’’ and a ‘‘postural’’ components. One would correspond a ‘‘Posturo-Kinetic Capacity’’ (PKC), and to the other, a ‘‘Foco-Kinetic Capacity’’ (FKC).

The first system FKC (Foco-Kinetic Capacity) means the ability to execute the voluntary movement *per se*, to mobilize the focal segments, the second one is the PKC (Posturo-Kinetic Capacity) the ability to develop a counter-perturbation to the posture perturbation induced by voluntary movement due to an anticipatory recruitment of postural muscles (15).

Figure 2 shows that the performance is the final product of the cooperation between PKC and FKC systems.

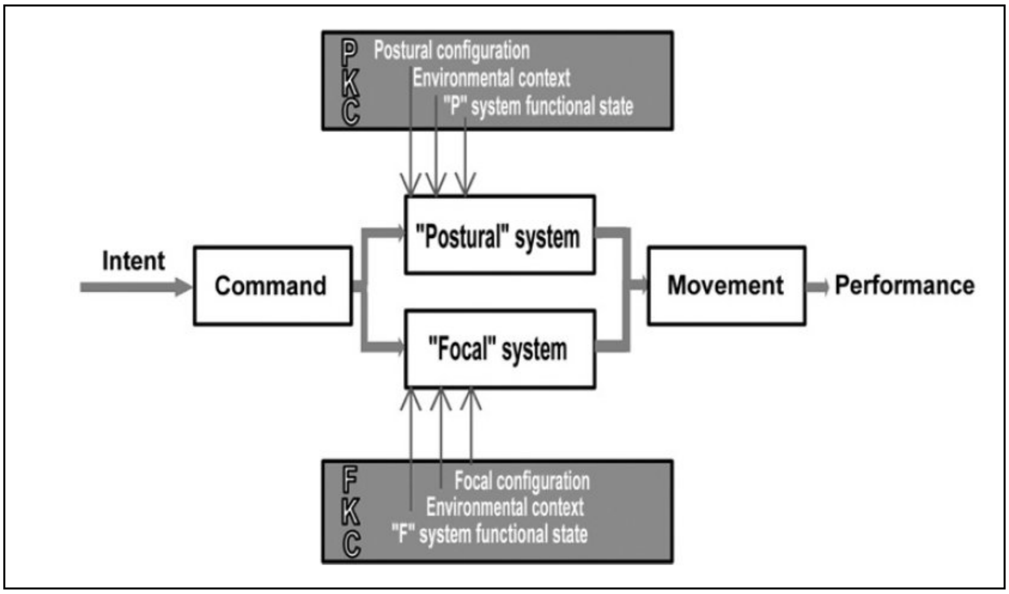

Figure 2: Postural Control during a movement (modified from(15)

Under a physiological condition, during a limb movement, there are many stabilizer muscles like the diaphragm, the pelvic floor, all the sections of the abdominal wall and the spinal extensors which automatically activate prior to purposeful movement in order to stabilize shoulders, pelvic girdle and the spine (63,97)

The aim of the postural organization is to maintain the balance or to produce movement combination of impulses from CNS to the muscular system.

Muscles and joints shouldn't have been considered isolated or individuals, but it's important to consider their reciprocal connections inside a functional complex system.

The locomotor system is built with an integration of apparatus and structures whose function is inside a system of rigid solids (15) like a "*tensegrity"* structure; the building principle that was first described by the architect R. Buckminster Fuller in 1961 and first defining "*tensegrity"* systems as structures that stabilize their shape by continuous tension or "tensional integrity" rather than by continuous compression (89).

Muscle fibres are connected through a intramuscular connective tissue: endomysium, perimysium and epimysium (170).

Their organization inside the body is structured by articulated “muscular chains”. The “muscular chains” have a longitudinal and transversal direction involving trunk and limbs (Figure 3).

Muscle chain interaction in human body is due to the French physiotherapist François Mézières in 1947 (132,134) who pointed out:

- The posterior muscular chain
- The anterior chain
- The anterior neck chain
- The brachial chain

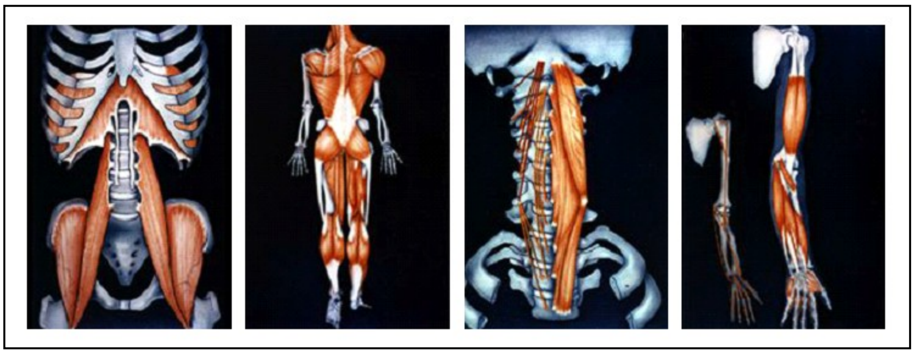

Figure 3: Muscle chain scheme discovered from F. Mézières (Modified from Nisand 1997)

In subsequent years, several authors including and Busquet and Dudal L. F. (24,55) have implemented knowledge of the muscular chains up to Thomas Myers in 1997 with the discovery of functional lines of movement which extension is throughout the body without solution of continuity (126,127).

The different degree of tension of the muscle chains (or a single muscle) at rest is guaranteed by the so-called muscle tone which may be subdivided into three different categories: hypo-tone (for example due to a peripheral lesion at the level of motor neuron), normo-tone, or hyper-tone (the abnormal reflex muscle contraction, at rest, according to the task required muscle).

It consists of a constant recruitment of neuromotor pathways which generate a permanent state of activity and excitement in the muscle (186).

In fact, in subjects with spastic dystonia or other types of spasticity, muscle tone in the limbs appears to be greatly increased compared to subjects without lesions of the central nervous system (60,186).

The transmission of the movement passes by a central area called "core region" composed of different muscle layers which have the purpose of stabilizing the complex lumbo-pelvic and orient the spine in order to transfer the force to the extremities in a more effective way (12).
The stabilization of the central area occurs, according to Panjabi, in a coordinated manner by the action of three distinct subsystems: the "passive subsystem", the "active subsystem" and "neural subsystem".

The "passive subsystem" consists of discs and facet joints ligaments. The stability of the core person is the domain of the bony structures and ligaments of the lumbar spine.

The main role of these structures is proprioception, rather than support. The passive subsystem is important in the maintenance of spinal ROM (141).

Bergmark divided the subsystem of the active muscles into two groups: "global" and "local", according to the role they have in the stabilization of the core; the system "global" consists of superficial muscles that are inserted in the low back and contribute to the performance of dynamic activities, while the group "local" is composed of the deep muscles that fit on the lumbar vertebrae and influence the control of movements lumbar (10).

The organization of this muscle nucleus is similar to a box:

- The diaphragm which composes the upper part.
- The oblique muscles as sides of the box.
- The transverse in front.
- multifidus and lumbar erector spinae in back

The diaphragm, the "roof" of the core region and its contraction, in synergy with the action of the transverse and the pelvic floor muscles, increases intra-abdominal pressure and the stability of the trunk, before the start of the movement (86).

O'Sullivan has shown that people with sacroiliac pain have a decreased recruitment of the diaphragm and pelvic floor, thus justifying breathing exercises within the core training programs to improve the functionality of the system (136).

The influence in the anticipatory recruitment of respiratory muscles (especially the diaphragm) during body segments motion is confirmed by extensive scientific evidence (4,26,49). The connections of the various segments with each other is commonly called "Regional interdépendance" (113,124,175).

The respiratory system is a basic life support system of the body. It helps to maintain homeostasis, which is the ability to maintain stable internal conditions (180) affecting motor control, postural stability and psychological regulation (176).

The muscles of breathing are uniquely supplied by both voluntary and autonomic nerves.

Voluntary control is required for the production of speech, creating abdominal pressurization during defecation and physical work, and the expression of emotions, for example laughing or crying (64,176).

Autonomic control primarily regulates breathing rate and blood supply of the lungs as well as vital reflexes such as coughing and sneezing (180)

The varying abdominal pressures during inhalation and exhalation also assist in the digestive process (180).

lThe correct functionality of the system relies on two processes: respiration and ventilation.

In summary:

- Respiration is the gaseous exchange between lung tissue and blood, and cells and blood whilst ventilation refers to the mechanical action of inhalation and exhalation (180).
- The respiratory system is composed of the nose, pharynx, larynx, trachea, bronchial tree, alveoli and the pleurae (115).
- A healthy adult takes approximately 12 breaths per minute, with each breath containing approximately 500 millilitres of air (64).

The process of breathing involves complex muscular contraction and relaxation, motion of fascial planes and the movement of nearly 150 joints (176).

Respiratory muscles are active primarily in inhalation but also have a role in forced exhalation, for example strenuous activity and coughing (151).

The diaphragm is the primary respiratory muscle, whilst other breathing muscles are referred to as accessory respiratory muscles. During inhalation the diaphragm contracts and flattens, increasing the volume of the thoracic cavity and thus causing a decrease in intrapleural pressure and a flow of air into the lungs. During exhalation the diaphragm relaxes and domes, reducing thoracic cavity volume and increasing intrapleural pressure, which, in addition to the gravitational pull on the thoracic cage and the elastic recoil of the ribs, causes air to be forced out of the lungs.

The respiratory muscles, like other skeletal muscles, can be classified according to its histological composition (121) so, depending on the type of fiber can be trained and stimulated in the most appropriate way, leading positive adaptations in this direction.

The series of events that are created when the breath is inefficient, is defined Breathing Pattern Disorders (BPD) or Dysfunctional Breathing (DB): breathing is suggested to be dysfunctional when it is inefficient or when it is insufficient for adapting to environmental conditions and changing requirements of the individual (43).
Dysfunctional Breathing is defined as chronic or recurrent changes in the breathing pattern, contributing to respiratory and non respiratory complaints (167).

The breathing pattern in dysfunctional breathing often includes over-breathing, irregularity and unsteadiness of respiratory effort, predominant use of chest and accessory muscles of respiration during quiet breathing, rather than of the diaphragm, and frequent sighing (81).
The consequences of breathing pattern disorders include different symptoms, including but not limited to neck and head pain, chronic fatigue, anxiety and panic attacks, cardiovascular distress, gastro-intestinal dysfunction, lowered pain threshold, spinal instability and hypertension(29,30).

The major biomechanical factors that contribute to breathing dysfunction include abnormal function of the diaphragm and abdominal musculature as well as hyperinflation (87). If a respiratory muscle is in a hypertonic and shortened state, the effectiveness of its contraction is limited (61,169); this inefficiency in turn leads to increased recruitment of accessory breathing muscles and contributes towards thoracic and paradoxical breathing (87).

Several consequences of breathing dysfunction have been suggested including dyspnoea (59,156), adverse fluid dynamics (11,185), impaired posture and motor control, pain, deep sighing, exercise induced breathlessness, frequent yawning and hyperventilation (29,79).

The function of the respiratory muscles is not limited to breathing. These muscles play important parts in other everyday functions such as swallowing, speech production, the stabilization of the spine for limbs motion (83,84,86,98–100) thanks to an increase of intra-muscular pressure (63,83). As breathing does not cease during most of these functions, a considerable amount of motor control is required to co-ordinate them with breathing (73,149).

This theme related to abdominal and lumbar stabilization through breathing will be discussed in detail during the elaborate.

To gain a more complete picture of DB, biomechanical and biochemical aspects breathing symptoms need to be evaluated (42–44).

There are multiple assessment tools available to evaluate these specific aspects. Measures that assess psychological aspects of breathing and breathing symptoms are questionnaire-based for example the Nijmegen questionnaire (54) and the Self-Evaluation of Breathing Questionnaire (42).

Biochemical and physiological measures are generally instrument-based and include capnography (44,91), breath holding time (48), breathing frequency (62), and spirometry (104).

Finally, biomechanical measures can also be instrument-based for example respiratory inductive plethysmography (RIP) (20), but this aspect may also be evaluated using palpation, as for example in the manual assessment of respiratory motion (MARM) (42–44).

1.2 Qualitative evaluation of movement: Functional Movement Screen^{TM} , Postural Assessment and Manual Assessment of Respiratory Motion (MARM)

To date, there is no “field” assessment which has passed the validation process ,which is reliable taking into account the person in his whole, which provides numerical parameters about the motor efficiency and quality of movement patterns.

In support of this, there is the philosophy introduced in 1995 by Gray Cook and Lee Burton called **Functional Movement System^{TM}** (37–41), which is a functional evaluation used to measure and quantify limitations or asymmetries in movement and provide corrective exercise solutions.

Inside this system there is the **Functional Movement Screen^{TM}** (FMS^{TM}) a screening tool used to identify deficits in human movement patterns that are key to functional movement quality in individuals with no pain or known musculoskeletal injury (37–41).

The Functional Movement Screen (FMS™) is a comprehensive exam that assesses quality of fundamental movement patterns to identify an individual’s limitations or asymmetries.
A fundamental movement pattern is a basic movement utilized to simultaneously test range of motion and stability.
The exam requires muscle strength, flexibility, range of motion, coordination, balance, and proprioception in order to successfully complete seven fundamental movement patterns.

The athlete is scored from zero to three on each of the seven movement patterns with a score of three considered normal. The scores from the seven movement patterns are summed and a composite score is obtained.

The scoring system was designed to capture major limitations and right-left asymmetries related to functional movement. Additionally, clearing tests were added to assess if pain is present when the athlete completes full spinal flexion and extension and shoulder internal rotation/flexion.
The seven tests utilize a variety of basic positions and movements which are thought to provide the foundation for more complex athletic abilities (figure 4).

They are:

- Deep Squat.
- In Line Lunge.
- Hurdle Step.
- Shoulder Mobility.
- Active Straigth Leg Raise.
- Trunk Stability Push Up.
- Rotary Stability.

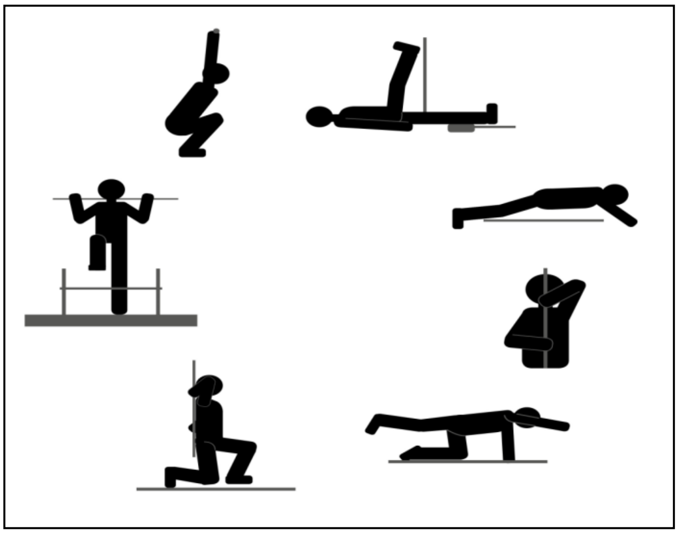

Figure 4: Functional Movement Screen™ protocol.

Current research studied various aspects related on the Functional Movement Screen™ to highlight its validity, reliability in order to prevent the risk of injury and performance optimization.

Reliability of the Functional Movement Screen has been established between and within raters across multiple studies examining of an ICC 0.80-0.98 scores (27,58,65,78,120,139,155).

Other studies have utilized screening statistics to establish a cut off score as being appropriate to identify individuals who have greater odds for sustaining an injury using 0-21 point scale, from <= 14(34,95) and <=16(142).

The differences between these studies are likely associated with the difference in the common magnitude of injuries related to the populations who is examined. Future research is needed with large sample sizes in additional populations to understand what factors on a movement screen are relevant to identify individuals with an elevated risk of injury as well as understanding how additional tests assist in identifying athletes with an elevated risk of injury.

The most widely accepted failure or cut-off score referenced in the literature, when using the 21-point FMS™, is a composite FMS™ score of 14, but it seems that a combination of scoring below the threshold and exhibiting at least one asymmetry are identifiable risk factors (96).

Multiple studies have correlated performance (core stability, vertical jump, sprint time) on the FMS™ with no significant relationships (31,107,138).

The second evaluation is the **Postural Assessment** (92), called morphological mapping (132,133), the precise and meticulous observation of body morphology to highlight asymmetries, segments deviations, muscular compensations and relationships about muscular chains one to each other, compared to an “ideal” prototype (50,92,132).

These postural features that each person possesses (observed in a static position) often tend to recur during a dynamic movement conditioning the correct entire body functions.

The creator of morphological mapping has been the already mentioned Françoise Mézières (132,134) who, through this examination, compares the deformations of the spine (and of the body in its entire) with respect to a morphological normality reference ensuring a criterion of reproducibility in which: the two sides should be symmetrical, the two body’s contours should be rectilinear and oblique with four sites of contact points between the lower limbs (50).

The morphological mapping is a 3D evaluation of subject’s static position in all three planes observing the body from the front side, the lateral sides, the back side, with an anterior toe touch spine flexion and from supine in a spontaneous position (50,133,134).

For reproducibility reasons , during the examination, the subject must remain stationary in a natural and spontaneous, with feet together from heel to toe, arms at your sides and an eye to the horizontal.
Everything is standardized and documented by photographic evaluation of the subject (131,152).

The patient stood in closed stance (with the big toes and heels touching, to ensure reproducibility). No instructions were given or intimated other than the need to look straight ahead and keep the head level.
Frontal, sagittal and posterior analyses were successively performed. This analysis is reproducible with respect to standard reference.

The key parameters documented in the morphological analysis are as follows:

- the symmetry or asymmetry of the body's contours, when viewed from the front and from the rear. Clinically, it is found that asymmetric contours reflect loss of the spine's frontal alignment-
- the sites of contact points between the legs, relative to a specific reference framework (depending on the posture examined). The optimal contact points are the medial malleoli, the upper third of the calves, the medial aspects of the knees and the upper third of the adductors.

- the head–thorax–pelvis alignment, in a sagittal view. This was assessed with respect to a virtual line running from the tragus of the ear to the apex of the skin over the humeral head, the great trochanter, the lateral femoral epicondyle and the base of the fifth toe. The angle of this line with respect to the vertical was also noted.

The third evaluation is a technique called the **Manual Assessment of Respiratory Motion (MARM)**, which can quantify the extent of thoracic dominant breathing as well as other aspects of breathing pattern.

It has been found to have high levels of inter-examiner reliability and to agree with measures made simultaneously with Respiratory Induction Plethysmography (44) and have clinical validity(42).

Normal healthy individuals appear to have balanced breathing with relatively equal motion of upper rib cage to lower rib cage abdominal motion.
The MARM procedure was first developed and applied in a follow-up study of breathing and relaxation therapy with cardiac patients in the 1980s.

The MARM is similar to other breathing assessment techniques that are based on the examiner's interpretation and estimation of the motion of their hands when placed at the posterior and lateral lower rib cage. (43)
The examiners were taught how to perform the MARM and how to record their findings (Figure 5) by drawing lines on a pie chart to indicate their estimation of thoracic/vertical or abdominal/lateral dominance, and by ticking a box to indicate either thoracic or abdominal breathing (44).

However, the MARM is of particular interest as a clinical and research tool because it includes a system of notation that allows the examiner to derive numerical values for two variables related to relative distribution of breathing motion and another numerical variable for area of breathing involvement.
The examiner can also gauge, rate and record their general impressions of breathing regularity, rib cage stiffness and symmetry of breathing.

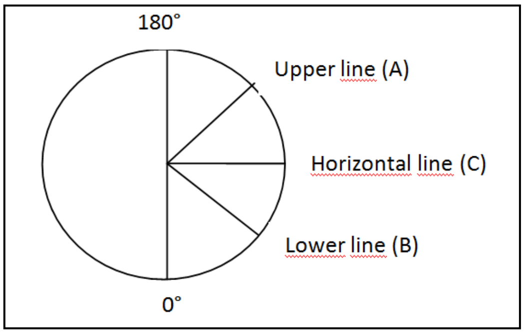

Figure 5: MARM diagram (modified from Courtney et al. 2011)

PART II

Study I: "E*ffects of different core exercises on respiratory parameters and abdominal strength".*

INTRODUCTION

In recent years abdominal training has gained increasing importance and exercises like "crunch" or "planks" have been widely used for both fitting and rehabilitation purposes.

In particular they can improve core stability, which is the ability to strengthen the lumbo-pelvic complex and to transfer forces from the upper to the lower limb of the body maintaining the spine neutral (12,183).

The most common progression model to train the core structures consists in static or dynamic contractions in many positions (supine, lateral) starting with isolate specific movements and continuing with more complex sequences (12,90).

However this kind of exercises, especially crunch or sit-up, are associated to repeated flexions and lateral bending motions which induce vertebral compression with high lumbar overloads, that could be injurious for the spine (28,82,116,163).

Moreover, these type of movements stresses core muscles in a posture which is uncommon for most daily life activities or sports actions.

On the other side, it has also been shown that respiratory muscles are directly involved during the most common core stability exercises (4,49,158).

DePalo et al. found that in many resistance training exercises, like sit-up, there is an active recruitment of the diaphragm (49). Even though it is well established that the respiratory muscles are involved in many non-respiratory activities (4,73,83), the diaphragm is a basic component in the foundation of core structure(83,97,98,100,130); in fact, as to our knowledge, only few publications evaluated the role of breathing when performing abdominal exercises.

Generally, breathing is considered one of the most important basic human patterns(29,63,97) which is directly related to the correct execution of human movement (18); an inefficient breath could result in muscular imbalance and motor control alterations and can modify the movement quality(18): an adequate or inadequate movement quality could be documented by a poor score on the Functional Movement Screen^{TM} (FMS^{TM}).

The FMS^{TM} is an assessment tool purported to identify the quality of human patterns assessing mobility, stability, dynamic balance, and coordination by performing dynamic movements(39,40).

Research confirms that mobility and stretching exercises performed with global postural re-education techniques are advantageous for improving the respiratory apparatus, but also the traditional rehabilitation pulmonary exercises are beneficial for people with breathing pattern disorders or spine pathologies like scoliosis (150).

So, we hypothesized that special manoeuvres based on the combination of global stretching postures and breathing exercises may have a simultaneous consequences on core structure and functional movement.

Therefore, the aim was to evaluate whether this different modality to perform abdominal training, using breathing exercises, would achieve adaptations on abdominal fitness, quality of movement and respiratory function similar to those achieved by traditional exercises (101).

METHODS

Measurements were performed in the laboratory of Biomedical Sciences for health of Università degli studi di Milano. All participants provided written informed consent in which there was explained the objectives and scope of this project, the procedures, risks, and benefits of the study. They could withdraw from the study at any time without prejudice. Procedures were in accordance with the Declaration of Helsinki, and institutional review board (Comitato Etico Università degli studi di Milano) approval was received for this study.

Subjects

Thirty-two healthy, volunteers, male subjects (age 29±3 yr, height 1.74±4 m, weight 68±0.3 kg) free from any pulmonary disease with no previous history of low back pain were enrolled.

Subjects were included in the study if they participated in physical activity at least 3 times a week with a training activity regime composed by aerobic activity at medium intensity (65-75% HRmax) for at least 45 minutes and a resistance training program which included free-weight and machine exercises to 60-70% 1RM for 2 d·wk_1.

Participants (n=32) were randomly assigned into two different groups without dropouts: Experimental Group (EG, n=16) and Traditional Group (TG, n=16).

Training protocols

Two treatment protocols were administered twice a week for 4 weeks.

All exercises were performed after a standardized warm up based on 10 minutes bike.

Both exercises routines had a duration of 15 minutes.

The Experimental Group (EG) exercises were focused on a correct diaphragmatic breathing pattern observing 2,3 seconds for inspiration and 8,10 seconds for expiration with a vocal sound emission, which induces an active recruitment of the pelvic floor and deep internal abdominals(29,145,146):

- N.1: the subject lies on his back with legs extended and arms overhead. On inhalation the subject stretches the arms upward and on exhalation produces a sound from the mouth, maintaining the spine aligned and stretched.
- N.2: the subject sits with the spine erected, with his right leg extended and with his left leg bent at the knee and pressing the sole of his foot into the inner thigh of the extended leg. During inhalation the subject raises his arms up over the head with his palms facing each other. During exhalation the subject produces sound and folds his upper body toward the extended leg hinging at the hips.
- N.3: the subject sits in a knelling position with his buttocks on his heels and his legs are slightly apart; the face is forward with the left arm bend overhead. During exhalation he produces a sound and bends his body laterally to the right-hand side feeling the stretching along the opposite side of the body.
- N.4: the subject sits in a knelling position with the left arm bent in front of his eyes and the right arm on the floor. During inhalation he rotates the trunk to the right without modifying the spine’s curves. During exhalation he produces a sound and remains with the body rotated.

All routine consists of 2 sets per exercise for 6 repetitions.

The Traditional Group (TG) exercises were chosen among a variety of common exercises (101) observing a spontaneous breathing rhythm (1 second for inspiration and 1 second for expiration):

- N1. Crunch: the subject lies on his back with his knees bent, his feet on the floor and his hands on the chest. During inhalation the subject lifts the shoulders off the ground and during exhalation he returns to the starting position.
- N.2 Crunch with rotation: The subject lies on his back with his knees bent and his feet on the floor. During exhalation the subject lifts and rotates the trunk; during inhalation he returns to the starting position.
- N.3 supine bridge: the subject lies on his back with his knees bent and his feet on the floor. During exhalation the subject raises and lifts his pelvis and inch form the floor pressing into the soles of the feet. During inhalation he returns with the pelvis down to the floor.
- N.4 Prone bridge: the subject begins prone in a “table position” with his knees under his hips and his arms under his shoulder; on inhalation simultaneously lifts his right leg straight behind him and lifts his left arm straight in front of him.

The routine for exercise number one and two is 2 series of 15 repetitions and for number three and four, 2 series holding the position for 10 seconds.

In order to guarantee an adequate exercise quality there was supervised by an expert instructor from the beginning till the end of the research period.

Measurements

Respiratory measurements

During the test sessions, the participant was comfortably seated with the trunk at a 90° angle. Pulmonary function was measured with a portable spirometer (Pony FX, Cosmed, Rome,Italy) while the participant was wearing a nose clip. The spirometer volume was calibrated with a 3-L syringe at the beginning of each test. The test was repeated three to five times in order to get at least two acceptable trials (variability below 100 ml). Two-minute rest was left between trials to ensure an adequate recovery. The best trial for each subject was used for analysis. Respiratory measurements were performed according to ERS/ATS guidelines (119).

The same experienced investigator interpreted the data according to established guidelines(143) to obtain a target value for each participant and to ensure that the maneuver had been performed correctly. All parameters were collected at baseline and after six weeks of training: Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV 1), and Peak Expiratory Flow (PEF).

Evaluation of abdominal muscles strength and endurance

Core endurance was evaluated with ACSM Curl-up (cadence) test: the subject lies on his back on mat with his knees bent at 90° and his feet on floor. The arms are extended to the sides with fingers touching a piece of masking tape. A second piece of tape is placed 12 cm beyond the first piece. We set a metronome at 40 beats per minute. At the first beep, the subject lifts the shoulder off the mat by flexing spine until finger tips reach the second piece of tape. At the next beep, the subject slowly returns shoulder to mat by flattening lower back. The subject performs as many curl-ups as possible without stopping, up to a maximum of 75 repetitions (106).

Evaluation of functional movement with Functional Movement Screen^{TM} (FMS)

The FMS^{TM} developed by Cook & Burton(39,40) consisting of 7 basic human patterns: deep squat (DS), hurdle step (HS), in line lung (ILL), shoulder mobility (SM), active straight leg raise (ASLR), trunk stability push up (TSPU), and rotary stability (RS).

The movement competency was quantified as 0 to 3 points–scale based on how the tasks were accomplished: 0 movement with pain, 1 unable to perform the pattern, 2 pattern performed with compensations or imperfections, 3 pattern performed as directed. Instruction

and administration of the FMS^{TM} were completed in accordance with previously published guidelines (39–41) by an FMS^{TM} certified instructor.

Statistical Analysis

Data were entered into a personal computer and All statistical analyses were performed using the Statistical Package for Social Sciences IBM™ SPSS™ Statistics (version 17.0, IBM Corp., Somers, Chicago, USA)

All data are presented as mean ± SD ranges. Results were tested for normal distribution using a Shapiro-Wilk test. Significant changes between before and after treatment in Curl up Cadence test and spirometry were evaluated using paired sample t-test. For FMS^{TM} composite score, due to the rank-order nature of the data, the Wilcoxon signed-rank tests were used. The level of significance was set at $\alpha<0.05$.

Finally, the effect size was calculated by using Cohen's d effect size (*d*) and it was used to examine where significant differences occurred.

RESULTS

All subjects completed their training routine. The experimental Group (EG) showed a statistically significant improvement in all parameters (abdominal endurance, functional movement patterns and pulmonary function) after treatment, while the TG group got only a minor improvement.

Figure 6 panel d shows the results of the ACSM Curl-up (cadence) test. The EG group improved by 23%, from 40±4.1 repetitions at baseline to 52±4.4 repetitions ($p<.05$), after the training period with a "large" effect size *d* (0.98), while the TG increased the number of repetitions by 7.5% from 39±2.8 to 43±3.4.

As a result of pulmonary measurements, in EG group forced vitality capacity showed a significant improvement by 7% ($p<.05$) with a 0.75 large effect size (5.06±0.7 L pre vs. 5.55±0.7 L post), FEV1 and PEF improved significantly by 9.3% and 11.3% ($p<.05$) from 4.15±0.5 L/min to 4.45±0.6 L/min and from 8.53±1.6 L/s to 9.62±1.8 L/s, respectively with a "moderate" effect size (0.69) (figure 6 panel a, b and c).

On the other hand, TG group did not obtain any significant improvement in terms of lung function ($p>.05$). FVC was 4.97±1.0 L at the beginning and 5.06±0.9 L in the end, FEV 1 was 4.03±1 L at baseline and 4.23±1 L after training and PEF was 8.38±3 L/s at baseline and 8.66±2.2 L/s at the end.

Finally, observing figure 6 panel e, it is demonstrated that also the quality of movement patterns is influenced by respiration: EG group had a significant improvement in FMS^{TM} of +44.2% with a "hudge" effect size (1.94) (composite score: 11±2.6 pre training vs. 16±2.0 post training). Also TG group increased significantly, but their amelioration were lower (+6,7%) with a "moderate" effect size (0.54) passing from a score out of 11±1.4 before training to a score of 12±1.7 after training.

DISCUSSION

The main finding of the study is that core exercises performed with the focus on muscular chain stretching and breathing techniques lead to a better improvement in respiratory function, abdominal muscles endurance and quality of movement patterns, compared to conventional one.

The results of this study suggest that a series of core exercises performed with a vocal sound emission, can be a valid strategy for enhancing proper diaphragmatic breathing pattern and deep internal abdominals activation(29,146), much more than common abdominal routines whose tendency is to hold or to produce a chest wall respiration (105).

In agreement with available data, our results show that also traditional core exercises are able to improve pulmonary function, but in the EG group the improvement was even more relevant than in the TG. This difference was expected because the exercises performed by the EG group were specifically designed to train the respiratory muscles.

Moreover, the EG group was superior to the TG not only in terms of improvement of lung function parameters, but also in abdominal muscles endurance.

Surprisingly, although the biomechanics' exercises in the EG was completely different from the evaluation process, the results of the Curl up Cadence test were significantly superior for this group compared to TG.

A possible explanation is that EG exercises performed in a long position with muscular chains stretched led to better flexibility, and so, during the ACSM endurance test, muscles could contract and relax more quickly increasing the number of repetitions.

As regard the biomechanics, the expiration phase promote an active recruitment of abdominals, contrasting the natural elevation of the rib cage (induced by raising the arms overhead); with arms elevated the anterior chest-wall is up, the toraco-lumbar column is hyperlordotic and the diaphragm is in an oblique position inhibiting its proper function.

During the exhalation, the toraco-lumbar spine becomes more neutral (opposing the previous hyperlordosis) and the diaphragm is more horizontal without posterior pelvic tilt(105).

This is promoted thanks to an abdominal muscle's co-contraction called the bracing technique, which ensure trunk stiffness and stability(117,173).

Focusing on diaphragmatic breath, is important not only to re-establish a correct respiratory pattern (29,97), but also to ensure lumbar spine stabilization (83–85,98,100) increasing an activation of the core structures which are important to transfer forces from the centre of the body to the lower extremities.

The EG modality to perform core exercises, not only was more effective than the conventional one, but also are associated other several advantages. First of all the recruitment of deep abdominals increases intra-abdominal pressure and a co-activation of the entire abdominal wall(105), which has a fundamental role in guaranteeing adequate spine support, and trunk stiffess(32,46). Secondly, differently from crunches, there are no repeated flexions with no compressive loads which may be injurious for the vertebrae(28,116,163).

Finally, the spine remains in a neutral posture (105), so abdominals could be trained in a long and normal position, in fact in sports or day life activities, people rarely flex the rib cage to the pelvis shortening the rectus abdominis(116).

CONCLUSION

In conclusion, this modality to stimulate the core muscles would be an easy alternative to traditional exercises, and could be useful for people to improve their overall abdominal fitness status maintaining a neutral spine position without disc compressions, ameliorating the pulmonary function and retraining a correct diaphragmatic function.

Future research is needed to compare breathing-abdominal programs with other core exercises and the role they have in treating painful disorders (low back pain, neck pain) or improving motor control in order to prevent injuries.

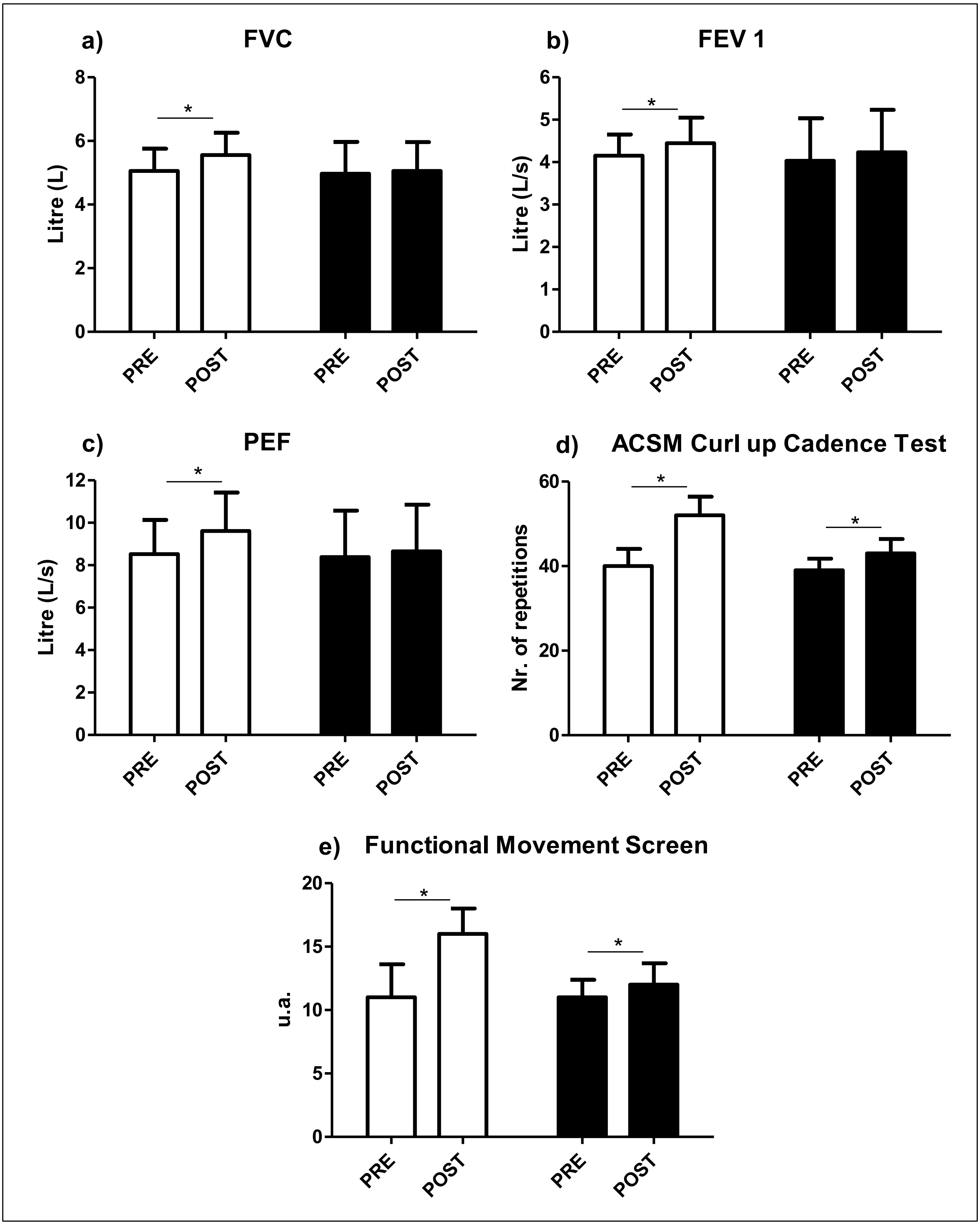

Figure 6: EG group Vs. TG group (*p<.05); panel a) FVC, panel b) Fev1, panel c) Pef, panel d) ACSM Curl up Cadence Test, panel d) FMS Composite Score

Study II: *"Resistance training with blood flow restriction using the modulation of the muscle's contraction velocity".*

INTRODUCTION

An emerging field of study in resistance training (RT) is the development of low-intensity training methods aimed to reduce the mechanical stress on muscle joints as well as keeping or improving the positive adaptations observed with traditional practices of RT.

This trend has been driven by the need to increase the number of potential users of RT by reducing the risks associated with its practice.

In athletes, sometime it is necessary to reduce the intensity of training loads because the mechanical stress on joints associated with common training activities, such as lifting and weight-bearing, if not performed in a progressive way, can increase the risk of injury (5,33,76,125).

The term "ischemia" comes from the Greek language and refers to an absolute or relative shortage of blood supply to an organ. The capacity to tolerate an ischemic condition is organ-specific; human muscle can tolerate ischemia between 2 and 4 hours at normothermia (57). In 1904, Harvey Cushing introduced the pneumatic tourniquet, a device able to compress blood vessels by using a gas source to inflate a cylindrical bladder. This replaced the Esmarch bandage that sometimes induced nerve palsy. The use of the pneumatic tourniquet was essential to restrict blood flow during operations on the lower extremities. Despite the significant increase in safety compared with previous techniques, it became important to study human metabolism during and after tourniquet ischemia, in particular to understand whether the few reported complications were consequences of the direct pressure applied by the tourniquet to a nerve or were consequences of tissue changes.

Sundberg (159) found a greater depletion in glycogen content in FT than in slow-twitch (ST) fibers in the trained leg with a reduced blood flow compared with the control, confirming that glycolytic fibers have to be activated to sustain the required force under hypoxic intramuscular conditions.

Takarada et al. (162) supposed that, if the muscle had been forced to contract during blood flow restriction, thereby reducing the clearance of metabolites by the blood, the intramuscular accumulation of these would have been elevated even with low-intensity exercises.

This confirmed that, even though the same force was generated, BFRRT produced a greater activation level in the muscle, agreeing with the previous findings of Moritani et al (122).

BFRRT is a safe training modality (128) that can be adopted by persons of different age groups and has been shown to increase cross-sectional area (CSA) in older women, highly trained athletes (162) and healthy men (1,184).

Subsequent studies confirmed that plasma GH is greatly increased using BFRRT(66,147,161), leading some authors to speculate that the rapid increase in CSA of muscle fibers often observed after this type of training is mediated by the action of GH on insulin-like growth factor 1 (IGF-1) (1).

However, few recent studies are questioning the role played by GH in enhancing myofibrillar protein synthesis(179,182).

Furthermore, it has been hypothesized that an early recruitment of FT fibers (108,118) together with training to failure (110,112) and cell swelling can be the key factors that explain the positive training-induced adaptations observed with BFRRT.

The majority of the studies investigating BFRRT produced the blood flow restriction with the application of an external mechanical pressure, using a wrapping device like a pneumatic restriction cuff, in the proximal part of the trained muscle.

However, it is also possible to decrease muscle’s blood flow without the application of an external device by considering the physiological role played by the intramuscular pressure and the relaxation time.

THE MODULATION OF MUSCLE OXYGENATION THROUGH THE VELOCITY OF CONTRACTION AND THE REDUCTION OF RELAXATION TIME

Intramuscular pressure and relaxation time

Blood flow during rhythmic muscle contractions involves the alternation between an increase and decrease of arterial inflow. The decrease is due to the amplified intramuscular pressure (IP) during the contraction cycle (both eccentric and concentric phases), whereas the increase is seen during relaxation time i.e. the time elapsed between two successive contractions (178).

Therefore, IP and relaxation play a fundamental role in regulating haematic flow into the muscle.

The relaxation period between contractions also modulates muscle oxygenation because blood flow occurs mainly during this period (8,93).

Therefore, methods that increase IP and reduce the relaxation time between muscle contractions are an alternative way to create a hypoxic condition without using an external mechanical device.

The role of the speed of contraction on modulation of muscle oxygenation

In 2005, Tanimoto et al.(164) compared the muscle oxygenation levels and La concentrations between BFRRT using external mechanical compression and three other types of exercise regimens.

In their study, six young, male bodybuilders and power-lifters performed three sets of knee extensions with an inter-set rest period of one minute using four different protocols:

1. BFRRT with low-intensity exercise at 30% 1 RM with vascular occlusion through a specially designed elastic belt, performed at normal speed (1 second for lifting, 1 second for lowering).
2. Medium intensity exercise at 50% 1 RM with slow movement (3 seconds for lowering, 3 seconds for lifting, 1 second pause and no relaxation phase) and tonic force generation (LST);.
3. High-intensity exercise (HI) at 80% 1 RM performed at the same speed as BFRRT.
4. Isometric exercise at 50% 1 RM that consisted of keeping a 45° knee angle for 56 seconds, the same load as LST exercise (ISO).

All exercise regimens produced a large decrease in muscle oxygenation, compared with resting levels, but only BFRRT, LST and HI caused an increase in La^- production.

This study confirmed that performing RT at low intensity with a slow contraction speed effectively decreases muscle oxygenation and increases blood lactate. However, as outlined by the authors, if the speed of contraction becomes too slow, the mechanical force produced will be insufficient to give rise to increased lactate concentrations.

High metabolic accumulation, due to changes of intramuscular environment, can enhance the adaptive stimulus given by muscle's blood flow restriction(109,112).

Based on the results of their previous studies (164), Tanimoto and Ishii proposed a moderate intensity (~50% 1 RM) RT that was designed to fulfill the need for a sustained contraction with concomitant high production of force, using a contraction modality of 3 seconds for both the eccentric and the concentric phase of the movement with a 1-second pause and no relaxation time. They called this modality LST, referring to the intensity of the external load, the slow speed of the movement and the tonic force generated.

Loenneke and Pujol (2009) suggested that, in order to produce an increase of hypertrophy, to respect an intensity of 20% 1RM for 3 to 5 series lead to volitional fatigue with shorts rest periods (111).

Several studies showed that the variation of the time between the eccentric and concentric phase of the muscle's contraction produces specific fiber type adaptations as well as mitochondrial and sarcoplasmatic protein synthesis (21,154).

Several studies have confirmed the capacity of this method to increase muscle size and strength, both in single and multi-joint exercises(165).

SUMMARY AND CONCLUSION

According to the disposable studies in literature, neuromuscular and metabolic benefits related to BFRRT, could be reached through the modulation of the velocity of muscle's contraction.

The phenomenon, associated with blood flow restriction, can help coaches to reduce the intensity and volume of RT without losing the benefits associated with its practice.

Coaches can modulate blood restriction by simply increasing the duration of the concentric and eccentric phases of movement and by reducing the relaxation time (the pause between full repetitions).

It’s also fundamental to underline that the slow speed of muscle action is a very important aspect of strength training regarding the *qualitative* aspects of movements, because it improves body control, reduces strength asymmetries and increase the body perception.

Thus, it is more correct to refer to an optimal zone for the duration of the repetition leading to a prolonged time under tension coupled with a relatively significant number of repetitions that will lead to an adequate metabolites accumulation into muscle.

A load at 50% 1 RM at slow speed is adequate to generate a sufficient IP that can immediately reduce the muscle’s blood flow while heavier loads would rapidly lead to fatigue and to an increasing difficulty of the trainee in maintaining an adequate exercise duration.

PART III

Study III: "From Bronze to Gold: A Gentle Approach to the Functional and Muscular Enhancement of an Elite Paralympic Swimmer"

3.1 INTRODUCTION

In recent years, from the first Paralympic Game in Rome in 1960 (171), this Movement has increased in popularity stimulating a great interest not only among people with disability, but also among educators, sports scientists and coaches (94).

Educators are interested in encouraging the practice of sport among people with disability because of the many beneficial effects on functional capacity, health promotion, relationship, and motivations aspects, which are crucial to achieve a better quality of life (22,25,88,181).

Sport scientists and coaches are interested in developing and applying specific training approaches to enhance the performance of athletes with disability.

Few studies have focused on Paralympic swimming and most of them investigated biomechanical or training methodology aspects (23,47,52,53,67,69,70,137,148).

it is demonstrated that in people with problems at the level of spinal cord injury (depending on the anatomical site of the injury) can have consequences in the respiratory tract (35,103,123,177) with a different distribution in muscles to control body to compensate for the loss of postural function (172).

Athletes with amputation have greater difficulty in maintaining the balance tends to fluctuate more with a marked reduction in proprioceptive control and muscular strength (172).

The Paralympic athlete with a limb amputation may have an impaired ability to hold an effective streamline (arm amputee) or an inefficient single-leg kick (leg amputee). Moreover amputees may have muscle imbalances and asymmetries of power in some area of the body; not yet known whether because of the type of sport or whether it is a

consequence of the type of disability (135).
The ability to express force may be penalized by a loss of the same stroke in the entire chain muscle because of asymmetries present: if there is a lower strength, coordination, and control the applied force will be dispersed to overload going to other areas of the entire muscle chain by implementing adjustments engines compensation (172).

Amputation athletes are naturally asymmetrical and may find more difficult to maintain balance, tending to oscillate more as they correct their balance, resulting in a less effective streamline position.
The ability to produce force and actual force propulsion may differ due to the loss of energy throughout the kinetic chain, i.e., if there is loss of strength, coordination or range of motion force will be lost or dissipated from the kinetic chain.
This loss may increase load on other areas or links in the kinetic chain, potentially leading to injury as a result of change of load on a particular structure or the result of a compensatory strategy (172).

Traditional dry-land swimming training is basically focused on strength training with high loads, few repetitions (from one to six) with emphasis on the concentric phase in major muscle groups (7).

One drawback of this approach is that, as the volume and intensity of training increases, the occurrence of injuries become more and more likely. An injury can jeopardize the entire swimming season and may become source of intense frustration.

In addition, a recent study by Fulton et al.(71) has pointed out that, contrary to expectation, swimmers who experience the greatest improvements in performance between competitions tend to train at lower volumes and intensities than swimmers with smaller improvements.

This counterintuitive finding provides justification for exploring alternative, non conventional training approaches.

As regards competitive sport for people disabilities, the International Paralympic Committee (IPC) offers guidelines and a classification based on function and health (171).

In swimming the functional classification is based on different classes in order to ensure the athletes with different types of disabilities to participate in competitions which are the most possible balanced.

Regardless of the type of disability (locomotor, visual or intelletual) for each athlete is attributed score corresponding to the functions that can still express and then he is inserted into one of the 14 classes.
Locomotor impairments are grouped for classes: class 1 the most severe disabilities, and class 10 the least severe disabilities.
Swimmers with a visual impairment are in classes 11-13. Athletes with intellectual impairment form class 14.
Inside the locomotor impairment classes there are a large range of physical disabilities that affect the whole body (e.g. cerebral palsy, leg amputee or spinal-cord injury, arm amputee, etc). The lower is the class, the less residual capacity has got the swimmer.
The swimming disability classes are:

- S for backstroke, front crawl and butterfly (S1-S14)
- SB for breaststroke (SB1-SB14)
- SM for individual medley (SM1-SM14)

Following this line of thought, the aim of this report is to describe a novel, gentler training strategy that was customized on the needs of three top-level Paralympic class swimmers we coached (one male S9-SB8-SM9, two women S7-SB6-SM7 and S5-SB4-SM5)

We placed emphasis on postural and breathing exercises capable to re-align and stabilize the athlete and resorted to slow-velocity resistance training with light-moderate loads to enhance his muscular strength.

We monitored the functional and strength features throughout two years of training, from the Paralympic games in London in August 2012, passing through the IPC World Championships in Montréal in 2013, to the to the IPC European Championship in Eindhoven in August 2014.

3.2 MATERIAL AND METHODS

The current research is a field descriptive observational study from 2012 to2014.

The first subject (S1) is a top-level male Italian swimmer (21 yr, 1.74 m height, 60 kg weight, 19.8 BMI) with a diagnosed congenital femoral hypoplasia in the left leg belonging to class S9-SM9.

The second subject (S2) is a top-level female Italian swimmer (20 yr, 1.69 m height, 60 kg weight, 21.0 IBM) with a diagnosed congenital spasticity called "Strumpell-Lorrain" belonging to class S7-SB6-SM7.

The third subject (S3) is another top-level female Italian swimmer (20 yr, 1.70 m height, 50 kg weight, 17.3 IBM) with a diagnosed spinal cord injury belonging to class S5-SB4-SM5.

The S1 disability leads to a non alignment of the pelvis, spine, and scapulas, with negative repercussions on biomechanical swimming ability and injuries such as an imbalance of the hands on entry to the water (butterfly stroke), limited trunk rotation on the right side (front crawl stroke), and frequent functional overload injuries on the right side.

Note that a swimmer with a lower-limb amputation should be able to maintain a similar stroke rate and stroke length profile as the able-bodied swimmer. However, the timing and type of kick during swimming techniques may vary.

The S2 disability leads to a muscular dystonia, presence of hyper excitability of muscle contraction in the absence of motor overactivity, co-contractions and spasms, augmented muscles tone at rest, inefficient fiber recruitment, lack of modulation of muscle action velocity, altered proprioception, altered sensory effort perception and poor flexibility.

Finally, S3 disability leads to a respiratory system dysfunction, an inability to use the lower limbs and limited trunk stabilization. A swimmer with a SCI injury has several factors to consider: avoiding to overload the shoulders because the athlete relies and uses the shoulder everyday to propel their wheelchair (a possible shoulder injury, daily mobility will be impaired). he/she also spends the majority of the day in a wheelchair, and when coupled with the low stimulation to the lower limbs, developing a "fixed" contracture at the hips.

In the prone freestyle, breaststroke, and butterfly strokes, this fixed hip contracture will create an excessive frontal drag profile and significantly affect the swimmer. In the supine backstroke position, the upright fixed hip position will exaggerate body roll and further challenge the limited abdominal control.

All subject provided informed, written consent to participate in this study, which was approved by the Ethical Committee of Università degli Studi di Milano, Italy.

Dry land Training Program

The subjects underwent a dry-land training program to increase strength, body control and flexibility.

Three times per week (Monday, Wednesday, Friday) for 9 months (from 1st October 2012 to 30th June 2014) the three swimmers performed exercises aimed to enhance their residual motor skills through a balanced improvement of the morphological alterations (identified with morphological mapping (50,133) associated with their disability.

The training program comprised (i) body alignment with a re-balance of muscular chains by global postural re-education(50,134,166). The starting position for the postures is varied and it's not possible to do an not exhaustive list, but the most commonly used are: lying supine with the lower limbs to the ground or raised vertically, upright with the spine to the wall, sitting with lower limbs elongated.

(ii) motor control with diaphragmatic breathing (e.g. lower rib cage-abdomen in lateral-posterior expansion in supine, kneeling or four kneeling positions with muscular chains overstretched, observing 3 seconds for inhalation, 8 seconds to exhalation amplifying it by a vocal sound emission, finally remaining 4 seconds in apnea) and (iii) neuromuscular stabilization (63,97) and dynamic motor control to re-establish the correct motor patterns (e.g. D1 Flexion with cable system using PNF principles, Deadlift Single Leg valgus correction with elastic band, Modified Bear Squat, Quadruped Rocking. All of them with "Bracing" technique in order to stabilize and centre joint position).

The training routine also included a slow-velocity (3) resistance training with global movements and specific multi-joints exercises with light-moderate loads aimed to improve the athlete’s muscle strength (e.g. bench press with 50%1RM observing 5 seconds both in concentric and eccentric phases without rest periods).

Intensity of the training varied from 50% 1RM to 90-95% 1RM through the mesocycles.

Physical, postural, functional and breathing assessment

Functional Movement Screen (FMS^{TM}) was used to document the functional profile proposed by Cook et al.(39–41). We used only 5 out of 7 tests (deep squat, shoulder mobility, active straight leg raise, trunk stability push up and rotary stability) and thus the maximum achievable Composite Score was 15. The FMS was applied three times, two weeks before the Paralympic Games held in London during August 2012, two weeks before the IPC World Championship held in Montréal during August 2013 and two weeks before European Championship in August 2014.

A Morphological Analysis(50) was carried out on the photos(131,152) taken at the beginning, after one year, and at the end of the two-year period of training.
We also evaluated, starting from a lateral view, the forward head position using four markers placed on the relevant anatomical landmarks of the subjects. They were: Heads Tilt (HT) angle between the forehead-to-tragus line and the y-axis, the Neck Flexion (NF) angle between the tragus-to-C7 line and the y-axis and the Forward Shoulder angle (FS) measured as the angle between the line connecting C7 and the end of the acromion and the y-axis(129,160).
All images were examined using the Kinovea an open-license easy to use video analysis software (Kinovea 0.8.21 for Windows; available at http://www.kinovea.org).

In order to evaluate *strength* parameters we used a *vertical jump* test: the countermovement jump with arm swing (CMJas) because it has got a high correlation with the dive start velocity.

The height was assessed using an infrared validated device, namely the Optojump system (14,75) (Microgate, Bolzano, Italy).

Such strength parameters were assessed in three different occasions: December 2012, August 2013 and August 2014.

The *Manual Assessment of Respiratory Motion (MARM)* is a clinical tool used to assess breathing pattern that has been shown to have clinical utility and validity (42,43).

Here a description of the MARM: the examiner sits behind the subject and places their hands on the lower lateral rib cage. The hands rest firmly but do not direct or restrict breathing motion. The hands are comfortably open with fingers spread so that the little finger approaches a horizontal orientation and the thumbs are approximately vertical. The examiner's lower fingers are below the lower ribs to feel abdominal expansion.

The examiner makes an assessment of the overall vertical motion relative to the overall lateral motion.

Simultaneously they evaluate to what extent the motion is predominantly upper rib cage, lower rib cage/abdomen, or in balance.

The examiner then draws two lines (figure 5 chapter 2.2) : an upper line (A) represents the degree of vertical and upper thoracic motion and the lower line (B) represents the degree of lower ribs and abdominal motion.

The horizontal line (C) represents the thoraco-lumbar junction.

A number of variables can be derived from the MARM procedure: the first of these is % rib cage motion (area above horizontal line (AC) / total area between upper line and lower line (AB) *100) and the second is the MARM balance (Difference between angle made by horizontal axis (C) and upper line (A) and horizontal line (C) and lower line (B).

This type of assessment has been introduced only recently (in October 2013) and is useful to support and confirm the results previously carried out.

3.3 RESULTS and DISCUSSION

3.3.1 Postural Assessment with morphological mapping

Table 1 with figures n. 7, 8 and 9 shows the degrees anterior head displacement measured at the beginning and at the end of each year from the sagittal view.

- S1:

in the three years from 2012 to 2014 obtained a percentage increase in the position of the head, neck and shoulders finding more and more alignment and linearity.
There is a trend towards improvement HT (55.3 , 57 ° and 55.3 °), a swing in the inclination of the NF (from -11.8% from 2012 to 2013, + 4.2% between 2013 and 2014 and -7.2% from 2012 to 2014) and finally a net improvement in the protraction forward of the shoulder girdle (FS) of + 42%.
The HT it has gone from a percentage decrease of 3.1% in the first year, and then got to the values of stabilization between 2012 and 2014. There has been a swing in NF (from -11.8% in 2012 to + 4.2% in 2013), and a net improvement in FS (58.6 °, 21.2 ° and 26.7 °).

- S2:

between 2013 and 2014, has slightly worsened in HT (from 65,8a 69.2 °), while it improved in NF (+ 19.5%) between 2013 and 2014, increasing from 46.7 ° to 37.6 °.
in FS there was a drastic improvement (from 32.1 ° to 15.4 ° from 2012 to 2014) with a peak value in the mid-year (43.4 °); this oscillating trend could be due to the physiological changes in the regulation of muscle tone of the tonic postural system typical of the disability of this athlete.

- S3:

obtained an increase of + 12.2% in Head's Tilt (76.9° pre Vs. 67.5° post), + 3.9% in Neck Flexion (from 33.3° pre Vs. 32° post) and + 42.6% in the Forward Shoulder position.

S1						
Angles	**year 2012**	**year 2013**	**year 2014**	**Δ %2012–2013**	**Δ %2013–2014**	**Δ %2012–2014**
head's tilt	55,3°	57°	55,3°	-3,1	3,0	0,0
neck's flexion	27,9°	31,2°	29,9°	-11,8	4,2	-7,2
forward shoulder	58,6°	21,2°	26,7°	63,8	-25,9	54,4
S2						
Angles	**year 2013**	**middle2013**	**year 2014**	**Δ %2013–middle**	**Δ %middle–2014**	**Δ %2012–2014**
head's tilt	65,8°	67,7°	69,2°	-2,9	-2,2	-5,2
neck's flexion	46,7°	33,1°	37,6°	29,1	-13,6	19,5
forward shoulder	32,1°	43,4°	15,4°	-35,2	64,5	52,0
S3						
Angles	**June 2014**		**October 2014**		**Δ %**	
head's tilt	76,9°		67,5°		12,2	
neck's flexion	33,3°		32°		3,9	
forward shoulder	46,9°		26,9°		42,6	

Table 1: Forward Head Posture Assessment rear view

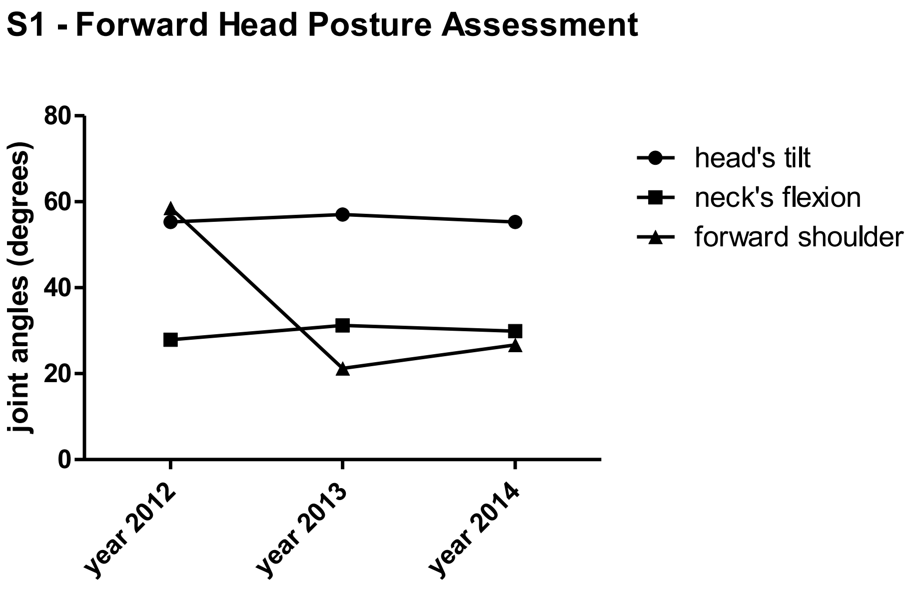

Figure 7: Forward Head posture assessment athlete S1

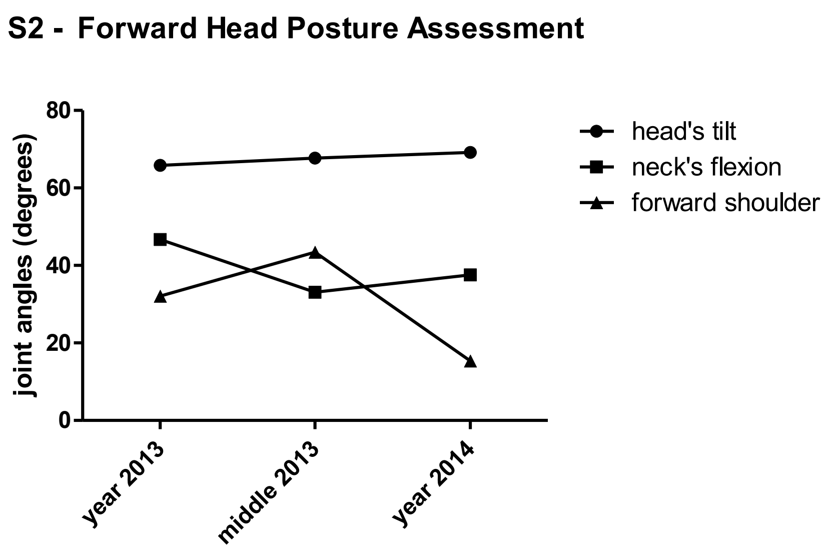

Figure 8: Forward Head posture assessment athlete S2

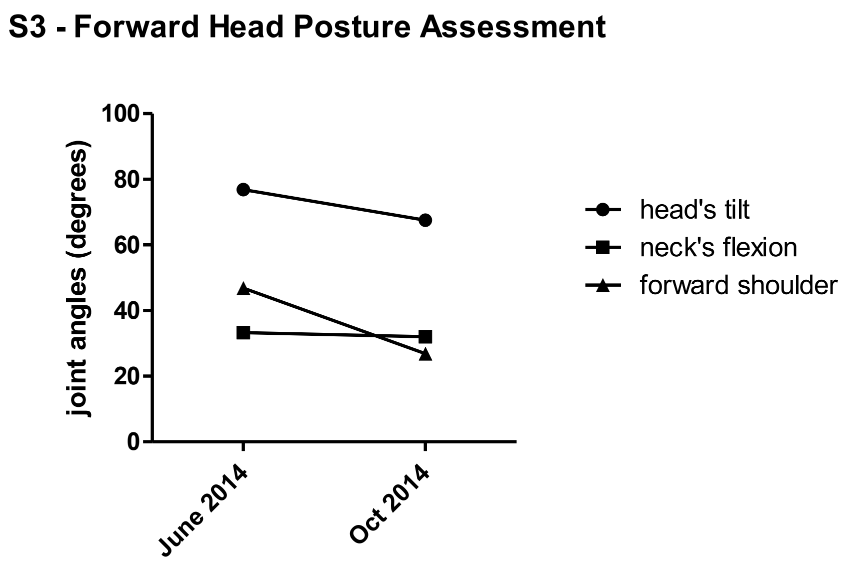

Figure 9: Forward Head posture assessment athlete S3

In Tables n. 2, 3, 4, 5, 6, 7, 8, and Figures n. 10, 11 and 12 is entirely described the morphological examination.

S1 – FRONTAL view		
post Paralympic Games (Oct 2012)	**post World Championship (Oct 2013)**	**post European Championship (Oct 2014)**
HEAD -lateral right tilt level I		
NECK -Right nekc-shoulder angle more closed level I		
SHOULDERS -Protraction right shoulder in a high and forward direction - left shoulder in a down direction - bilateral medial rotation of the humerus level II -right shoulder elevated	-head less in left rotation -head's tilt decreased -reduction in neck-shoulder angle closure	-improvement in neck and head position in a more centred way -Trapezius muscle's profile less prominent
CLAVICLES -left clavicule in an horizontal position with SCC joint clearly visible -sternal part of right clavicule more depressed		
TRUNK - Left thorax more protruted -Asymmetry in iliac crests: the left part more concave il thoraco-lumbar tract; the right part more concave in the lumbar tract	-left clavicle more visible - rigth clavicle less anteriorly rotated	-better simmetry in shoulder position -thorax less protruded
UPPER LIMBS -left homerus more medially rotated -bilateral pronation of forearms but more apparent in the rigth segment	-left shoulder less elevated -left thorax less prominent	-simmetry in breast profile -body's contour's more simmetry
BODY'S CONTOUR -the rigth lateral shape is shorter starting from the iliac crest to the breast profile -the left lateral shappe is longer starting from the iliac crest till the	-counter balance rotation of right thorax -bilateral humerus less medially rotated	-rigth part of pelvis less anteriorly rotated

spine of the scapula		
PELVIS -the left part (prothesis) seems more elevated -the right part seems more anteriorly rotated with a projection of ASIS		
LOWER LIMBS -knee in recurvatum with patella externally positioned -distal part of tibia more externally rotated -foot in supination		
S1 – REAR view		
post Paralympic Games (Oct 2012)	**post World Championship (Oct 2013)**	**post European Championship (Oct 2014)**
HEAD -lateral right tilt level I -lateral right rotation level I	-	
NECK -Right Nekc-shoulder angle more closed level I - left Trapezius muscle's profile more prominent - vertebrae C7 more prominent -cervical left lordosys at C7 level	-head less in left rotation -head's tilt decreased	-better shoulder simmetry -Trapezius muscle's profile less prominent
SHOULDERS -Protraction right shoulder in a high and forward direction - left shoulder in a down direction - bilateral medial rotation of the humerus level II -right shoulder elevated	-reduction in neck-shoulder angle closure - better symmetry in shoulder blades position with the left one more elevated	-better alignment of inferior bord of scapula with less noticeable medial bord -better direction of lumbar lordosis
SHOULDER BLADES -left side: medial bord of scapula more prominent level I -right side: inferior bord of scapula	-medial bord of left scapula less noticeable -bilateral Homerus less medially	-better alignment in body's contour's -iliac crests more simmetry

more depressed. Internal bord more noticeable level II -infrascapular lordosys more with a right curvature	rotated -thoraco-lumbar lordosis better centred always in a right direction - less lumbar “coup-de-hache” with an symmetry in the iliac crest ’ s high -knee less medially rotated	
TRUNK - Asymmetries in thorax contours; left side with a lumbar “coup-de-hache” - Lumbar lordosis pronounced in left direction with a lumbo-sacral apex		
UPPER LIMBS left homerus more medially rotated -bilateral pronation of forearms but more apparent in the rigth segment		
PELVIS -the left part (prothesis) seems more elevated -the right part seems more anteriorly rotated with a projection of ASIS		
LOWER LIMBS knee in recurvatum with medial femoral condyles internally rotated -distal part of tibia more externally rotated -foot in supination		

Table 2: frontal and rear view morphological mapping athlete S1 in erected posture

S1 – SUPINE position		
post Paralympic Games (Oct 2012)	**post World Championship (Oct 2013)**	**post European Championship (Oct 2014)**
-right head’s tilt -shoulders are elevated to the ground -bilateral upper limb medial rotation -right clavicle more visible -left thorax more elevatd -lower part of right costal arch more	-less head’s tilt -thoraco-lumbar lordosis better positioned -left thorax less elevated -lower limb without noticeable variations	-head more centred -thoraco-lumbar lordosis better positioned in the body without any apex -better simmetry in costa arches -foot less in supination

depressed -lordosis apex in thoracolumbar site -superior part of right tibia externally rotated -foot in supination		

Table 3: Morphological mapping athlete S1 in supine position

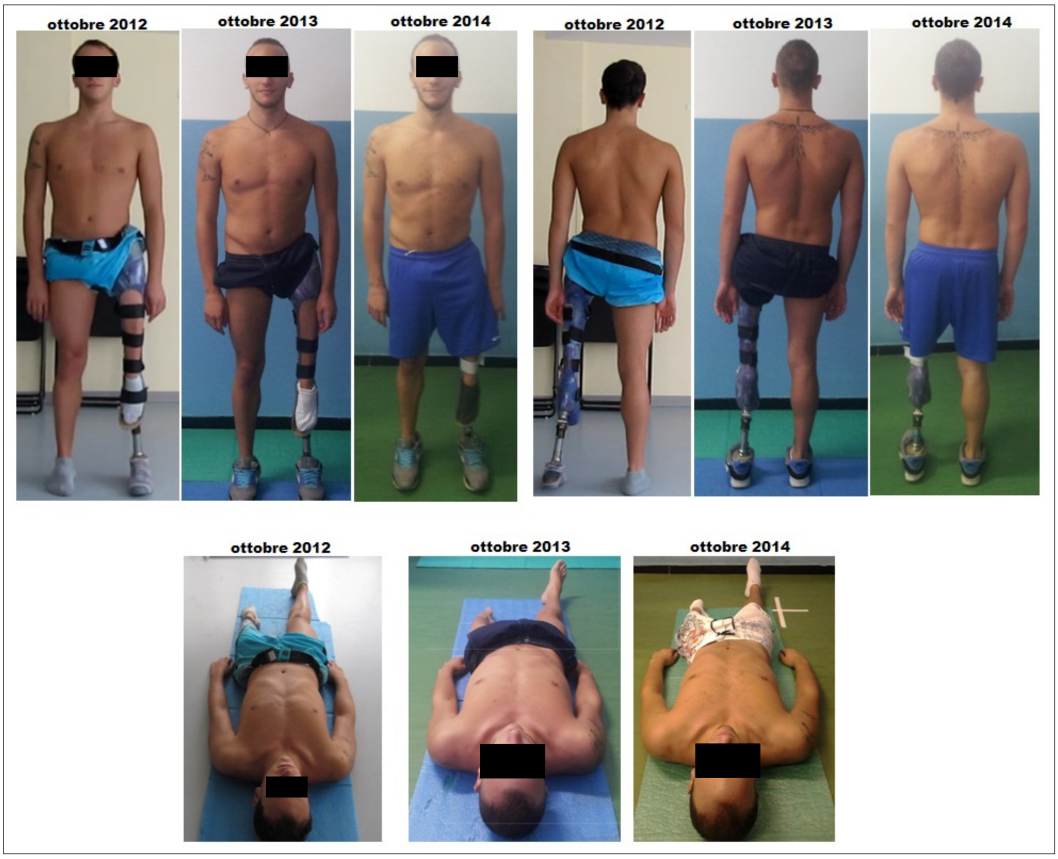

Figure 10: Photographic analysis in athlete S1

S2 – FRONTAL view		
post World Championship (Oct 2013)	**Middle period (april 2013)**	**post European Championship (Oct 2014)**
HEAD -lateral right tilt level I		
NECK -Right nekc-shoulder angle more closed level I		
SHOULDERS		

-bilateral medial rotation of the humerus level II -right shoulder elevated	-less head's lateral right tilt (moderate counter-rotation on the other side)	-lateral left head's tilt level I
CLAVICLES -bilaterally depressed		-right shoulder is in a lower position -left shoulder elevated with left humerus medially rotated
TRUNK -right thorax more pronounced and right rotated	-left SCC joint visible -Right nekc-shoulder angle less closed	
UPPER LIMBS -right medial rotation of the humerus more pronounced -right forearm in pronation -moderate supination left forearm	-right shoulder less elevated -better simmetry of body's contour's	-left thorax pronounced and rotated -body's contour's are inverted compared to October 2013
BODY'S CONTOUR -right side more longer extended from iliac crest till the breastbone - the left side is more vertically orientated	-right hip less rotated -lower limbs in a better position: left knee in a normal position	-lower limbs in a better position with knees aligned
PELVIS -the right hip seems left rotated **LOWR LIMBS** -right knee in recurvatum -right tibia more externally rotated -left knee in flexum with foot in pronation - bilateral hallux valugs level III -lack of balance perception	- foot better positioned - more balance perception	

Table 4: Table 2: frontal view of morphological mapping athlete S2 in erected posture

S2 – REAR view		
post World Championship (Oct 2013)	**Middle period (april 2013)**	**post European Championship (Oct 2014)**
HEAD -lateral right tilt level I **NECK** -Right nekc-shoulder angle more closed level I **SHOULDERS BLADES** -the right scapula is pulled back and down -the left scapula is forward rotated **TRUNK** -right side more longer extended from iliac crest till the breastbone - the left side is more vertically orientated **UPPER LIMBS** -left arm forward rotated -right humerus more internally rotated **PELVIS** -left hip more elevated -left hip is right turned **LOWER LIMBS** -left knee more medially rotated - right knee in recurvatum	-medial bordo f left scapula more noticeable -counter right body rotation -thoraco-lumbar lordisis extended till the neck -right shoulder less elevated -forearms less medially pronated -better simmetry body's contour's -left hip less rotated -left knee in a normal position (neither recurvatum, nor flexum) -feet in a better positon -perception of a better balance	-head more aligned -thoraco-lumbar lordosis less pronounced -better shoulder blades simmetry -left hip elevated -bilateral knee are less in valgus

Table 5: rear view of morphological mapping athlete S2 in erected posture

Figure 11: Photographic analysis in athlete S2

S3 – FRONTAL view	
pre European Championship (June 2014)	**post European Championship (Oct 2014)**
HEAD - right tilt inclination level I - right tilt rotation level II	
NECK -Right nekc-shoulder angle more closed level I -physiological neck lordosis seems to be in an inverted position	-less right head's tilt inclination -less right head's tilt rotation
SHOULDERS -left shoulder elevated and forward rotated -left shoulder pulled back and down -bilateral prominence of Trapezius muscle's profile	-SCC joint bilaterally noticeable -left shoulder more elevated -right hip position is unchanged
CLAVICLES -the right one is more oblique and forward rotated -the left one is posteriorly rotated	-better body weight position on the left ischium

TRUNK -left side pronounced and rotated -inferior part of left costal arch noticeable	
UPPER LIMBS -bilateral humerus medially rotated	
BODY'S CONTOUR -the right side is shorter - the left side is longer	
PELVIS - theleft hip seems rotated -the body weight seems greater on the left ischium	

Table 6: frontal view of morphological mapping athlete S3 in sitting position

S3 – REAR view	
pre European Championship (June 2014)	**post European Championship (Oct 2014)**
HEAD - right tilt inclination level I - right tilt rotation level II	- less right head's tilt inclination -less right head's tilt rotation - infrascapular lordosis unchanged -left side rotated in a right direction -better body weight position on the left ischium
NECK Right nekc-shoulder angle more closed level I -physiological neck lordosis seems to be in an inverted position -infrascapular lordosis more pronounced	
SHOULDERS -bilateral humerus medially rotated; right level II, left level I	
SHOULDER BLADES -medial left bord slightly evident	
TRUNK -left side forward rotated	

UPPER LIMBS - bilateral humerus medially rotated	
PELVIS -the body weight seems greater on the left ischium	

Table 7: rear view of morphological mapping athlete S3 in sitting position

S3 – SUPINE position	
pre European Championship (June 2014)	**post European Championship (Oct 2014)**
- right head's tilt inclination -physiological neck lordosis seems to be in an inverted position - shoulders are elevated to the ground -right hemithorax more elevated -right elbow in recurvatum -right body contour more concave -body weight seems to be more on the left side -right ASIS more elevated	**-** head more centred -right elbow less in recurvatum -body's contour's more symmetrical -body weight seems to be more symmetrical (slightly shifted on the right side)

Table 8: Morphological mapping athlete S3 in supine position

Figure 12: Photographic analysis in athlete S3.

3.3.2 Functional Movement Screen™

The results obtained from the FMS™ confirm what the feedback that the static evaluation (postural assessment) had shown (Figure 13).

- S1:

The total Composite Score improved from 16 u.a. to 18 u.a. in a year (from June 2012 to June 2013) and from 18 u.a. to 20 u.a. in the next year (June 2013, June 2014).
In detail, the static and dynamic capacity to stabilize the spine is improved (Trunk stability Push Up and Rotary Stability) passing from average value of 2 u.a. to the maximum value of 3 u.a.; above all this amelioration in observed especially in the left area of the body (the prostheses side), while the right side was already stable and this stability was maintained.

From June 2012 to June 2014, the shoulder mobility (right and left side) and pelvis (ASRL) remained unchanged, reaching at high levels, while as regards the Deep Squat has improved over time: from a lower score of 1 u.a., then this ability increased with an average values of 2 u.a. (from June 2013 to June 2014).

- S2:

From June 2012 to June 2014 we can observe an improvement in overall Composite Score from 9 u.a. in 2012, from 10 u.a. in 2013 and 11 u.a. in 2014. Analyzing the individual score we can denote a bilateral restrictions in mobility of shoulders and hips; Shoulder Mobility and Active Straigth Leg Raise score remained at 1 u.a. through the years with only small improvements. Probably the ameliorations did not increase enough to drop from a score of 1 to a score of 2 and this may be due to the type of disability.

Finally, the ability to stabilize the trunk (Rotary Stability) is slightly improved over time starting from a low score of 1 u.a. coming to an average value of of 2u.a. from both sides.

Even the ability to control the lumbar (Trunk Stability Push Up) obtained small improvements getting a score of average of 2 u.a..

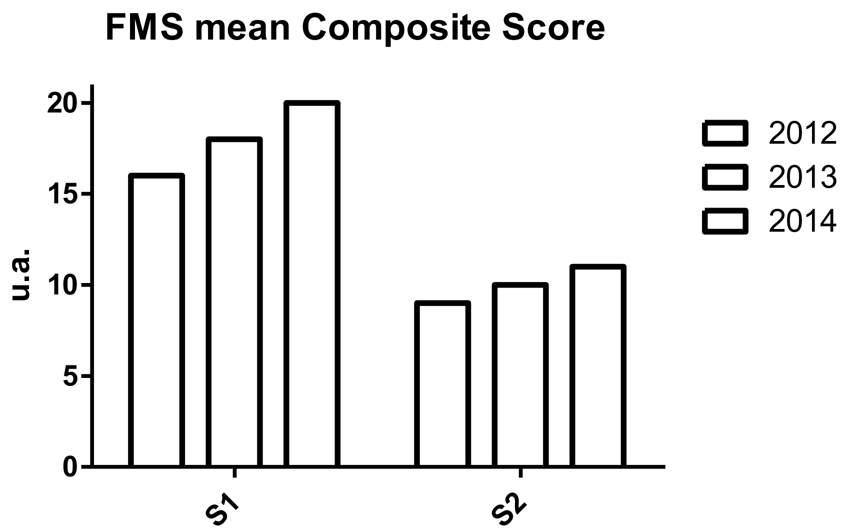

Figure 13: FMS composite score

We have also, the mean values of functional movement (expressed as overall Composite Score) collected in the three different distributions of able-bodied professional subjects: basketball players (N = 17), rugby players (N = 26) and football players (N = 21) compared to S1.

It is interesting to note that the score of S1 is perfectly placed inside the samples distribution, and its doesn't remain on the on the border.

Observing the average value of S1 the composite score we can affirm that this value is greater than team sports: + 31.6% compared to soccer players, + 37% compared to basketball players and + 17% compared to rugby players (Figure 14).

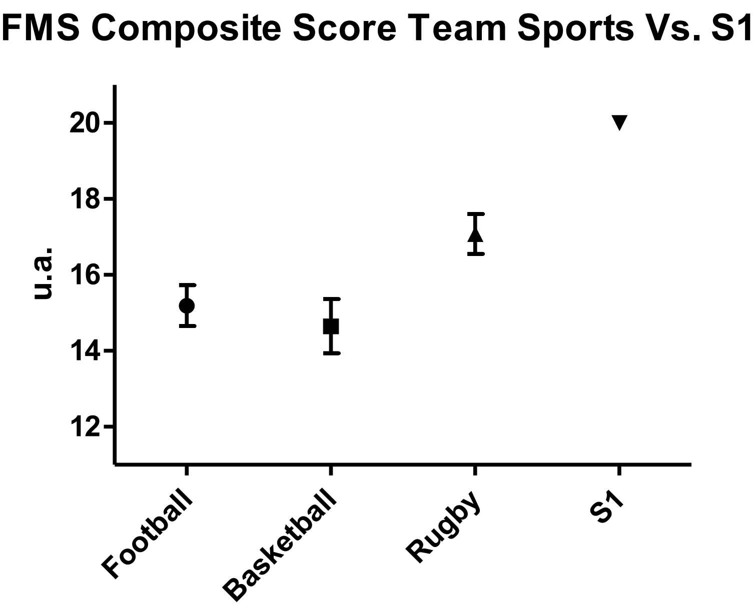

Figure 14: FMS Composite Score S1 compared to team sports

3.3.3 Muscular strength and Manual Assessment of Respiratory Motion

- S1:

Figure 15 shows the results obtained for **muscular strength**. The height of vertical jump in countermovement one leg with arm swing was 26.5 cm in October 2012, it's increased to 27.3 cm in February 2013 until reaching 30.1 cm before the World Championships in Montreal (June 2013).

In the next year, there was a physiological decline in jump in height (corresponding to the transitional period between the two seasons from june 2013 to october 2013), obtaining a value of 25.8 cm in October: the jump height subsequently increased to 27.9 cm in February 2014 till reaching 31 cm in June 2014 (just before European Championships in Eindhoven).

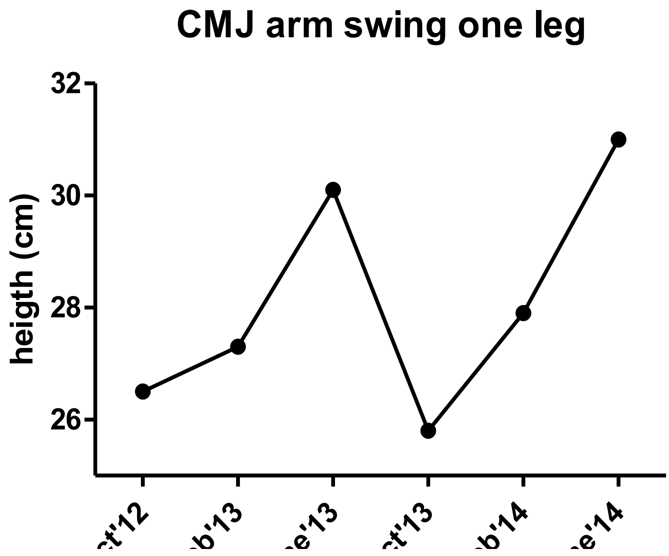

Figure 15: CMJ in one leg stance with arm swing athlete S1

Analyzing the jumping values expressed by able-bodied football, rugby and basketball players we can observe that they obtain values of CMJ bipodalic stance of 42.4 ± 3.8cm, 40.8 ± 4.8cm and 45.8 ± 6.3 cm, compared 31 cm recorded by S1 (Figures 16 and 17). This discrepancy, is relevant, because the force expressed with both limbs is greater compared to a monopodalic stance, in fact S1 reaches -26.9% compared to football players, -32.3% compared to -22.5% and basketball players with rugby players. The difference mean percentage of jumps in team sports compared compared with S1 is +27.2%.

Noting the data of monopodalic stance jumps we can highlight that the soccer players reaches 25.5 ± 2.8 cm, basketball players 26 ± 3.8cm and 19.7 ± 3.8 cm for rugby players.
The uniqueness is that, despite S1 sport activity isn't characterized by jumps and change of directions performed in an erected posture, his value of vertical jump on one leg is greater of + 35% compared to team sports.

compared to team sports.

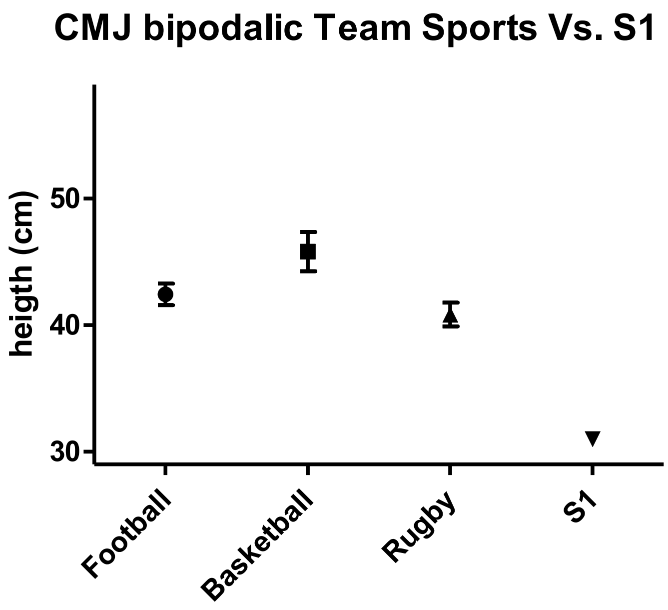

Figure 16: CMJ bipodalic stance from team sports compared to S1.

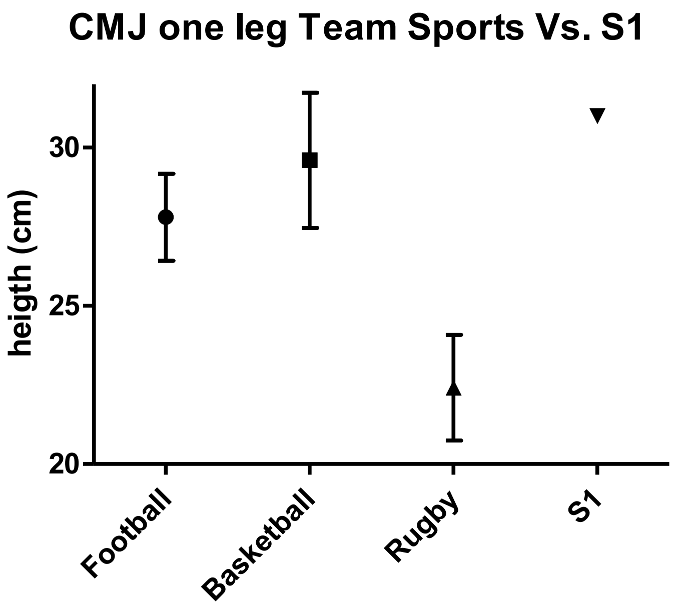

Figure 17: CMJ on one leg from team sports compared to S1

Finally, looking at the value of balance parameter among upper thoracic pattern compared to lower abdominal pattern of **MARM** (figure 18) it can be observed an improvement between chest and diaphragmatic pattern with a tendency to abdominal breathing: from a value of 33.8° of thoracic breathing in 2013 (cut off score of the thoracic pattern is for values >29°), a to a lower rib-abdomen expansion of -10.1° in 2014 (cut off score of the diaphragmatic pattern is for values >20).

- S2:

We can denote an improvement in the ability to expand the back and lateral side of the lower rib passing from a complete chest breathing pattern (38.8° in 2013) to a more diaphragmatic pattern (-6.5°% in 2014).

- S3:

The respiratory patterns of this athlete moved slightly to a more diaphragmatic typology, but with minor improvements (clearly, the breathing pattern which typical of a disability such like the SCI could be less influenced by respiratory muscles training). As for the balance parameter we started in June from a value which typically considered as "thoracic" of 37.5 °, arriving to 12.5 ° in October with a more normal breathing pattern.

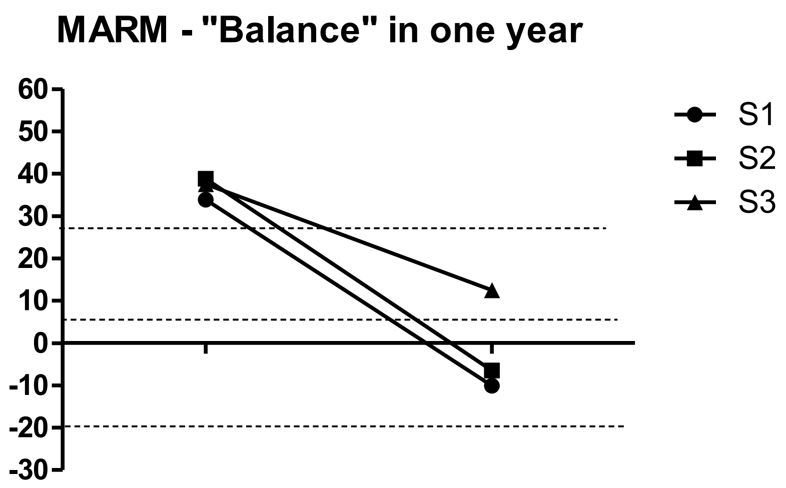

Figure 18: MARM "Balance"

The sum of these improvements led to important sport gratifications in major, world-class competitions.

S1 is progressed from three bronze medals obtained in the Paralympics in London in 2012, to a gold, a silver and a bronze at the World Championships in Montreal in 2013, and finally to get five consecutive gold medals at the recent European Championships in Eindhoven in 2014.

S2, during the three years, has increased her performances by improving the chronometric times related to the Italian record signed by in the past, until a silver and two bronze medals (one with an Italian record) at the European Championships Eindhoven in August 2014.

Also S3, despite a short period of experimentation, was able to obtain the European Championships in 2014 a bronze and a silver medal with Italian record.

In this study we determined the feasibility of an integrative training approach aimed to improve the performance of a Paralympic swimmer

We looked for alternative approaches and we were encouraged to read the report of Fulton et al. who, in Paralympic swimmers, challenged the training philosophy that “more is better”.

He found that “swimmers who had the greater improvements in performance between competitions trained at lower volumes and intensities, and swimmers who raced closer to the world record time trained at lower intensities”. Although this observation needs to be backed up by further research with larger numbers of Paralympic swimmers, we thought that maybe the key to the improvement of our athlete’s performance could be searched from a different perspective.

Starting from the premise that sport performance is an integrated combination of several factors (technical, tactical, physical, psychological, etc) for both team and individual sports(9,102) we designed an approach that, while maintaining the emphasis on dry-land training volume and training distance, also included a global postural training in order to normalize the state of excitability of the postural tone muscles(50,132,134,166). The neuromuscular stabilization function is an unconscious and automatic pattern, and when body stability is compromised, it is not simple to re-train. Body asymmetries are related to the level of disability(51) and there are many factors such as flexibility, muscular imbalances and strength which limit the force production and the correct propulsion during the swimming performance (47,114,168).

Studies carried out in disabled athletes have shown that parameters like dysfunctional movement patterns and musco-skeletal asymmetries may compromise the swimmer's technique, while compensatory patterns may lead to further muscle imbalances and potential injury (51,153). Therefore, a corrective stabilization training should be the first step in any rehabilitation or conditioning program(2,63,97).

A functional program can be designed to re-train dysfunctional patterns and reestablish normal movements. An improved symmetry, correct force production/transmission, and a normal tone of muscular chains increases body stability and motion efficiency.

The respiratory muscle training was aimed to teach a proper diaphragmatic breathing.

Although it has been shown that swimmers subjected to respiratory muscle training achieve only small improvements in respiratory muscle strength (80), our respiratory training was mainly aimed to integrate the above-mentioned postural training.

In fact, respiratory muscle training not only leads to a correct respiratory function and an amelioration of lung parameters, but also enhances spine stability and "core" control (46,83,98,100). Prior to any movement, an adequate *core bracing* coupled with a correct diaphragmatic function is fundamental to be stiff and stable (13,77,86).

The low-speed strength training was aimed to enhance the strength of our athlete while minimizing the risk of injuries. For a swimmer with a disability, strength training is of paramount importance to reduce the muscular imbalances that reduce the mean force production (51), as well as to generate symmetrical muscular power (148).

One approach to increase muscle power is to increase the volume and intensity of strength training. However, this also increases the occurrence of injuries.

We devised a safe muscular training by using moderate intensities (low loads) and slow speed without pause between repetitions nor between phases (concentric or eccentric). This helped maintaining an elevated intramuscular pressure, thereby interfering with local blood flow. Such training has been purported to increase muscle mass by mimicking blood flow restriction (without external devices) (3).

Thanks to this gentler approach, our athlete increased his muscular mass and strength without incurring any injuries.

However general safety rules such as ensuring appropriate spotting techniques to guarantee the safety of the athlete, a balance agonist and antagonists' muscles around the area with disability and creative ways of presenting the training program should be sought in order to motivate the athletes and facilitate comprehension of prescribed exercise routines are essential parameters for each type of training that have been scrupulously observed (172) .

As confirmed in able-bodied swimmers (6,74) this research demonstrates that increases in swimming performance are greater in a combined swimming-dry-land training program, compared with a swim only program.

Our training strategy was customized on the needs of the swimmers that we coached and is not a one-fits-it-all approach. Thus, this study obviously does not possess any statistical validity and our conclusions cannot be generalized to other swimmers. Further studies are needed to better elucidate the relative contribution of the components of the intervention (e.g. postural vs. breathing exercises or slow-velocity strength training) and to evaluate the compliance, the persistence of the benefits as well as the effectiveness of the intervention in swimmers with similar disabilities.

Performance at international competitions depends on many factors such as the athlete's long-term training background, the level of fitness immediately before the competition, constancy in striving for technique refinement, as well as psychological wellness and stress management. Since this study is an observational study conducted on three subjects only, we cannot purport that our dry-land training method based on postural alignment, breathing and slow-velocity resistance training was the quid that allowed our swimmers to win lots of medal in the major competition.

Nevertheless, the consistency between the improvement in the periodic objective evaluations and the improvement in the official competition performances is encouraging.

Of course, to investigate the relationship between the training and competition performance, an experimental study in a sufficiently large group of subjects would be needed.

Analyzing the temporal evolution of the chronometric times recorded by the athlete F.M . in Paralympics Games in London in 2012, in the World Championships in Montreal in 2013 and in the European Championships in Eindhoven in 2014, they are in line with the average percentage of increasing performances suggested by scientific evidence(68), that is around +1- 2%: in detail S1 in the 100m butterfly got an average percentage increase of + 1%, in the 400m front crawl + 1.5% + 0.9% and finally in the 200m medley.

Despite its limitations, this study provides valuable preliminary data about an integrated approach that could be an option for *Coaches* and *Strength and Conditioning Coach* aiming to design training protocols for athletes with disabilities similar to the ones of this thesis subjects.

The methodology adopted by the three swimmers is general as regards to the contents, but it is specific and individualized in relation to the morphological characteristics that every athlete intrinsically possesses.

Depending on the features that each type of disability requires, observing what the international evidence suggests, were planned training programs for that purpose.

Athletes with amputation have greater difficulty in maintaining the balance and tends to fluctuate more with a marked reduction in proprioceptive control and muscular strength (172). The ability to produce force and actual force propulsion may differ due to the loss of energy throughout the kinetic chain, i.e., if there is loss of strength, coordination or range of motion force will be lost or dissipated from the kinetic chain.

This loss may increase load on other areas or links in the kinetic chain, potentially leading to injury as a result of change of load on a particular structure or the result of a compensatory strategy.

An athlete with spinal cord injury (in relation to the anatomical site of injury) is encouraged a respiratory muscles and strength training because they may have consequences in the respiratory tract (177) with a different body control between phasic and tonic muscles to compensate for the loss of postural function (172).

A carefully strength training of may also have positive effects on endurance performance (187).

An athlete with spasticity, the basal tone appears to be strongly increased compared to subjects without lesions of the central nervous system: there is an increased excitatory motoneuronic pathway level, a lack in the control in the excitation-inhibition system, co-contractions, a general soft- tissue stiffness which fixes muscles in a shortened position in a permanent level of contracture (60,186).

With this type of subjects, it is advisable to program a workout based on proprioceptive, neuromuscular control and joint mobilization because the Range of Motion appears reduced (19).

The philosophy of placing emphasis on factors like posture, breathing, spine stabilization and muscular strength training at slow speed with lower loads could be profitably applied to swimmers with other disabilities and even to able-bodied swimmers

3.4 CONCLUSION

In conclusion, the results document the physical fitness evolution of three élite Paralympic swimmers belonging to different disability classes.

This philosophy can be an useful adjunct to conventional training in Paralympic swimmers because it allows the athletes to move more fluidly safeguarding their physical integrity by reducing the chances of injuries.

In our athletes, such improvements were accompanied by important sport gratifications.
It’s fundamental to consider that each type of disability has got different residual motor skills, movement strategies and postural control, and every coach should take into account these characteristics during the training program planning.

This strategy could be also beneficial for able-bodied athletes, because we can do what a "mechanics" makes during car’s cutting: i.e. checking the suspensions, the fluid levels, the air and oil filters, etc.
Only when every car’s component functions properly, we can work on the "engine".

In humans, it is exactly the same: first of all should be screened the structure starting from his/her own body morphology to highlight misalignments or asymmetries, detected if the basic human patterns (fundamental motor patterns, breathing, stability, mobility) are at an acceptable entry level in terms efficiency and quality of execution, or if there are some dysfunctional aspects that limit the correct motor function. After we know this, we must monitor fitness performance parameters.

4 GENERAL CONCLUSIONS

The purpose of this thesis is to describe an approach of dry land "non-conventional" training in élite Paralympic swimmers.

The primary aim is to shift the focus from the "Quantified Self" (basically to quantify conditioning parameters) through a reliable and validated assessments which are able to measure the quality of the movement: the goal is to quantify the functional motor deficits which are related or independent to the type of disability.

Once measured the efficiency of movement parameters, it has been programmed an individualized training protocol that underwent different aspects such as:

- Postural alignment.
- Respiratory muscles training.
- Neuromuscular stabilization linked with diaphragmatic breath.
- Wrong motor patterns reprogram.
- Increase of muscle strength through a method that reduces the velocity of muscle action for a better motor control without using equipment like straps or sleeves (typical of Blood Flow Restriction Resistance Training).

This integrated “total body” approach develops the *upper body* strength for increases in propulsion in the water, strengthen and stabilize the *hip-core-scapula* complex to minizing the injury risks, the *lower body* strength and power to improve velocity during the dive start, and a better recruitment of *core muscles* to maintain an aligned body position in the water.

This philosophy could be also effective with swimmers who have the same typologies of disabilities of our athletes, as well as could be valid with able-bodied subjects, who may have morphological deviations and functional movement limitations despite their body functions are still present.

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