

Review paper

“Correct deep respiration allows excellent toning of the work of the heart and of the central nervous system, and improves blood circulation” [1].

IMPORTANCE OF RELATIONSHIP BETWEEN MOVEMENT RHYTHM AND RESPIRATION IN PHYSICAL EDUCATION AND IN TOP-LEVEL SPORT

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Abstract

The existence of a human body is conditioned by: food, sleep, respiration. Without air man can live approximately 4 minutes. A longer break in access of oxygen to the brain results in irreversible changes of its functioning. **Majority of adults cannot breathe economically and rhythmically. If respiration has such importance for the normal life of a man it should constitute a significant part of educational system. Only in few national cultures, including Asia (e.g. in Japan and China) the ability to breathe was made into an art.** There, this art is subject to special care throughout many years of life of a person and is an essential component of mental hygiene. Respiration has particular importance while practicing physical exercise. The correct combination of respiration rhythm and movement is a prerequisite to remain healthy and to keep the ability to work, as well as to achieve high results in sport. Scarce information about this important issue could be found in some handbooks concerning health maintenance, but they were not found in the theory of: movement teaching, recreation, anthropokinesiology. It was a little number of papers published about this very important problem [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16]. The issue of rational respiration was the subject of particular interest of scientists several years ago, but recently it has become only marginal. Consequently, the **aim** of this paper was to: 1. Study the literature connected with respiration and movement rhythm. 2. To define which phase of respiration: expiration or inspiration is more important in different sport exercises. 3. Elaboration a classification of kind respiration phase and different sports. 4. Methods for creating the art of rational respiration. 5. Relation of rational respiration rhythm to endurance.

Key words: rhythm of respiration, rhythm of movements, classification of kind respiration in different sports

Introduction

Each four seconds our organism takes in oxygen, and gets rid of carbon dioxide, i.e. breathes. At rest respiration is automatic, which does not always guarantee its rationality. **A human being may survive ca. 4 min. without air** (athletes ca. 5 min.). **A longer gap in supply of oxygen to the brain leads to irreversible changes in its functioning.** Rational respiration was of greatest importance in ancient Egypt – at that time it was called **a medicine that healed monarchs. The Chinese and the Egyptians considered respiration as a source of life** [17]. Buddha taught that respiration was life.

Respiration acquires special magnitude in execution of physical exercises. **The correct combination of respiration rhythm and movement is a prerequisite to remain healthy and to keep the ability to work, as well as to achieve high results in sport.** A great number of works have been published on the rational methods of nutrition and sleep, whereas not much was published about the rhythm of rational respiration, especially

when one considers its value for the health of a human being, his life and success achieved in various types of activity. Scarce information about this important issue could be found in some handbooks concerning health maintenance [1], but they were not found in the theory of: movement teaching, recreation, anthropokinesiology [18, 19, 20, 21, 22, 23, 24, 25], theory of physical education or even sport [2, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39]. It seems that **one of the first specialists who drew attention to this extremely important issue was Farfel in his handbook on sport physiology** [2], and a few years afterwards Ter-Owanesjan in a monograph on sport [15]. Some time later an interesting monograph was published on the respiration of athletes, the author of which was Jewgeniewa [3] and parts in other authors books [10, 11, 12, 13, 14].

The issue of rational respiration was the subject of particular interest of scientists several years ago, but recently it has become only marginal. Consequently, the **aim** of this paper was to:
1. Review selected items from available literature related to relations between respiration rhythm and movements.

2. Determine the most important phase in respiration during the execution of exercises.
3. Elaboration a classification of kind respiration phase and different sports.
4. Define methods of mastering the art of rational respiration.
5. Determine the relation between rational respiration and endurance.

1. The most important phase of respiration

Respiration comprises inspiration, pause and expiration. The pause may not be mistaken with holding back the breath, the time of which is consciously regulated by an individual. Usually at rest an individual breathes approximately 16 times per minute and almost 1000 times per hour. Lung ventilation at rest is 6-8 litres per minute, and during physical effort it may even exceed 100 litres. During high intensity training those values are still higher. During a period of 24 hours a human inspires and expires 1300 litres of air. The adaptation ability to air shortage is determined genetically, but may be developed to a certain extent. This depends, to a considerable extent, on the lung capacity, the maximum values of which ranging between 5-7 litres and may be found among others in swimmers. The lung capacity of M. Phelps, 8-time champion of the Olympic Games in Beijing, equals to 12 litres (2.5 times more than the average for a human being), is a biological phenomenon.

According to Lukianow: *"When exercising respiration muscles, particular attention shall be drawn to the expiration, and instead of stopping it rather enhancing it. During walking the respiration has to be coordinated, preserving for example the following rhythm: 2-3 steps – inspiration, 4-5 steps – expiration. The longer the expiration, the deeper and the more valuable is the inspiration. It is not recommended to have a conversation during such a curing type of walking, because it disturbs the respiration rhythm. It is necessary to learn to breathe through the nose, and not through the mouth. When respiration through the nose the air warms up, frees itself of dust and other mechanical contamination. Deep correct respiration provides excellent toning of the work of the heart and the central nervous system, improves the circulation"* [1].

Intensified expiration, in many cases associated with an exclamation, activates additional motor units, and in fencing, for example, has a strong psychological influence on the opponent. The ability of rational respiration in sport was taken from the Italian singing school. Its basis is a more prolonged intense expiration than the inspiration, because emptied lungs fill with air without conscious involvement of the individual. Based on numerous facts it was found that: *"...the expiration increases the muscle power, and the inspiration decreases it. That is why the expiration shall be taking place at the moment of the greatest effort, and the inspiration at a moment of the smallest effort."* (Fig. 1) and further on: *"...if movements contain moments that require great effort, they shall be associated with the expiration, independently of the position assumed by the body at the time, which may be conducive or not conducive to the expansion of the chest"* [5].

Only infants breathe in a rational way. The majority of adults are unable to breathe economically and in a rational way. How can this be explained? Human behaviour is adversely modified by environmental factors, which deprive him of his natural ability of correct respiration! The everyday style of living, which is dominated by work requiring a seated position and the frequently dominating stress are conducive to assuming a shallow and arrhythmic respiration. This impairs the brain oxygen supply and consequently causes worse well being, sleepiness, laziness, anxieties, aggression, impatience etc. To restore the ability of correct respiration it is necessary to apply respiration exercises, e.g. of yogis.

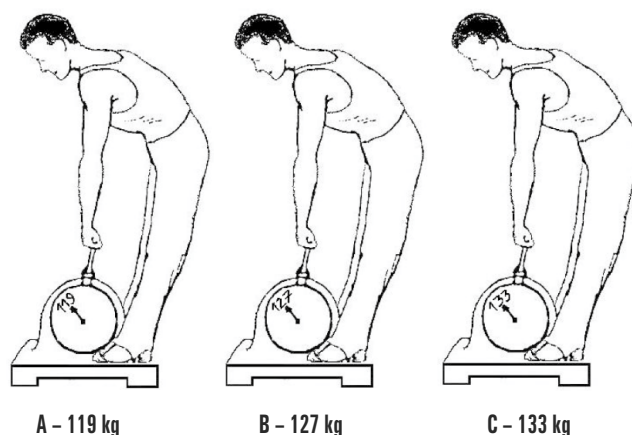


Figure 1. Strength of back (spine) muscles during inspiration (A), expiration (B) and respiration holding (standstill) (C) [Farfel, Freidberg, 1948]

If respiration is so important for the normal living of an individual, it should become a part of the education system. In few national cultures, e.g. in Japan and China, the respiration ability has been turned into real art which is the subject of particular care during many years of life of an individual and an essential part of mental hygiene.

2. Rhythm of respiration during the execution of various exercises

Rational respiration is especially vital for the correct performance of physical exercises. The greater the intensity of the performed exercises, the bigger the importance of the ability to breathe rationally. This concerns not only correct time proportions between inspiration and expiration and pauses between them, but also their appropriately accented intensity. This is not easy, taking into account the great diversification of exercises applied in various sport disciplines. This issue is illustrated by the classification of respiration rhythm dependent on the type of movements (Fig. 2). This is only its preliminary variant, because despite the importance of this issue, we have been able to trace only a single attempt to define it [13, 15].

Much simpler is the harmonisation of the movement rhythm and respiration in the so-called cyclical sport disciplines, e.g. in kayak rowing or single sculls rowing boat (see Fig. 2). This is complicated in both disciplines during rowing of multiple teams. Working out the appropriate rhythm for the team is extremely difficult and remains on the borderline of "art", being a sort of "secret component of the training programme". "Art" which is adapted in each case to the particular team. In cyclical sport disciplines there is a significant differentiation of this rhythm, because for example in a 100 m sprinter run, despite cyclical movements, there is no sufficient time for rational respiration, which is replaced by a shallow one. For this reason the oxygen indebtedness of sprinters equals to 94-96%.

Particularly complicated is the reconciliation of rhythm of movements with respiration in swimming which requires special coaching, because it remains on the borderline of the water and air environments. Passing from one environment to the other during swimming requires special adaptation of the organism. This adaptation is complicated by the number of different swimming styles. An analysis made of the technique applied by participants of world championships and the Olympic Games pointed to the existence of a differentiation in respiration rhythmic dependent on the style and distance. In this respect, worthy of special attention was the multi-medallist M.

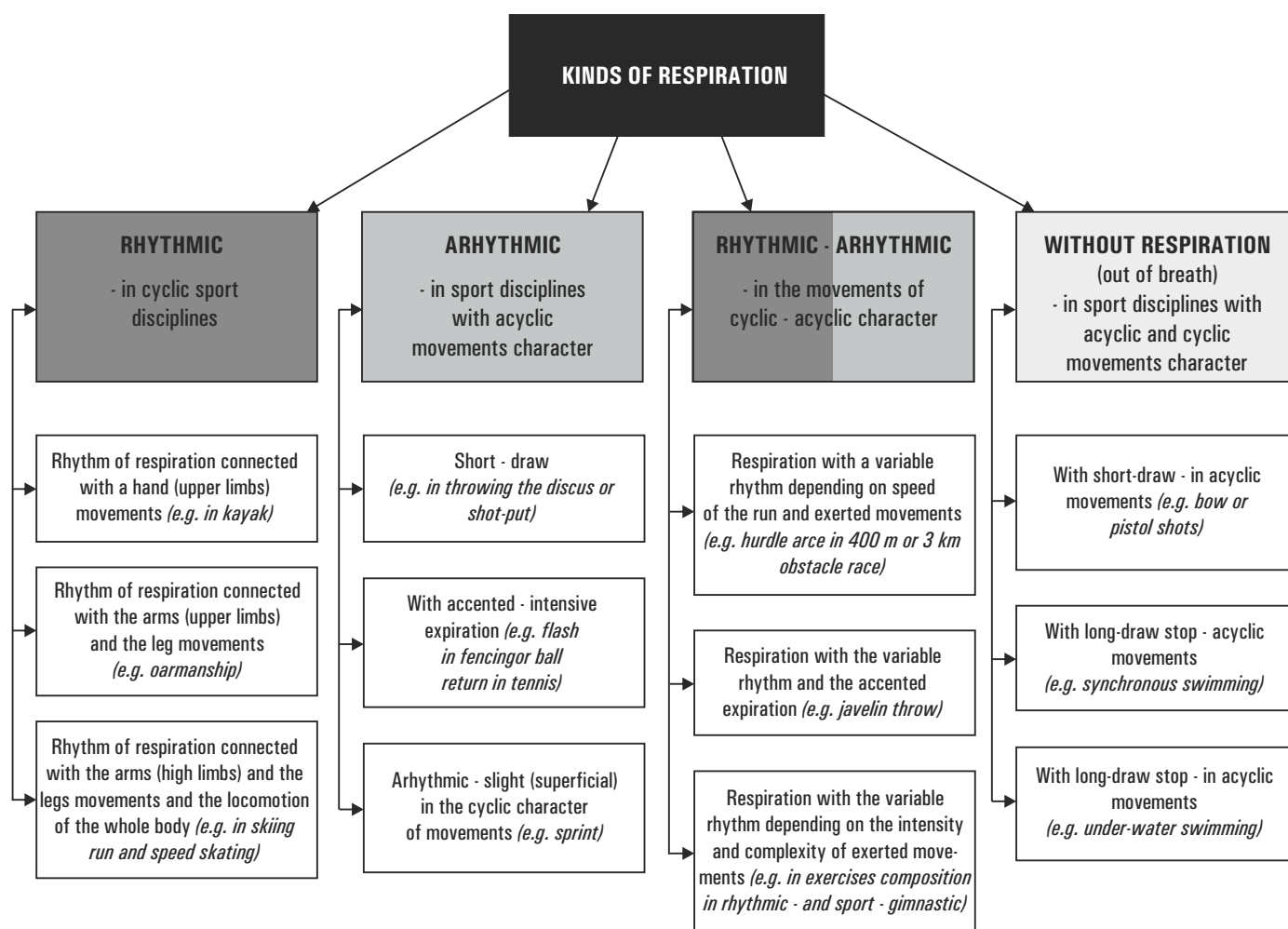


Figure 2. The interrelation between respiration and character of the exerted movements – kind of sports [Starosta, 1994]

Phelps, who professed abilities which could be associated with his body structure and his exceptional lung capacity. The importance of respiration in swimming is correctly illustrated by the following aphorism: “**A person unable to breathe correctly would not be able to swim**”.

Complex relations between the rhythm of movement and respiration may also be found in disciplines which involve **cyclical and acyclical movements**, e.g. in javelin throw or jumps in track and field events, in which after a cyclical start-up the acyclical phase of throw or take off for jump takes place (see Fig.2). Both those phases are the most important fragments of the contest, which are strictly connected with a very intense expiration.

The most complex variants of this rhythmic may be found in sport disciplines dominated by **acyclical** movements, e.g. shot put, hammer throw or on weight lifting (see Fig. 2). They are performed in “**apnoea**” (held respiration) and in the final movement fragment – during maximum effort (in put or in throw) – an intense expiration takes place, which is frequently accompanied by an exclamation. Holding air back in the lungs immobilises the chest and creates better conditions for muscle contraction in the lower and upper extremities. The weightlifters before making the jerk (Fig. 3), when gripping the barbell make an inspiration and pause respiration as they lift the barbell onto the chest. Holding the barbell on the chest they inspire, then expire, and then expire along with the jerk. An intensified expiration also accompanies the take off in jumps, hitting the ball with the racquet in tennis and thrusts in fencing.

Such expiration activates additional motor units, and in fencing, judo, karate, tennis works even better with concurrent exclamation.

JERK phase 1



JERK phase 2



Figure 3. The weightlifter before making the jerk, when gripping the barbell make an inspiration and pause respiration as they lift the barbell onto the chest. Holding the barbell on the chest they inspire, then expire, and then expire along with the jerk

Disturbance of rational respiration rhythm during the execution of exercises, e.g. inspiring during take off in high jump or jerk of the barbell may disturb this technique and render the achievement of the desired result impossible. The excep-

tionally complex relations between movements and respiration arrhythmicity may be found in synchronic swimming which is generally associated with prolonged holding back of the breath, low audibility of music while the women athletes remain under water and the necessity of adapting the respiration rhythm to the specific nature of the exercise arrangement being performed. Performance of team exercise arrangements in such conditions requires considerable lung capacity, high level of numerous coordination abilities and “partners feeling”.

Short holding back of the breath may be found in archery and pistol shooting. During “the preparations to taking a shot” – aiming, letting go of a bow or pulling the trigger, the majority of athletes tend to hold their breath on a “semi-expiration” or “semi-inspiration”. This is necessary to avoid swaying of the chest and immobilisation of the shoulders. Holding the breath for 12-15 seconds allows better concentration on the movements which are being performed [15]. Such disciplines affect adversely the organism of a young person, who is still growing and developing.

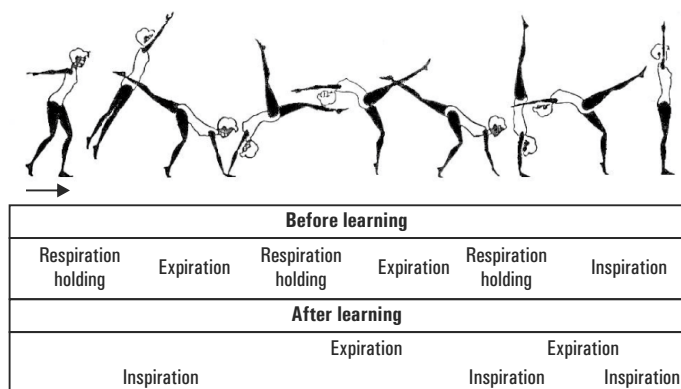
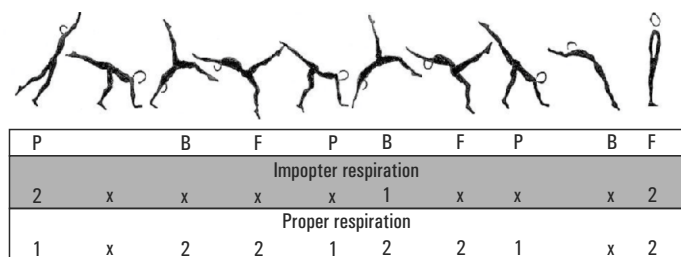


Figure 4. Interrelation between phase of respiration and movements [Farfel, 1976, after Mironow, 1967]



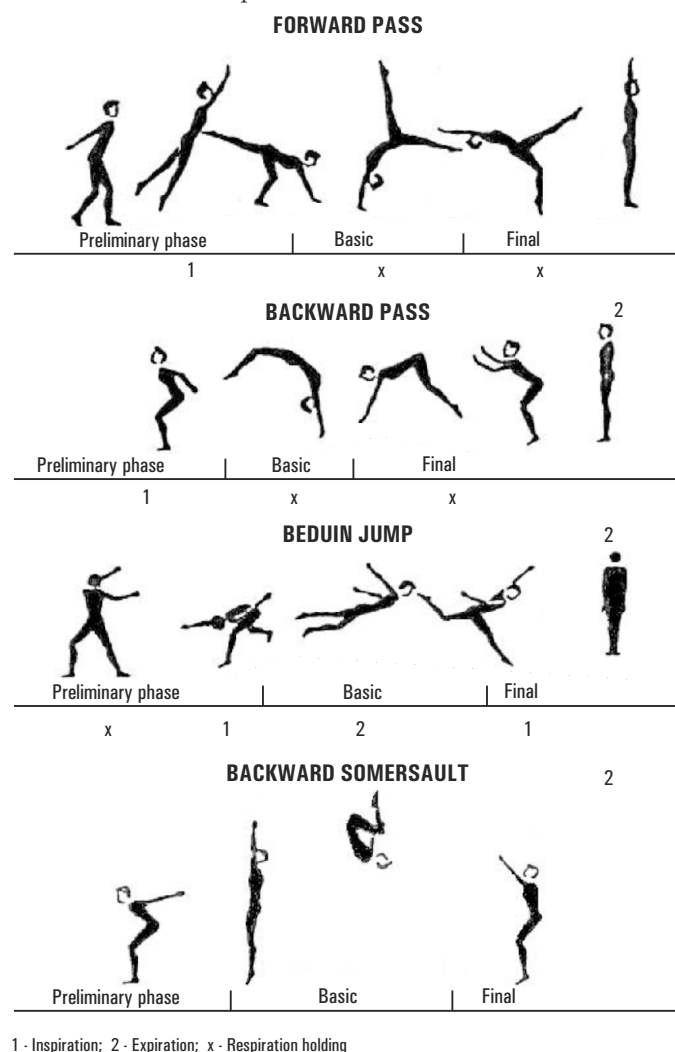
1 - Inspiration; 2 - Expiration; x - Respiration holding; P - Preparatory phase; B - Basic phase; F - Final phase

Figure 5. Interrelation between phases of respiration and movements in execution of gymnastic exercises [Jewgeniewa, 1974, after Farfel, 1945]

The exceptionally complex type of relations between the movement rhythm and respiration may be found in team sport games. In those games respiration is “regulated” by the opponent’s behaviour. This leads to a great variability in respiration rhythm. In those disciplines the respiration rhythm changes depending on the applied technical elements during the contest and its rhythmicity interweaves with arrhythmicity, as well as with its stopping. This variability depends to a large extent on speed of the game. In the opinion of some authors the greatest dynamics in the competition may be found in ice hockey.

As regards relations of movement rhythm and respiration, a special group is made up by sport disciplines, which require executing exercises accompanied by music. This concerns for example sport gymnastics (Fig. 4) and rhythmic gymnastics,

figure ice skating and roller skating, synchronic swimming or sport ballroom dance. **In those disciplines the music rhythm imposes the rhythm of movements, and the latter one in turn – the rhythm of respiration. Harmonisation of those three constituent components into one optimally functioning ability – a coupled and co-dependent system – is highly complicated and requires not only training over many years, but also a high movement coordination level.** This harmonisation is particularly complex in arrangements of various forms of gymnastics strictly limited by time and musical rhythm. Consequently, to allow some women athletes to achieve significant success it becomes necessary to work out a certain “**respiration score**” during the execution of selected gymnastic exercises (Fig. 5) or acrobatic exercises (Fig. 6). In rhythmic gymnastics the combination of the rhythm of music and respiration is complicated by concurrent performance of exercises and by juggling the accessories. The overlapping of interdependencies of so many components significantly hinders the harmonisation of rhythmicity of movements and respiration.



1 - Inspiration; 2 - Expiration; x - Respiration holding

Figure 6. Connection of respiration phases and movements in acrobatic exercises [Mironow, 1969]

A short review of various types of respiration rhythm depending on the specific nature of the movement (see Fig. 2) indicates the existence of complex conditions for the functioning of an athlete in sport. To be able to achieve even an insignificant success, the athlete has to adapt to the method of respiration imposed by the specific nature of the practiced sport discipline.

In each sport discipline training requires learning the technique of various exercises, as well as the skill of respiration during their execution. What is more, the performance of identical exercises, but of varied intensity requires a different combination of movement with the inspiration and expiration (Fig. 7). Here are two examples that illustrate this difference. When a **weightlifter** lifts the barbell on extended hands, he expires or holds the breath, concurrently tensing the respiration muscles. During pulling the oars the **rower** straightens the torso and the legs, bringing the oars to the chest and expires. And vice versa, when carrying the oars over the water he bends the torso at the same time bending the legs (riding a vehicle) and despite the fact that at that moment advantageous anatomic conditions are created for the expiration, it is at that particular moment when the oarsmen inhales. This is another difficulty and another type of adaptation. **This review clearly shows the complex and variable conditions which may appear during sport training. They force the athlete to continuous adaptation, i.e. readaptation of the organism to the new type of interdependency of respiration with the specific nature of exercises.** Athletes with a higher level of movement coordination are able to master those relations much quicker and consequently master them to the largest extent possible within a shorter time.

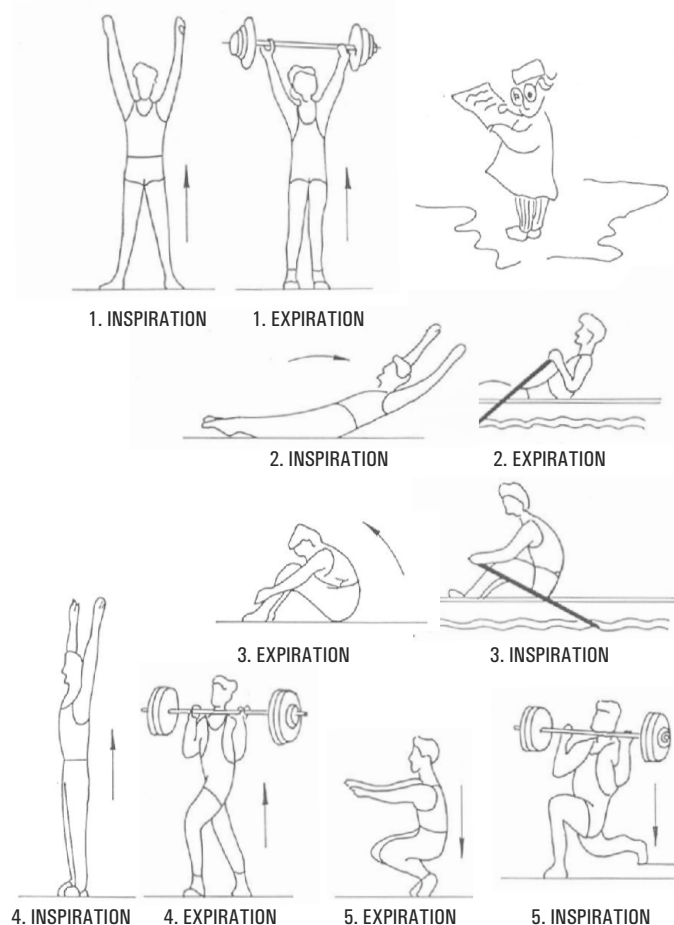


Figure 7. Respiration phases in combination with movement, depending on kind and intensity of exercise (selected examples) [Farfel, 1960]

Record breaking achievements in various sport disciplines are related to a high level of ability of reconciling the movement rhythm and respiration. This harmony should be formed and mastered during long-lasting training as a subject of directed measures and well planned exercise system.

3. Methods for creating the art of rational respiration

Rational respiration is crucial for the optimum functioning of an individual in every day and professional life. Its role becomes crucial during performance of movement exercises. **The greater their intensity, the more effective must be the supply of the organism with oxygen.** This requires a high endurance level and mastering the art of respiration that is adequate to the practiced sport discipline. This seems to have been forgotten even in handbooks related to teaching and mastering of the sport technique. Almost each exercise requires a different respiration rhythm, i.e. spacing during inspiration and expiration.

Rational respiration is easier to reconcile with the movement in particular exercises. This means optimum combination e.g. locomotion movements (among others during running) with chest movements. This is manifested in rational coordination of the nervous and muscular system with the respiratory and cardiovascular system. This process does not proceed in an automatic way. **It requires constant advancement of the athletes and the coach, as well as “experimenting” – seeking optimum solutions based on feelings of the athletes compiled during training programmes.** The high level of such harmonisation is an important part of the self advancement of an athlete, it differs in particular athletes and depends on the level of movement coordination, as well as on the specific nature of the practiced sport discipline. In the case of athletes with exceptional movement skills this process proceeds relatively quickly and so it seems that it does not require any external interference. Nevertheless, even such athletes need to be taught certain dependencies which function in this respect. However, it is simply not possible to “select individual specific solutions” for them, which may only be adapted to the specific character of their organism.

Of particular importance is to teach respiration almost concurrently with mastering the technique of exercises, i.e. first mastering the basic structure of the exercise, and consequently its combination with respiration. **New exercises give rise to intensified emotions, which is not conducive to better selfcontrol of movements, and all the more respiration. Some athletes perform a part of an exercise or even the entire exercise holding back their breath (Fig. 8).** Fixing of this type of error causes quicker fatigue and less precise execution of the given exercise. In case of a serial performance of exercises, e.g. in martial arts or in presentation of exercise arrangements in gymnastics, this causes relatively quick exhaustion, even in the event of excellent endurance preparation. And vice versa, athletes with a lower level of such preparation, but with the mastered “**respiration art**” tend to achieve better success in sport.

Shortages with respect to rational respiration during performance of exercises have been observed even in athletes from the national team of Poland. This is a proof of deficiencies of the applied methods of teaching exercises, but also of the unused reserves of the athletes. Their activation requires, however, an information “**empowerment**” of both athletes and coaches. **Insufficient empowerment of coaches arises from lack of information with respect to interdependencies between respiration rhythm and exercises in the theory of movement teaching, physical education, sport and science on human movements (anthropokinesiology) [40, 41].**

This has also been observed in wrestlers in the national team of Poland during the execution of a special test battery, such as mannequin throw or bar push ups. Sporadic instructions given before their execution allowed many wrestlers to increase the number of repetitions in the execution of test tasks related to general and special fitness [41, 42]. The achieved results, in many cases “**new life records**” of high class wrestlers based on “**ad hoc**” instructions prove there is a possibility to correct certain earlier mistakes with respect to respiration even in adult

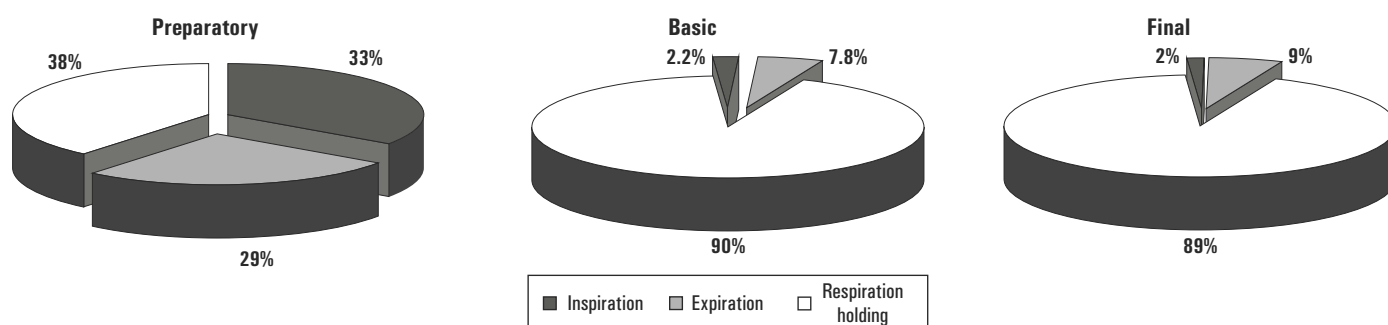


Figure 8. Connections of respiration phases with movement phases in execution of elements and combinations of acrobatic jumps (x in %) [Mironow, 1969]

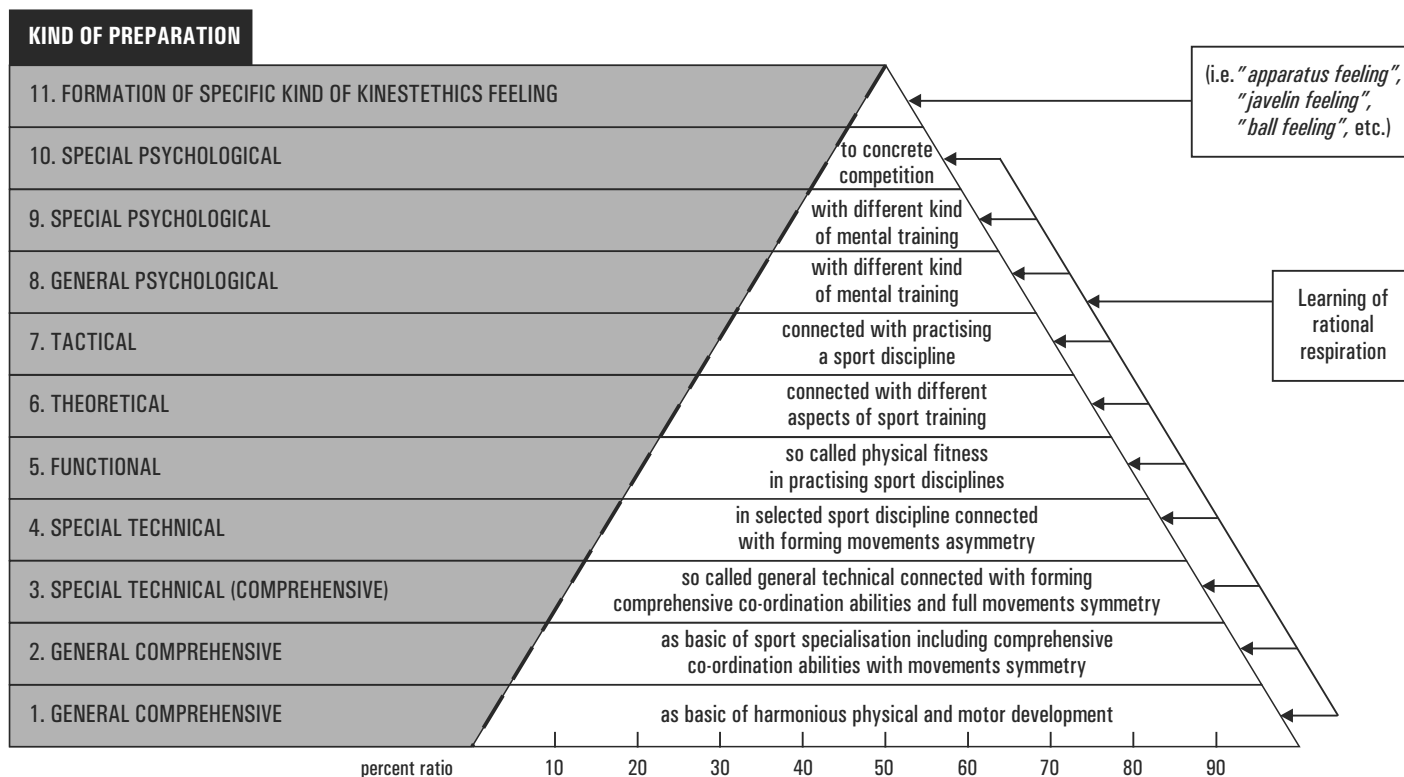


Figure 9. Formation of specific kinesthetic feeling by competitors in comprehensive preparation and many years training [Starosta, 2009]

athletes with long training experience. Its effectiveness is further enhanced by integrating the rational respiration technique in various types of preparation, including theoretical, technical, tactical, conditioning, psychical preparation (Fig. 9).

4. Relation of rational respiration rhythm to endurance

Many authors insist that a strict dependency exists between the ability of rational respiration and general and special endurance. Failing to notice this interdependency lowers potential capacity of an athlete, including also the ability to achieve an important sport success. Particularly interesting are remarks of the former world champion in figure ice skating Jackson: "In an effort to try and keep my muscles in appropriate tension I also performed exercises when not on ice. **The exercises performed by me were meant to advance the cardiovascular system.** On my way to school and classes I would execute respiration exercises: **I practiced controlled respiration that increased the lung capacity.** This technique comprised inspiration through the nose during, for example, ten steps, paus-

ing respiration for the next two steps and expiration – expelling the used air from the lungs – through the mouth for the subsequent ten steps plus two. **When I would start such controlled respiration, for almost a week I experienced pain in the chest, but I do know exactly that this helped me to enhance by endurance by at least 25%. I could easily perform my 5-minute free programme with all the jumps two times running**" [43].

The fact taken from the training practice of the great champion is worthy of attention. It is not new, because the **hypoxia method** was used many years ago by the excellent runner E. Zatopek, and by Olympic Game champions in swimming, siblings Ilza and John Kondrats [44]. This method shapes the adapting capability of the heart and the entire organism, but its application should be subject to medical control [44]. Results of tests executed on two groups of athletes have indicated an increase of 37-88% in effort efficiency on a cycle ergometer in particular persons in the group who did the respiration in more difficult conditions during effort they had to breathe air saturated by a higher level of carbon dioxide [45].

Summary

The presented facts suggest the existence of a great importance of correct respiration and movement rhythm for the health and life of a human being, for his intensified and diversified activity, as well as for his sport achievements. For this reason rational respiration during movement exercises should be subject of special care of coaches of various disciplines which involve movement activity. **Rules for rational respiration should be included not only in the theory of movement teaching, but also in physical education, recreation, rehabilitation, tourism, and especially in the theory of particular sport disciplines.**

Conclusions and recommendations

1. Rational respiration was of greatest importance in ancient Egypt – at that time it was called a medicine that healed monarchs. The Chinese and the Egyptians considered respiration as a source of life.
2. Respiration acquires special magnitude in execution of physical exercises. The correct combination of respiration rhythm and movement is a prerequisite to remain healthy and to keep the ability to work, as well as to achieve high results in sport.
3. A great number of works have been published on the rational methods of nutrition and sleep, whereas not much was published about rhythm of rational respiration, especially when one considers its value for the health of a human being, his life and success achieved in various types of activity.
4. **Respiration comprises inspiration, pause and expiration. The pause may not be mistaken with holding back the breath, the time of which is consciously regulated by an individual.** Lung ventilation at rest is 6-8 litres per minute, and during physical effort it may even exceed 100 litres. During high intensity training those values are still higher.
5. When exercising respiration muscles, particular attention shall be drawn to the expiration, and instead of stopping it rather enhancing it. **The longer the expiration, the deeper and the more valuable is the inspiration. Deep correct respiration provides excellent toning of the work of the heart and the central nervous system, improves the circulation.**
6. The skill of rational respiration in sport was taken from the Italian singing school. Its basis is a more prolonged intense expiration than the inspiration, because emptied lungs fill with air without conscious involvement of the individual.
7. **Only infants breathe in a rational way. The majority of adults are unable to breathe economically and in a rational way. How can this be explained? Human behaviour is adversely modified by environmental factors, which deprive him of his natural ability of correct respiration!**
8. **If respiration is so important for the normal living of an individual, it should become a part of the education system. In few national cultures, e.g. in Japan and China, the respiration ability has been turned into real art which is the subject of particular care during many years of life of an individual and an essential part of mental hygiene.**
9. Rational respiration is especially vital for the correct performance of physical exercises. **The greater the intensity of the performed exercises, the bigger the importance of the ability to breathe rationally.** This concerns not only correct time proportions between inspiration and expiration and pauses between them, but also their appropriately accented intensity.
10. Much simpler is the harmonisation of the movement rhythm and respiration in the so-called cyclical sport disciplines, e.g. in kayak rowing or single sculls rowing boat. This is complicated in both disciplines during rowing of multiple teams. **Working out the appropriate rhythm for the team is extremely difficult and remains on the borderline of “art”, being a sort of “secret component of the coach workshop”.**
11. The most complex variants of this rhythmicity may be found in sport disciplines dominated by acyclical movements, e.g. shot put, hammer throw or on weight lifting. **They are performed in “apnoea” (held respiration) and in the final movement fragment – during maximum effort (in put or in throw) – an intense expiration takes place, which is frequently accompanied by an exclamation.**
12. Disturbance of rational respiration rhythm during the execution of exercises, e.g. inspiring during take-off in high jump or jerk of the barbell may disturb this technique and render the achievement of the desired result impossible.
13. **The exceptionally complex type of relations between the movement rhythm and respiration may be found in team sport games. In those games respiration is “regulated” by the opponent's behaviour. This leads to a great variability in respiration rhythm.**
14. **This harmonization is particularly complex in arrangements of various kinds of gymnastics strictly limited by time and musical rhythm.** Consequently, to allow some women athletes to achieve significant success it becomes necessary to work out a certain “**respiration score**” during the execution of selected gymnastic exercises.
15. In each sport discipline training requires learning the technique of various exercises, as well as the skill of respiration during their execution.
16. **Record breaking achievements in various sport disciplines are related to a high level of ability of reconciling the movement rhythm and respiration.** This harmony should be formed and mastered during long-lasting training as a subject of directed measures and well planned exercise system.
17. **Shortages with respect to rational respiration during performance of exercises have been observed even in athletes from the national team of Poland.** This is a proof of deficiencies of the applied methods of teaching exercises, but also of the unused reserves of the athletes. Their activation requires, however, an information “empowerment” of both athletes and coaches.
18. **New exercises give rise to intensified emotions, which is not conducive to better self-control of movements, and all the more respiration. Some athletes perform a part of an exercise or even the entire exercise holding back their breath.**
19. **Principles for rational respiration should be included not only in the theory of movement teaching, but also in physical education, recreation, rehabilitation, tourism, and especially in the theory of particular sport disciplines.**

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