Sleep-Wake Disturbances in Childhood and Adolescence

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Adequate sleep is essential for the child's growth, development, learning and well-being. Insufficient and/or poor-quality sleep are associated with increased occurrence of mood disorders, behavioral disorders, and learning difficulties due to inattention. Similarly, untreated sleep apnea in childhood is associated with increased irritability, inattention, emotional dysregulation, unsatisfactory academic performance, impairment of growth. Although more rarely, systemic arterial hypertension and pulmonary hypertension can also be related to some sleep-related breathing disorders [1–3].

Sleep disorders are very common in the pediatric population, with a worldwide prevalence ranging from 20 to 40% [4–6]. A Brazilian study using validated child sleep questionnaires estimated an alarming prevalence of sleep disorders of 25.5% among individuals aged 0–19 years [7]. It is also noteworthy that sleep habits of the child are very rarely approached by health-care professionals in order to identify, prevent and treat possible sleep disorders [8].

The American Academy of Sleep Disorders (AASM) developed a consensus published in 2016 with the amount of sleep needed to promote health among children and adolescents, according to each age group [Table 1]. Infants aged less than 4 months were not included in this consensus due to the great variation of normality regarding duration and sleep patterns [9].

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Table 1 Recommendation of AASM consensus (2016) on total sleep time according to each age group in children and adolescents

Age	Total sleep time
4–12 months	12–16 hours (including naps)
1–2 years	11–14 hours (including naps)
3–5 years	10–13 hours (including naps)
6–12 years old	9–12 hours
13–18 years old	8–10 hours

Table 2 Characteristics of sleep biology and ontogenesis according to each age group of childhood and adolescence

Age	Characteristics of sleep
0–6 months	Categories: awake, quiet sleep, active sleep and indeterminate sleep (transitional sleep) At 6 months, begins to consolidate the night sleep Initiates sleep by REM. REM sleep represents 50–60% of total sleep time
6 months–2 years	One or two daytime naps Starts sleep by NREM. REM sleep represents 25–30% of total sleep time
2–6 years	Transition from two naps to one. Nap usually disappears after 5 years. REM sleep is concentrated in the second half of the night
6–12 years	No naps, 9–12 hours of night sleep
12–18 years	Delayed sleep phase syndrome is common during teenage years

1 Sleep States from Newborn to Adolescent

The characterization of the sleep patterns is based mainly on the electroencephalographic tracings and behavioral characteristics [Table 2].

Up to 6 months of life, the child's states of consciousness are classified into 4 categories: awake, quiet sleep, active sleep and indeterminate sleep (transitional sleep) and indeterminate sleep (transitional sleep). The newborn falls asleep in REM sleep and remains in this state of sleep for about 60% of the total sleep time. This percentage can reach 80% preterm neonates.

Around 6 months the baby comes to sleep up to 6 hours uninterrupted, a period in which the longest night sleep begins to consolidate. Still in this phase, infant initiates the sleep cycle in NREM sleep, which is the predominant phase (70–75% of the total sleep time).

Between 2 and 5 years old, the child usually sleeps between 10 and 14 hours a day, with only one nap during afternoon, which usually disappears around 5 years old. In this phase, a predominance of REM sleep occurs in the second half of the night, as observed in adults.

Adolescents after 12 years of age begin to present a typical alteration called delayed sleep phase syndrome, that is characterized by difficulty in falling asleep at a socially acceptable time and by the need to wake up later. Depending on the social

demand (e.g., going to school in the morning), this factor can contribute to the occurrence of sleep deprivation and its consequences [10–12].

2 Sleep-Related Breathing Disorders

2.1 Obstructive Sleep Apnea in the Pediatric Population

In the pediatric population, the peak incidence of obstructive sleep apnea (OSA) occurs in preschoolers, a period in which there is an imbalance between the growth of palatine tonsils and adenoid, concerning the growth of the upper airway, that allied to the physiology of sleep/muscle relaxation favors the occurrence of obstructive respiratory events [13, 14].

Unlike the adult, the diagnosis of sleep apnea in the child requires the presence of an apnea index (AHI) greater than 1 event per hour of sleep, often accompanied by multiple awakenings and oxyhemoglobin desaturation. The following table summarizes the indications of polysomnography (PSG) in the pediatric age group [Chart 1] [13].

Adenotonsillectomy is the most widely used treatment for children with OSA. In cases of moderate or severe OSA in which adenotonsillectomy did not show satisfactory results or was contraindicated, the use of continuous positive airway pressure (CPAP) devices should be considered. The greatest limitation of the use of CPAP in children is the low adherence. Also, the chronic use of these devices can lead to facial deformities due to the pressure of the mask on the facial bones. Care with choosing the best mask can minimize these effects [14, 15].

The treatment of the child's OSA should always be multidisciplinary. It is known that about 20% of the children submitted to adenotonsillectomy continue with residual apnea resulting, in its great majority, of the alteration in the relation between the maxilla and mandible, of dental malocclusion. Several studies show the benefit of the use of orthodontic devices and the palatal circuit breakers that make the maxilla

Chart 1 Main indications of PSG in childhood and adolescence. Presence of two or more of the following criteria:

Snoring for at least 4 nights a week associated with restless sleep, frequent awakenings, hyperactive, aggressive, or impulsive behavior, learning difficulties, enuresis, malnutrition, recurrent upper airways infections
Apnea observed by the family
Excessive daytime sleepiness
Laborious breathing during sleep
Polycythemia
Cor pulmonale
Patient will perform any elective surgery and presents suggestive OSA symptoms
Some genetic syndromes and craniofacial malformations

expansion fast are the most indicated. Phonoaudiology has a recent and important role in the recovery of the child's stomatognathic functions, whether it has residual apnea or not. It has been proposed that the increase of muscle tone improves the upper airways patency, which provides adequate chewing, sucking, swallowing, and nasal breathing functions, and even influences phonation [16, 17].

Also, we enphasize the physiotherapist's work by correcting of postural alterations observed in the mouth-breathing child [18].

2.2 Primary alveolar hypoventilation

They comprise a group of diseases associated with an elevation in $PaCO_2$ above 45 mmHg. During sleep we can use as rules, Paco2 exhaled, measured by nasal cannula, 55 mmHg for at least 10 minutes or 10 mmHg increase in Paco2 in vigil and supine position for values above 50 mmHg and for at least 10 minutes during total sleep time [13].

Alveolar hypoventilation may occur in association with several diseases in which there is a restrictive rib cage disorder such as neuromuscular diseases associated with obesity, in central sleep apnea due to impairment of the respiratory center located in the bulb or cardiac dysfunctions, and in chronic obstructive pulmonary diseases. Associated with hypercapnia, hypoxemia is often developed, which intensifies clinical manifestations and increases morbidity. Hypoventilation may begin during sleep and is sometimes underestimated by waking evaluations. The treatment of hypoventilation syndromes will depend on the underlying causes, it is usually multidisciplinary, and it may be necessary to use ventilation devices [13, 19, 20].

The performance of respiratory physiotherapy with the use of bag valve mask is frequently recommended in any age group, and motor physiotherapy, when indicated, is used mainly for stretching and maintenance of joint mobility, without the use of load [21].

3 Insomnia

The child's insomnia is almost always a complaint from parents or caregivers and is characterized by the child's difficulty in initiating and/or maintaining long periods of sleep. A behavioral component is almost always present and can be associated with a problem of clinical, neurological, psychiatric, and even, physiological cause that served as a trigger for the difficulty with sleep, such as the eruption of teeth, for example [22].

Behavioral insomnia can be classified into association disorder and/or lack-of-limit disorder and association of these two types. However, behavioral insomnia is

an exclusion diagnosis that needs evaluation to rule out clinical causes or other sleep disorders [22, 23].

In the 3rd edition of the International Classification of Sleep Disorders (ISCD-3), insomnia was subdivided into acute insomnia (duration less than 3 months) and chronic insomnia. The criteria for the diagnosis, in addition to the difficulty in initiating and/or maintaining sleep, are the daytime symptoms, the absence of inadequate environmental factors, the presence of insomnia at least 3 times a week, and the absence of another sleep disorder that may justify the complaint [13].

The evaluation of insomnia complaints includes detailed interview questioning sleeping routines, evaluation of cognitive functions, mood, and daytime behavior. It is recommended to use sleep diaries asking parents to register bedtime and wake up times, night awakenings and naps for at least 7 days. The following table shows the summary of the main indications of complementary examinations in the context of childhood insomnia [Table 3].

3.1 Pharmacological Treatment of Childhood Insomnia

Behavioral therapy has been successfully used to treat the child's insomnia. The American Academy of Sleep Medicine consensus (2017) noted that according to published articles, 80% of children treated with behavioral therapy for insomnia showed significant and lasting improvement for up to 6 months with techniques of absolute or gradual extinction of negative associations with sleep, positive reinforcement, sleep hygiene and preventive education of parents [26].

Behavioral therapy includes guidance on sleep hygiene, physical activities, use of monitors and the appropriate times to perform them, appropriate feeding times including breastfeeding and the institution of repetitive activities (bedtime ritual). The control of stimuli close to bedtime favors the reduction of awakenings and the period of physiological and cognitive alert before sleep. In addition to relaxing massage techniques such as Shantala, there are no references to the use of physiotherapy techniques as a treatment for children's insomnia [26–29].

Table 3 Complementary tests for the etiological investigation of insomnia in the pediatric age group [24–28]

Examination	Referral
Laboratory tests	CBC, iron profile (anemia and RLS investigation) Thyroid function (investigation of hypo/hyperthyroidism)
Polysomnography	Suspected sleep-related breathing disorder, PLMD
Actigraphy	Accurate evaluation of sleep/waking periods Evaluation of circadian rhythm disorders
Electroencephalogram	Epilepsy

3.2 Non-pharmacological Treatment of Childhood Insomnia

The institution of drug treatment aims mainly to interfere in the long period of insomnia to facilitate the performance of behavioral work. Another indication is the presence of neurological, psychiatric, and child comorbidities with marked visual impairment. Melatonin is indicated and mainly used in children with autism spectrum disorders, with global developmental delays and in blind children. Melatonin reduces sleep latency and wake-up frequency and should be ingested 1 to 2 hours before bedtime. Antihistamines such as diphenhydramine, promethazine, and hydroxyzine promote blocking of H1 histaminergic receptors by reducing sleep latency and awakening due to sedation. Benzodiazepine hypnotic drugs (such as clonazepam) act as gamma-aminobutyric acid (GABA) receptor agonists, reducing sleep latency. The effect of muscle relaxation associated with this drug should be considered, especially in the suspicion of sleep-related breathing disorders [30, 31].

4 Sleep-Related Movement Disorders

4.1 Restless Legs Syndrome (RLS)

Restless legs syndrome (RLS) is a sensorimotor disorder that affects the sleep and quality of life of the child or adolescent. The affected child describes its symptom as an irresistible need to move the legs, usually accompanied by discomfort, unpleasant feeling, and/or restlessness [32–34].

The clinical course is variable, moderate to severe forms can behave as chronic and progressive. Difficulty in initiating and/or maintaining sleep, feeling that you have not slept enough, tiredness, and weakness are common complaints in children with RLS. Positive family history and the presence of periodic limb movements of the members (identified in PSG) are considered support criteria for RLS, according ICSD-3 [33, 34].

The diagnosis of RLS in the pediatric population, as it occurs among adults, is eminently clinical, as shown below [Chart 2]. If the child cannot describe their discomfort, it must have at least two of these criteria: sleep disorder, a first-degree family member with a diagnosis of RLS and periodic limb movement index (PLMDi) >5/h in polysomnography [13].

Should always be requested. Several studies show an association of RLS symptoms with a ferritin dosage of less than 50 mcg/L and that iron supplementation surprisingly improves symptoms. In addition to iron supplementation in severe RLS, other drugs can be used such as gabapentin, benzodiazepines such as clonazepam and temazepam, clonidine, dopaminergic agonists and *H. perforatum* [33, 34].

Chart 2 Diagnostic criteria for restless legs syndrome (ICSD-3) [13]

Need to move the legs, caused by an unpleasant sensation
Unpleasant feeling worsens in rest periods
Unpleasant feeling is totally or partially relieved by movement
Need for movement and the feeling of discomfort are worse at night
Symptoms cannot be explained by other medical conditions
Report of the child himself describing with his words the unpleasant sensation and/or discomfort in the legs

We did not find studies of the use of physiotherapy techniques for the treatment of RLS; however, as personal experience of the authors it is worth mentioning that the caregivers refer that vigorous massage on the legs and even the placing of cushions or heavy covers on them helps in the conciliation of sleep [33, 34].

4.2 Periodic Limb Movement Disorder (PLMD)

PLMD is characterized by repetitive, intermittent, and stereotyped movements that most frequently affect the lower limbs. Often the caregivers complain that the child has restless sleep or drops the covers or kicks, while sleeping. This complaint, to be relevant, should be associated with symptoms associated with nonrestorative sleep such as behavior and/or mood changes and learning difficulties, among others. For the diagnosis, we should request a PSG where muscle movements/contractions will be counted with a duration of 0.5 to 10 seconds and with an increase of the tibial electromyogram of at least 8 mV. A 5/h periodic movement index is considered significant. Likely RLS, blood tests may be necessary to evaluate iron metabolism and its supplementation (when indicated) may improve the symptoms [32–34].

4.3 Restless Sleep Disorder in Children

In 2020 a new sleep-related movement disorder was described. It refers to the complaint of restless sleep reported by parents or caregivers and was studied in the pediatric age group, between 6 and 18 years of age. For the diagnosis, all criteria defined by consensus must be present [Chart 3].

The authors found serum ferritin rates even lower than those observed in patients with IPS, but this was reported in oral communication (not yet published). Again, we must emphasize the importance of analyzing the iron profile in these patients.

Chart 3 Diagnostic criteria for child agitated sleep disorder [35]

Complaint of restless sleep
Observed large body movements during sleep (movements should comprise large muscle groups of the whole body, of the four limbs, arms, legs, or head)
Movements occur during sleep or when the child appears to be sleeping
Video-polysomnographic documentation of 5 or more large body movements/hour
Occurrence at least three times a week for at least three months
Restless sleep is associated with daytime behavioral/mood/cognitive complaints
Restless sleep cannot be caused by a clinical or psychiatric or environmental condition or other sleep disorder

4.4 Sleep Bruxism

Sleep bruxism is a rhythmic, involuntary movement of tightening and/or friction of teeth during sleep, associated with repeated contractions of the masseter, temporal, medial and lateral pterygoid muscles, that may or may not produce noises [13].

Polysomnographic studies showed that episodes predominate in NREM sleep. As a result of muscular effort, headache, mandibular pain, tooth wear, pain in the temporal-mandibular joint, and even limitation of mandibular movement may occur. The annual incidence of some episodes of bruxism is 15%, for the age10 group of 20 years, the most affected. Children with intellectual disability, ASD and cerebral palsy have a higher incidence [34].

Bruxism can occur in situations of stress and anxiety or association with other sleep disorders such as snoring, obstructive sleep apnea, RLS, PLMD movements and epilepsy associated with sleep. The diagnosis is clinical, but the PSG exam may be requested to confirm the diagnosis and also evaluate the occurrence of other sleep disorders [33, 34].

Dental evaluation is always recommended because it may be necessary to treat tooth wear, or its prevention, with the placement of resin protection or use of intra-oral devices in children with established permanent dentition [33, 34].

Pharmacological treatment may be used in cases with dental impairment and/or clinical symptoms. Children with severe encephalopathies and sleep bruxism can also benefit from pharmacological management. The medications used are mainly benzodiazepines (clonazepam) and alpha-agonists (clonidine) in low doses [33, 34].

5 Child Neurology and Sleep Medicine Interface

5.1 Cerebral Palsy (CP)

CP is a chronic motor condition secondary to nonprogressive brain damage in a brain during its development [36]. The worldwide prevalence of CP is 2.11 per 1000 live births and obeys an inverse proportion to gestational age and birth weight [37]. The prevalence of sleep disorders in children with CP varies from 23 to 46%. Some

variables can influence these high rates, such as: greater occurrence of pain, epileptic seizures, impaired mobility [38, 39]. The presence of sleep disorders impairs cognitive and emotional development of these children and impacting their physical rehabilitation [38].

Horwood et al. observed that the presence of untreated pain was a strong predictor for abnormal scores in the pediatric sleep scale among children with CP, with an odds ratio of 6.5 [39]. The non-pharmacological approach to pain with physical therapy may be an interesting path for the treatment and prevention of sleep disorders in patients with CP, but there are still no studies proving the effectiveness of this type of intervention. A randomized controlled clinical trial involving 142 children diagnosed with CP found that the Cranial Osteopathy technique did not promote sustained improvement in motor function, quality of sleep, and life [40].

5.2 Autistic Spectrum Disorder

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by impairment of communication and social skills associated with repetitive behaviors. The prevalence of ASD can reach 1 per 59 individuals [41]. 50 to 80% of children with ASD have problems initiating and/or maintaining sleep, and the occurrence of sleep disorders may contribute to the worsening of behavior problems [42].

Preschoolers and schoolers with ASD have a higher prevalence of behavioral insomnia and parasomnia, while adolescents with ASD have a higher occurrence of short-term sleep and excessive daytime sleepiness. Several reasons are proposed to justify the higher prevalence of sleep disorders in this group of children: alteration of endogenous melatonin synthesis, sleep neurotransmitter system dysfunction, sensory dysregulation, gene mutations related to rhythm disorders and also the increased occurrence of comorbidities (epilepsy, attention deficit hyperactivity disorder, anxiety, and mood disorders) [43, 44].

Several systematic reviews have already been carried out to evaluate the effectiveness of pharmacological and non-pharmacological treatments to approach sleep disorders in children with ASD. Unfortunately, the findings were inconclusive and often controversial. It is a clearly heterogeneous group of patients with different clinical picture and comorbidities [45].

The most evident therapeutic modalities in this context were melatonin use (0.75 to 10 mg/day), behavioral intervention (e.g., sleep hygiene, extinction, positive reinforcement, and sleep restriction), and parental education [45]. A study identified that parental massage therapy reduced the occurrence of sleep disorders in ASD patients. Although promising, this study used a sample of only 20 children; therefore it still lacks replication of its results [46]. Therefore, the role of the professional physiotherapist in parental education seems to be an effective option of intervention.

5.3 Attention Deficit Hyperactivity Disorder

Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder characterized by the presence of symptoms of inattention, hyperactivity and impulsivity that generate social, emotional and/or cognitive functioning impacts. The prevalence of ADHD is around 5% and the prevalence of sleep disorders among ADHD patients ranges from 35 to 70%, varying according to age, the subtype of ADHD, use of medications and presence of comorbidities [47, 48].

The relationship between ADHD and sleep disorders is multifaceted and complex, as sleep disorders can aggravate ADHD symptoms and even mimic them. More than half of children and adolescents diagnosed with ADHD have at least one comorbidity associated with sleep problems, such as anxiety, depression, bipolar affective disorder, ASD, obsessive-compulsive disorder, conduct disorder and Tourette's syndrome. Besides, the use of psychostimulants, first-line drugs to treat ADHD, directly affects sleep [48].

The most commonly reported sleep disorders in association with ADHD are behavioral insomnia, sleep-related breathing disorders and RLS. The promotion of sleep hygiene associated with behavioral strategies remains as first-line therapy for insomnia in the context of ADHD. Adenotonsillectomy is the main strategy for treating obstructive sleep apnea and may even contribute to improving part of the symptoms of ADHD. Sleep hygiene, avoiding medications that worsen symptoms of RLS (especially neuroleptics and serotonin reuptake inhibitors) and oral or venous iron supplementation (in some specific cases) have scientific evidence for the treatment of RLS in the context of ADHD [48]. Unfortunately, there are no specific studies addressing the role of physiotherapy for the treatment of sleep disorders in patients with ADHD.

5.4 Neuromuscular Diseases

Neuromuscular diseases are characterized by progressive weakening muscles, and may affect skeletal, respiratory and/or bulbar muscles. In some specific cases, there is heart muscle involvement. Some children experience fragmented sleep with low efficiency and oxyhemoglobin desaturation during REM sleep, even in the absence of a sleep-related breathing disorder. This phenomenon happens due to the association of muscle weakness and stiffness or chest deformities potentiated by the physiological mechanisms of REM sleep. In this situation, measuring the exhaled carbon dioxide (CO_2) during sleep is essential for evaluating possible hypoventilation during sleep. Also, children with neuromuscular diseases may experience obstructive sleep apnea which should also be treated to avoid muscle fatigue and its consequences. Polysomnographic studies of patients with neuromuscular diseases show that an increase of CO_2 of 3–7 mmHg and reduction of SpO_2 of 2% is associated with increased upper airways resistance, lower diaphragmatic contraction in the

supine position, hypotonia of intercostal muscles and accessories, reduction of central sensitivity to hypercapnia, hypoxemia, mechanical stimuli for pulmonary insufflation and reduction of central respiratory stimuli [19, 20, 49].

During disease progression, it is known that the inability to cough effectively and clean the airways can cause respiratory failure needing hospitalization in intensive care units.

Normal breathing consists of cycles of variable flowing volumes interspersed with deep breaths or sighs. Periodic hyperinflation is necessary to prevent the closure of some pulmonary units (alveoli). Patients with neuromuscular diseases may present marked weakness of both the inspiratory musculature and the expiratory musculature. This weakness causes decreased current volume and expiratory flow, resulting in decreased lung expansibility. During a normal cough, about 2.5 liters of air are expelled from the lungs at a speed of 6 to 20 liters per second (peak cough flow). High thoracic-abdominal pressure is required to generate an effective and sufficient cough flow to eliminate secretions. Therefore, for an effective cough to occur, high current volumes are required. Deep inspiration dilates the airways and increases the force of contraction of the expiratory musculature, thus making the cough effective in eliminating pulmonary secretions [49–51].

Breath-stacking technique exercises are recommended so that the patient can perform the cough effectively through the maximum capacity of insufflation, which is the largest amount of air that can enter our lungs through the bag valve mask [Table 4; Fig. 1]. The effects of breath-stacking are alveolar recruitment, increased oxygenation, stretching of the chest muscles, and help the cough. Furthermore, stacking facilitates the elimination of secretions and the use of positive pressure devices. The assisted cough maneuver can also be used in the presence of infections or the patient with increased secretion trachea-bronchial is the compression of the chest downward and inward that increases the amount of air expelled. Thus, these maneuvers give strength to the cough and eliminate pulmonary secretions [21].

Below, some practical guidelines on breath-stacking technique: [21]

- It is recommended to perform the breath-stacking technique at least 3 times a day without the assisted cough maneuver when the patient does not present secretion and/or respiratory infections. In the patient who uses positive pressure apparatus, it shall be performed on waking as soon as the positive pressure apparatus is removed and before putting the ventilation apparatus to sleep. The third breath-stack should be done preferably before one of the big meals. In patients with increased bronchial secretion, breath-stacking always before meals to avoid nausea/vomiting caused by secretion.
- The breath-stacking should not be carried out for longer than 10 minutes because it can cause dizziness and nausea.
- Always try to reach the maximum inflation capacity.
- Remember to encourage the patient to sustain the amount of air he has placed in the lungs for 6 seconds, which is necessary for air distribution to the bases of the lungs.

Table 4 Guidance on breath-stacking technique [21]

Position the patient in a seated position
Accommodate the bag valve mask around the patient's nose and mouth
Press the mask firmly (pressure upwards) so that no air escapes
Inflate bag valve mask as many times as necessary to fill the patient's entire lung (usually two to five breaths are required)
After stacking as many bag valve mask inflations as possible, quickly remove the mask, and encourage the patient to hold that amount of air for 6 seconds
In case of flu or pulmonary secretion, help the patient in the expiration (assisted cough that is performed with chest pressure during expiration)
Insist on assisted coughing as often as necessary until the patient can eliminate all lung secretion
Exercise as many times as necessary during the day, that is, every time the patient has secretion and cannot cough without help

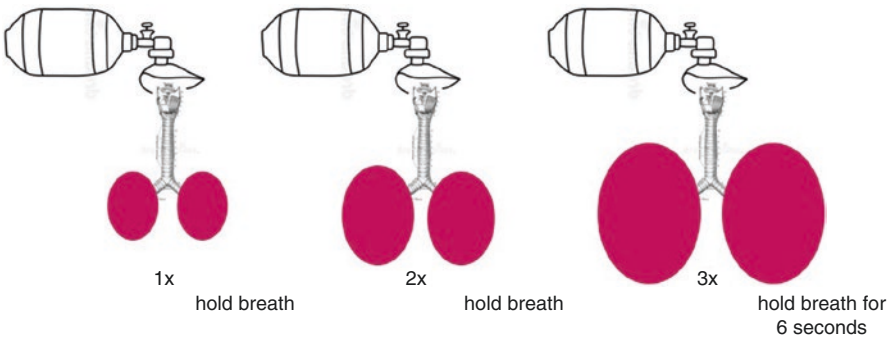

Fig. 1 Schematic drawing on breath-stacking using bag valve mask [21]

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