MANAGING BREATHING PATTERN DISORDERS IN TENNIS PLAYERS

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Tennis players' capacity to appropriately ventilate their lungs is fundamental to their physical fitness and movement efficiency during training and matches. Like many athletes, when compared to the general population, tennis players are more likely to experience exercise respiratory symptoms (e.g. shortness of breath, chest tightness, cough, wheeze, difficulty in breathing) and airway dysfunction (e.g. exercise induced bronchoconstriction [EIB])[1]. Although EIB may explain the presence of these exercise respiratory symptoms in some tennis players, the symptoms may also be caused by other conditions, such as breathing pattern disorders (BPD), exercise induced laryngeal obstruction (EILO) or upper airway obstruction/rhinitis. This review article will explain what a BPD is, highlight considerations for management of BPD in tennis players, and briefly present potential future BPD management strategies.

Table 1

Respiratory Symptoms	*Non-Respiratory Symptoms*
Shortness of breath (dyspnoea)	*Persistent muscle tightness in back, shoulders and/or neck*
Not able to take a satisfying breath	*Early onset of fatigue*
Dry, persistent cough	*Prolonged time to recover from high intensity exercise*
Wheeze when breathing in	*Lightheaded during or immediately after exercise*
Difficulty in breathing through nose	*Fainting*
Tightness around chest when breathing in	

Table 1: BPD symptoms.

What is a breathing pattern disorder (BPD)?

BPD is a pattern of breathing characterised by inefficient movement of the rib cage and abdomen and can lead to respiratory and/or non-respiratory symptoms (Table 1).

In most cases of BPD in tennis players, the player experiences disproportionate breathlessness and an inability to sustain high intensity (HI) performance, or to recover from HI training efforts. BPDs can present in many forms. A pattern commonly presenting in tennis players with BPD is excessive breathing relative to the physiological demands of the match activity. This can be observed as prolonged, elevated breathing rates, during recovery windows between points and sets, and is a typical characteristic of a BPD. Players may have a BPD in isolation, but it can also present in conjunction with other respiratory conditions such as EIB, EILO, or rhinitis.

Not all athletes have the same form of BPD, but a BPD usually incorporates one or more of the following (see Figure 1).

Tennis players with BPD could typically experience any of these different patterns

Figure 1: Categories of breathing pattern disorders.

during HI phases of their training sessions or matches. The symptoms usually last between 1-5 minutes, and occur once the tennis player slows or stops activity; however, despite resolution of symptoms, the episode may have impacted the quality of the training session, or their ability to recover between points during a match. In terms of chronic symptoms, players with BPD may report a persistent, dry cough that can last up to 24 hours post-training, and frequent, recurring tightness in their back or shoulders. BPD may not be consistent, occurring only at certain times, for example, during/after particularly hard training sessions, HI and/or high-stakes matches, and under specific environmental conditions (E.g. wind, cold).

Prevalence and diagnosis of BPD in tennis players

Prevalence of BPD in tennis players is unknown, due to the lack of gold-standard methodologies to diagnose athlete BPD however, BPD is reported to occur in approximately 20% of elite UK based athletes[2]. The recognition of a BPD symptoms (see Table 1) may be identified by any member of the athlete's support team. Observations should be discussed within the athlete's multidisciplinary review meetings which may then instigate further assessment with the wider team. It is important that other cardiopulmonary conditions are excluded. Differential diagnosis may include cardiovascular and/or haematological conditions (E.g. anaemia), asthma, rhinitis, EIB, EILO, psychological aspects or a combination of these conditions.

When considering diagnosis of BPD, it is advisable to incorporate a systematic respiratory assessment, so the practitioner can consider whether upper and lower airway conditions are present, which may contribute to the development of the respiratory symptoms reported by the player.[1] Assessment methods for BPD include, evaluating breathing during cardiopulmonary exercise tests (CPET) or other respiratory evaluations, such as, Fractional Expired Nitric Oxide (FeNO) Spirometry and a Eucapnic Voluntary Hyperpnoea (EVH) challenge. A combination of symptom questionnaires, visual and manual assessment of the breathing pattern will support the diagnosis. Consideration must be given to the psychological factors (such as stress, performance anxiety) that may contribute to the development of or sustain a BPD.

A cardiopulmonary exercise test (CPET) can be used to identify a potential BPD, by observing the volume and breathing frequency output during the test. A normal response to the increased levels of work load during a CPET is an increase in minute ventilation throughout the test. Increase in minute ventilation achieved by predominantly increases in volume during the early exercise stages of the CPET. When volume comes towards a plateau there is an increase in breathing frequency to continue to increase minute ventilation through to the termination of the CPET. A player with BPD may show an erratic combination of

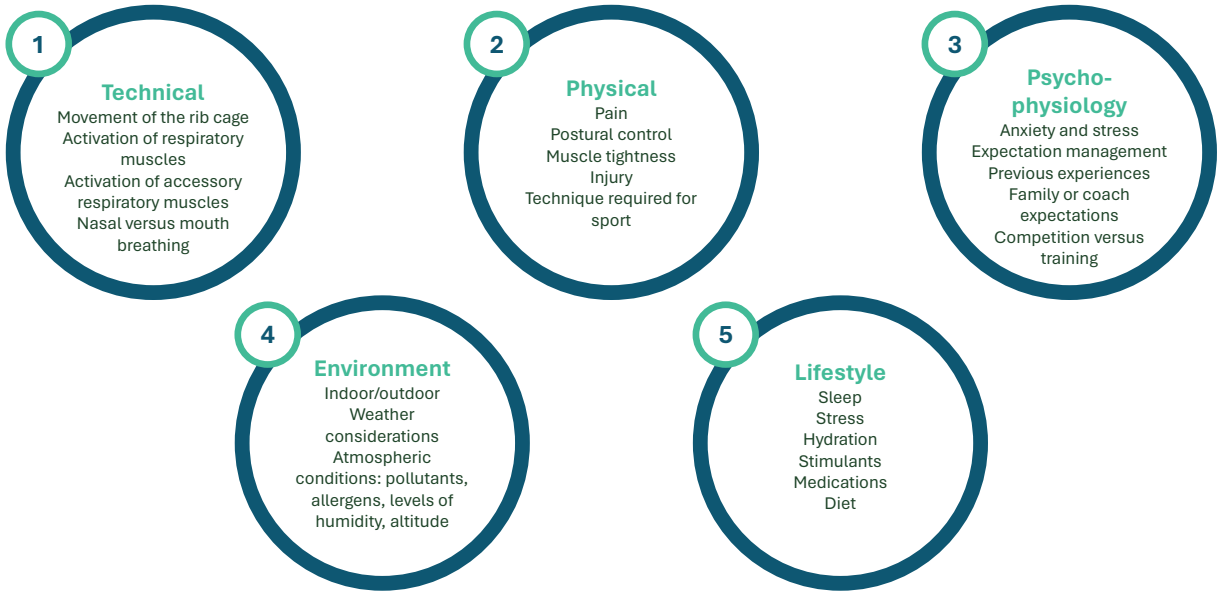

Figure 2: Areas of consideration for the management of BPD in tennis players.

volumes and breathing frequency through out the test.

To better understand what form of BPD the player has (Figure 1), we advise observing the player's breathing pattern during and directly after a high intensity phase of exercise that triggers the player's respiratory symptoms. The can be a live observation but can also be a taken as a video, which can be helpful to show the player their breathing. Breathing pattern should be observed from the front, side on view and from behind the athlete. Assessment of the thoracic complex and posture are important components.

Screening tools, like the breathing pattern assessment tool (BPAT) [3] is conducted with the athlete seated and at rest. A score ≥4 is thought to be suggestive of BPD.[3] In addition to the BPAT, the breathing assessment involves asking the player questions related to the respiratory symptoms they are experiencing, whilst listening to the responses the practitioner is also noting signs of a breathing pattern disorder. The Nijmegen questionnaire can be used for assessing hyperventilation symptoms. The Nijmegen questionnaire has 16 items (related to symptoms of hyperventilation syndrome) to be answered on a 5-point scale ranging from 'never' (0) to 'very often' (4). A total score of more than 23 out of 64 points suggests hyperventilation. Additionally, the exercise-induced laryngeal obstruction - dyspnoea index [4] (EILO-DI) questionnaire offers insights during exercise, aiding in identifying individuals with EILO and BPD.

Figure 3: Athlete practising rested breathing to promote diaphragm movement: hand on upper abdomen moves, with little movement of hand on upper ribcage.

Figure 4: Athlete practising optimised breathing pattern, initiating breathing in with lower rib cage movement, so the lower rib cage expands into the band.

Emerging techniques, such as opto-electronic plethysmography that uses 3D motion capture has been shown to detect differences between healthy and disordered breathing patterns[2] .

Management of BPD in tennis players

Management of BPD in tennis players should always take the individual into consideration and examine possible factors implicated in BPD development. Figure 2 presents five areas that should be considered when dealing with breathing pattern disorder: Technical, Physical, Psycho-physiological, Environmental and Lifestyle. The subsequent sections of this review discuss methods to support tennis players by optimising each of these five aspects of breathing, with the aim of helping them overcome BPD and to enhance their performance.

Optimising the technical aspects of breathing

A healthy breathing pattern at rest is different from breathing during exercise. At rest, breathing should be quiet, in and out through the nose, small volume (approximately 500mls per breath), accompanied by a slight descending movement of the diaphragm, and expiration via passive recoil. The athlete can check this by themselves using this online tool: (https://www.physiotherapyforbpd.org.uk/test-your-breathing/).

When the athlete starts to move, characteristics such as breathing rate and volume change in response to activity demand, a process initiated by movement in the lower rib cage between the 10th and 12th pairs of ribs. Initially, lower ribcage movement is lateral and, as exercise demand increases, the ribcage also moves forwards, backwards and upwards to accommodate larger volumes (deeper breaths), and there is an increase in breathing rate and tidal volume, according to ventilatory demand for oxygen and carbon dioxide exchange[2].

Figure 5: Athlete practising expanding lower rib cage, whilst performing a core stability exercise.

Using our understanding of a healthy breath, tennis players with BPD should be educated in optimal movement of the chest and diaphragm during breathing. Exercises which encourage breathing optimally both at rest and to ensure lateral movement of the lower rib cage, as the body starts to move (Figures 3 and 4) can then be prescribed for the tennis player.[5] These exercises are typically performed initially in a stationary position, usually standing or sitting, before progressing to functionally more complex movement, to help the tennis player adopt the optimised breathing pattern whilst in a sport-specific position.

Once the player is competent at taking optimal breaths at rest and during sport-specific actions, breathing intensities can be modified to start to mimic those the player may reach during HI phases of training or match play (Figure 5). Players may also consider using respiratory muscle training (RMT), with a focus on adopting an optimised breathing pattern and with the aim of transferring this to practice and match play.

Optimising the physical aspects of breathing

A comprehensive examination of physical factors contributing to BPD ensures consideration beyond addressing movements of the rib cage. Tennis

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players may present with respiratory and musculoskeletal adaptations and experience muscular imbalances, alterations in motor control, and physiological adaptations that influence breathing pattern and movement dynamics[5].

Tennis players with BPD may present with shortening of the upper, middle and lower trapezius and the levator scapulae posteriorly, and shortening of the pectoralis major and minor, and weakness of the deep cervical flexors, anteriorly. These structural adaptations are accompanied by a change in posture, commonly characterised by forward head posture, increased cervical lordosis and thoracic kyphosis, an elevated and protracted shoulder girdle, and abduction and internal rotation of the scapulae. This presentation is typical of the hypothesised 'upper crossed syndrome', as described by Janda[7] however, the proposal that upper crossed syndrome leads to musculoskeletal injury has not been substantiated by rigorous scientific study[8]. Adaptations in posture can influence economy of breathing patterns, leading to accessory respiratory muscles working excessively at rest. This can result in myofascial changes, which in turn may detrimentally effect shoulder girdle movement and increase pain[9].

Considerations in management of physical aspects of BPD/breathing dysfunction include assessing for weakness or tightness in muscle groups identified above, evaluating head posture and neck posture, and encouraging players to avoid holding postural tension in respiratory and accessory respiratory muscles. In support of this approach, diaphragmatic muscle training has been shown to be effective in improving shoulder pain and mobility[10].

Optimising the psycho-physiological aspects of breathing

From a psycho-physiological perspective, breathing is a unique behaviour, being a vital function that is both autonomic and subconscious and able to be unconsciously and consciously controlled. Although the respiratory system is tightly and continually regulated, to maintain homeostasis via the respiratory centre, we can consciously control our breathing for short periods of time when awake. Considering this, breathing presents a unique set of challenges, as well as opportunities, for the athlete.

Challenges include the conscious brain interfering with autonomic regulation of body systems, as well as autonomic system regulation being misunderstood/misinterpreted by the brain, leading to breathing dysregulation/disorder. For example, those with anxiety about their performance may overstimulate the sympathetic nervous system, provoking an exaggerated 'fight or flight' response, which can be detrimental to performance. In addition, negative emotions and unhelpful thoughts can activate the amygdala region of the brain leading to air hunger, and creating a physiologically stronger than necessary desire to breathe, causing a cycle of hyperventilation and an associated drop in performance.

Opportunities include educating athletes about the bi-directional relationship between mind and body, and the key roles the autonomic and sympathetic nervous systems play during performance, which can directly benefit the athlete, as they learn how to work with these systems, and use them to their advantage. For example, athletes who experience hyperventilation at high intensity, and during high stakes performances, may welcome guidance on understanding how they can control their breathing rate and prevent the detrimental effects of over-breathing. In addition, learning how to calm the sympathetic nervous system by adopting slow or slower breathing pre-, during and post-performance, is speculated to yield performance benefits, although evidence into the effectiveness of this strategy in athletes is still lacking'.

Optimising environmental responses

Environments that are cold and of low humidity will increase the prevalence of airway dysfunction. However, there is limited evidence for how environmental factors, such as air temperature, humidity, and wind speed, impact a tennis players' breathing pattern. Anecdotal subjective evidence, gathered from consultations with players, suggests that uncomfortable environments increase the likelihood of respiratory symptoms and BPD occurrence, indicating that research into the impact of the environment and how it may promote BPD development is needed. Furthermore, uncomfortable environments may cause athletes to alter posture and affect upper respiratory muscle tension, which may also contribute to athlete BPD.

When athletes encounter environments that are uncomfortable, they should be encouraged to relax their breathing and maintain good sporting posture, and to avoid forcing their breathing pattern and holding a rigid posture. In cold conditions, athletes may also consider wearing face coverings, which have been shown to be beneficial in reducing airway dysfunction in athletes exercising at lower temperatures.

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Optimising lifestyle

In managing BPD in tennis players, we also have the opportunity to consider the individual from a holistic perspective and recognise the importance of taking time to uncover and understand lifestyle factors that may be exacerbating the breathing pattern disorder. Many things influence the way we breathe, as a starting point we would encourage assessment of:

- Sleep hygiene (e.g. encourage nose breathing)
- Stress awareness and the impact it has on breathing pattern (increases apical breathing and breathing rate)
- Ensuring good hydration (the lungs are approximately 90% water)
- Awareness of the effects of stimulants on breathing (e.g. caffeine promotes sympathetic NS activity, which can increase apical breathing and breathing rate)
- Awareness of medications and their effects on breathing (e.g. overuse of asthma therapy, such as inhaled salbutamol, will increase heart rate and heighten sympathetic NS activity)
- Optimal diet to promote stable blood sugar, as this can also influence breathing rate and pattern during performance

Future advances in management of BPD

Breathing pattern training should be a holistic and multi-dimensional intervention that is individualised and athlete specific. Interventions focussing on optimising respiratory rate, depth of breathing, chest wall movement and synchrony are frequently used. These components rely on active participation for effective rehabilitation. Innovative techniques and technologies are being developed to engage both clinicians and end users to further improve breathing patterns and outcomes. An avenue of emerging research targeting rehabilitation involves gathering real-time data to analyse breathing patterns and physiological parameters; examples of this approach include use of biofeedback, virtual reality (VR) training, and digital breathing coaches incorporating smart phone technology (SPT), together with the increased use of respiratory muscle training (RMT) and optoelectronic plethysmography (OEP). Figure 6 illustrates proposed benefits of future therapies.

Biofeedback can include visual, auditory, or haptic options, which widens its potential use. VR programmes to simulate training environments, and SPT to support home use, could provide tailored protocols and position the user at the core of the rehabilitation process. RMT, used within health and sport disciplines for a considerable time, has demonstrated secondary improvements in breathing pattern, for example, an increase in inspiratory flow, volume, and power, together with changes in respiratory timing and should be further explored. 3-D motion OEP is another non-invasive method of objectively measuring chest wall movement and breathing pattern characteristics that holds promise. Dysfunctional breathing patterns can be acutely improved with real-time OEP phase angle feedback, which highlights the potential of this method and suggests that this, alongside other interventions highlighted, could be valuable additions to current interventional approaches.

Practical tips for tennis players

Try these between points and games:

- Reset posture in breaks – relax shoulders, adopt good posture
- Focus on 3-5 good quality lower rib cage breaths in-between points
- Relax and let the breath out
- When comfortable, breathe in through the nose
- Post-match reset breathing, relax shoulders and calm the breath
- Remember: good tennis form promotes good breathing patterns.

Points to remember when considering BPD (see Figure 7 on the next page)

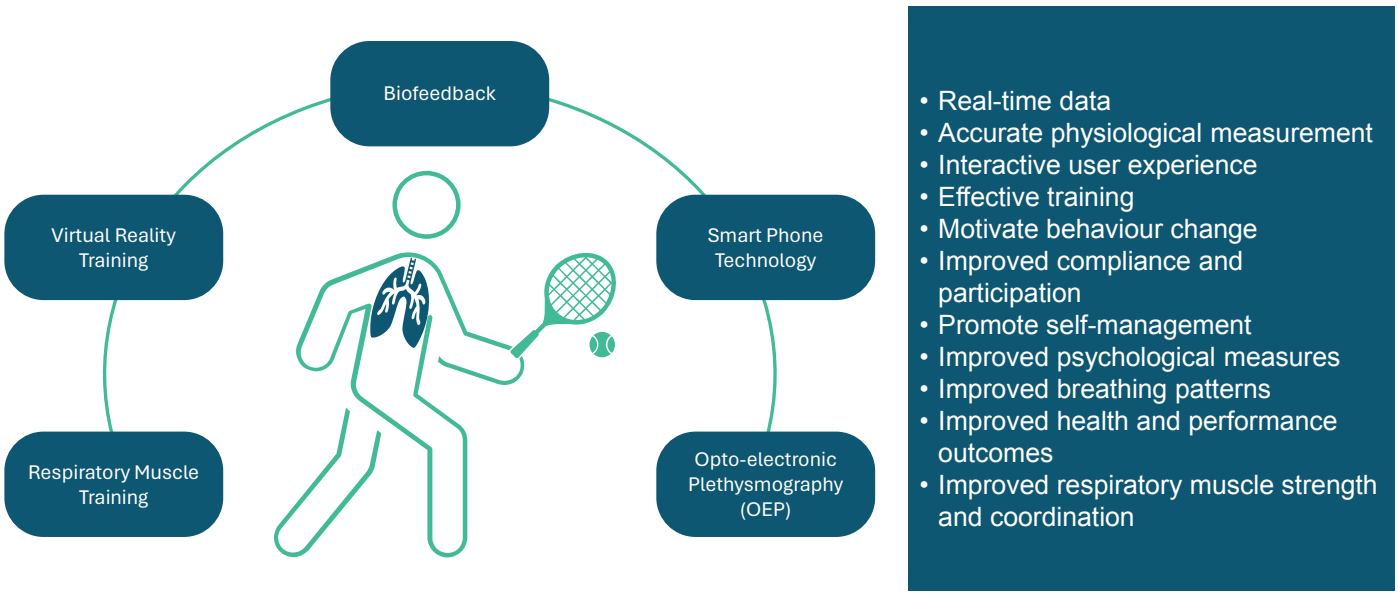

Figure 6: Proposed benefits for future therapies.

Muscle imbalance	**S**tress factors
Accessory muscle use	**E**xpectations
Tightness and injury	**R**ib cage movement
Cough and wheeze	**V**entilation rate
Head position and posture	**E**nvironment

Figure 7: Points to remember when considering BPD.

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