Review

Functional Anatomy of the Soft Palate Applied to Wind Playing

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Wind players must be able to sustain high intraoral pressures in order to play their instruments. Prolonged exposure to these high pressures may lead to the performance-related disorder velopharyngeal insufficiency (VPI). This disorder occurs when the soft palate fails to completely close the air passage between the oral and nasal cavities in the upper respiratory cavity during blowing tasks, this closure being necessary for optimum performance on a wind instrument. VPI is potentially career threatening. Improving music teachers' and students' knowledge of the mechanism of velopharyngeal closure may assist in avoiding potentially catastrophic performance-related disorders arising from dysfunction of the soft palate. In the functional anatomy of the soft palate as applied to wind playing, seven muscles of the soft palate involved in the velopharyngeal closure mechanism are reviewed. These are the tensor veli palatini, levator veli palatini, palatopharyngeus, palatoglossus, musculus uvulae, superior pharyngeal constrictor, and salpingopharyngeus. These muscles contribute to either a palatal or a pharyngeal component of velopharyngeal closure. This information should guide further research into targeted methods of assessment, management, and treatment of VPI in wind musicians. *Med Probl Perform Art* 2010; 25:183–189.

Studies have shown that the physical demands of playing a wind instrument may cause upper respiratory tract injury due to high pharyngeal pressures associated with performance.[1,2] These pressures result from the expired air stream meeting resistance as it reaches the instrument mouthpiece, causing variable instrument-specific pressure levels to build up in the oral cavity.[3] The normal maximum pressures required to play a wind instrument range from 10 to 126 mm Hg, with the highest pressure of 158 mm Hg being measured in a muted trombone.[3] To prevent air escaping into the nasal cavity, the increase of intraoral pressure must be controlled by the soft palate. By closing the isthmus between the oral and nasal cavities, the soft palate ensures the air stream is directed only through the mouth from the oral cavity.

Prolonged exposure to high levels of intraoral pressure may lead to the performance-related condition known as stress velopharyngeal insufficiency (VPI).[4] Normally this condition occurs because of a structural deformity, such as with cleft palate. It is also associated with some other speech disorders. VPI occurs when the soft palate fails to completely close the oronasal cavity while attempting to blow air through the mouth, resulting in air escaping from the nose.[5] Without a tight air seal, the air passes into the nasal cavity and can then escape out the nose. This has a disastrous effect on wind playing, as the power behind the wind musicians' sound relies on enough controlled expired air through the mouth. Understandably, this disorder may potentially end the musician's career.[6]

Little is known of the prevalence, cause, and treatment of VPI in musicians, and case reports of this phenomenon are limited. Published estimates of VPI prevalence in small samples of musicians range from 7%[5] to 34%.[7] Anecdotal reports suggest that the problem frequently occurs in advanced students aspiring for a professional career, due to their physically demanding practice regimen.[8] Evidence from these reports and the available literature suggest that musicians who experience VPI are at significant risk of having limited performance careers.

Current treatment of VPI for musicians has been either speech therapy, a prosthesis worn during performance, or, in severe cases, corrective surgery. Most of the literature dealing with the anatomy of the velopharyngeal mechanism is concerned with speech activities in both normal patients and those with cleft palates. It has been observed that the level of activity of the velopharyngeal muscles differs between speech and blowing tasks,[9,10] which casts doubt on the efficacy of speech therapy activities for treating musicians having VPI. Some authors suggest that treating VPI with oral motor exercises, while effective for disorders such as those associated with cleft palate conditions, is inadequate in training pharyngeal muscles for tasks with different synergistic characteristics and requirements, such as blowing.[11] In contrast, there is some evidence that using continuous positive air pressure (CPAP) may strengthen the velopharyngeal closure muscles.[12] During therapy, the CPAP device delivers positive air pressure to the nasal cavity, thus providing resistance against velopharyngeal opening. While CPAP has been used successfully in treating patients with hypernasality and sleep apnoea, its efficacy in treating stress VPI in musicians needs further research.

The aim of this paper is to review the functional anatomy of the velopharyngeal muscles in order to provide an under-

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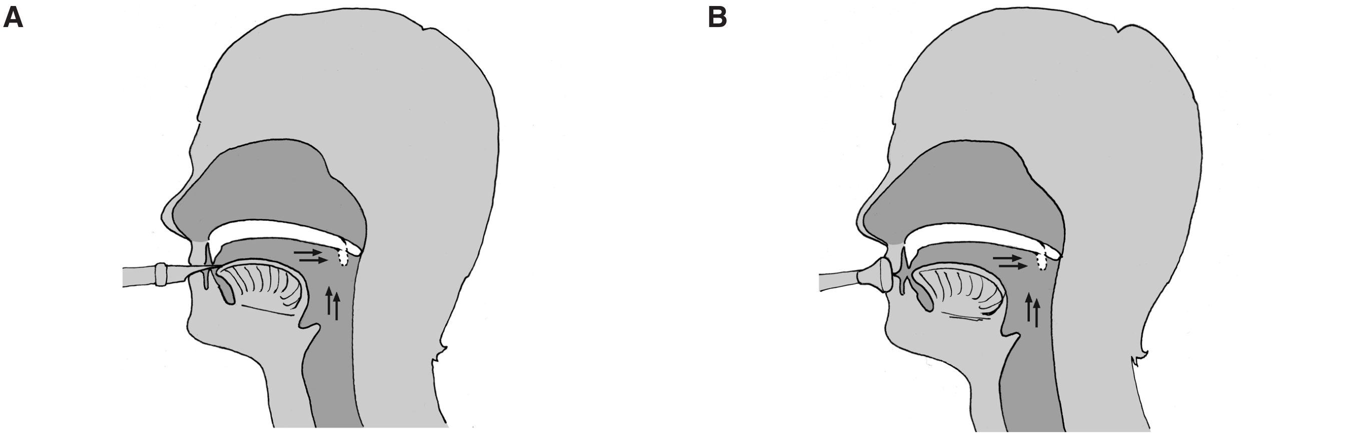

FIGURE 1. Sagittal view of the head: *A*, a bassoon reed in the mouth; *B*, with a brass mouthpiece. Up arrows represent airflow out of the mouth, and back arrows represent resistance provided from the mouthpiece. The soft palate is open in normal resting position (*dotted line*) and is closed in playing position (shown elevated touching the posterior pharyngeal wall).

standing of how the velopharyngeal mechanism functions during wind instrument performance. This should enable teachers and students to improve performance and, hopefully, decrease the occurrence and resulting disability of VPI.

WIND PLAYING TECHNIQUE

Playing a wind instrument involves directing a controlled stream of expired air from the lungs, through the throat and mouth, and into the mouthpiece of the instrument.[13] To maintain intraoral pressure and to sustain airflow through the instrument, there must be sufficient velopharyngeal closure. This was observed in a study of bassoon players by Kahane et al. (2006)[14] who found that the soft palate remains in an elevated position when blowing out through the instrument. If velopharyngeal closure is not sufficient, this may lead to the air escaping via the nasal cavity and leaking out through the nose.

Wind players are able to perform different techniques by employing different positioning of the soft palate and tongue. Nasal coupling, achieved by lowering the soft palate to open the velopharyngeal valve between the oral and nasal cavities, is similar to that seen in VPI. Although this is often detrimental to wind performance, it can be used occasionally to the instrumentalist's advantage. For example, some oboe or trumpet players may periodically exhale through the nose while playing to release pressure in the oral cavity, thereby releasing any tension or excess air before taking another breath.[8,15] However, it is unclear how often wind players use this technique.

Another instance of useful nasal coupling is circular breathing. This involves the simultaneous expiration of air through the mouth and inspiration through the nose, which allows the player to maintain a continuous air stream through the instrument during extended musical phrases. To achieve this, the player seals the oral cavity by lowering the soft palate down onto the raised back of the tongue, and whilst blowing air out the mouth by contracting the cheek muscles, the player is then able to take a rapid breath in through the nose.[6]

There are complex musical requirements, such as articulating notes on both woodwind and brass instruments that involve concurrent complex actions of the soft palate and the tongue, which are different from the typical actions employed during speech. "Single" tonguing refers to the movement of the tongue interrupting the air stream through the lips to the reed or mouthpiece. When players need to articulate notes rapidly, they may use "double" tonguing to play two consecutive notes or "triple" tonguing, which is a combination of both single and double tonguing, to play notes grouped in threes. Both woodwind and brass players can produce "double" tonguing by alternating their tongue between two positions (*t–k*). The first note is produced when the tongue is released from the reed and retracts toward the back of the mouth. The second note is produced when the tongue is released from the soft palate on its return path toward the starting point on the reed. Although these advanced techniques are discussed in the music pedagogical literature, the anatomical mechanisms behind these actions are as yet unknown.

VELOPHARYNGEAL CLOSURE

The soft palate (or velum) separates the nasopharynx from the oropharynx. During quiet breathing the soft palate suspends between the nasal and oral cavities, allowing air to freely move through the mouth or through the nose. During active breathing in and out through only the mouth, the soft palate will elevate to touch the posterior pharyngeal wall, thus closing the opening between the oropharynx and nasopharynx.[16] This velar closure is known as velopharyngeal or palatopharyngeal closure and is important for swallowing, speech, and blowing. The velopharyngeal mechanism is demonstrated in Figure 1.

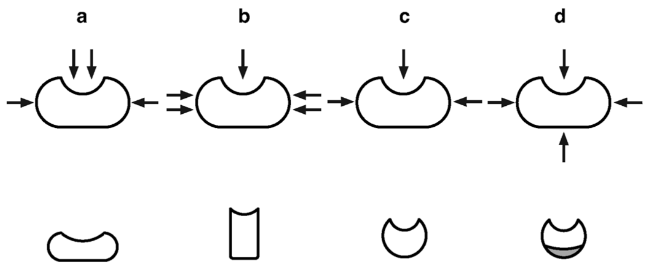

FIGURE 2. Patterns of velopharyngeal closure: *a*, coronal; *b*, sagittal; *c*, circular; *d*, circular with Passavant's pad. Each diagram shows the uvula (*top*), the lateral pharyngeal wall (*sides*), and the posterior pharyngeal wall (*bottom*). The arrows represent the degree of superior, lateral, and/or posterior movement of the velopharyngeal muscles. Below each diagram, the valve pattern is depicted after velopharyngeal closure.

Velopharyngeal closure is achieved by a sphincteric mechanism involving two components. Firstly, the velar component involves the elevation and posterior movement of the velum. Secondly, the pharyngeal component involves the movement of the pharyngeal walls encompassing the oropharynx and nasopharynx.[17] The mechanism of closure of the velopharyngeal port differs between individuals, and the degree of closure varies depending on the task involved, such as whether these muscles are engaged during blowing, speech, or sucking actions.[18]

Croft et al. (1981)[19] observed four main types of closure patterns (Fig. 2). Each pattern involves different muscle movements or a combination of velar and pharyngeal wall movements to achieve closure.

1. Coronal closure (see Fig. 2, *part a*) is achieved by the elevation of the velum to touch the posterior pharyngeal wall;
2. Sagittal closure (*part b*) involves the medial movement of the lateral pharyngeal walls to meet the velum;
3. Circular closure (*part c*) requires an equal movement from both the velum and the lateral pharyngeal walls; and
4. Circular closure with Passavant's pad (described later, *part d*) is a combination of the circular closure with the anterior movement of the posterior pharyngeal wall.

SOFT PALATE AND VELOPHARYNGEAL MUSCLES

The soft palate extends posteriorly from the bony hard palate and includes five main muscles that arise in pairs, one on either side of the midline of the soft palate (Figs. 3 and 4). The muscles that control its movement can be grouped based on their respective actions on the soft palate. They include elevators, depressors, and tensors. The soft palate elevators are the levator veli palatini and musculus uvulae. The two depressors are the palatopharyngeus and palatoglossus. Lastly, the tensor veli palatini is a tensor muscle acting on the soft palate apparatus.[20]

In addition to the five soft palate muscles, there are two other pharyngeal muscles that also arise in pairs and assist in the functional mechanism of velopharyngeal closure: namely, the superior pharyngeal constrictor and the salpingopharyngeus.

Tensor Veli Palatini

The tensor veli palatini (TVP) is innervated by the mandibular branch of the trigeminal nerve (cranial nerve V).[21] The muscle is found bilaterally and is attached superiorly to the scaphoid fossa of the medial pterygoid plate, the spine of the sphenoid bone, and the cartilage of the pharyngotympanic tube. The muscle courses down and then hooks around the pterygoid hamulus, before continuing medially and inferiorly to form part of the palatine aponeurosis.[21] The hamulus acts as a pulley, assisting the muscle to apply tension horizontally on the aponeurosis.[22]

From the literature, anatomical descriptions of the TVP have been controversial. Dickson (1972)[23] and his researchers were of the opinion that the TVP consisted of two bellies—one part attached to the cranial base and coursed down the pterygoid plate to the hamulus, and a second part extended to the lateral walls of the Eustachian tube. In contrast, Huang et al. (1997)[24] found that the TVP was a single sheet of muscle. In terms of functional anatomy, most anatomical texts today agree with the original statement made by Valsalva in 1704, that the primary function of the TVP is to open the Eustachian tube.[25] In addition, when the muscle contracts, it depresses the anterior part of the soft palate,

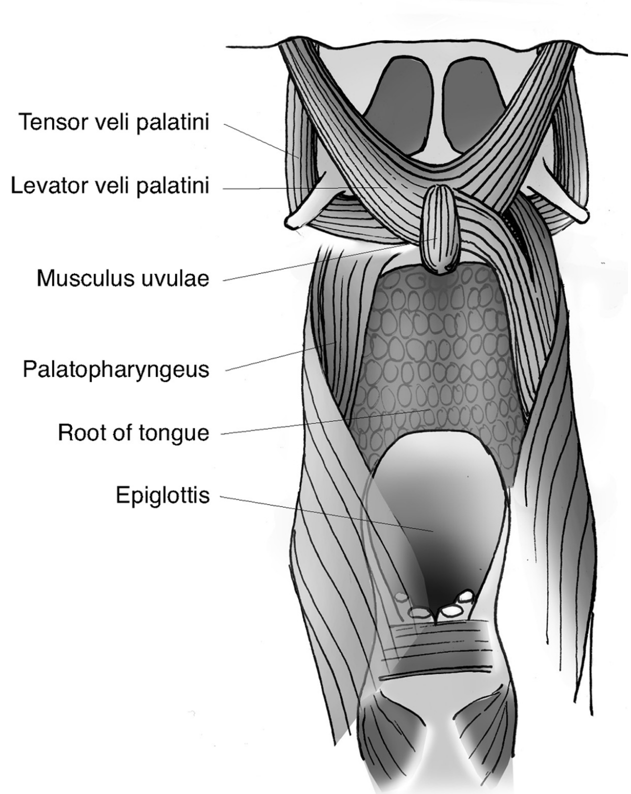

FIGURE 3. Posterior view of nasopharynx and oropharynx that shows levator veli palatini, tensor veli palatini, musculus uvulae, and palatopharyngeus, and the superior constrictor (not shown) wraps superiorly and medially.

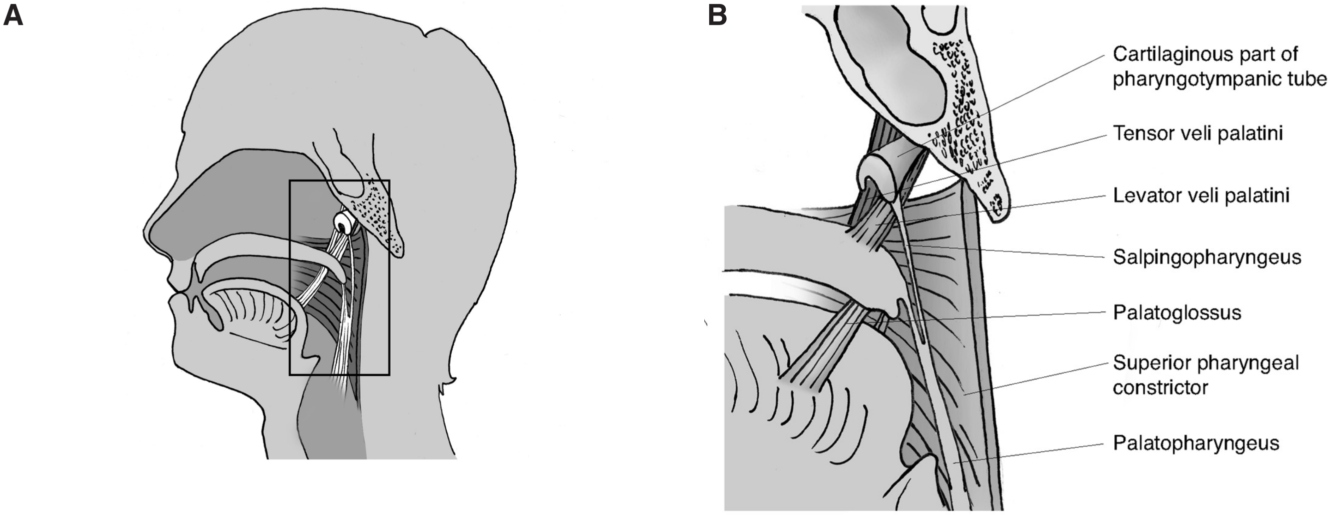

FIGURE 4. *A*, Sagittal view of head, and *B*, close up view of oropharynx that shows tensor veli palatini, levator veli palatini, palatoglossus, palatopharyngeus, salpingopharyngeus and superior pharyngeal constrictor.

pulling the soft palate to the sides and thereby opening the pharyngotympanic tube during swallowing and yawning.[26]

The TVP acts synergistically with the levator veli palatini to dilate the Eustachian tube.[24] Rather than elevating the soft palate, it is thought that the tension applied by the TVP increases stiffness in the velum due to the tensor's palatal aponeurosis component[26] and hence assists the levator veli palatini in coordinating velopharyngeal closure.[20]

A recent histochemical investigation found that the tensor consists of slow-twitch fibres (type I), which allow slower contraction of the muscle to assist in stretching the velum for a long duration of time.[27] It is not clear what role TVP has in producing speech; however, it is presumed that the tensor coordinates with the levator veli palatini during velar elevation and the synergistic action of both TVP and palatoglossus may combine to produce nasal speech sounds (i.e., *m*, *n*, and *ng*).[25]

Levator Veli Palatini

The levator veli palatini (LVP) is innervated by the pharyngeal plexus from the accessory (XI) and vagus (X) nerves.[21] Bilaterally, the muscle is superiorly attached to the cartilage of the pharyngotympanic tube and the temporal bone and inferiorly attached to the palatine aponeurosis.[22] Since 1953, it has been acknowledged that the principal function of the LVP is to elevate the soft palate.[28] According to Casey (1983),[29] the LVP elevates the middle one-third portion of the soft palate superiorly and posteriorly to touch the posterior pharyngeal wall and moves the lateral pharyngeal walls medially and posteriorly to close the opening between the oropharynx and nasopharynx.

The LVP spreads in between the two heads of the palatopharyngeus, acting as a muscular sling that, when it contracts, pulls the velum upward towards the sides and backward towards the posterior pharyngeal wall.[30] The action of the LVP is the principal velar component to velopharyngeal closure and is important in maintaining closure, particularly for expiration at high intraoral pressures.[30]

According to Stal and Lindman (2000),[27] the muscle fibers of the LVP consist primarily of type I fibers. As with the TVP, the higher proportion of slow twitch fibers is best suited to endurance activities and thereby allows the LVP to remain elevated for long periods of time without fatigue. As described above, the LVP acts with the tensor veli palatini in dilating the Eustachian tube, and as an antagonist to the action of the palatopharyngeus to control the degree of velopharyngeal closure.[30] The LVP is the primary muscle involved in velopharyngeal closure, which is important for normal speech and in the production of oral sounds, and is also active in non-speech activities, such as blowing or sucking.[25] The soft palate is lowered for the production of three nasal sounds, but it is either fully or partially elevated for the production of all other English vowel sounds.[31]

Past studies have observed that the soft palate is elevated when blowing a wind instrument[14] and that the LVP muscle is more active in blowing actions.[10] This suggests the action of the LVP muscle may be primarily important in ensuring the oronasal cavity is closed, thereby directing the airflow out through the mouth.

Palatopharyngeus

The palatopharyngeus is innervated by the pharyngeal plexus derived from the accessory and vagus nerves.[21] The palatopharyngeus is a muscle of both the soft palate and the pharynx. Anteriorly, the muscle fibres are attached to the anterior hard palate, and posterior fibres attach to the palatine aponeurosis. These muscle attachments are separated by the levator veli palatini. The muscle fibres then course downward and insert into the salpingopharyngeus and inferiorly to the lateral wall of the pharynx and posterior thyroid cartilage, which form the posterior faucial pillar. Huang and Lee (1998)[30] note that the palatopharyngeus has two components: the velar component consisting of two heads that clasp around and insert into the levator, and the pharyngeal component which inserts into the superior constrictor in the lateral and posterior pharyngeal walls. The palatopharyngeus predominantly consists of fast twitch (type II) fibers, allowing quick contraction of the muscle but potentially making it more susceptible to fatigue if required to contract for prolonged periods of time.[27]

The function of the palatopharyngeus is primarily to lower the palate, which assists the swallowing of food. It may elevate the larynx, which assists in the phonation of high-pitched sounds.[20] According to Fritzell (1969),[25] during contraction of the palatopharyngeus the soft palate moves posteriorly, the posterior faucial pillars are adducted, the lateral walls of the pharynx move medially, and the larynx and pharyngeal walls are elevated. The opposing or antagonistic action of the palatopharyngeus with the LVP has been suggested to be important in achieving velopharyngeal closure,[25] although this has been the subject of some controversy.[23,29] The palatopharyngeus may also assist in increasing the size of the velum, allowing a greater area to make contact with the pharyngeal wall, and also contributing to the medial movement of the lateral pharyngeal walls.[30]

Although there have been conflicting descriptions of the role of the palatopharyngeus, the general consensus is that it lowers the soft palate[21] and narrows the pharyngeal cavity by its action on the lateral pharyngeal walls during swallowing and speech.[29] The palatopharyngeus is active in the production of oral sounds as well as nasal speech sounds, although the contribution of this muscle is more variable than the LVP with the palatopharyngeus being more important in swallowing.[25] The synergistic arrangement of palatopharyngeus and superior constrictor are thought to be important in supporting the primary role of LVP in velopharyngeal closure.[32]

Palatoglossus

The palatoglossus is innervated by the pharyngeal plexus arising from the accessory and vagus nerves.[21] The palatoglossus is attached superiorly to the palatine aponeurosis and inferiorly to the sides of the tongue.[22] The muscle fibres form the anterior faucial pillar.

The function of this muscle is to elevate the posterior part of the tongue and assist in depressing the soft palate onto the tongue.[22] Although most researchers agree on the action of the palatoglossus, some differ on its role in velopharyngeal closure during normal speech. Casey (1983)[29] suggested that the muscle was not active during speech because of the lowered soft palate. In contrast, Fritzell (1969)[25] described that the muscle works as an antagonist to the LVP muscle in controlling the amount of superior pull of this muscle. The palatoglossus coordinates with the TVP to lower the soft palate to produce nasal sounds.[25]

The combined action of elevating the tongue to close the oral cavity and lowering the soft palate to open the nasal cavity may assist some wind instrumentalists in circular breathing.[6] As the palatoglossus raises the tongue against the soft palate to pronounce the consonant *k* or *g*, this same action may also assist wind players in producing double tonguing.[33]

Musculus Uvulae

The musculus uvulae is innervated by the pharyngeal plexus arising from the accessory and vagus nerves.[21] This muscle is found bilaterally, attaching to the posterior nasal spine and the palatine aponeurosis superiorly and inserting into the mucosa of the uvula inferiorly.[22] The main action of this muscle is to shorten the uvula[31] and add bulk to the soft palate, thereby assisting the levator veli palatini in velopharyngeal closure.[34] This is particularly due to the thickness of the fibres in the middle one-third of the soft palate, often known as the "levator eminence," where the levator muscles contract at right angles to the musculus uvulae.[29] The musculus uvulae consists of predominantly type II fibers, which allow the muscle to contract quickly, but consequently it may be more susceptible to fatigue.[27]

There have been differing opinions as to whether the musculus uvulae is single or paired and whether or not the muscle has a passive or active role in contributing to velopharyngeal closure during normal speech. The musculus uvulae may serve passively to protect the nasal surface of the velum from weakening upon LVP contraction, and actively to contribute to the bulk of the levator eminence during LVP contraction and consequently assist velopharyngeal closure.[35]

Superior Constrictor

The superior pharyngeal constrictor is innervated by the accessory and vagus nerves from the pharyngeal plexus.[21] The superior pharyngeal constrictor is superiorly attached to the pterygoid hamulus, the pterygomandibular raphe, the posterior end of the mylohyoid, and the side of the tongue.[22] The muscle on either side sweeps around superiorly and medially to form the lateral and posterior walls of the pharynx and inserts at the midline into the pharyngeal ligament, thus encircling the nasopharynx and upper oropharynx. The palatopharyngeus inserts into the superior constrictor, and together both muscles form a sphincter that surrounds the opening between the nasopharynx and the oropharynx.[30]

The action of the superior constrictor is to elevate the pharyngeal wall and draw the pharyngeal walls inward, assisting the action of palatopharyngeus in the pharyngeal component of velopharyngeal closure by reducing the pharyngeal diameter.[30] The role of the muscle is to prevent the bolus of food from entering the nasopharynx during swallowing, while its potential role during speech is not clear.[29] It was initially thought that the superior fibres of the muscle inserted into the velum[36] and that its superior fibers may assist in retracting the velum.[31] However Huang and Lee (1998)[30] disputed this fact, arguing instead that the fibres of the palatopharyngeus muscle insert into the superior constrictor, and the hemispheric mechanism formed by both muscles contracts to move the lateral pharyngeal walls medially.

Where the uppermost fibres of this muscle originate from the medial pterygoid plate, it is known as Passavant's pad, named after Gustav Passavant (1860s) who first observed a ridge on the posterior pharyngeal wall in cleft palate patients.[25] When present, this pad may assist in effecting a seal with the soft palate as it moves anteriorly with contraction of the superior constrictor muscle.[25] Passavant's pad has been reported to be more marked in individuals with palatal insufficiency, suggesting that this ridge may develop further when acting to compensate for ineffective velopharyngeal closure[29] (although some authors dispute this claim[19]).

Salpingopharyngeus

The salpingopharyngeus is innervated by the accessory and vagus nerves from the pharyngeal plexus.[21] The salpingopharyngeus is attached superiorly to the cartilaginous part of the pharyngotympanic tube and inferiorly to the palatopharyngeal muscle.[22] There have been conflicting descriptions of the main action of this muscle. It was first believed that the muscle elevates the larynx and shortens the pharynx during swallowing and speaking.[22] Some of the fibres of the salpingopharyngeus blend with the fibres of the superior constrictor, which may indicate that the salpingopharyngeus assists the superior constrictor in elevating the pharyngeal wall.[21] It is unclear whether the elevation of the lateral pharyngeal wall contributes to the pharyngeal component of velopharyngeal closure. The small size of this muscle suggests that this has a minor functional importance, although it may assist in the elevation of the lateral pharyngeal wall.[24]

APPLICATION OF THE FUNCTIONAL ANATOMY TO WIND PLAYING

The complex anatomy of the soft palate muscles, as described above, has not been investigated in depth when applied to blowing tasks such as those required for playing a wind instrument. During instrumental blowing tasks, the soft palate must withstand a great increase in pressures compared to speech, and the degree of velopharyngeal closure is achieved by a number of synergistic arrangements. This is further complicated by such musical tasks as tonguing and circular breathing.

The most important muscle for velopharyngeal closure is the levator veli palatini (LVP). It is known that the soft palate is elevated more during blowing tasks compared to speech, and this has been assumed to be due to greater LVP activity.[10] It is likely that all of the velopharyngeal muscles coordinate with each other to achieve closure in blowing, but the patterns of this are as yet unknown. From the available literature it appears that the LVP muscle may be the most important in maintaining the soft palate elevation and velopharyngeal closure during blowing of a wind instrument. Further studies are needed to identify the specific muscle activation patterns during blowing tasks. This information is crucial in developing targeted rehabilitation protocols.

CONCLUSION

This review shows that the function of the soft palate is essential for maintaining upper respiratory tract structure and function under pressure and hence for allowing optimal airflow. It is crucial for wind and brass players to be able to maintain firm velopharyngeal closure for optimum performance. This area has received little attention in research, and it is important to increase understanding of the functional anatomy of the soft palate to help prevent potential performance-related disorders and better manage injuries that may arise from overuse or misuse of the soft palate muscles. It is likely that the current management protocol of speech exercises may be insufficient for strengthening muscles implicated in stress VPI in musicians, because the degree of contraction and synergistic arrangements of the muscles involved in wind playing will be considerably different to those employed in speech.

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