A SCIENTIFIC CHARACTERIZATION OF TRUMPET MOUTHPIECE FORCES IN THE CONTEXT OF PEDAGOGICAL BRASS LITERATURE

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Embouchure dysfunctions, including those from acute injury to the obicularis oris muscle, represent potential and serious occupational health problems for trumpeters. Forces generated between the mouthpiece and lips, generally a result of how a trumpeter plays, are believed to be the origin for such problems. In response to insights gained from new technologies that are currently being used to measure mouthpiece forces, belief systems and teaching methodologies may need to change in order to resolve possible conflicting terminology, pedagogical instructions, and performance advice. As a basis for such change, the purpose of this study was to investigate, develop and propose an operational definition of mouthpiece forces applicable to trumpet pedagogy. The methodology for this study included an analysis of writings by selected brass pedagogues regarding mouthpiece force. Finding were extracted, compared, and contrasted with scientifically derived mouthpiece force concepts developed from scientific studies including one done at the UNT Texas Center for Music & Medicine. Results characterized five mouthpiece force principles as the basis for an operational definition of mouthpiece force. This definition recognizes the relationships between average mouthpiece force and mouthpiece force variability. Mouthpiece force principles as presented in this study may contribute to a better understanding of mouthpiece force and its link to lip related injuries. However, additional studies are needed to better understanding the relationships between how the trumpet is taught and learned and the resulting mouthpiece forces produced when playing the trumpet.

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INTRODUCTION, RATIONALE, AND PURPOSE OF STUDY

Introduction

In 2001, the National Association of Schools of Music (NASM) recommended that institutions assist students in acquiring knowledge about the prevention of performance-related injuries.[1] One precedent for achieving this objective is the formation of a coherent body of knowledge about music and medicine. Prevalence and prospective studies, based on scientific verification and not subjective experiences and calculated guessing, are currently needed and mandated. Therefore, research into every aspect of music pedagogy and performance is necessary to support the efforts of NASM and other national organizations including the Performing Arts Medicine Association (PAMA).[2]

One area that calls for immediate attention concerns the lip injuries suffered by trumpet players. There have been several notable examples of lip problems among trumpet players including Freddie Hubbard.[3] The best-known example was Louis Armstrong in 1935. His condition, later described as Satchmo's Syndrome, forced him to stop playing for one year. Unfortunately, these career-ending or –altering lip injuries are not uncommon among brass instrumentalists, specifically trumpet players.[4]

The University of North Texas survey, called the UNT Musician Health Survey (UNT-HMS), was among the first to quantify, on a national level, the prevalence rates for medical problems among musicians. The UNT-HMS surveyed 4017 musicians via an online survey. The UNT-HMS reported on the frequency of problems among symphony and non-symphony musicians, gender- and age-related risks, and the identification of musculoskeletal and nonmusculoskeletal problem locations. The UNT-

HMS was also used to generate insights into the extent of medical problems within particular subgroups based on the primary instrument including brass instrumentalists,[5] clarinetists,[6] flutists,[7] pianists,[8] double reeds,[9] and saxophone.[10]

The UNT-HMS report of brass instrumentalists showed that 60% of musicians primarily performing trumpet, trombone, french horn, or low brass reported having at least one musculoskeletal medical problem.[11] Prevalence rates for medical problems of brass instrumentalists show that loss of lip, influenced by mouthpiece force, were higher for trumpet (23.9%) compared to horn (18%), trombone (13.5%), or low brass (9.5%).[12] The report suggests that the physical demands associated with holding and positioning the instrument, pressing the mouthpiece against the lips, and sustaining blowing pressure contributes to specific performance-related medical problems.[13]

Existing experimental and clinical studies support this hypothesis. Playing brass instruments contribute to medical problems. Orofacial dysfunction,[14] injury to the obicularis oris muscle,[15] lip pain,[16] tooth displacement,[17] hand and wrist problems,[18] overuse syndromes, and focal dystonia[19] have all been linked to the mouthpiece forces generated during brass performance. According to the experimental mouthpiece force studies, all trumpet players use a substantial amount of mouthpiece force. In some cases these mouthpiece forces were observed to exceed 100 Newtons (*N*).[20] The studies found that mouthpiece forces could be substantial enough to alter tooth position up to 100 microns (μm)[21] and cause serious injury to the obicularis oris muscle.[22] Regardless of performance level or style, mouthpiece force is unquestionably an important risk factor in understanding the etiology of medical problems associated with trumpet performance.

Rationale of the Study

Mouthpiece force is believed to be the result of how a trumpeter performs or practices.[23] The skills necessary to become a proficient trumpet player are typically developed, perfected, and maintained through thoughtful practice under the guidance of a master teacher.[24] There is concern that the widely accepted teaching methodologies and brass playing concepts of brass pedagogues provide conflicting terminology, instructions, and advice.[25] An overview of the pedagogical literature on mouthpiece force reveals unsupported and unsubstantiated concepts about mouthpiece force, possibly due to the lack of available credible information regarding mouthpiece force characteristics.[26]

Performing arts medicine researchers, Alice Brandfonbrener and Richard Lederman, have recommended that “historically accepted pedagogical concepts need to be objectively tested for their short and long term implications in musical ease, health, and longevity.”[27] No study, however, has specifically assessed the pedagogical concepts concerning mouthpiece force. To fulfill this need, the following question must be considered. How is mouthpiece force conceptualized within the pedagogical literature?

Purpose of the Study

In light of this question, the purpose of this study is to develop and propose an operational definition of mouthpiece force suitable for trumpet pedagogy.

The specific aims of this study are:

1) Review selected pedagogical concepts and methodologies pertaining to mouthpiece force as found in the trumpet/brass literature.

2) Review all experimental literature pertaining to the mouthpiece forces generated during trumpet performance.

3) Examine the selected pedagogical concepts using the experimental mouthpiece force studies.

4) Propose an operational definition of mouthpiece force suitable for trumpet pedagogy.

An operational definition of mouthpiece force will help teachers and performers understand the physical nature of mouthpiece force during trumpet performance and thus lead to more efficient ways to practice, perform, and teach.[28] The potential alleviation of lip injuries, due to mouthpiece force, may be an ancillary but important result of the study.

REVIEW OF BRASS PEDAGOGICAL LITERATRURE

Existing experimental and clinical studies suggest that lip-related medical problems including orofacial dysfunction,[29] injury to the obicularis oris muscle,[30] lip pain,[31] tooth displacement,[32] hand and wrist problems,[33] overuse syndromes, and focal dystonia,[34] may be associated with mouthpiece forces generated during trumpet performance. Because of performance-related medical problems like these, performing arts medicine researchers Alice Brandfonbrener and Richard Lederman recommend that "historically accepted pedagogical concepts need to be objectively tested."[35] In order to objectively test the pedagogical concepts related to mouthpiece force, all pedagogical concepts related to mouthpiece force found within the brass pedagogical literature must be reviewed. Therefore, this section provides the preliminary work needed to review the pedagogical literature and later examine the pedagogical concepts related to mouthpiece force.

This review of the brass pedagogical literature was organized into four sections. The first section, selection of pedagogical methods, describes the criteria for inclusion. The pedagogical methods were chosen from a list of trumpet studies and etudes provided within Matthew R. Inkster's dissertation on trumpet pedagogy.[36] From Inkster's list, only the most frequently cited pedagogical methods, excluding etude books, were considered for this review. The next section, classification of terms, addressed terminology and clarified misused terms related to mouthpiece force and intra-oral pressure. First, both terms were defined/described using the Webster's Dictionary of the American Language, the music literature, and the scientific literature. Next, suggested definitions were recommended in order for the music definitions to be consistent with

definitions found within the Webster's Dictionary and the scientific literature. Additional terms used throughout the paper were also defined. The third section, review of selected brass pedagogical literature, provided the pedagogical source, date, extracted mouthpiece force concept, and summary of the selected pedagogical methods. The final section, mouthpiece force concepts, described why and how mouthpiece force concepts were grouped together. By grouping concepts that were the same (cited by more than one pedagogue) together and unique concepts that provide distinct insights (cited by only one pedagogue) separately, a short list of general mouthpiece force concepts was created.

Selection of Pedagogical Methods

One the most comprehensive sources about brass pedagogy come from surveys administered by Mathew R. Inkster. Inkster's dissertation, entitled A Review of Twelve Outstanding University Trumpet Studios: A Comparison of Methodology, Pedagogy, and Structure, provide a "series of narratives through conversations with exemplars of the best trumpet pedagogical practice and theory" including Richard Burkart, Leonard Candelaria, Vincent Cichowicz, Vincent DiMartino, Armando Ghitalla, Bryan Goff, David Hickman, Stephen Jones, William Pfund, John Rommel, Michael Sachs, and Britton Theurer.[37]

The Inkster dissertation surveyed the aforementioned trumpet teachers of distinction by asking twelve formulated question that would unveil their philosophies and theories about trumpet pedagogy.[38] Each teacher provided their insights into several major areas of trumpet pedagogy including influences, teaching concepts, curriculum,

lesson structure, teaching assistants, masterclass, “high” trumpets, embouchure, scales/digital technique, transposition, practice, and daily routine.

The survey concluded, “while many pedagogical threads were discovered, many different means can achieve the same end.”[39] Inkster asked each pedagogue “What would you consider to be the ‘core’ curriculum for the undergraduate trumpet performance major?” Responses to this “curriculum” question were found to be extensive and broad-ranging.[40] The twelve teachers cited the use of a total of 33 different pedagogical sources they considered essential to the core curriculum of the undergraduate trumpet major.

By frequency of response and then alphabetically, Inkster provided a list of the trumpet studies and etude books used by the teachers of these outstanding university trumpet studios (Appendix A). Reginald Caffarelli’s 100 Melodic Studies, Theo Charlier’s 36 Etudes Transcendentes, and Herbert L. Clarke’s Technical Studies received the highest number of responses, a total of nine. In addition, Jean-Baptiste Arban’s Complete Conservatory Method, Marcel Bitsch’s 20 Etudes, Giulio Marco Bordogni’s 24 Vocalises, and Vassily Brandt’s 34 Orchestral Studies received the second highest number of responses, a total of seven.

In light of the current call for pedagogical methods to be objectively tested, it would seem appropriate and beneficial to review the pedagogical methods currently in use. Therefore, pedagogical methods for the current review of brass pedagogical literature were selected from Matthew R. Inkster’s dissertation because his account of current philosophical and pedagogical practices of outstanding university trumpet

teachers is the most current and relevant. In addition, Inkster provided a list of the trumpet studies and etudes used in their outstanding trumpet studios.

The pedagogical methods from the Inkster dissertation fall into three categories including method books with text to describe and explain various pedagogical concepts, method books with text and music intended to reinforce specific pedagogical concepts, and etude books with music only. For this review of pedagogical methods concerning mouthpiece force, only method books with text and method books with text and music (with five or more responses from the Inkster list) were included. The pedagogical sources selected for this review of pedagogical literature include the methods of Herbert L. Clarke, Joseph Jean-Baptiste Arban, and James Stamp.

In addition, the pedagogical concepts concerning mouthpiece force of brass pedagogues Philip Farkas, Donald Reinhardt, and Arnold Jacobs, were included because of their specific interests and writings about the medical problems of wind players, the mechanics of the embouchure, and the mechanics of breathing.

Classification of Terms

Before reviewing the pedagogical literature, an issue related to misunderstood and/or misused terminology concerning mouthpiece pressure and force must be addressed. The Webster's New World Dictionary of the American Language has defined pressure as the force per unit area acting perpendicular to a surface.[41] In addition, force (a term recently confused with pressure) was defined as the strength, power, and physical coercion against a person or thing.[42] This is important because these terms have created problems and confusion. For instance, within the pedagogical

brass literature, “pressure” was used to describe the “air pressure” within the oral cavity. In addition, the term “pressure” was also used to describe or define the amount of force between the player’s lips and mouthpiece.

To be consistent with the recent scientific mouthpiece force studies, it was important that this pedagogical review differentiate “mouthpiece force” from “intra-oral pressure.” Intra-oral pressure should be defined as the force per unit area exerted within the oral cavity as found in the scientific studies of Fletcher and Kitajima.[43] Accordingly, mouthpiece force may be defined as the strength, power, and physical coercion between a performer’s lips and mouthpiece as established in the scientific mouthpiece force studies of Barbenel, Kenny, and Davies.[44] Throughout this study, the term [force] in brackets was used and substituted for pedagogical references to mouthpiece “pressure” in cases which this author determined that “mouthpiece force” was the intent.

Consistency in the use of these terms will aid in effective teaching and understanding new research involving combinations of mouthpiece force and intra-oral pressure measurements. More importantly, the uniform and consistent use of the term mouthpiece force in pedagogy will allow teachers and students to clearly and thoroughly understand mouthpiece force as it is applied in both the musical and scientific fields.

The Performing Arts Medicine Association (PAMA) has recognized similar problems concerning terminology derived from both the musical and medical fields.[45] To address this problem, PAMA formed a Standards Committee to create clear, concise, and useful definitions pertinent to the performing arts community that resulted in the publication of the article “What’s in a Name? Terminologic Issues in Performing Arts Medicine.”[46]

Review of Selected Pedagogical Literature

In the following six reviews, all pedagogical concepts concerning mouthpiece force were chronologically extracted from the selected pedagogical brass methods. In light of the scientific mouthpiece force studies available prior to the writing of the selected pedagogical methods, this review of brass pedagogical literature also sought to uncover, by finding references within the pedagogical methods, whether empirical evidence was used to formulate or support these pedagogical concepts concerning mouthpiece force.

Pedagogical Method 1

Joseph Jean-Baptiste Arban (1825-1889), in his Complete Conservatory Method for Trumpet, provided what has become an absolute necessity to anyone studying and playing the trumpet or cornet.[47] It was Arban's intent to provide all players with the "secret and salutary traditions" used by conservatory professors.[48] This pedagogical method contained both text and music including sections on range, alternate fingering, attack, breathing, slurring or legato playing, scales, ornaments, tonguing, and the art of phrasing. In addition, 14 characteristic studies, 12 celebrated fantasies, and aires were included.

Arban's pedagogical concepts concerning mouthpiece force suggested that, "in order to produce the higher notes, it is necessary to press the instrument against the lips, so as to produce an amount of tension proportionate to the needs of the note to be produced…."[49] In addition, "for descending passages it is necessary to apply the mouthpiece more lightly, in order to allow a larger opening for the passage of air."[50]

Pedagogical Method 2

In his Technical Studies for the Cornet, Herbert Lincoln Clarke (1867-1945), provided exercises that would "enable the cornet student to conquer any technical difficulties he might encounter in the literature for the instrument."[51] In addition, Clarke advised the student that if the instructions were carefully followed "the student will build up strength and endurance without strain or injury."[52] This pedagogical text with music did not provide concepts concerning mouthpiece force.

However, Setting Up Drills, another pedagogical text with music by Clarke published in 1935 provided one general concept concerning mouthpiece force.[53] Clarke suggested that "if you must use [force], and it is necessary at times, especially when playing very loud and in the upper register, confine it to the lower lip…." No other mouthpiece force concepts were provided in this method.[54]

Pedagogical Method 3

Philip Farkas (1914-1992), in The Art of Brass Playing, provide many pedagogical concepts on brass playing. Farkas wrote this pedagogical text to offer brass players "a clear, well-defined solution to his particular embouchure problem or problems."[55] This pedagogical text contains no music, but offers several pictures, charts, and illustrations to reinforce his pedagogical concepts.

In reference to mouthpiece force, Farkas stated, "there should be a comfortable, normal [force] which hermetically seals the lips to the mouthpiece - a [force] which keeps the mouthpiece from skidding on the lips and gives a general feeling of security."[56] Farkas suggested that this "normal" force varied in several ways. For

instance, “[force] will differ between individual players; it will differ on various types of mouthpieces; normally, it will increase as the player goes into the higher register; and it will increase as a player becomes fatigued.”[57]

Farkas also suggested that all brass players were occasionally tempted to use “undue” force.[58] Because of the “fine line of differentiation between fairly heavy, but allowable [force], and embouchure destroying [force]”, Farkas suggested that it was difficult for the teacher to define “undue” force.[59]

In addition, Farkas defined “lateral” force as force exerted in any direction, side to side, or up and down and claimed that many players had the tendency of pushing their mouthpieces laterally at a right angle to the direction of the mouthpiece.[60]

Pedagogical Method 4

Donald Reinhardt (1908-1989), in his Encyclopedia of the Pivot System for Trumpet for all Cupped Mouthpiece Brass Instruments, provided a unique method of approaching the mechanics of brass playing. Reinhardt believed that after a thorough analysis and adoption of his “scientific” principles the player could obtain maximum efficiency on his or her instrument.[61] This pedagogical method without music offered several pedagogical concepts concerning mouthpiece force.

Reinhardt suggested that players “use a minimum of [force] at all times.”[62] Similar to Farkas’ assertions, Reinhardt’s method suggested that “a minimum of mouthpiece [force] should be used at all times, just enough to keep a firm lip contact throughout your various playing requirements.”[63] In addition, “mouthpiece force varied with every individual.”[64] Unlike the previous pedagogical sources, Reinhardt expressed

that “slightly more [force] was essential to play a tongued passage than a legato passage.”

Pedagogical Method 5

Pedagogue James Stamp’s (1904-1985) Warm-Ups and Studies were designed to “develop the mechanics demanded of today’s player.”[65] This pedagogical text with music provided suggestions for many brass areas including breathing, basic warm-ups, slur exercises, trill exercises, bending exercises, octave studies, scale velocity, concentration, and staccato control.

Stamp’s pedagogical concepts concerning mouthpiece force instructed the player that there should be “no [force] of the mouthpiece on the lips until the breath is finished.”[66]

Pedagogical Method 6

Arnold Jacobs (1915-1998) was recognized as both the master performer and the foremost teacher of wind instruments.[67] Jacobs’ assistant, Brian Frederiksen, wrote the definitive book on Jacobs’s career entitled Song and Wind.[68] This pedagogical text without music included material from master classes, private interviews, previously published writings, and contributions from Jacobs’s students and colleagues.

Jacobs concentrated on issues of musicality, but offered these comments concerning mouthpiece force. He pointed out that “some mouthpiece [force] against the lips is important to ensure a proper seal around the vibrating portion of the lips.”[69] However, he warned, “if too much mouthpiece [force] is applied, tissue can be

damaged."[70] For example, "when a player holds the mouthpiece on the lips too long, swelling develops."[71] To remedy this swelling Jacobs suggested that, "rest is the best cure."[72] However, when rest was not possible the "use of a slightly smaller dynamic range and avoiding the very top notes of the instrument are advised."[73]

Summary of Reviews 1-6

Table 1 shows the mouthpiece force concepts as defined/described within the selected pedagogical methods including the author, date of publication and mouthpiece force concept. (The mouthpiece force concepts extracted from the six selected sources consistently reflect 47 other pedagogical texts reviewed in Appendix B).

The review indicates that some mouthpiece force concepts were the same. Pedagogues Farkas, Reinhardt, and Jacobs agreed that mouthpiece force facilitated the lips' seal with the mouthpiece. In addition, Arban, Clarke, and Farkas agreed that mouthpiece force increased as the player performed in the high register.

Table 1. Mouthpiece Force Concepts as defined/described* within the Selected Pedagogical Methods		
Author	Date	Mouthpiece Force Concepts
Joseph Arban	1894	• In order to produce the higher notes, it is necessary to press the instrument against the lips, so as to produce an amount of tension proportionate to the needs of the note to be produced…. • For descending passages it is necessary to apply the mouthpiece more lightly, in order to allow a larger opening for the passage of air.
Herbert L. Clarke	1935	• If you must use [force], and it is necessary at times, especially when playing very loud and in the upper register, confine it to the lower lip.
Philip Farkas	1962	• Normal [force] hermetically seals the lips to the mouthpiece. • [Force] will differ between individual players. • [Force] will increase as the player goes into the higher register. • [Force] will increase as a player becomes fatigued. • [Force] will differ on various types mouthpieces.
Donald Reinhardt	1973	• A minimum of mouthpiece [force] should be used at all times, just enough to keep a firm lip contact throughout your various playing requirements. • Mouthpiece [force] varies with every individual. • Slightly more [force] is essential to play a tongued passage than a legato passage.
James Stamp	1978	• No [force] of the mouthpiece on the lips until the breath was finished. • What [force] is needed is added after the breath.
Arnold Jacobs	1996	• Some mouthpiece [force] against the lips is important to ensure a proper seal around the vibrating portion of the lips. • If too much mouthpiece [force] is applied, tissue can be damaged. • When a player holds the mouthpiece on the lips too long, swelling develops.

Note: The term pressure has been replaced with the term force. *Each entry is a direct quote from the primary sources as indicated in the previous reviews.

The review of the selected brass pedagogical methods also found concepts that provided unique insights about mouthpiece force. These unique concepts, provided by only one pedagogue, addressed specific tasks or skills related to performance. Only

Farkas stated that mouthpiece force increased as a player became fatigued. Farkas also stated that mouthpiece force would differ on various types of mouthpieces.

Table 2. General Mouthpiece Force Concepts shows the similar and unique mouthpiece force concepts derived from the selected pedagogical methods. Mouthpiece force concepts that provided the same suggestions about mouthpiece force were grouped together. Mouthpiece force concepts that provided unique (provided by one pedagogue) suggestions about mouthpiece force were listed separately. As a result, ten general mouthpiece force concepts were identified from this grouping of mouthpiece force concepts. The concepts were then rank ordered by frequency of response. Even though the mouthpiece force concepts were the same or unique they did not contradict one another.

Table 2. General Pedagogical Mouthpiece Force Concepts

Concept #	Mouthpiece Force Concepts	**Source**
1	Mouthpiece force is required to create a seal between the embouchure and the mouthpiece.	Farkas Reinhardt Jacobs
2	High levels of mouthpiece force are generated in higher registers.	Arban Clarke Farkas
3	Mouthpiece force varies between players.	Farkas Reinhardt
4	Excessive Mouthpiece force will cause injury.	Jacobs Farkas
5	Higher levels of mouthpiece force are generated at higher loudness levels.	Clarke
6	Mouthpiece force is increased, as a player becomes fatigued.	Farkas
7	Mouthpiece force differs on various sizes of mouthpieces.	Farkas
8	Mouthpiece force varies using different articulation.	Reinhardt
9	Minimal mouthpiece force is required at all times.	Reinhardt
10	Mouthpiece force is added after the breath.	Stamp

While various mouthpiece force studies were available when several of these pedagogical methods were written/compiled, there was no evidence that these mouthpiece force studies were consulted. Although Reinhardt stated that the “Pivot System” was a “scientific, practical, and proven method,” he provided no empirical evidence.[74] What was found in several of the brass pedagogical methods were statements from the pedagogues that informed readers that their methods were the result of years of teaching and observing.

REVIEW OF TRUMPET MOUTHPIECE FORCE LITERATURE

Trumpet Mouthpiece Force Studies

Several trumpet mouthpiece force studies were initiated to determine exactly what mouthpiece forces were being generated during trumpet performance. In order to further examine the historically accepted pedagogical concepts, all experimental trumpet mouthpiece force studies were reviewed. This section provides an overview of the scientific literature.

This review of experimental scientific mouthpiece force studies was organized into three sections. The first section, selection of mouthpiece force studies, describes the criteria for inclusion. The mouthpiece force studies were selected from a list of studies cited in Marc Horowitz's review of the medical and scientific trumpet literature. From Horowitz's "Trumpet Citations in Recent Medical and Scientific Literature" article, only the studies related to mouthpiece force were included for this review. The second section, review of mouthpiece force studies, provides a concise summary of the studies. Details of each study including the purpose, methodology, and results were presented chronologically. The third section, mouthpiece force concepts, describes why and how the scientific mouthpiece force concepts were grouped together. By grouping the scientific mouthpiece force concepts that were the same (cited by more that one study) together and unique concepts that provide distinct insights (cited by only one study) separately, a list of general scientific mouthpiece force concepts was created.

Selection of Mouthpiece Force Studies

In 1997, Marc David Horowitz published, “Trumpet citations in recent medical and scientific literature.”[75] Horowitz’s review of the literature includes twenty articles of interest from approximately 25 predominately scientific and technical databases. Of the twenty articles, three articles were found concerning the mouthpiece forces generated during trumpet performance. Two addition studies were found within the bibliographies of the three articles. Because Horowitz specifically targeted the scientific and technical databases, a search using general databases like First Search and the Music Index was conducted. As a result, five trumpet mouthpiece force studies were found.

Review of Trumpet Mouthpiece Force Studies

Mouthpiece Force Study 1

The first known attempt to quantify trumpet mouthpiece force and “air-pressure” was reported by Hayward Henderson in 1942.[76] Inspired by the “pressure vs. no pressure” debate of the time, Henderson sought to determine the underlying principles contributing to an efficient embouchure. This first attempt at measuring mouthpiece force suspended a trumpet by a wire so that the bell was in contact with a spring-loaded piston. Forces directed along the horizontal axis of the mouthpiece and lead-pipe compressed the spring, giving an indication of the load. While measuring mouthpiece forces, the subjects (n=3) were not allowed to hold the instrument in their normal playing position.

Henderson concluded “as higher tones are played there is a definite increase in [force] by all players and players should use a low range of mouthpiece [force] variation.”[77]

Mouthpiece Force Study 2

Ardell Hake and Robert Weast were the second investigators to quantify trumpet mouthpiece force.[78] Hake and Weast wanted to determine precisely what mouthpiece forces were being used and by whom. The experimenters attached the bell of an instrument to a simple weight scale. The weight scale was mounted with a set of felt-padded rods that fitted into the bell of the trumpet. Using this weight scale, Hake and Weast measured the forces applied to the trumpet while the subjects (n=30) held the instrument on the palm of their hand.

Hake and Weast reported that “trumpet players could, at will, use varying amounts of [force] on any note; [force] was gradually applied while ascending or crescendoing; [force] increases as fatigue sets in.”[79]

Mouthpiece Force Study 3

The third study by Elmer Russel White recorded the electromyographic potentials of selected facial muscles and labial mouthpiece [force] measurements in the embouchure of trumpet players (n=18).[80] White attached the bell of the trumpet to a postal scale placed on its side by means of a tripodal connector. The leadpipe of the trumpet was suspended from the ceiling with a cord in such a manner that when the trumpet was played the amount of force the mouthpiece exerted on the player’s lips was

registered on the postal weight scale. White's method of quantifying mouthpiece force was similar to Weast and Hake's method.

White reported "labial mouthpiece [forces] are greater in the high register than in the low register; and both are greater at high intensity than at low intensity. Register has a greater effect than intensity. And subject proficiency level had no differential effect on mouthpiece [force] variation with changing register or intensity and total levels of [force]."[81]

Mouthpiece Force Study 4

During the late 1980s a group of researchers from Glasgow, Scotland turned their interests towards the use of mouthpiece force in trumpet players. Joe Barbenel, Patrick Kenny, and John Booth Davies attempted to determine if playing proficiency was related to the magnitude of mouthpiece forces used by the player (n=60). The researchers designed a device that would provide a dynamic, continuous record of mouthpiece forces. However, the measuring device inserted between the mouthpiece and the leadpipe altered the pitch and playing characteristics of the trumpet.

The investigators concluded that all players use substantial amounts of force; increases in intensity and increases in frequency, both produce increases in applied force; there are large individual differences in levels of force used by different players, but individual players show high levels of consistency, force levels of individuals stayed constant over time; players using higher force levels at the top of the range tended to use relatively higher force levels throughout the range; an analysis of force increments

showed that, at all dynamic levels, increments were larger as the upper register was approached."[82]

Mouthpiece Force Study 5

Through an interdisciplinary collaboration of musicians, medical doctors, engineers, and audiologists the Texas Center for Music and Medicine (TCMM) investigated the biomechanics of trumpet performance.[83] TCMM wanted to "develop and utilize an objective and reliable approach for assessing mouthpiece forces generated during trumpet performance in order to increase the understanding of mouthpiece force and its impact on the etiology, progression, treatment and prevention of embouchure and upper extremity musculoskeletal problems among this occupational group."[84]

The TCMM devised a measurement device affixed to the mouthpiece receiver of a test trumpet that, unlike those in the previous studies, collects and records continuous data including changes in mouthpiece force, instrument/mouthpiece angles involving vertical and horizontal changes, sound level, and live video. The performers (n=23) were allowed to use their normal performing techniques and personal mouthpieces while the measurements were being recorded.

The researchers reported that "mouthpiece forces generally changed as a function of increased pitch, loudness, and length of performance time; some individuals do play high pitches and loudness levels without using high mouthpiece force levels; there were substantial differences in levels of force used by different players regardless of task, but individuals showed high levels of consistency across tasks."[85]

Summary of Mouthpiece Force Study Findings

Table 3 shows the findings from the mouthpiece force studies including the investigator, date, and mouthpiece force findings. Despite differences in measurement protocol and methodology, the reviews of mouthpiece force studies indicate that their findings were similar. All mouthpiece force studies agreed that mouthpiece forces increased as higher pitches were performed. In addition, all studies agreed that all players used varying amounts of mouthpiece force.

Table 3. Summary Table of Mouthpiece Force Study Findings*
Hayward Henderson – 1942 • As higher pitches are played there is a definite increase in [force] by all players. • The most important factor in the use of mouthpiece [force] is not only a small [force] for every tone, as is commonly thought, but the use of a low range of [force].
Robert D. Weast and Ardell Hake –1965 • Players can, at will use varying amounts of [force] on any note. • [Force] is gradually applied while ascending, or crescendoing. • [Force] increases as fatigue sets in.
Elmer R. White – 1972 • Forces are greater in the high register than in the low. • Forces in low and high register are greater at high intensity than at low intensity. • Proficiency level had no effect on force variation.
J.C. Barbenel, P. Kenny, and J.B. Davies – 1988 • All players use substantial amounts of force. • Increases in intensity and increases in frequency, both produce increases in applied force. • There are large individual differences in levels of force used by different players, but individual players show high levels of consistency. Force levels of individuals stayed constant over time; players using higher force levels at the top of the range tended to use relatively higher force levels throughout the range. • Analysis of force increments showed that, at all dynamic levels, increments were larger as the upper register was approached.
TCMM – 2002 • Mouthpiece forces generally changed as a function of increased pitch, loudness, and length of performance time. • Some individuals do play high pitches and loudness levels without using high mouthpiece force levels. • There were substantial differences in levels of force used by different players regardless of task. • Individuals shared high levels of consistency across tasks.

Note: The term pressure has been replaced with the term force. *Each entry is a direct quote from the primary sources as indicated in the previous reviews.

The review of mouthpiece force studies also provided several similar and unique insights. Table 4 General Experimental Mouthpiece Force Concepts shows the similar and unique mouthpiece force concepts derived from the experimental trumpet mouthpiece force studies. Similar to the pedagogical concepts, mouthpiece force

concepts that provided the same findings about mouthpiece force were grouped together. Mouthpiece force concepts that provided unique (provided by one pedagogue) findings about mouthpiece force were listed separately. As a result, ten general experimental mouthpiece force concepts were identified from this grouping of mouthpiece force concepts. The concepts were then rank ordered by frequency of response.

Table 4. General Scientific Mouthpiece Force Concepts

Concept	Mouthpiece Force Concepts	Source
1	As higher pitches are played there is a definite increase in [force].	Henderson, Weast & Hake, White, Barbenel, TCMM
2	Players should strive to use a narrow range of mouthpiece force	Henderson, TCMM
3	Players can use varying amounts of force on any note.	Weast & Hake, Barbenel, TCMM
4	Mouthpiece force generally increases while crescendoing.	Weast & Hake, White, Barbenel
5	Force increases as fatigue sets in.	Weast & Hake TCMM
6	Proficiency level had no effect on force variation.	White
7	There are large individual differences in levels of force used by different players, but individual players show high levels of consistency.	Barbenel TCMM
8	There were larger changes in force as the upper register was approached	Barbenel
9	Mouthpiece forces generally changed as a function of increased pitch, loudness, and length of performance time.	TCMM
10	Some individuals do play high pitches and loudness levels without using high mouthpiece force levels.	TCMM

There were several common findings among the scientific and pedagogical studies concerning mouthpiece force. The mouthpiece force studies also contain unique findings that may provide some very useful insights about mouthpiece force.

EXAMINATION OF PEDAGOGICAL AND SCIENTIFIC MOUTHPIECE FORCE CONCEPTS

Several experimental studies have generated data from music performance to compare or validate methodologies and specific playing techniques.[86] Frank Heuser and Jill L. McNitt-Gray used electromyography during trumpet instruction to uncover whether the findings could "provide empirical evidence validating relationships between pedagogical information and improvements in performance-related motor skills."[87] The researchers found that the data generated did "effectively supplement pedagogical information, facilitate skill acquisition, and validate pedagogical practice."[88] This finding suggests that the use of scientifically derived data may be an effective tool in the learning process. In light of the need to objectively test the historically accepted pedagogical mouthpiece force concepts, all pedagogical and scientifically derived mouthpiece force concepts must be examined. Therefore, this section examines by comparison the concepts and later establishes fundamental principles related to trumpet mouthpiece force.

This examination of mouthpiece force is organized into two sections. The first section, comparison of pedagogical and scientific mouthpiece force concepts, examines the mouthpiece force concepts by comparison, discusses the similarities and differences, and provides insights into the mouthpiece force concepts. The next section, mouthpiece force principles, describes why and how mouthpiece force principles were derived from the similar and unique concepts.

Comparison of Pedagogical and Scientific Mouthpiece Force Concepts

Table 5 shows a list of similar pedagogical and scientific mouthpiece force concepts extracted from reviews of the pedagogical brass literature and experimental trumpet mouthpiece force studies. As in the previous reviews, mouthpiece force concepts were grouped together based on their similar statements and findings about mouthpiece force. This table shows the similarities between the two groups. Both lists confirm that force increases as a function of pitch, loudness and fatigue. Similarly, mouthpiece force was found to vary between players.

Table 5. Similar Pedagogical and Scientific Mouthpiece Force Concepts

Pedagogical Concepts	Scientific Concepts
High levels of mouthpiece force are generated in higher registers.	As higher pitches are played there is a definite increase in [force] by all players.
Higher levels of mouthpiece force are generated at higher loudness levels.	Force is gradually applied while ascending, or crescendoing.
Mouthpiece force is increased as a player becomes fatigued.	Force increases as fatigue sets in.
Mouthpiece force varies between players.	Mouthpiece force varies between players.

There were also unique concepts for both groups (Table 6). In total, 8 mouthpiece force concepts were found to be unique. Of the 8 unique concepts, 5 were from the pedagogical concepts and 3 from the scientific concepts. Early indications suggest that the unique findings may provide further insight about the true nature of mouthpiece force. For example, findings from the scientific literature suggest that players should strive to use low force and a low range of force.[89] This finding may

provide the insight needed to alleviate and possibly prevent the incidence of mouthpiece force induced injuries.

Table 6. Unique Pedagogical and Scientific Mouthpiece Force Concepts
Pedagogical Concepts
Minimal mouthpiece force is required at all times.
Mouthpiece force is required to create a seal between the embouchure and the mouthpiece.
Mouthpiece force varies using different articulation.
Mouthpiece force differs on various sizes of mouthpieces.
Excessive mouthpiece force will cause injury.
Scientific Concepts
The most important factor in the use of mouthpiece force is not only a small [force] for every tone, as is commonly thought, but the use of a low range of force.
Some individuals do play high pitches and loudness levels without using high mouthpiece force levels.
There are large individual differences in levels of force used by different players, but individual players show high levels of consistency.

Although not reported in their findings, the scientific studies support two of the unique pedagogical findings. For example, a minimal force is required at all times and mouthpiece force is required to create a seal between the embouchure and the mouthpiece are both supported by the Barbenel study. There was only one instance where a scientific study challenged one pedagogical concept. The pedagogues suggested that mouthpiece force varies using different articulation. However, the TCMM study found that “articulation style or type of approach had little impact on force.”[90] Speculations were made within the Weast and Hake study concerning the mouthpiece

force differences on different sizes of mouthpieces but data supporting this speculation was not reported within the Weast and Hake mouthpiece force study.

The results of the comparison show that the pedagogical concepts were supported by the scientific studies. However, there were a few additional findings reported within the scientific studies. This indicates that the pedagogues were accurate but limited in their understanding about mouthpiece force. The experimental mouthpiece force studies identified three addition concepts concerning mouthpiece force that were never mentioned within the brass pedagogical literature. In light of these findings, concepts, and principles, a definition of mouthpiece force based on scientific verification and not subjective experiences and calculated guessing are required.

Mouthpiece Force Principles

Before forming the mouthpiece force principles, it is important to define "concept" and "principle" and understand why and how the following mouthpiece force concepts were formed into mouthpiece force principles. The Webster's New World Dictionary of the American Language has defined "concept" as an idea.[91] "Principle" was defined as a fundamental truth, law, upon which others may be based.[92] This is important because the previous review of selected brass pedagogical literature and scientific mouthpiece force studies has revealed, in a general way, a list of mouthpiece force concepts (ideas) that provide the basis for some general mouthpiece force principles (fundamental truth or law).

Using the pedagogical and scientific mouthpiece force concepts from Tables 5 and 6, five general principles about mouthpiece force (Table 7) were formulated through

inductive reasoning as described by music education researchers Edward Rainbow and Hildegard Froehlich.[93] This line of inductive reasoning moves from a specific premise (the mouthpiece force concept) to a general conclusion and/or law (the mouthpiece force principle).

Table 7. Mouthpiece Force Principles
Principle 1. There are always mouthpiece forces generated during trumpet performance.
Principle 2. The mouthpiece forces generated during trumpet performance are constantly changing.
Principle 3. Mouthpiece forces in trumpet performance may vary as a function of the demands of the music including pitch, loudness, and duration (fatigue).
Principle 4. Mouthpiece forces may represent how a trumpeter performs.
Principle 5. The mouthpiece forces generated during trumpet performance may have the potential to precipitate injury for all individuals.

To support and illustrate the discussion of the trumpet mouthpiece force principles two graphs were extracted from the Texas Center for Music and Medicine (TCMM) Trumpet Study. The TCMM study was selected to support the mouthpiece force principles because the study provides the most current and relevant data concerning trumpet mouthpiece force.

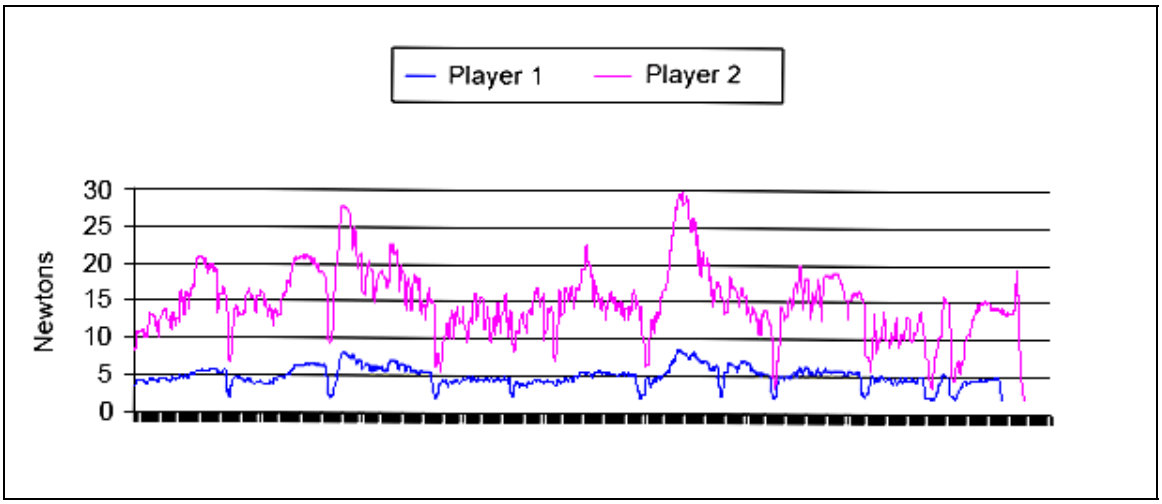

Figure 1. Mouthpiece Forces for Pollard's Etude #87

Figure 1 shows the mouthpiece forces generated by two players performing the Pollard's Etude #87. The graph in Figure 1 represents the typical waveforms generated by trumpet mouthpiece forces. The mouthpiece forces, represented in Newtons (*N*), are shown along the Y-axis with the X-axis representing the length of the etude. This graphical representation shows that during trumpet performance mouthpiece forces were always being generated. The mouthpiece forces generated between the embouchure and the trumpet mouthpiece involve forces referred to as contact forces. General concepts of force define contact forces as the physical contact between two objects.[94] Because there is always physical contact between the embouchure and mouthpiece while performing, there will always be mouthpiece force. In fact there were no instances reported within the trumpet mouthpiece force studies that recorded zero mouthpiece force.

The graph in Figure 1 also reveals that the trumpet mouthpiece forces were not static forces but forces that were able to change and did change constantly. There were

no findings from the mouthpiece force studies that showed examples of unchanging mouthpiece forces, even when performing longtones.

The changing mouthpiece forces were associated with changes in pitch, dynamics, and length.[95] Specifically, the variability (change) of mouthpiece force was highly influenced by the characteristics of Etude #87 including the intervals, range, articulations, dynamics, rests, and length. In general, the mouthpiece forces rose and fell similar to the rising and falling of the pitch and dynamics. As a result, the mouthpiece forces created an identifiable pattern of mouthpiece forces linked to the changes of pitch and dynamics. Even though two different players performed Etude #87 both players generated comparable patterns of mouthpiece forces that reflect the changes of pitch and dynamics. Although the patterns for both players showed similar fluctuations of mouthpiece force there were several notable differences including the overall average and variability of mouthpiece forces.

Figure 1 shows that Player 1, represented by the blue line, performed Etude #87 with a low average and low variability of mouthpiece forces. The mouthpiece forces generated by Player 1 seem to suggest that Etude #95 was performed with more control and consistency. In contrast, Player 2 generated a high average and high variability of mouthpiece forces and showed less stability or control of mouthpiece force. It is important to note that the TCMM study found that average mouthpiece forces were highly correlated to mouthpiece force variability. In other words, higher average mouthpiece forces resulted in higher variability in mouthpiece force. Mouthpiece force variability was also correlated with the player's proficiency or expertise on the trumpet.

The better players showed less variability and therefore showed lower average mouthpiece forces and more stability or control of mouthpiece force over time.

The TCMM study also observed that individual players were consistent in their use of mouthpiece force. Figure 2 shows the mouthpiece forces generated by two players performing the Clarke's Technical Study #2. This graph represents two consecutive performances of the last four measures of Study #2 in F played in 16ths tongued at metronome marking 120. The mouthpiece forces generated by Player 1, show that the first and second performances of the technical exercise were identical. As stated earlier, Player 1's performance was more consistent and stable because a low average mouthpiece force and less variability was generated. The graph reveals that the average and variability of mouthpiece force of Player 2 was also consistent until the end of the second performance of the technical exercise. The inconsistency displayed by Player 2 may be attributed to the high average and high variability of mouthpiece forces generated.

In general, the average mouthpiece force and variability of mouthpiece forces were different for all players of the TCMM study. This trend was also observed from all the trumpet mouthpiece force studies found within the review of trumpet mouthpiece force literature. Several assumptions can be suggested that may contribute to the differences in mouthpiece forces generated by different players; however, no studies have investigated these differences. These differences strongly suggest that mouthpiece forces may represent how a trumpeter performs.

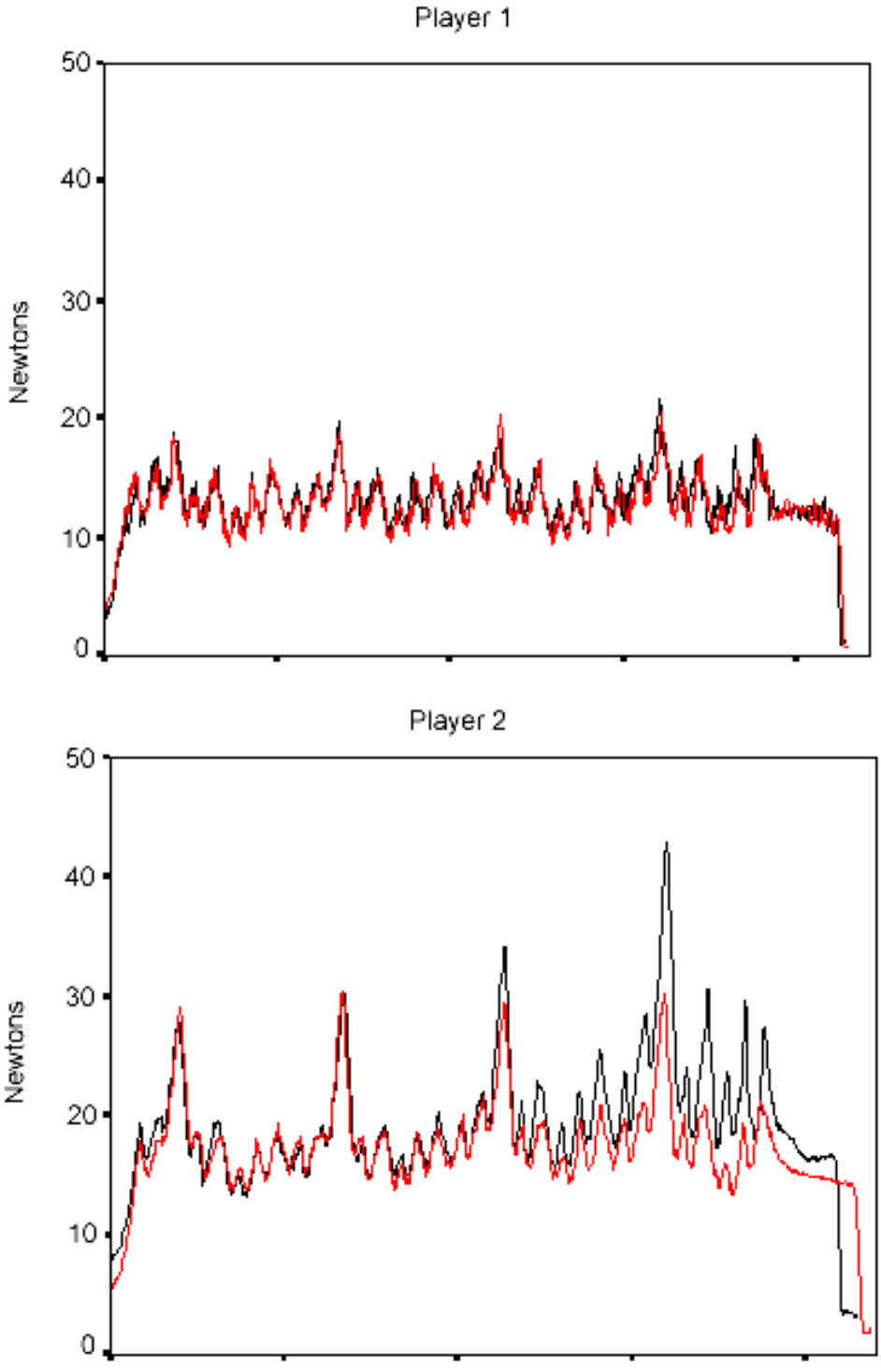

Figure 2. Mouthpiece Forces for the Clarke's Technical Study No. 2 in F

The mouthpiece forces generated during trumpet performance may have potential to precipitate injury for all individuals. According to the Performing Arts

Medicine Association (PAMA), the amount of activity required to precipitate injury "differs from person to person and seems to be, in part, a function of an individual's anatomy and physiology. Factors involved include one's genetic makeup, age, level of physical conditioning, degree and duration of musical/…. training, life stresses, and other contributing factors, which together establish the biologic limits for a particular person at a specific time."[96]

Although this review, grouping, and formation of principles of mouthpiece force may not represent all brass pedagogical methods and mouthpiece force, the mouthpiece force principles outlined do appear to capture the fundamental nature of the mouthpiece force concepts provided within the selected brass pedagogical methods and the mouthpiece force studies. These mouthpiece force principles provide the foundation upon which a more detailed understanding and proposed operational definition of mouthpiece force may be developed.

In the clarification of terms section mouthpiece force was defined as the strength, power, and physical coercion between a performer's lips and mouthpiece as established in the scientific mouthpiece force studies of Barbenel, Kenny, and Davies.[97] However, there were several distinguishing characteristics/principles established within this study. As a result mouthpiece force should not be absolutely defined but characterized by the aforementioned principles. These principles may provide trumpet pedagogues with a better understanding of mouthpiece force.

Conclusion

The purpose of this study was to propose an operational definition of mouthpiece force applicable to trumpet pedagogy. The results of this study did not define mouthpiece force but identified five mouthpiece force principles derived from the pedagogical brass literature and trumpet mouthpiece force studies that characterize mouthpiece force. The insights gained from the mouthpiece force principles may contribute to a better understanding of the true nature of mouthpiece force and its link to lip related injuries.

There were limitations associated with this study. It is not currently known how pedagogical methods may influence the development of mouthpiece force. The skills needed to become a trumpet player are often developed under the guidance of a knowledgeable educator. However, the pedagogical brass literature is currently insufficient in guiding educators with recommendations about when, what, and how to practice so that the mouthpiece force characteristics may be developed correctly. More research is still needed to further understand mouthpiece force. The TCMM Trumpet study has recently added new measurement protocols including, multi-directional mouthpiece forces, horn angles, and intra-oral pressures. Hopefully the new analysis into the relationships between mouthpiece force and intra-oral pressure will yield several insightful results.

What does this study mean to trumpet pedagogy and performance? There are ways to enhance trumpet pedagogy currently available. Traditional methods of learning the trumpet should be revised to reflect information gained from this study and similar studies. Because of the recorded incidence of lip related injuries it is clear that trumpet

players may not be aware of the limitations associated with mouthpiece force. Considering the potential for injury, all players should take the necessary steps to promote musical ease, health, and longevity in their careers.

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APPENDIX A

A REVIEW OF TWELVE OUTSTANDING UNIVERSITY TRUMPET STUDIOS: A COMPARISON OF METHODOLOGY, PEDAGOGY, AND STRUCTURE

A Review of Twelve Outstanding University Trumpet Studios: A Comparison of Methodology, Pedagogy, and Structure

Trumpet Studies and Etudes

(Categorized by Frequency of Response)

Nine (9) Responses

Caffarelli, Reginaldo. *100 Melodic Studies*. Milan, Italy: C. Ricordi. 1957.

Charlier, Theo. *36 Etudes Transcendentes*. Paris: Alphonse Leduc. 1946.

Clarke, Herbert L. *Technical Studies*. New York: Carl Fischer. 1934.

Seven (7) Responses

Arban, Jean-Baptiste. *Complete Conservatory Method*. New York: Carl Fisher. 1936.

Bitsch, Marcel. *20 Etudes*. Paris: Alphonse Leduc. 1950.

Bordogni, Giulio Marco. *24 Vocalises*. Paris: Alphonse Leduc. 1951.

Brandt, Vassily. (Ed. Willam Vacchiano). *34 Orchestral Studies*. New York: MCA Music. 1945.

Six (6) Responses

Concone, Giuseppe. (Trans. John F. Sawyer). *Lyrical Studies*. Nashville, Tennessee: The Brass Press. *1972.*

Sachse, Ernest. *100 Studies*. New York: International. 19--.

Five (5) Responses

Stamp, James. *Warmup and Studies*. Switzerland: Editions BIM. 1978.

Four (4) Responses

Colin, Charles. *Advanced Lip Flexibilities*. New York: Charles Colin. 1972.

Schlossberg, Max. *Daily Drills and Technical Studies*. New York: M. Baron. 1941.

Three (3) Responses

Collins, Phil. *In the Singing Style*. Cincinnati, Ohio: Queen City Publishing. 1982.

Getchell, Robert. *First and Second Book of Practical Studies*. Miami, Florida: Belwin. 1955.

Goldman, Edwin Franco. *Practical Studies*. New York: Carl Fisher. *19--.*

Irons, Earl D. *27 Groups of Exercises*. San Antonio, Texas: Southern Music. 1966.

Longinotti, Paolo. Studies *in Classical and Modern Style*. New York: International. 1962.

Nagel, Robert. *Speed Studies*. Broodfield, Connecticut: Mentor Music. 1965.

Smith, Walter. *Top Tones*. New York: Carl Fischer. 1936.

Vizzutti, Allen. *Trumpet Method*. Van Nuys, California: Alfred Publishing. 1990.

Dufesne, Claude and Roger Voisin. *Develop Sight Reading*. New York: Charles Colin. 1972.

Williams, Ernest S. *Method for Transposition*. New York: Charles Colin. 1938.

Two (2) Responses

Bordogni, Giulio Marco. (Trans. Joannes Rochut). *Melodious Etudes for Trombone*. New York: Carl Fischer. 1928.

Bousquet, Narcisse. 36 *Celebrated Studies*. New York: Carl Fischer. 19--.

Broiles, Mel. *Transposition for Orchestral Trumpet*. New York: McGinnis and Marks. 1958.

Chaynes, Charles. *15 Etudes*. Paris: Alphonse Leduc. 1959.

Dubois, Pierre Max. *12 Etudes*. Paris: Alphonse Leduc. 1959.

Gates, Everett. *Odd Meter Etudes*. New York: Fox. 1954.

Saint-Jacome. *Grand Method Complete*. New York: Carl Fischer. 1894.

Small, J.L. *27 Melodious and Rhythmical Exercises*. New York: Carl Fisher. 1962.

Staigers, Del. *Flexibility Studies* (Books 1 and 2). New York: Carl Fischer. 1950.

Vannetelbosch, L. *20 Melodic and Technical Etudes*. Paris: Alphonse Leduc. 1965.

Voxman, Himie. *Selected Studies*. Chicago: Rubank. 1942.

APPENDIX B

CHRONOLOGICAL LISTING OF MOUTHPIECE FORCE CONCEPTS

Chronological Listing of Mouthpiece force concepts		
Date	Author	Mouthpiece Force Concept
1795	Altenburg	
1894	Arban	"In order to produce the higher notes, it is necessary to press the instrument against the lips, so as to produce an amount of tension proportionate to the needs of the note to be produced…." "For descending passages it is necessary to apply the mouthpiece more lightly, in order to allow a larger opening for the passage of air."
1931	Hayden Shepard	"Use as little pressure as possible. A certain amount of pressure is needed and essential in order that the mouthpiece may sit firmly upon the lips."
1934	William Costello	p.2 "ease in playing is the foundation of all stress" "to produce high notes by sheer force of mouthpiece pressure and hard blowing, he cannot hope to master the wide range required of the present day brass player.
1935	Herbert Clarke	"If you must use pressure, and it is necessary at times…, confine it to the lower lip."
1952	Clifford Lillya	
1953	John Haynie	"Actually there is no such thing as no pressure, but I do believe in a minimum of pressure. All you can do is use as little pressure as possible."
1953	Leslie Sweeney	"Playing without pressure of the mouthpiece on the lips is an ideal for which all brass players strive." "It is necessary to realize that in the no-pressure system there are times when some pressure must be used. However, as one develops his strength and suppleness in his embouchure, learns how to control his breath and place the tones, the amount of pressure necessary will decrease." "When playing the higher tones, or when playing loud, more air force is necessary, and firmer contact is required."
1954	E.C. Moore	"We certainly know that it takes more firmness to get the upper register and that there is no such thing as actual no pressure method of playing, but the sensation of directing the air column will induce ease and confidence."
1954	Lowell Little	"Forcing the lips into a vibrating position through excessive pressure can only result in stiffening the vibrating area or in causing irreparable damage to the lip tissues. Many brass players use too much muscular contraction and mouthpiece pressure in the middle

		registers leaving nothing for the higher notes." "It is wise to allow the majority of what mouthpiece pressure is necessary to rest on the muscular pad formed by the lower lip."
1956	Fisher A. Tull Jr.	p.26 "Defined as that force exerted from the player's arms and hands, pressing the instrument to the lips and teeth and the mouthpiece." "Pressure is necessary to seal the area around the mouthpiece rim to prevent air from escaping."
1956	Jean Maire	"To play high notes, it is necessary to exert a certain pressure on the lips. For the low register, it is necessary, on the contrary, to pose the mouthpiece more lightly."
1960	Joseph L. Bellamah	"The majority of trombone and baritone teachers emphasize the pressure factor, all the way from a minimum of pressure on the upper."
1961	Rafael Mendez	p.24 "The type of playing referred to as "strong arm" playing, "heavy pressure" playing, the substitute of pressure for muscular development, this I lament, and condemn!" "The pressure of the mouthpiece should only be slight, so slight that there will be no imprint of the cup on our lips after playing, a slight, but firm, pressure that will allow for fusion of lips and mouthpiece." p.38 "You are not to press the mouthpiece into the lips. Should the mirror show a deep imprint of the cup on your lips, then you are pressing too much. Keep in mind that the slight, but firm, pressure necessary to prevent air from escaping, and to establish a connection between yourself and the mouthpiece does not vary. You are to depend upon flexibility of muscles - not pressure."
1962	Philip Farkas	p.53 "Some small amount of mouthpiece pressure is always present, and is quite harmless. There should be a comfortable normal pressure, which hermetically seals the lips to the mouthpiece-a pressure which keeps the mouthpiece from skidding around on the lips and gives a general feeling of security." "This normal pressure will vary in several ways. It will differ between individual players; it will differ on various type mouthpieces; normally, it will increase as the player goes into the higher register; it will increase as the player becomes fatigued." "This undue pressure is rather difficult to define, as there is a rather narrow line of demarcation between fairly heavy, but acceptable, pressure, and that

		embouchure-destroying pressure about which I warn." "But these varying pressures are relative to many things beside the fatigue element, and our object is to help relieve pressure even if only to a small degree, for those players who even suspect that they are using too much." "Mouthpiece pressure is a substitute method used to fulfill two important requirements in the attainment of high notes: extremely small lip apertures and very firm flesh." "firm resilient lip muscles are an indispensable requirement for the production of high notes." "Lateral Pressure- but pressure, of course, can exert itself in any direction, and many players have a habit of pushing the mouthpiece laterally-at a right angle to the direction of the mouthpiece. This force could be to either side, or up, or down." "One of the best ways to begin breaking a bad habit Is to know what caused it in the first place."
1962	Irving Bush	p.64 "Mouthpiece pressure is merely a matter of degree. Either extreme, too much or too little pressure brings undesirable results. Excessive pressure forces the tone, weakens the player's endurance, and brings about embouchure or lip problems, whereas the opposite results in a small thin tone." "Excessive pressure is the greatest detriment to embouchure development."
1962	Gunter Schuller	"Now there are four ways in which pitches can be altered by the embouchure: one is by pressure upon the lips." p.20 "It can not be emphasized sufficiently that all these movements, especially those which involve pressure on the lips, must be moderate and in proportion to the interval change desired."
1963/ 1997	Edward Kleinhammer	"Too much mouthpiece pressure on the lips is one of the most damaging influences to endurance, tone quality, and playing under the pressures of performance." "A moderate pressure of the mouthpiece to lips is necessary so that air does not escape between the embouchure and the mouthpiece rim."
1966	Philip Bate	"We have already seen that the higher notes of the harmonic series are elicited by the player by means of increased tension in the lips. Some players habitually foster this by increasing the pressure of the mouthpiece against the mouth. Others believe this to be

		unnecessary and bad practice. Some years ago there was considerable controversy regarding the so-called "no-pressure" system-something of a misnomer since obviously there must be some pressure, however light, between the mouthpiece and the lips – but no really useful conclusion emerged. It seems likely that in fact every player uses just as much or as little pressure as suits him, and is little concerned by theories."
1966	James H. Winter	"Almost all brass players must continually guard against excessive mouthpiece pressure, and the teacher must be on alert at all times to watch for it, for it is harmful, and may do permanent damage." "There must be sufficient pressure to seal the mouthpiece hermetically."
1967	Maurice Porter	p.25 "A certain degree of pressure of the mouthpiece against the lips, it is always necessary. Obviously, the lighter this is, the better." "When there is continually excessive pressure of the mouthpiece against the lips it will, sooner or later, interfere with an embouchure of comfort." "Compression of any soft tissues such as skin, mucous membrane, muscle tends to restrict the blood supply, at fist causing blanching of the skin, then numbness, and if excessive and prolonged, even damage."
1967	Daryl Gibson	p.33 "Do not use mouthpiece pressure."
1968	Norman J. Hunt	"Avoid any undue pressure."
1968	Fay Hanson	p.62 "Mashing the stretched lips between the hard mouthpiece and teeth can be disastrous to endurance as well as tone quality."
1968	Roger Spaulding	p.14 "Never use a brute force method of holding your instrument. The less pressure you use on your lips with the mouthpiece, the more sound vibrations you can generate." p.178 "The student must never use a pressure-type system for reaching the high notes. The steam should be generated from within the body itself. If any pressure is used externally at all, it should be on the lower lip."
1969	Vincent Bach	p.13 "pressure against the mouthpiece rim depends on how loud one has to play. But the pressure should always be a little as the volume requires." p.14. "It is necessary to learn to use the lip muscles by contracting them, not by squeezing them together continually or by pressing the mouthpiece hard against them.
1969	Maurice M.	p.25 "a certain degree of pressure on the mouthpiece is

	Porter	always necessary. Obviously the lighter that is the better." "For accuracy sake, therefore, it would be better to speak of a 'minimum pressure" system or light pressure system rather than of a non-pressure system."
1970	Louis Davidson	p.5 "the question may arise as to what constitutes normal pressure. While there are some so-called non pressure systems" of playing that advocate no pressure at all, realistically and in all practicality, the normal amount of pressure is that which, together with the normal degree of tension permits the lips to function freely and easily in order to achieve both an open sound and great flexibility."
1972	Charles Colin	p.29 "We must never force the mouthpiece into our lips." "Actually there is no such thing as lip pressure. The accurate term is arm pressure. The greater the tension of the arm, wrist, and hand grip on our horn, the greater will be the damaging effect on our lips." "The protective formula is to relieve our lips of every possible responsibility except their primary one; to vibrate with the greatest possible freedom, unhampered by any unnecessary pressure… Our goal is to minimize this pressure, by transferring the burden of support to our entire system." "The fallacy in lip stretching or range weakens and pulls the muscles away to all foreign directions. The great revelation is displayed by bunching together all the muscles. Surrounding the embouchure in a tense puckered manner, so as to form a tightened embouchure. Subsequently, the pressure of the mouthpiece on the lips will be cut down to a minimum."
1973	Jerome Callet	"Excessive pressure on both lips can be very destructive."
1973	Donald Reinhardt	p.9 "There is no such thing as no pressure, but you should use a minimum of mouthpiece pressure at all times, just enough to keep a firm lip-contact throughout your various playing requirements. "Mouthpiece pressure varies with every individual." p10. "Use a minimum of pressure at all times. Slightly more pressure is essential to play a tongued passage than a legato passage.
1976	Carmine Caruso	"Mouthpiece must be in contact with the lips throughout the placing of each exercise until no notes are sounding and regardless of force or feel."
1977	Harry Berv	"Excessive mouthpiece pressure is a bad habit and one

		that is easy to fall into." p.76 "Never force sound or put too much pressure on the lips in order to attain the high notes. Naturally, when you go to the upper register you must use more pressure, but it must be applied to the lips gradually, in delicate stages – until, with much practice and patience, the very least amount of pressure necessary is used in order to attain the upper register. "Mouthpiece pressure should be evenly distributed on both the upper and lower lips." "It is up to each individual to ascertain this amount of pressure he will need to cope with all registers of the horn."
1977	Gene Young	"Pressure of the mouthpiece against the embouchure impairs circulation, restricts vibration, and prevents ease of response. Such pressure often flattens the lips against the teeth. This results in a distorted aperture. When too much pressure is used, the mouthpiece acts like a vice."
1977	Reginald Fink	"Use only enough pressure to make an airtight seal between the lips and the mouthpiece." "Use as little mouthpiece pressure as possible and this usually means that you should us less pressure than you are using at present."
1978	James Stamp	"No pressure of the mouthpiece on the lips until the breath was finished." "What force is needed is added after the breath."
1978	Barry Tuckwell	"A certain amount of mouthpiece pressure is necessary if an airtight seal is to be made between mouthpiece and lips, but it should be kept to a minimum. If there is sufficient pursing of the lips, the mouthpiece will have a good cushion to rest on; if , however, the muscles are slack, they will be bruised."
1978	Fred Fox	p.73 "True, there is a varying of pressure on the mouthpiece between the high and low notes, but the contact point of rim to upper lip always remains in the identical place."
1979	Roger Sherman	p.21 "Mouthpiece pressure has a significant relationship to tone quality." "There must be some seal where the mouthpiece contacts the lips." "Many problems relating to excessive pressure can be traced to incorrect hand positions."

1979	Robert Weast	p.34. “Too much pressure i.e. pressure applied prematurely, pins the lips down, causing the player to lose flexibility and range. Too little pressure precludes louder volumes, surety of attack and the high register.” “If the highest one can play is high F, that note alone will receive the player’s maximum pressure. Every note below that must receive less.”
1982	Bengt Belfrage	“The mouthpiece must never be pressed so hard against the lips that they lose their resilience… Excessive “pressing,” too, leads to the disappearance of “tone” – the essence of any note - by reducing the lip’s vibrations.”
1983	Robert Foster	“The red ring that is found on our lips after playing hard or a long period of time is caused by pressure of the mouthpiece rim against the tissue or skin. The rim of the mouthpiece cuts off the circulation of the small surface blood vessels.”
1984	Denis Wick	“There is a natural tendency for beginners to press too hard on the mouthpiece… The best results are never accomplished with heavy mouthpiece pressure, and for 95 percent of the time even the toughest professional uses little more than minimum pressure needed for an air-seal.”
1985	Delbert Dale	“The only use of mouthpiece pressure on the lips should be to prevent air from escaping between the lips and the mouthpiece. There is no non-pressure system of playing the trumpet, contrary to what some would have you believe. There is, however, a light-pressure system, and this is what the student should attempt to develop.” “The pressure must be distributed evenly over both lips.”
1989	Scott Whitener	p.119 “Excessive Pressure. While no viable non-pressure system exists, brass players should always be alert to any indication of excessive mouthpiece pressure. A certain minimal pressure is required, and undue pressure can best be prevented by good habits of tone production.”
1990	Allen Vizzutti	“..Avoid too much left-hand pressure or right hand finger ring pressure. Too much pressure cuts blood flow to the lips and will reduce your range and endurance without fail! Any lip cuts or soreness indicate to much pressure.”
1990	Don Jacoby	Discusses distribution of pressure “…the same amount of pressure around the mouthpiece.”
1995	Arturo Sandoval	“It is important to lower the pressure of the mouthpiece on the lips.”

1996	Arnold Jacobs	“Some mouthpiece force against the lips is important to ensure a proper seal around the vibrating portion of the lips.” “If too much mouthpiece force is applied, tissue can be damaged.” “When a player holds the mouthpiece on the lips too long, swelling develops.”
1997	Chase Sanborn	“Pressing the mouthpiece against the lips causes them to vibrate faster, thus playing higher notes. Unfortunately, too much pressure causes them to bruise and blister, taking away much of the enjoyment if playing a brass instrument. The goal is to avoid using excessive pressure, and not to rely on it for our high notes. The minimum pressure that is actually required to playing just enough to maintain a seal between the mouthpiece and your lips, so that air doesn’t leak out under the rim. Any more pressure than this must be counter-balanced by muscular tension in the embouchure.”
1997	Verne Reynolds	“Ideally there should be little difference in mouthpiece pressure between piano and mezzo forte. At forte and fortissimo, some additional pressure may be necessary to maintain the air sea around the mouthpiece.”
2002	Keith Johnson	
2005	Frank Campos	“The pressure that all brass players must use to achieve a good seal between the embouchure and mouthpiece will normally increase when playing loudly and/or in the high register, and even the greatest players in the world use a bit of excess pressure at certain times.

APPENDIX C

TCMM TRUMPET STUDY

TCMM Trumpet Study: Quantification and Analysis of Biomechanical Forces Generated During Trumpet Performance

Kris Chesky, Bernard Rubin, George Kondraske, and Leonard Candelaria

Introduction

In brass performance, particularly with trumpet, excessive and prolonged mouthpiece forces may lead to occupational injuries, including permanent deformation of the lip, rupture of the obicularis oris muscle, periodontal problems, TMJ, and focal distonia of the embouchure. However, these physical phenomena, including the relationships between mouthpiece forces, intra-oral pressures, dynamics, and pitch are not fully understood.

Purpose

The purpose of this study was to develop and utilize an objective and reliable approach for assessing mouthpiece force generated during trumpet performance in order to increase the understanding of mouthpiece force and its impact on the etiology, progression, treatment and prevention of embouchure and upper extremity musculoskeletal problems among this occupational group.

Methods

Twenty-three (23) professional level trumpeters participated by performing a series of musical exercises designed to mimic a typical practice session. The overall sequence included 1) technical exercises, 2) tone production over a pitch range of two octaves, 3) musical pieces including etudes and play-along jazz recordings, and 4)

range exercise. In order to examine the effects of fatigue, the fifth section was a repeat of the first. Mouthpiece forces were measured using a custom Trumpet Sensor System. Six channels (3 force axis including vertical and horizontal sheer forces, trumpet angles, loudness levels, and metronome timing) were sampled at a rate of 40Hz using continuous recording software.

Results

Results indicated successful quantitative analysis of mouthpiece force. This descriptive data shows that trumpeters do generate excessive amounts of mouthpiece force. For instance, the average peak mouthpiece force over the entire session was 56.37 *N* (S.D. = 26.79 *N*) with the range from 23 to 115. Furthermore, mouthpiece forces generally changed as a function of increased pitch, loudness and length of performance time. However it is clear that some high level trumpeters can perform excessively high pitch and volume levels with minimal mouthpiece force.

Conclusions

Among the many interesting findings, the data show that there are substantial differences in levels of force used by different players regardless of task, but that individuals show high levels of consistency across tasks. Current efforts are directed towards expanding this model to include concurrent measurement of intra-oral pressure and fundamental frequency of the tones produced during trumpet performance.

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