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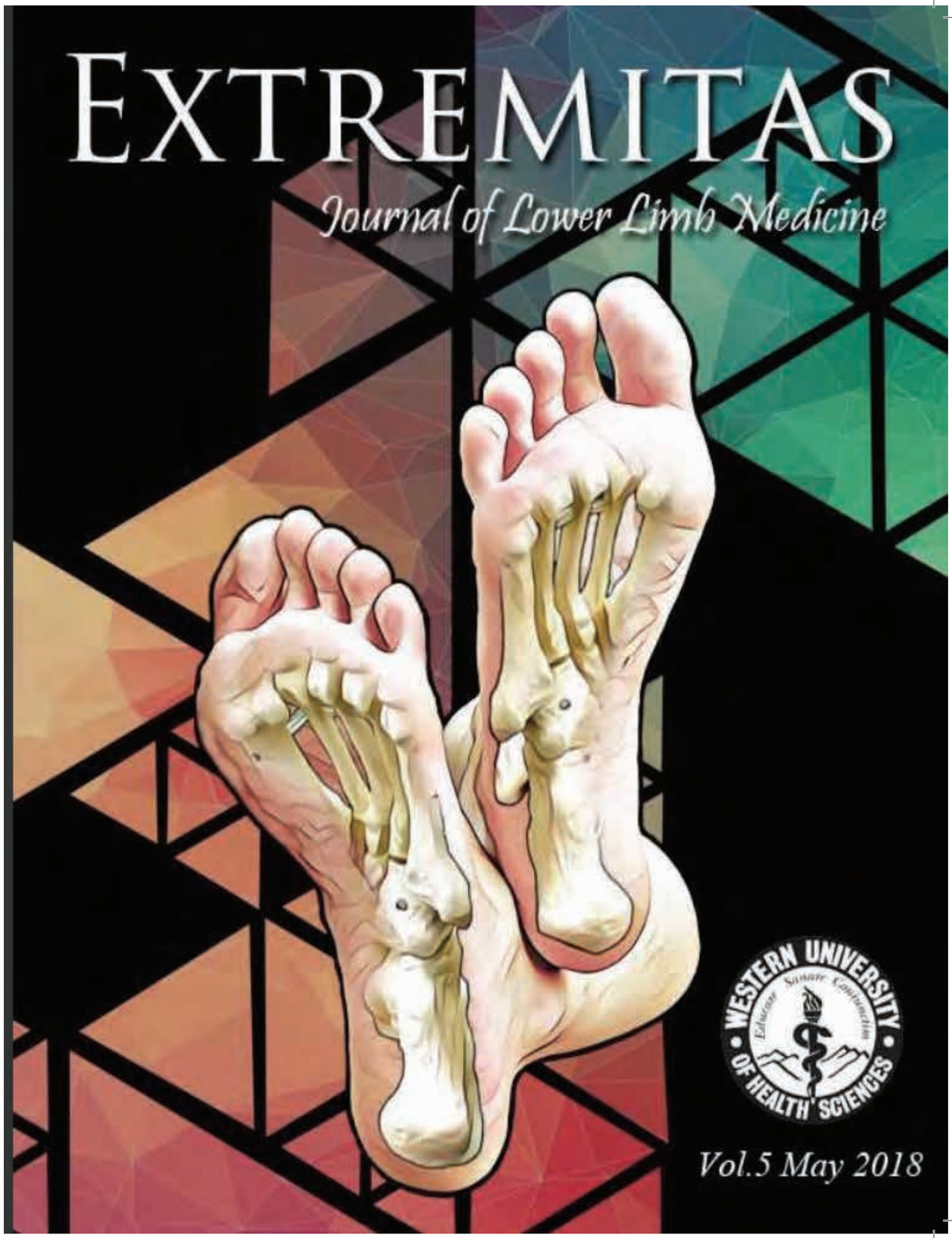

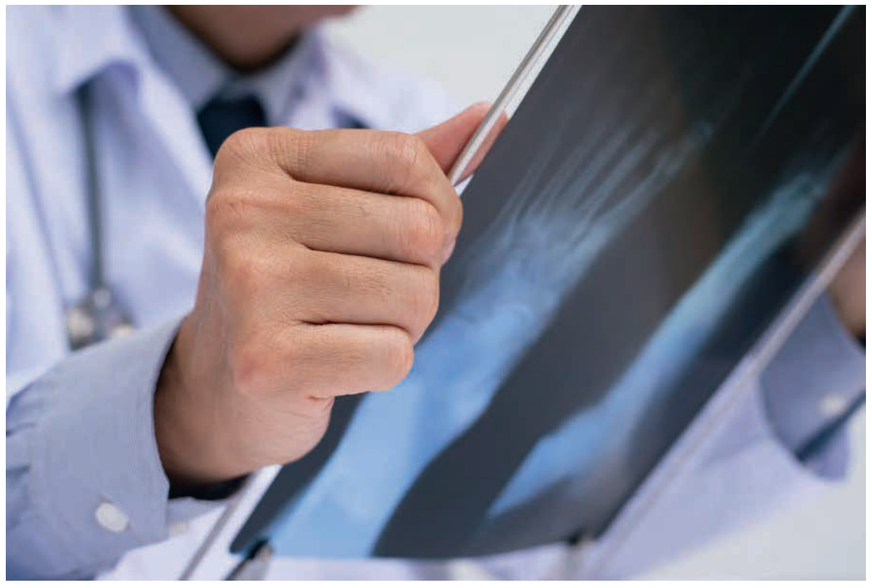

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A special thank you to Dr. Jarrod Shapiro, DPM, for his guidance and encouragement

Please contribute your thoughts and feedback about this published work to the editors at: **ExtremitasJournal@westernu.edu**

May 2018

To our readers,

It is incredible what can develop from the work of individuals who are dedicated to achieving a goal. Five years ago, the Extremitas Journal of Lower Limb Medicine was developed from the combined efforts of WesternU College of Podiatric Medicine faculty and the student body. The success of the first edition, however, can largely be attributed to the support received from WesternU founding president, Dr. Philip Pumerantz, who recently passed away in December 2017.

Dr. Pumerantz was known for his dedication to humanistic approach to medical care, and a philosophy of inter-professional education. This lower-limb focused journal was inspired by his vision, and has since then been a yearly collection of research articles published by students across multiple disciplines. Our editors believe that enhancing exposure to academic research will advance critical thinking and communication skills in medical education.

Dr. Pumerantz was known for bringing to life an "impossible dream," and created a legacy that others continue to build upon. Each year, the Extremitas Journal continues to expand. This past year, we received a record-breaking number of article submissions. As future healthcare providers, it is our hope to inspire others to further pursue scientific research for a better tomorrow.

Lastly, this publication would not be possible without the financial support from our donors. We express our deep appreciation to those who choose to support our student run journal.

It is my honor and pleasure to present the 5th annual issue of the Extremitas Journal of Lower Limb Medicine!

All the best,

Brittany Mammano
Editor-in-Chief

Letter from the Staff

Brittany Mammano
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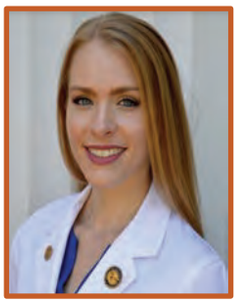

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Dear Reader,

We are extremely excited to present to you the 5th edition of our Extremitas: Journal of Lower Limb Medicine. Between your fingertips is a tradition built from many individuals since our 2014 edition. From the research from of students, we have together aimed to bring you an "interdisciplinary eye into the world of the lower limb." We are also thrilled to announce this edition as our largest version to date with review articles and case studies covering a variety of topics from sports medicine to diabetic wound care. Our goal is to advance the care and medical treatment of the lower extremity through collaboration and evidence based approaches.

We would like to thank Western University of Health Sciences and the College of Podiatric Medicine for their continued support. We'd also like to recognize our donors for this edition for supporting students and podiatric medical research: Pica Insurance, Wright Medical, Blaine Labs, American Board of Podiatric Medicine, California Podiatric Medical Association, and Present Podiatry. It is evident that alone our opportunities are limited, but together the possibilities are endless.

Sincerely,
The Extremitas Team

Table of Contents

REPORTS AND REVIEWS:

CONSERVATIVE THERAPIES:

SURGICAL TREATMENTS:

Developing a Direct Assessment Tool for Podiatric Surgery Residents

Emily Shibata, MS-2, Eric Duffin, MS-2, David Shofler, DPM, MSHS, Dr. Jarrod Shapiro, DPM

Abstract

In podiatric residency training, surgical assessment of resident physicians is inadequate. Currently, a system of minimum activity volume (MAV) numbers is utilized. These numbers represent the fixed minimum volume of surgical cases necessary to be logged prior to graduation from an accredited residency program. While these MAVs help ensure that residents have a sufficient number of repetitions of categorized surgical procedures prior to graduation, the numbers also have significant shortcomings. First, MAV numbers only provide reference to activity volume. There is no assurance that the procedures are performed correctly, competently, or if improvement in specific areas is required. There is no required feedback generated and there is no skill level identified. Second, MAVs have been found to be subjective and arbitrary by both residency directors and podiatric surgery residents. A 2015 investigation published in the Journal of Foot and Ankle Surgery surveyed both podiatric surgery residency directors and residents nationwide (1). Respondents identified all of the existing MAV procedural requirements as being too low in number, as they are very easily attained well before graduation. Further, the consensus opinion of both directors and residents was that the use of MAVs was ineffective, and that a method involving direct assessment would be potentially more effective.

Introduction

Direct assessment tools have been utilized by many surgical specialties within medicine to better educate and provide feedback for residents. Objective Structured Assessment for Technical Skills (OSATS) have served as the primary method of direct assessment. Examples of OSATS can be found in cardiothoracic surgery, general surgery, orthopedic surgery, and many others surgical specialties within medicine (2,5,8). The aim of this study is to measure the reliability of a standardized direct assessment form in podiatric surgical training that can be utilized throughout all podiatric residency programs. The hypothesis is that direct assessment is a valid way to determine the competency of podiatric surgical residents, just as it has been demonstrated to be valid in other surgical specialties. When used in conjunction with MAVs, direct assessment will have the potential to educate and train the next generation of podiatric physicians.

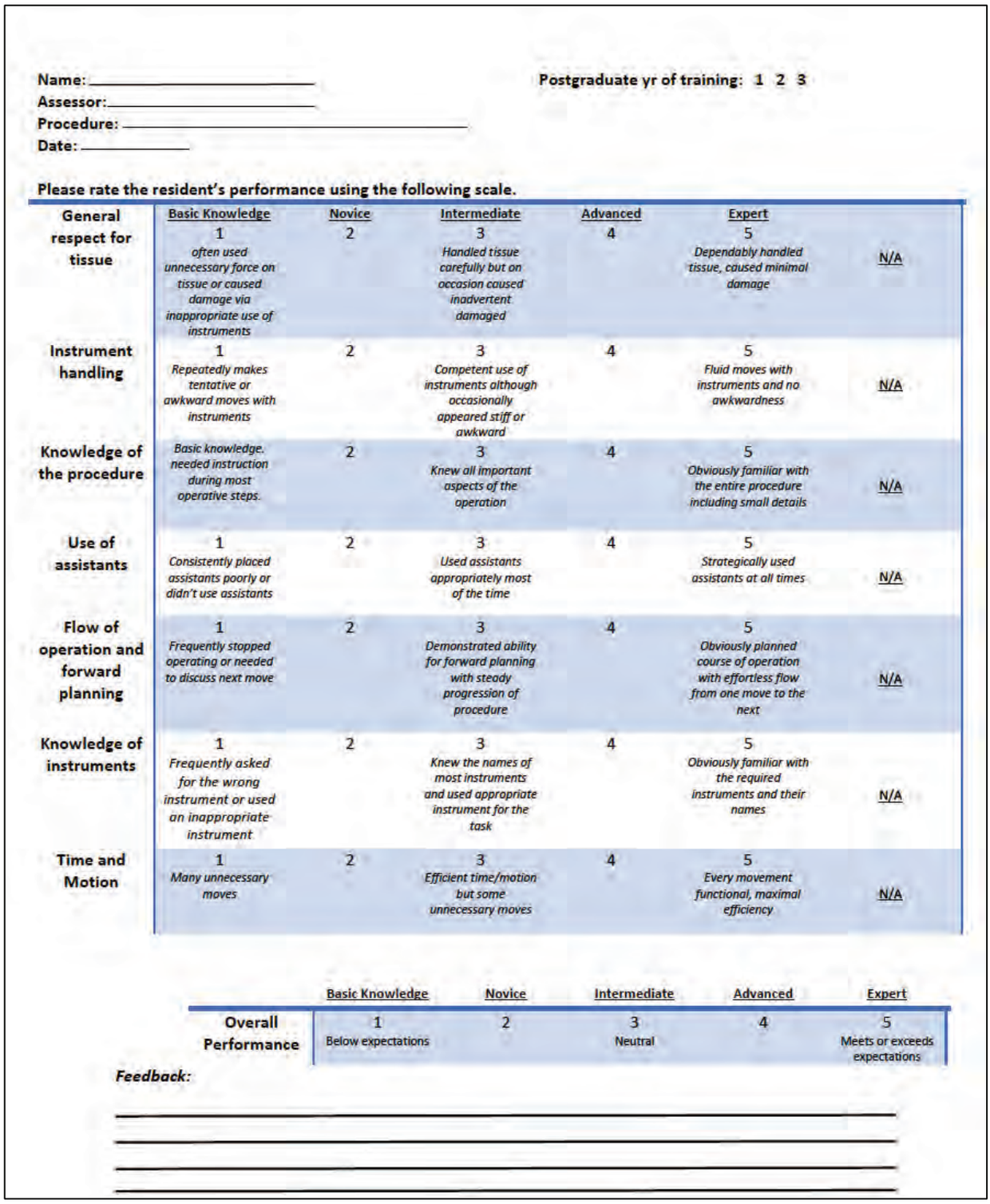
Methods

This study involved two stages. The first stage involved creating a form that could serve as an accurate and direct assessment tool of podiatric surgery residents. The second stage of the study involved trial implementation of the direct assessment tool among a small cohort of podiatric surgery residents. These results were analyzed to determine the reliability of the assessment form.

Stage 1

To develop the direct assessment tool used to assess the residents (Figure 1), a review of literature was performed to determine which content would be appropriate and imperative to include. The most recently published articles all made reference to, and overlapped with, a less recently published article written in the British Journal of Surgery entitled "Objective structured assessment of technical skill (OSATS) for surgical residents"(7). The assessment tool used in this study served as a basis for the assessment tool seen in figure 1. Assessment tools from more recent publications helped to further refine the form and make smaller changes.

The form consists of seven categories to grade specific areas of surgical performance and an eighth category to grade the residents on overall performance. Each category is graded on a scale of one to five. A score of "1" refers to fundamental awareness or a basic knowledge and a score of "5" refers to expert performance. “N/A” was also included in the scale in case any category did not apply to a specific procedure. The grading scale was derived from the National Institute of Health's competency proficiency scale which was designed to measure one’s ability to demonstrate on the job competency (3). The NIH proficiency scale outlines each level of competency very specifically which helped to avoid rater bias and misunderstandings as to what constituted a specific score. Before implementing the direct assessment tool, interprofessional feedback was compiled by sending the form to local podiatrists in Southern California, Western University of Health Sciences, College of Podiatric Medicine staff members, and residency directors nationwide. All of the feedback received was taken into account before final revisions were made to the assessment tool.



Name: _____ Postgraduate yr of training: 1 2 3

Assessor: _____

Procedure: _____

Date: _____

Please rate the resident's performance using the following scale.

	Basic Knowledge	Novice	Intermediate	Advanced	Expert	
General respect for tissue	1 *often used unnecessary force on tissue or caused damage via inappropriate use of instruments*	2	3 *Handled tissue carefully but on occasion caused inadvertent damaged*	4	5 *Dependably handled tissue, caused minimal damage*	N/A
Instrument handling	1 *Repeatedly makes tentative or awkward moves with instruments*	2	3 *Competent use of instruments although occasionally appeared stiff or awkward*	4	5 *Fluid moves with instruments and no awkwardness*	N/A
Knowledge of the procedure	*Basic knowledge. needed instruction during most operative steps.*	2	3 *Knew all important aspects of the operation*	4	5 *Obviously familiar with the entire procedure including small details*	N/A
Use of assistants	1 *Consistently placed assistants poorly or didn't use assistants*	2	3 *Used assistants appropriately most of the time*	4	5 *Strategically used assistants at all times*	N/A
Flow of operation and forward planning	1 *Frequently stopped operating or needed to discuss next move*	2	3 *Demonstrated ability for forward planning with steady progression of procedure*	4	5 *Obviously planned course of operation with effortless flow from one move to the next*	N/A
Knowledge of instruments	1 *Frequently asked for the wrong instrument or used an inappropriate instrument*	2	3 *Knew the names of most instruments and used appropriate instrument for the task*	4	5 *Obviously familiar with the required instruments and their names*	N/A
Time and Motion	1 *Many unnecessary moves*	2	3 *Efficient time/motion but some unnecessary moves*	4	5 *Every movement functional, maximal efficiency*	N/A

	Basic Knowledge	Novice	Intermediate	Advanced	Expert
Overall Performance	1 Below expectations	2	3 Neutral	4	5 Meets or exceeds expectations

Feedback:

_____

_____

_____

_____

Figure 1: Resident Assessment Form

Stage 2

Stage two began with the distribution of the assessment forms to attending physicians at Chino Valley Medical Center's podiatric surgery residency program. First through third year podiatric surgery residents from the program were recruited to be evaluated in this study. There was no exclusion based on gender, ethnic background, disability, religion, or sexual orientation. Exclusion only occurred if residents declined to participate or sign the informed consent.

All attending physicians were asked to read over the NIH Competency Proficiency Scale prior to filling out the direct assessment tool. Educating attending physicians on how to use the scale served to provide consistency in methods of scoring resident surgical performance. Data was collected over the course of four months and then analyzed.

Results

Two 1st year residents, one 2nd year resident, and one 3rd year resident participated in the study and produced a total of 42 completed assessment forms as seen in figure 2. First year residents produced 22 forms with a mean score of 2.93 per item with a standard deviation of 0.44. Second year residents produced 1 form with a mean score 2.75 per item. Third year residents produced 19 forms with a mean score of 4.38 per item and a standard deviation of 0.45, as seen in figure 3.

Figure 4 displays the average scores of all items without comparison with post graduate year (PGY). The average scores fall within 3.14 and 3.89, which supports the consistency each item on the resident assessment form. Every item on the assessment tool contributes to the accurate overall score within each form.

PGY	No. of forms	Mean Score ± SD
PGY-1	22	2.93 ± 0.44
PGY-2	1	2.75
PGY-3	19	4.38 ± 0.45
All	42	3.58 ± 0.85

Figure 2: Resident Assessment Tool, categorized by postgraduate year and number of collected forms

PGY	Total No. of residents	Total No. of forms
PGY-1	2	22
PGY-2	1	1
PGY-3	1	19

Figure 3: Mean scores for Resident Assessment Tool items 1-8 categorized by postgraduate year

Resident Assessment Tool Score Item	Total No. Scores	Min Score	Max Score	Mean Score ± SD
Item 1: General Respect for Soft Tissue	28	1	5	3.12 ± 0.88
Item 2: Instrument Handling	28	1	5	3.43 ± 0.84
Item 3: Knowledge of the Procedure	28	2	5	3.68 ± 0.82
Item 4: Use of Assistants	28	1	5	3.39 ± 1.17
Item 5: Flow and Operation and Forward Planning	26	1	5	3.46 ± 1.21
Item 6: Knowledge of Instruments	28	3	5	3.89 ± 0.83
Item 7: Time and Motion	26	1	5	3.31 ± 1.35
Item 8: Overall Performance	23	2	5	3.65 ± 0.71

Figure 4: Descriptive Statistics for the Items on the Eight Resident Assessment Tool

Item 1	r =0.853 p = 0.00
Item 2	r = 0.797 p = 0.00
Item 3	r = 0.800 p = 0.00
Item 4	r = 0.853 p = 0.00
Item 5	r = 0.884 p =0.00
Item 6	r = 0.816 p = 0.00
Item 7	r = 0.893 p = 0.00

Figure 5: Correlations of each item on the assessment tool and the overall score for all PGY's ranging from 0.079-0.893

Statistically significant correlations between each item on the assessment tool as they relate to the overall score demonstrates content validity of the assessment tool. Correlations ranged from (0.797 – 0.893) as seen in Figure 5. Comparison between first and third year resident's overall scores revealed a statistically significant difference, reflecting that third-year residents performed at a higher level than first year residents ($p<0.001$).

Figure 6 illustrates the average scores for each item based on PGY. On average, each item demonstrates an increasing score and supports a positive slope for the line of best-fit. A third-year resident is expected to demonstrate a higher skill level, and therefore, and higher overall scores on the assessment tool when compared to a first-year resident. The data suggests a positive correlation between resident performance on individual scoring items and overall performance as a function of PGY.

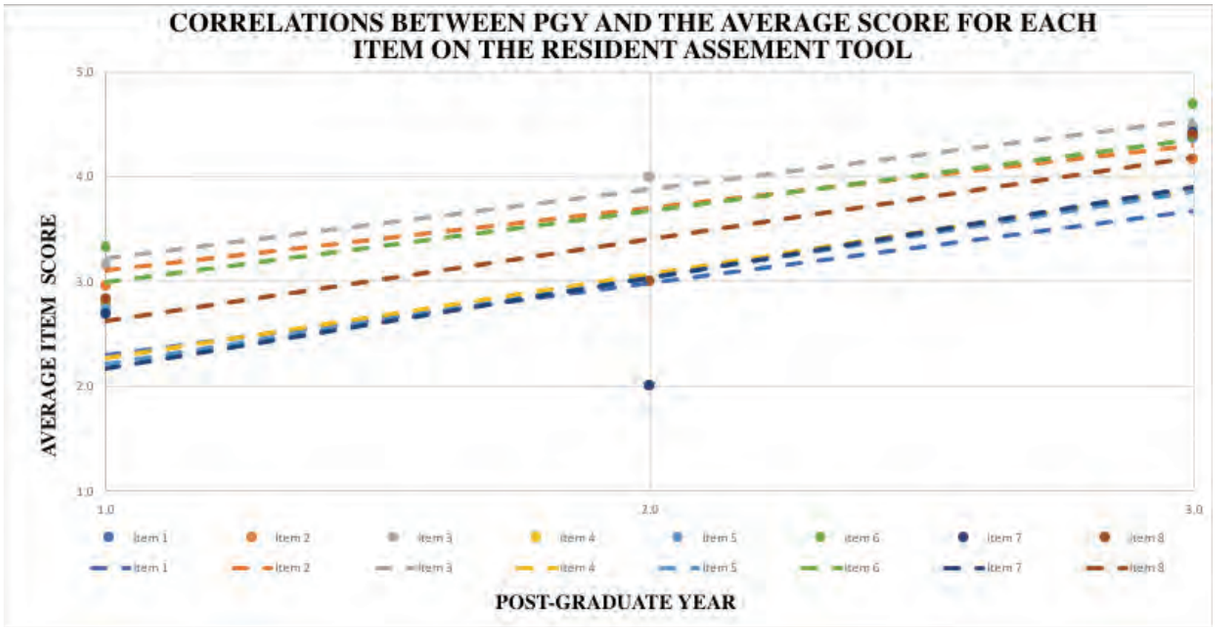


Figure 6: Correlations of PGY and average scores of the assessment tools. The X-axis represents the PGY from 1-3 and the Y-axis represents the average scores received from each item on the assessment tool for PGYs 1-3

Conclusion

Although valid direct assessment does show some setbacks, it is a valid way to determine the competency level of podiatric surgical residents. Feedback from attending physicians who were asked to assess the residents stated that the direct assessment tool took a substantial amount of time to complete. Another concern was that direct assessment alone eliminates the repetitions necessary for residents to encounter surgical complications that serve as a valuable teaching tool that ultimately protect patients once residents have graduated.

Continuing research on implementing direct assessment with MAVs needs to be done to determine how direct assessment and MAVs can most efficaciously complement one another. Further research is also warranted to determine interrater reliability of direct assessment. Despite the minor setbacks associated with

direct assessment, direct assessment has the ability to ensure that procedures are performed correctly and competently. This method also ensures that feedback is provided to residents to address where improvement is needed in specific areas. Direct assessment has the potential to improve residency training and ultimately improve patient outcomes nationwide.

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Lower Extremity Biomechanics: A Work in Progress

Eduardo Glass, MS-1 and Garrett Wireman, MS-1

Abstract:

Lower extremity biomechanics is a highly-debated field amongst a wide range of professionals. The discrepancies over the past 60 years led to the development of multiple theories for foot orthosis to correct abnormal gait or pathomechanics. Merton L. Root, DPM favored the idea of having a standardized way of conducting foot orthoses by developing his theory in the 1950's. Within decades after Root's initial influence, many more theories came to be practiced. These new theories highly contrasted Root's theory but all had an underlying agreement on basic foot/ankle biomechanics surrounding the talus and Windlass mechanisms. Newer approaches are formed today that consider various parts of the popular theories and unify them. While other emerging theories disband the idea of an orthoses to help reestablish a normal subtalar joint neutral all together. Discussing the evolution of lower extremity biomechanical theory is of interest to the practicing podiatrist, orthopedist and physical therapist and helps manifest novel ideas to forward the field of biomechanics.

Introduction

Biomechanics is defined as "the application of mechanical laws to living structures, as to a locomotor system." (1) Within the field of podiatric medicine, biomechanics is most frequently applied in the clinical setting with the fitting of an orthosis (1). However, the methodology to apply the science of podiatric biomechanics is one of contest and debate, and still evolving (2). Although highly contested, Merton L. Root, DPM, is hailed as the founder of modern day functional biomechanical orthosis. Root's theories, although mostly modified and improved upon, laid the groundbreaking work for future lower extremity biomechanics to progress (2,3). Dr. Root wrote minimal text on his orthosis methods. Therefore, it is suspected that other practitioners used many of his terminology that Dr. Root may have disagreed on the interpretation of. This difficulty in understanding Dr. Roots terminology led to discrepancies in the field of medicine and healthcare in the realm of LEGB (2). One of Root's theories, called the subtalar joint neutral theory (also foot morphology theory), was paradigm for many years despite argument over his teachings. Decades later as new research and technologies were conceived, a paradigm shift was swiftly developing (1). This gave way to new theorists such as Howard Dananberg, DPM, who developed sagittal plane theory and Kevin Kirby, DPM, who developed the tissue stress theory based on STJ movements.

This review attempts to evaluate the available literature on the development of lower extremity biomechanics theory within the field of podiatric medicine; assessing the past and present congruencies and inconsistency within theories and literature, considering future paths forward within the subject.

Overarching Biomechanical Theories, Root and beyond

Three dominant theories have emerged in literature regarding management of lower extremity symptoms: the subtalar joint neutral/foot morphology theory (STJN/FM), tissue stress (TS) theory, and sagittal plane facilitation (SPF) theory. Usual treatment outcomes of lower extremity symptoms established from all three theories appear to be positive despite the diversity of the paradigms and their application (2). Alternative models of overall foot function have also been developed and compiled, such as preferred movement pathway and muscle tuning (Breno Nigg); MASS positional theory (Edward Glaser) and neoteric biomechanics (Dennis Shavelson) (4). As stated, all three dominant theories had positive clinical outcomes, therefore, the clinical applications will be emphasized in the discussion of the theories. At the time of Dr. Root's entrance into the field of podiatric medicine in the 50s, biomechanical theory was a large torrent of theories, philosophies and techniques (5). The state of biomechanical theory prior to Root has been described as a "jumble of jigsaw pieces to the puzzle lacking congruence" (4). Dr. Root personally stated that: "most of the treatment procedures then in vogue were successful only in a small number of cases, and in most cases the prognosis in each course of treatment was unpredictable" (5)/ The profession needed a unification of its approach towards treating mechanical pathology in the lower extremity (5).

In his attempt to address this issue, Root suggested a knowledge of foot morphology is necessary to understand foot function. He stated that the shape of bone structure influences the motion of the various functional joints and gross appearance of the foot. Ultimately, he postured that the bone structure shape determines foot musculature that creates necessary motion and stability. His own clinical research and the amalgamation of various work from his colleagues lead to the publication in 1971 of *Biomechanical Examination of the Foot: Volume 1*, a text that would gradually form the basis of Root STJN theory as the profession recognizes (5).

STJN/foot morphology (FM) theory is based on the premise that normal function of the foot is derived from the neutral position of the subtalar joint occurring immediately after heel strike and at the end of

the midstance phase of gait, resulting in motion and position referred to as the ideal foot (Figure 1).

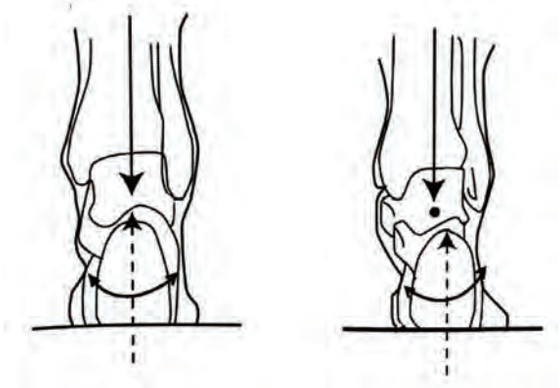

Figure 1: Left ideal foot: Vertical force from leg downward aligns with the center of the ground reaction force, resulting in equal inversion and eversion moment around the ankle joint (also viewed as the NCSP). B) If ground reaction force is misaligned (lateral) with the downward force of the leg, there is net movement occurring on the calcaneus (net eversion). Adapted from Normal and Abnormal Function of the Foot (4,10).

This STJN position formed the core of the theory's foot morphology characterization and abnormal function establishment. Model of management within this theory consists of properly identifying FM as abnormal and prescribing the appropriate orthotic device to prevent further abnormal joint compensation, otherwise placing the foot in the determined ideal (normal) position.

Orthosis within the FM theory aims to balance a specific foot deformity with posting applied to a rigid bespoke shell. A cast of the foot in a non-weightbearing neutral position starts the prescription protocol for the balancing. The neutral cast's shape is vital to capture correct forefoot-to-rearfoot alignment and calcaneal inclination angle for the foot's overall morphology. The cast is then angled to place the heel bisection at the needed location, utilizing the patient's neutral calcaneal stance position (NCSP) and necessary angling to allow normal pronation (Figure 2) (2).

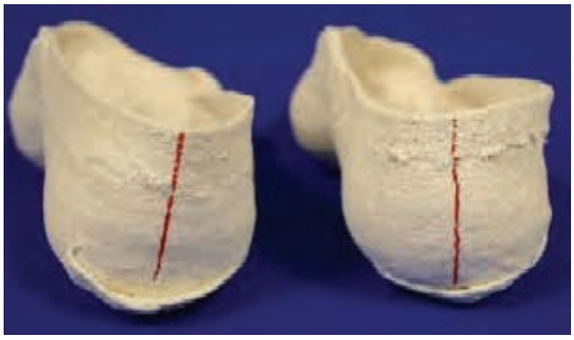

Figure 2: An example of evaluating NCSP and forefoot-to-rearfoot relationships in negative casts. The cast on the left inverts when placed on a supporting surface, indicating the cast has captured a valgus forefoot-to-rearfoot position. The cast on the right has a perpendicular heel (and NCSP) indicating a perpendicular forefoot to rearfoot relationship. Adapted from ProLab Orthotics (11).

In summary, Dr. Root's work helped establish the concept of a neutral position for the subtalar joint (STJ) which aided in the creation of a classification scheme for lower extremity deformities, a biophysical criteria that defines what is normal for foot structure, and casting and manufacturing techniques for modern foot orthosis (3).

Howard Dananberg, DPM, started developing the Sagittal Plane Facilitation (SPF) theory in 1986 which underlined the importance of the foot as a pivot that rocks forward from heel to toe, allowing adequate hip extension leading up to the propulsive phase of gait. This hip extension, theorized by Dananberg, is what allows a normal stride, and ultimately an efficient and erect gait (2).

Functional hallux limitus and ankle equinus are examples of foot pathologies that restrict movement and that result in what Dananberg theorizes as a sagittal plane blockade that generates pathology. SPF theory has been mainly related to more proximal posture-related problems, but there is possibility in SPF theory helps explain foot related symptoms. The joints of the lower extremity must be free to move and respond to loading and unloading to accommodate normal walking. The motion of one joint will affect the motion of others, and Dananberg has stated that over 80° of sagittal plane motion is required during the single support phase of the gait cycle. As well, concurrent internal and external rotation the stance phase extremity is also required during this period and accounts for around 15° of motion. The foot acts as a pivotal site to dissipate compressive, shear and tensile forces as well as facilitate rotary forces during the weightbearing phase of walking. In podiatric biomechanics, the foot must also act as a shock absorber, a mobile adapter and a rigid lever. This means that during single limb support, the body's center of mass must pass over the plantigrade foot, resulting in several rocker stages of the foot (heel, ankle and forefoot) necessary to allow smooth transition of the body's center of mass. Interfering with such movements in the sagittal plane can disrupt this smooth transition and generate pathology (4).

Orthotic prescription in the SPF theory is conducted via informed trial and error using video gait analysis and in-shoe pressure system measures, thus specific orthotic modifications are determined without utilizing forefoot-to-rearfoot relationship or axis height such as in the FM theory. The actual prescription method within the SPF theory remains under documented and Dananberg has not produced an exact formula of his methodology, making direct replication difficult (2). More recently, there has been concern over the limitations and inaccuracies of modern in-shoe pressure measurement systems regarding orthotic treatment; which may impact the reliability of methods within SPF theory (7).

The Tissue Stress theory is based on assessment of moments across the STJ and ways of altering these moments to decrease stress upon anatomical structures. The theory dates to work by Kevin Kirby, DPM, on the variations in the STJ axis initially in 1987 and onward (Figure 3).

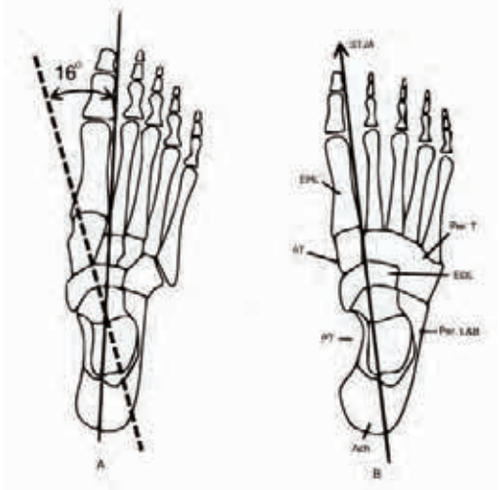

Figure 3: A comparison of STJ axis locations from the Root FM theory (A) versus Kirby's projection of the axis (B). Kirby shows the axis lying lateral to the first metatarsal head. Adapted from Lower Extremity Biomechanics: Theory & Practice: Volume 1 (4).

The theory denotes an alternate method in palpation of the STJ axis (Figure 4).

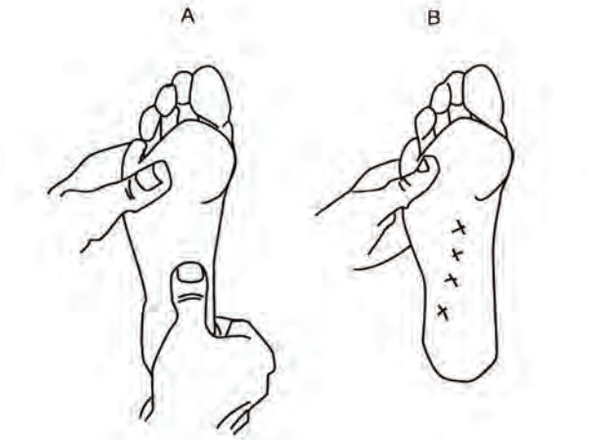

Figure 4: Kirby's methodology of identifying the STJ axis via pushing on the plantar aspect of the foot A) Direct superior pressure applied to the plantar surface B) Markings on the plantar surface that when pushed upward, produces no net moment of the STJ (pronation or supination). Adapted from Lower Extremity Biomechanics: Theory & Practice: Volume 1. (4).

TS theory is based more on the kinetics of gait as opposed to the kinematics of gait. The core of theory is that pronation or supination does not cause harm but halting either motion does (2). As a specific example of this, Kirby notes that "inadequate supination motion or pronation motion of the subtalar joint during late midstance will lead to the common gait finding of abductory twist at the instant of heel lift" (8). Symptom reduction dominates the treatment methodology rather than attempting to place the foot in an ideal position, which is reflected in orthotic prescription (Figure 5).

Figure 5: Medial skive technique as suggested by Kirby. Left) Original cross-section shape of a foot orthosis Right) Arrow points to a removal of material from the medial side of the heel pad impression, such that a molded orthosis is higher and can push harder against the medial side of the heel pad. This results in increase of the supination torque that the orthosis can generate around the STJ axis. This is an example of providing supinatory motion that would be halted in the relevant foot pathology. Adapted from Lower Extremity Biomechanics: Theory & Practice: Volume 1 (4).

In addition, Kirby has contested the criteria of normality set by Root et al as irrelevant to achieving normal function with an orthosis. A change in the magnitude of forces acting on the foot is necessary to reduce symptoms, not in joint position; which differs from the FM theory. Like the SPF theory, there is no absolute direct prescription protocol available for orthotic production based on TS theory (2). There has been some recent work on gathering intratest reliability on some of Kirby's methodology, showing reliability on the STJ palpation technique itself but not on the classification of the palpated axis location. Replication for greater accuracy and more data is required, as well as expansion into more validity testing regarding the entire subject of biomechanics (9). Overall from the literature to this date, the points that Harradine and Payne bring up for more work needed on empirical testing of theory methodology, protocol creation and theory comparison still stand today (1,2).

The Unified Approach: A Modern Mechanical Theory for function

A new method which takes part of each theory called the Unified Approach may also be applied. The three theories, (FM, SPF, and TS) all have major discrepancies and beliefs between them but within each theory, there is common ground on some highly critical cornerstones of lower extremity gait biomechanics. Such a move towards combining positive aspects of the theories was proposed by Paul Harradine.[2] First, during stance phase, the foot/ankle complex can form a secure and rigid model. Secondly, the limb in contact with the ground (contact limb) acts as a pivot to vault the body over its current point in space. And thirdly, supination and pronation are a product of the STJ joint through the influence of the tibia with external and internal rotation assuming a closed kinetic chain order.

When the contact phase begins, and heel strike is occurring, initial double leg stance is starting. At this point, the tibia is internally rotating and causing STJ pronation. STJ pronation causes accommodation with the surface by allowing the foot to depress its arch. Simultaneously the arch is also becoming stretched so that any soft tissue constraint that passes over the midtarsal joint is becoming taut. This leads these structures around the midtarsal joint to bear a closed-pack position, making the MTJ a rigid joint. From this point, a reverse windlass mechanism may be observed. As the foot arch drops, the plantar fascia becomes taut due to tensile strain, causing the reverse windlass mechanism. The stretched Plantar fascia not only adds to the strength of the MTJ but contracts the digits to the plantar surface due to the plantar distal insertion into the phalanges (2).

Following heel strike/contact phase, is midstance, where an alternative shift in biomechanics occur. The foot is coming to the end of ground accommodation phase and into a more rigid foot in preparation for heel off. As the hips rotate, the tibia will now externally rotate on the STJ and cause STJ supination. This now causes the arch and plantar fascia to elevate. This allows structures being held by the tight plantar fascia in the STJ pronated phase to now loosen. This loosening is only happening for a short time. As heel lift occurs, the first phalanx is dorsiflexed as the body's center of mass is translating anterior to the stance limb. This dorsiflexion of the hallux then induces the windlass mechanism and pulls the calcaneus proximal to the hallux. Thus, tightening the plantar fascia and all its associated structures making a rigid model. The concentration to the plantar fascia is not an attempt to downplay the other forces contributing to the influence of foot/ankle biomechanics, however, the plantar fascia is a necessary component in providing MTJ support to aid in the resupination as the stance limb is moving towards heel lift (2).

Future of Biomechanics

Newer ideas are suggesting that proprioceptive, neuromechanical, and neurophysiological forces make more contributions to the effectiveness of an orthoses than originally thought. The idea is that a normal input of proprioception can be altered over time as dysfunction is learned over time and an abnormal foot function is gained. It is believed that the interosseous ligament has proprioceptive abilities. This feedback system is best optimized when the STJ is going into supination and less feedback loop when the STJ is starting to pronate. Another theory is the idea of retraining the foot by acting on the central nervous system. By using an orthosis that places progression forces on targeted structures, one may observe a short time period after which the orthoses are removed that a normalcy in foot function is gained (2,4).

Some people at this forefront would like to reform the theory of "aligning the skeleton". One such researcher is Benno Nigg, Ph.D. at the University of Calgary. Nigg downplays the roles that orthosis, shoes and popular noninvasive corrective devices contribute to impact loading. His research questions the established principles that suggest that foot pronation should be minimized. Dr. Nigg has since offered two of his own theories, Muscles Tuning Theory for running and Preferred Movement Pathway that rebukes the call for orthoses due to a lessening of muscle activity that would otherwise be engage (4).

Conclusion

What does it take to have a community change its ideas after years of tradition? To change tradition, there must be theories challenging current mainstream

ideas amongst a large population. Secondly, there must be a push from the majority of the population that is highly invested within the subject. There are several new theories being developed that are currently creating a new paradigm or contributing to the established theory today (4).

These theories mentioned are but just a few of the more modern ideas coming to light and are by no means the only emerging congruent theories. Just as Root faced in the unification of biomechanical theory of his time, a second approach to amalgamation of developed theory occurred in recent time as research and technologies developed. This cyclic turn of events within LEGB is an interesting observation and confirms what Payne has written on Kuhnian philosophy regarding the scientific development within LEGB (1). As stated before, empirical research is still needed overall in analyzing the theories separately and together, to better refine theory with absolute scientific backing (1,2). Regardless of the need for empirical data, Foot Morphology, Tissue Stress and Sagittal Plane Facilitation theory each contributes a part to the unified approach of biomechanical function.

Overall, the development of lower extremity gait and biomechanics has been a very intriguing process, a continued and expanded review of the state of LEGB today in 2018 like the work of Harradine (2) and Payne (1) would be most welcomed. Such an updated review would bring fruitful discussion and critique that has led to the blossoming of the subject so far. Lee has also noted cross-discipline contributions to the subject such as physical therapy and orthopedics (5). An endeavor focused on reviewing these disciplines literature in relation to podiatric biomechanics would also be warranted, as Payne has shown there has been significant confusion on the crossover of definitions and terms in the past (1). Finally, more empirical research should be done with reliability/validity testing of the related biomechanical theories and comparison of all major theories in literature today. Despite some recent work in this regard, the need for such research since called for by Payne has not changed by much (1,9). The revolution of the wheel of science is churning in this area, and continued diligence on matters within podiatric biomechanics is needed to follow in the footsteps of those who laid a beautiful groundwork for the profession.

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Assessing the Reliability and Reproducibility of Determining Planal Dominance of Pes Planovalgus

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Project Abstract:
Surgical correction of pes planovalgus deformity is necessary when conservative treatments fail to provide lasting symptomatic relief. The preferred method for a definitive diagnosis is measuring radiographic angles to assess the plane of dominance in order to determine the appropriate surgical procedure. The purpose of this study is to assess the reliability and reproducibility of this evaluation method, as there is no prior research addressing the consistency of diagnoses amongst podiatrists. Twelve podiatrists reviewed a series of radiographs with symptomatic pes planovalgus. While the kappa value for intra-rater reliability was greater than that of inter-rater reliability, both values indicated poor agreement and suggest an inconsistency in evaluation methods between podiatrists.

Introduction:
Pes planovalgus, or flat foot is a primarily descriptive term used to describe an extensive class of foot ailments. (1) These foot deformities stem from a variety of pathologies ranging from structural to neurological which can affect people of all ages. The range of pathologies can be further divided into causing flexible (with compensation) or rigid (without compensation) pes planus, all characterized by a loss in the height of the medial longitudinal arch. The first step of treatment is often conservative, however, surgical intervention may be warranted in patients who achieve minimal relief with conservative treatment and for whom the deformity causes the greatest impedance on quality of life. While physical examinations and symptomatic presentations of flatfoot are essential to determining if surgery is necessary, radiographic evaluation is equally crucial because it allows podiatrists to pinpoint skeletal abnormalities in pes planovalgus and accordingly, determine the correct surgical procedure. (1) This is achieved by measuring various radiographic angles, primarily on weight-bearing lateral and dorsoplantar views.

Radiographic measurements performed on the weight-bearing lateral view include the cyma line, calcaneal inclination angle, first metatarsal declination angle, talocalcaneal angle, talar declination angle, and talo-first metatarsal angle (Meary's angle). Radiographic measurements performed on the weight-bearing dorsoplantar view include calcaneocuboid angle, metatarsus adductus angle, talocalcaneal (Kite's) angle, talo-first metatarsal angle, cyma line, and talonavicular congruency. (1)

While pes planovalgus deformities may exist in all three cardinal planes (frontal, sagittal, and transverse), it is believed that there is one plane where the deformity is strongest called the plane of dominance (POD). This dominant plane is the focus of treatment as well as compensation, dependent upon the orientation of both the subtalar and midtarsal joints which allow for isolation of the pathologic axes. (2) The POD of the deformity determines the axis around which the foot will have excess motion. For example, the subtalar joint axis is oriented 16 degrees from the sagittal plane and 42 degrees from the frontal and transverse planes. If the axis is more parallel to the ground and towards the transverse plane or the axis lies between the transverse and sagittal plane, these would result in increased inversion and inversion within the frontal plane. If the axis is more perpendicular to the ground and towards the sagittal plane, this results in increased abduction and adduction within the transverse plane. If the axis is oriented more mediolaterally, then primary motion will exist in the sagittal plane. Therefore, determining the POD may then aid in the selection of an appropriate surgical procedure that will correct the deformity and negate the excess motion. (1)

The purpose of this study is to determine the reliability and reproducibility of identifying the plane of dominance (POD) of flatfoot using radiographic evaluation method. This information may be of immediate value because, while existing studies acknowledge the importance of POD, there is no current study which specifically addresses the reliability and reproducibility of determining POD from radiographic evaluation in surgical recommendation.

Study Methodology:
De-identified weight-bearing dorsal-plantar and lateral radiographs of 30 different feet with symptomatic pes planus were obtained from West Coast Foot & Ankle Associates Inc. in Huntington Beach, CA courtesy of Dr. Kazuto Augustus, DPM. Five of the 30 radiographs, without obvious identifiers, were copied twice, and randomly inserted into the collection of images without the knowledge of participants, resulting in a total of 40 images for the participants to evaluate. Choosing images without obvious identifiers was

important to ensure that participants made a true assessment of each image without the interference of priming. The random insertion of the duplicated images was intended to test each participant's ability to identify the plane of dominance for the same radiographs in order to assess intra-rater reliability. Twelve podiatrists were recruited as participants via the American Podiatric Medical Association's "Find a Podiatrist". Participants were asked to review the 40 images and identify the dominant POD choosing between the frontal, sagittal, and transverse planes. Participants were presented with the option to use ImageJ software to measure the angles to better aid their assessment.

Results:

A. Inter-Rater Reliability

Of the 360 total radiographs presented to participants, 83 feet (23.1%) were identified as having a frontal plane deformity, 143 feet (39.7%) with a sagittal plane deformity, and 134 feet with a transverse plane deformity (37.2%). The free marginal kappa value, a metric for calculating inter-rater reliability, was measured to be 0.09924 for the assessment thereby indicative of barely slight agreement between individual participants in assessing the same radiographs.

B. Intra-Rater Reliability

Table 1: Free Marginal Kappa Measuring Intra-Rater Reliability

Participant	Free Marginal Kappa	Participant	Free Marginal Kappa
1	0.40	7	0.60
2	0.20	8	0.20
3	0.40	9	0.30
4	0.10	10	0.10
5	0.20	11	0.20
6	0.00	12	0.30
Average Free Marginal Kappa			0.30

The table above summarizes the marginal kappa values for individual participants' evaluation of repeated radiographs. Three out of twelve podiatrists were in poor agreement (25.0%), six out of twelve podiatrists were in fair agreement (66.7%), and one of twelve podiatrists was in moderate agreement (8.3%) with their respective assessments of the same radiographs.

Image 1. A sample image from the survey in which participants were evenly split in determining the plane of dominance between all three cardinal planes.

Discussion:

With regards to inter-rater reliability, the low kappa value obtained leads to the conclusion that there is low agreement amongst podiatrists evaluating the same radiographs. The low inter-rater reliability value may be due to a wide variety of reasons including differences in training and education amongst participants. Intra-rater reliability also fell below what was expected suggesting that podiatrists may not assess planal dominance consistently even by their own radiographic evaluation. This may be due to a lack of consistency in approach to evaluation or failure to physically measure relevant angles. This last suggestion is supported by the fact that the participant with the highest intra-rater reliability score meticulously measured out every angle she felt was relevant for every radiograph she encountered. However, participants with lower scores tended to take few, if any, measurements. Our calculated inter-rater reliability (0.09924) was nonetheless, lower than intra-rater reliability (0.30), suggesting that individual podiatrists are more consistent when evaluating similar cases presented to them.

Limitations of this study include a lack of adherence to the utilization of ImageJ software. While an instruction guide was provided to guide podiatrists to use a uniform platform to determine the radiographic angles, podiatrists were more inclined to use their own systematic approach in assessing the dominant plane. Podiatrists may also have had more familiarity with specific surgical treatments of symptomatic pes planus or been instructed and trained differently, guiding them to their various diagnoses thus resulting in a lower consistency among different podiatrists evaluating the same cases. While intra-rater reliability was in lesser agreement as well, it was noted that individual scores were higher when podiatrists used a uniform approach to determining the radiographic angles. Further evaluation of the reliability and reproducibility of determining POD, with a larger sample size, could

address the effects of a uniform standard of assessing POD on clinical outcomes in patients.

Conclusion:
The assessment sought out to understand the concordance among physicians, both unaccompanied and collectively, in determining the planal dominance of pre-surgical symptomatic pes planus. It was expected that the inter-rater reliability there would be greater variance as each participant may veer to a particular assessment based on their specialties and experience. Intra-rater reliability differences would indicate further review of a standardized approach to assessing planal dominance. Investigating such an approach would determine the benefits of a standardized means of assessment in selecting the appropriate procedure for symptomatic relief.

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Ulcerative Dermatologic Conditions of the Lower Extremities: A Review

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Abstract:
Venous, arterial and diabetic ulcers are common ulcerative diseases in clinical practice that primarily occur on the lower extremities. Many other potentially ulcerative diseases affect the lower extremities with much lower prevalence; as such, their coverage in the literature is limited. Some such examples, listed here in order of most to least common, include pyoderma gangrenosum, lichen planus, necrobiosis lipoidica, and leukocytoclastic vasculitis. This article will provide a brief review of each of these diseases and describe keys to identifying ulcerative subtypes.

Introduction:
The most common ulcerative skin conditions to affect the lower extremities include those of venous, arterial and diabetic etiologies. A significant number of wound clinic visits deal with the care of these conditions, which are nearly always found on the lower legs; because of their prevalence, they are extensively covered in the literature of many specialties. It is important to remember that many other less common ulcerative diseases also occur on the lower extremities, though their representation in the literature may be less extensive. Quality care and accurate diagnosis of these diseases can prevent unnecessary pain, financial burden and even surgical amputation in some cases.

Pyoderma Gangrenosum
Pyoderma Gangrenosum (PG) is an ulcerative dermatologic condition that is classified as a neutrophilic dermatosis, and believed to be immune-mediated. The incidence is estimated at 3-10 patients per million per year, however it is most often seen in dermatologic, wound care or podiatric clinics, presumably making it's prevalence in these practices higher(1). PG is commonly mistaken for other ulcerative conditions (and vice versa) and is, in turn, improperly treated, which can be devastating for patients(2). While multiple subtypes of PG exist, the most common subtype is termed classic or ulcerative PG. This subtype can be associated with underlying systemic disorders and should prompt further investigation if present(3,4). Treatment is focused upon immune system modification along with standard wound care strategies.

Pathogenesis
While the exact etiology and pathogenesis remain unclear, much progress has been made in understanding PG in an effort to guide effective treatment. The condition has long been considered a neutrophilic dermatosis without infectious involvement[5]. In this regard, it is categorically related to both Behcet disease and Sweets syndrome, among others. A genetic component has been suggested as a potential etiology, particularly when seen alongside pyogenic arthritis and acne in PAPA syndrome (pyogenic arthritis, pyoderma gangrenosum and acne) or alongside acne and hydradenitis suppuritiva in PASH syndrome (pyoderma gangrenosum, acne, and suppurative hidradenitis)(6,7). Genetic implications are supported by PG's commonality in various genetic diseases of immune deficiency (8). Regardless of the root cause, evidence supports the theory that neutrophils of normal structure but deranged chemotactic and phagocytic responsiveness cause neutrophilic infiltration into the dermis and subsequent development of the clinical lesions seen in PG(9).

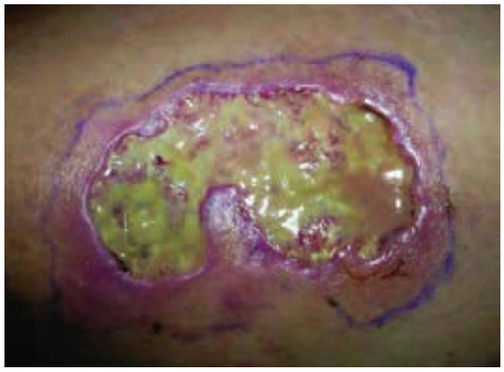

Figure 1: Serpiginous, violaceous borders characteristic of ulcerative PG (adapted from Fonder M, 2006).

Figure 2: Progressive PG lesions become larger and borders become deeper and more diffuse (adapted from Teagle A, 2014).

Clinical Presentation
Clinically, PG typically presents as a painful, rapidly progressing ulcerative lesion on the lower leg, without clear inciting cause, in middle-aged patients of both genders(12). Even in the classical subtype, a variety of lesions are possible upon presentation as the progression encompasses multiple stages(13). The development of classic PG lesions starts with a painful nodule, plaque or pustule that progresses in a matter of days into an ulcer. The borders of said ulcer are characteristically violaceous and undermined with a continuous yet serpiginous shape. Necrotic central areas are common, with the red-purple ulcerative rim representing skin that is currently undergoing necrotic changes(13).

In roughly 1 of 5 cases, PG is seen to follow either minor or major physical trauma, a phenomena termed pathergy, the most common example of which is peristomal PG(14,15). This becomes particularly important when PG isn't considered during the development of a diagnosis, or is mistaken for necrotizing fasciitis or any other condition in which surgical debridement is indicated. Debridement further exacerbates the condition, eliciting a pathergic response, and ,in some cases, has led to unnecessary limb amputation.

As with other immune mediated and auto-inflammatory conditions, PG is strongly associated with many systemic illnesses. Along with proper wound care, an investigation for an underlying condition should be initiated by the treating physician. In a case review of 86 patients, Bennett et al. found that roughly 50% of patients had some associated systemic condition, most commonly ulcerative colitis, Crohn's disease, rheumatoid arthritis, hematologic malignancy or other hematologic abnormality such as monoclonal gammopathy(16). Only 19% of patients studied had no other medical conditions. When associated conditions are present, they are usually antecedent to the development of PG, although PG can be a presenting complaint of those with undiagnosed Inflammatory Bowel Disease, Rheumatoid Arthritis or hematologic abnormalities(8). Because of this, thorough history and physical exam along with laboratory and/or imaging tests are prudent.

Despite advances in understanding the pathogenesis and systemic associations of PG, it remains a diagnosis of exclusion. Although inflammatory marker elevations and certain histopathologic findings are characteristic of PG, none are specific(8). Only in concert with the appropriate clinical picture and the assurance of exclusion of other conditions may one confidently make the diagnosis of PG.

Principles of Treatment
The cornerstone of treatment for PG is gentle wound care(17). It is vital to keep the wound bed clean and clear of infection to optimize healing. Furthermore, debridement is contraindicated secondary to pathergy as discussed above. Wet to dry dressings or caustic substances should also be avoided(8,12).

Prednisone is the first line systemic treatment given in doses ranging from 1-2 mg/kg/day or pulse doses of 10-20 mg/kg of methylprednisone if the disease is aggressive at onset. Treatment with cyclosporine or tacrolimus is warranted if prednisone is contraindicated or causes adverse side effects(17).

Topical corticosteroids, sodium cromoglycate and topical mesalazine have been shown to be effective for localized disease, whereas azathioprine and mycophenolate mofetil are appropriate for extensive disease(18,19). Biologics targeting tumor necrosis factor-alpha such as infliximab, adalimumab, and etanercept have demonstrated efficacy as well(20). Severe, refractory cases can be treated with either IVIG or alkylating agents such as cyclophosphamide(21,22).

Lichen Planus
Lichen planus (LP) is a common immunodermatosis that affects both men and women throughout mid-life. Since its discovery in the 1800s, multiple subtypes have been defined, some of which affect the lower extremities with disproportionate frequency. The classic presentation is very easily recognized by the astute physician; those who are frequently consulted for care of the skin of the lower extremities should become familiar with the rarer variants.

Pathogenesis
Pathologically, LP is the end result of a dysfunctional immune response to unknown antigens, though viral, bacterial or autoimmune culprits are suspected(23). The activation of T cells is followed by their localized migration into the dermis with focality at the dermal-epidermal junction(24). Once present, these T Cells resist apoptosis while simultaneously inducing apoptosis of basal keratinocytes mainly via the fas-fas ligand pathway(25).

Clinical Presentation
The classic lesions of LP are nearly pathognomonic; small papules mainly on the flexor wrists, dorsal hands, shins, trunk or genitals which quickly become pruritic, purple, polygonal papules and plaques, often with overlying lacy white reticulate scale (Wickham striae)(26). However, the hypertrophic and erosive

variants are more easily misdiagnosed and frequently occur on the lower extremities.

The hypertrophic variant presents with thick, pruritic verrucous-like plaques that are deeply red, gray or brown in color and occur most commonly on the anterior lower leg(27). Occasionally, these lesions can be surrounded by the papules or plaques of classic lichen planus(26). At times, these lesions can appear neoplastic or psoriatic in nature both clinically and histologically and require special attention to accurately diagnose(26,27).

Erosive LP is most often a mucosal disease, though when cutaneous it is often localized to the plantar foot and presents with painful, chronic ulcers with poorly defined borders(27). This inherently creates difficulty in differentiating between erosive LP and other causes of lower extremity ulcers, particularly diabetic ulcers. For this reason, biopsy of the lesion can be invaluable as the tissue shows characteristic lichenoid features and allows differentiation from other ulcerative diseases(28).

Figure 3: Erosive LP can present as a painful ulcer on the plantar foot (adapted from Dabiri G, 2013).

Principles of Treatment

First line treatment for LP most often involves the use of topical corticosteroids, though the efficacy of this treatment has yet to be definitively proven by clinical trials(30). Some purport intralesional acitretin as an alternative first line therapy(31) and a slough of other options are reported as therapeutic alternatives including intralesional or systemic steroids in severe or resistant cases. A recent analysis of the available literature suggests that encouraging results have been shown in treatment with systemic acitretin, griseofulvin or sulfasalazine.

Other treatment options include Methotrexate, Hydroxychloroquine, Dapsone, and light therapy. A variety of studies have been conducted comparing some of these individual therapies to one another, though no conclusive evidence suggests a dominant therapeutic ladder(32). Topical and intralesional steroid or intralesional acitretin injections remain first line therapies.

Necrobiosis Lipoidica

Necrobiosis lipoidica (NL) is a rare granulomatous disease of the lower extremities which has long been associated with diabetes mellitus(33). The traditional name of NL was necrobiosis lipoidica diabeticorum. However, studies conducted throughout the years have shown a lower tie to diabetes than once believed and, as such, the condition is now known simply as necrobiosis lipoidica.

Pathogenesis

Much is yet to be learned regarding the pathogenesis of NL. Investigative efforts have shown that a key component of the disease is the degeneration or necrosis of collagen fibers subsequent to granulomatous dermal infiltration and vascular thickening(34,35). Other theories, including neutrophil dysfunction and glycoprotein deposition continue to be investigated(36).

Clinical Presentation

Clinically, the lesion presentation in NL is fairly recognizable, particularly in its location of involvement. Atrophic, yellow-brown plaques with telangiectasias and red-brown borders are typical of NL; ulceration is a potential sequelae of NL lesions, particularly in males(33). Nearly all cases present localized to the anterior lower leg; rarely are any other body regions involved(34).

Figure 4: A typical lesion of necrobiosis lipoidica is a yellow-brown plaque with superficial telangiectasias and atropy located on the anterior lower leg (adapted from CMAJ, 2007).

While malignant transformation to squamous cell carcinoma has been reported[38], ulceration and development into a chronic non-healing are common sequelae. Providers should monitor for such changes and be prepared to refer to wound care providers for chronic management.

Principles of Treatment
Treatment prior to ulceration is ideal, but yields an impressively difficult task for physicians as no standard, single-most effective treatment strategy has been established(33). While there are many options available to physicians to utilize on a case by case basis, topical or intralesional steroids have been the most commonly implemented first-line therapy. Topical immunomodulators such as Infliximab or Tacrolimus, systemic anti-inflammatories, light therapy, and a host of other treatment options have been studied with mixed results. The most highly studied modality has been psoralen plus UVA (PUVA) therapy. A total of 103 cases have been documented utilizing PUVA treatment, with only 11 reporting worsening symptoms or no change. Including PUVA, many treatment options have been found capable of resolving current lesions over time, though few have been successful at preventing the development of new lesions(35). Optimization of glycemic control is paramount in maintaining overall health of the patient, and has been associated with improvement of NL lesions in case reports(39). Lastly, and perhaps most importantly, is the finding that nearly 1 in 5 lesions will resolve spontaneously(40). Even with spontaneous resolution, however, development of new lesions is far from uncommon.

Leukocytoclastic Vasculitis
Leukocytoclastic vasculitis (LCV) is a histopathological term which is generally used to refer to a variety of small vessel vasculidities, of which there are multiple subtypes. While most cases are either idiopathic, infectious or drug- associated, the list of all subtypes is vast and beyond the scope of this review. LCV is a rather common dermatologic condition that nearly always presents with lower extremity involvement either in isolation or as part of a more widespread finding. In advanced lesions, ischemic ulceration can develop, creating chronic wounds that are inherently difficult to treat.

LCV is a frequently encountered finding in various specialties of medicine, though more typically seen in tertiary care centers than primary care practices(41). Arora, et al. found that the incidence was roughly 4.5 per 100,000 persons per year, which was significantly higher than prior reports(42, 43). While the prevalence of various LCV etiologies varies, idiopathic cases appear to be most common, followed by those caused by infections and medications(42).

Pathogenesis
While the detailed pathologic mechanisms underlying LCV remain elusive, the overlying principle is as follows: in response to a variety of insults or exposures, immune complexes are deposited preferentially within the walls of the post-capillary venules and other small vessels. LCV most often represents a type III hypersensitivity reaction, though it is important to note that some authors suggest any mechanism of hypersensitivity can cause LCV(41). Along with this, neutrophilic infiltrate follows and proceeds to cause necrosis of the tunica intima(44). A recent study indicates that various T Lymphocytes are also involved in the development and progression of LCV(45). When this process has progressed far enough to affect the structural integrity of the vessel wall, rupture can occur and result in extravasation of blood into the surrounding tissue. Additionally, occlusion of the small vessels can occur and cause downstream ischemia and necrosis which presents clinically as lesional ulceration.

Clinical Presentation
This pathologic explanation helps to conceptualize the expected physical exam findings in a patient with acute LCV. Patients with LCV most often present with rapid onset (hours to days) of petechiae and palpable purpura which is usually confined to the lower extremities(26). Alkim et al. found that 64% of patients with LCV had signs of palpable purpura at presentation, while 36% had petechial macules, and lower proportions had a variety of other findings such as ulcers, vesicles and non-purpuric papules(46). At least 80% of cases were found to have lesions isolated to the lower extremities.

Figure 5: Leukocytoclastic vasculitis characteristically presents with palpable purpuric papules and petechial

macules of the lower extremities (adapted from Einhorn J, 2015).

Diagnosis can often be made clinically, but histopathologic support by way of biopsy of a new lesion helps to confirm the diagnosis. When collecting a biopsy of a lesion, it is important to consider the fact that fresh lesions yield a higher sensitivity in diagnosis than older lesions(48). Moreover, ESR, CRP and WBC elevations are supportive of the diagnosis of LCV but do not help to differentiate the cause.

In a subset of patients with LCV, systemic symptoms may be present and can be useful in determining the underlying cause of the vasculitis. Arthritis, GI upset, and renal findings can be found in 27%, 19%, and 27% of patients, respectively. In some instances, the discovery of said symptoms can help elucidate cause and guide treatment. For example, symptoms of hematuria or melena can suggest renal or GI involvement as a result of Henoch-Schonlein purpura, whereas a recent hospitalization may suggest drug-induced disease(46).

Principles of Treatment

Once diagnosed, treatment varies according to the subtype and cause of LCV. If drugs are suspected, the primary treatment measure would be to discontinue use of the offending agent. If infection is suspected, adequate antimicrobial treatment is appropriate.

First line medical therapy for the treatment of small vessel vasculidities is systemic corticosteroids. The recommended dose is 0.5 mg/kg/day until the lesion closes which is usually 2-4 weeks, but can be longer(49). Second line therapy consists of Dapsone and Colchicine, although either of these can be used in addition to systemic corticosteroids. In refractory cases, more aggressive treatment is initiated with immunosuppressants. Azathioprine, Methotrexate and Mycophenolate Mofetil have demonstrated efficacy(50, 51, 52).

Conclusion:

Many dermatologic diseases affecting the lower extremities have primary or secondary ulcerative potential, including pyoderma gangrenosum, lichen planus, necrobiosis lipoidica and leukocytoclastic vasculitis. Their accurate diagnosis and effective treatment is essential in order to prevent complications. Misdiagnosis can lead to improper treatments as severe as limb amputation. While many of these diseases lack standard treatment protocols, early diagnosis and consideration of the treatment options presented provide an acceptable first approach. Complicated and refractory cases may require referral to dermatologic or wound care clinics.

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Autism and Toe-walking - A Review of Current Literature

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Abstract

The goal of this article is to present a review of the current evidence-based literature regarding the development of toe walking in children with Autism Spectrum Disorder (ASD), methods of diagnosis, and current conservative and surgical treatment options. Toe walking is described as the lack of contact between the heels and the ground during the stance phase of gait. It is considered an abnormal finding when present in children over the age of two. Although, the etiology of ASD has yet to be fully understood, it is thought that there are abnormalities in the neurotransmission of hormonal pathways involving serotonin, dopamine, and GABA. Another possible assumption may be the link between severe motor deficits and toe walking. Literature supports the interplay between abnormal neurological pathways and motor deficits may result in the consequence of toe walking seen in children with ASD. Conservative treatments include stretching, serial casting, ankle-foot orthoses and botulinum toxin A injections with minimal to moderate improvements in long term toe walking correction. Surgical treatments, such as gastrocnemius-soleus or Achilles tendon lengthening, were found to have a more lasting impact on toe walking in the long-term.

Introduction

Children diagnosed with autism spectrum disorder (ASD) present with impairments in social interaction, language, speech development and repetitive behaviors. Motor impairments such as hypotonia, motor apraxia, reduced ankle mobility, gross motor delay and toe-walking are also associated with individuals affected with ASD (1). Rate of toe-walking among children with autism has been reported to be as high as 63% (2). Toe walking refers to the lack of contact between the heels and the ground during the stance phase of gait (Image 1). It is a normal variation of gait that is seen in children below the age of two, but may be associated with cerebral palsy, muscular dystrophy, and ASD in children above the age of 2-3 (3). Patients with ASD present with characteristics that are typically recognized within the first 2 years of life. These characteristics include social problems due to difficulty communicating and interacting with others, as well as repetitive behaviors, and limited interests or activities (4).

Although ASD has not been associated with severe motor deficits, motor impairments in these patients are referred to as “associated symptoms” and include changes in motor milestone development, motor incoordination, deficits in fine motor movements, and impaired postural control (5). Although the severity of autism has not been linked to the presence of toe walking, the severity of language delay has shown a strong correlation (5). Toe walking has been correlated to higher levels of intellectual disability in children with ASD (5).

Idiopathic toe walking (ITW) is also a common trait seen in children with neurodevelopmental disorders. The diagnosis of idiopathic toe walking is a diagnosis of exclusion used for children with persistent toe walking and no associated medical condition (3). The purpose of this article is to present a review of the current evidence-based literature on how toe walking possibly develops in children with ASD, how it is diagnosed, and the current treatment methods, both conservative and surgical, used to correct this abnormality.

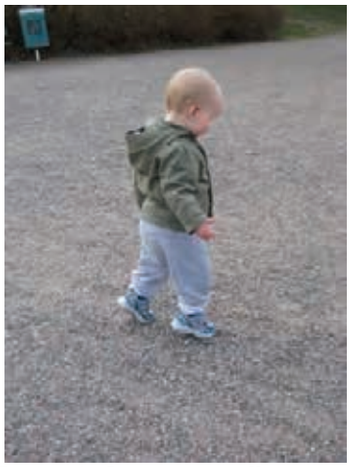

Image 1: Severe toe walking seen in an infant. Adapted from Tanglewood Foot Specialists.

Etiology

The etiology of ASD is still not clear, but multiple studies have indicated abnormalities in the neurotransmission of serotonin, dopamine, and GABA hormonal pathways (6). These abnormalities may have an effect on the motor performance seen in children with ASD. Studies suggest there are abnormalities seen in the cerebellum and subcortical white matter which are responsible for impaired motor function (6). A possible hypothesis for the etiology of ASD is that it may be due to the interaction between neurologic abnormalities and the cognitive components of the mind (6). This may influence the behavioral symptoms seen in children with ASD (6). The motor deficits, such as

impaired vestibular control and fine motor abnormalities are associated with cerebellar deficits, which are reported in patients with ASD (7). Furthermore, neuroimaging studies performed in children with ASD report decreased activation of the cerebellum, specifically during motor movement (7). The abnormalities in the cerebellum have neural connections to several other regions of the brain, specifically cortical and subcortical areas, which may also contribute to the motor deficits (7). Literature also indicates dysfunctions in the sensory pathways which involve the cerebellum that may contribute to the abnormality of postural control and unsteady gait (7).

Diagnosis

The first study that looked at the kinetic gait patterns in adults was by Hallett et al (7). The study suggested that adults with ASD show mild inept with gait, and the only pertinent physical foot exam finding was reduced range of motion at the ankle joint which is a positive finding (7) . A few studies have examined gait analysis by measuring the following temporospatial parameters: stride length, step length, step width, cadence (steps per minute), velocity, stance time, and double support.

Some studies reported a significant reduction of stride length/step length in children with ASD (7). Another study reported reduced dorsiflexion of the ankle joint at ground contact (8). M. Nobile et al. reported that plantar flexion was significantly reduced at toe-off in children with ASD (9).

A study by Kindregan et al. investigated the effect of speed on the gait patterns of children with ASD. Children were asked to walk at their normal pace, faster pace, and then slower pace. The study reported the children widened their base of support while walking at increased speed (7).

Additionally, there is a toe walking tool questionnaire developed by Williams et al. published in 2010. This is a screening tool used to help differentiate between ITW versus toe walking related to an underlying medical condition such as ASD (10). This tool can be utilized to help rule out idiopathic toe walkers and ensure accuracy in data collection from the correct sample size.

Treatment

A meta-analysis conducted on ASD and motor coordination by Fournier et al. argued that motor control deficits are a core feature of ASD, with findings of significant alterations in motor control compared to control groups (11). The presence of these motor symptoms may interfere with the children's ability to partake in daily living activities. The authors concluded that more interventions for these findings are required. They argued that treatments should include focus on gait and balance, arm functions, movement planning, and total motor performance involved with motor coordination. Both conservative and invasive methods have been utilized in the treatment of toe walking in children with ASD.

Conservative Approach

Stretching through physical therapy is an attempt to maintain adequate range of motion at the ankle joint (3). Stretching exercises for the Achilles tendon, gastrocnemius and soleus are involved. Physical therapy may also focus on the improvement of standing balance (12).

Serial casting, followed by ankle-foot orthosis use, has been shown to be a valid method to increase passive dorsiflexion and improve gait in children with autism who toe walk (12). The cast, seen in Image 2A, is placed on the foot and lower leg and leads to immobilization of the foot and ankle joints (13). The casts are placed while the foot is in a dorsiflexed position and replaced every 2-4 weeks; although different studies vary in the time that the cast is left in place (14). This allows for constant manipulation of the joints involved (13). Measurements of active and passive dorsiflexion of the ankle joint are taken when the cast is removed, before the next cast is placed. In a study by Fox et al., the casts were removed after 3-10 weeks, and parents were taught how to perform passive Achilles tendon stretching exercises for their children.

Toe-walking and ankle dorsiflexion in the study group of 44 children were then analyzed and 66% of children stopped toe-walking or improved enough to please their parents. The study showed that the younger the child was, the more likely they were to improve.

Ankle-foot orthoses (AFO, Image 3) and foot orthoses (Image 4) have been utilized in the treatment of toe walking (12, 13, 16, 17). A study by Herrin et al. compared the use of AFOs versus rigid foot orthoses. The study found that both AFOs and foot orthoses improved kinematics versus baseline. But, children who used AFOs were more likely to revert back to toe walking after discontinuation of treatment.

Botulinum toxin A injections in the calf muscles have also been used to reduce toe walking (3, 12, 15). A study by Engstrom et al. followed patients treated with a single 6 units/kilogram body weight Botulinum Toxin A injection, in conjunction with exercise, and found that 3/11 children had ceased toe walking, 4/11 had decreased toe walking, and 4/11 continued toe walking at 12-month follow-up (15). Surgical treatment is an option when all conservative treatments have failed.

Image 2: Serial plaster casting used to immobilize foot and ankle joint movement. Adapted from One Project Closer.

Image 3: An Ankle-Foot orthosis (AFO), used to control the position and motion of the ankle. Adapted from Sports Braces.

Image 4: Foot orthosis, custom made to correct foot imbalances.

There have been very few studies based on behavioral intervention of toe walking (16). A study by Persicke et al. used a method of treatment called TAGteach to decrease toe walking in a four-year-old boy with autism. TAGteach enables positive reinforcement of a particular behavior using acoustical signals to notify a child that they have performed an action or behavior correctly. TAG stands for teaching with acoustical guidance, it is described as a method for teaching behaviors via positive reinforcement. They used a conditioned auditory stimulus, such as a "click" sound, to reinforce positive behaviors. The auditory click was paired with a preferred item, in this case, a potato chip. The child was given a preferred item at the end of every session immediately following the auditory stimulus. Pairing of the preferred item and auditory stimulus began prior to the correction phase of the study, during one-on-one therapy sessions. During the correction only phase of the study, the child was walked down a 20-foot long hallway with an assistant. If the child took two consecutive steps on his toes, the assistant would stop him from moving forward, and slightly apply pressure to his shoulders until his heels were flat on the ground. This was repeated about five times per day. During the correction + TAG phase, differential reinforcement of an incompatible response was added to the procedure. The patient walked down the hallway with an assistant, whom once again implemented the correction procedure after every two toe steps, and a "click" sound was played after every flat foot step. The percent of flat-foot steps in the correction + TAG phase was 73-100%, this was the most effective phase in correcting toe walking in this patient. The authors concluded that TAGteach may be implemented, along with minimal correction procedures, to correct toe walking in children with autism (16). A limitation to this study is that only one patient was evaluated, thus, this study needs to be replicated using other participants displaying similar behaviors.

Surgical Approach

If toe-walking does not improve with time or through conservative measures such as serial stretching, physical therapy or bracing, there can be negative long-term consequences. Long-term adverse effects of toe-walking include moderate to severe ankle plantarflexion and increased knee extension during initial contact in gait. In a study conducted by Stott et al, the development of hindfoot valgus, out-toeing leading to the development of increased external tibial torsion, were a few of the compensations seen in children who toe-walked for long periods of time. The gastrocnemius and soleus provide a large portion of the propulsion required during gait. With toe-walking there can be calf contractures, which impede ankle motion and make it difficult to walk normally. In this case, surgical techniques such as heel cord lengthening, gastrocnemius-soleus lengthening or Achilles lengthening can help.

Lengthening tight muscles serves to allow greater range of motion, giving the patient greater function of the foot and ankle. This can enable children to better tolerate AFOs and walk with a flatter foot compared to only walking on their toes. Surgery to lengthen the Achilles tendon can be done

percutaneously or as an open procedure. Solan, Kohls-Gatzoulis, and Stephens' study demonstrated the benefit of Achilles tendon lengthening done percutaneously. In the follow-up, they noted that mean ankle dorsiflexion with the knee extended improved from -7.5 degrees preoperatively to 11.6 degrees postoperatively. The study showed that there was also an increase in power at push-off postoperatively. It was shown that Achilles lengthening was successful in toe-walkers when conservative treatment failed. Similarly, based on the study conducted by Dietz and Songak 2012, 45 children with a mean age of 4 years old were treated surgically for toe-walking. It was shown that triceps surae lengthening and heel cord lengthening surgeries can help change and improve gait, and increase muscle lengths. Collectively, recent findings suggest surgical treatment provides the most promising long-term results (17).

Discussion

This study investigated the existing literature for the etiology, diagnostic screening, and treatment methods for toe-walking in children with ASD. The findings of motor deficits due to specific neurological impairments which attributes to the etiology of ASD in children is supported by literature. These findings suggest that toe-walking is not a mere result of behavioral symptoms see in children with ASD. A few articles have used kinetic analysis as diagnostic tools to investigate what frequent abnormal findings exist in children with ASD. Apart from the common gait patterns observed in these children during gait analysis it is essential to have radiographic images which show specific measurements of different angles in the foot. This will help validate the abnormal patterns observed and allow future studies to reproduce the particular measurements for accuracy.

In regards to the conservative treatments there are several options supported by literature such as physical therapy, AFOs, foot orthoses, botulinum toxin A injections, and TAGteach therapy. The evidence behind the significance of each of these modalities does not have strong support due to small sample size used which decreases the statistical power of the study. Additionally, most of the studies have applied these conservative treatments for idiopathic toe-walking, not specifically for children with ASD. Subsequent studies should increase their sample size and restrict their target population to children with ASD for more accurate data representation. Surgical treatments such as heel cord lengthening, gastrocnemius-soleus lengthening, or Achilles lengthening are the suggested treatments for children with ASD who toe-walk.

There is insufficient research performed to compare and contrast the success rates of these procedures which may or may not provide the best resolution for toe-walking for children with ASD. The possible complications related to these procedures also needs to be further investigated to ensure benefits outweigh the risks. This will help physicians to choose the best option between conservative or non-conservative methods. Overall, there is limited data on the adverse effects of the various treatments, and the lacking evidence of the long-term follow-up success rates in children who underwent specific treatments.

Conclusion

In conclusion, the overall findings of current research conducted on the topic of ASD, toe walking, and its etiology and treatments are inconclusive. The current perspective on gait patterns of children with ASD is that there are a number of deviations present in terms of temporospatial, kinematic, and kinetic parameters, and that gait, along with other movement pattern changes, may be used to allow for earlier diagnosis of ASD. There is, however, some consensus regarding the involvement of the cerebellum and basal ganglia in children with ASD and its relationship with observed motor deficits. Several limitations have been acknowledged and future research will need to address these more rigorously. With regards to what treatment is most effective, it is not clear from studies that have been conducted thus far. Whether it is Botox, serial casting, or the use of AFO, it is not certain which is most optimal; however, surgery is more effective towards improving toe-walking, even though gait is not always normalized. Further research studies should be performed comparing children with ASD to other diagnostic groups to determine the degree of specificity of deficits and whether observed deficits influence treatment planning. Extensive research should be conducted to explore additional diagnostic tools which can be used to determine the presence of toe walking in children with ASD.

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Interdisciplinary Approach for Recognizing and Treating Toe Walking in Autistic Pediatric Patients

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Abstract

Autism awareness has increased over the years by physicians. Podiatrists should be aware of the developmental milestones and gait features associated with Autism. Many new therapeutic techniques have been shown to specifically treat toe-walking in toddlers. This review will discuss the implications of Osteopathic Therapy as an additional therapy to conservative treatment from an Osteopathic Medicine standpoint. This article aims to examine the indications for treatment, conservative options, and surgical interventions available for podiatrists.

Introduction

Autism Spectrum Disorder (ASD) is associated with repetitive and restrictive behavior, with difficulty communicating and socializing in verbal and nonverbal settings (1). Children diagnosed with ASD can vary in severity. The term "low functioning" refers to children who need high levels of social support from caregivers; whereas "high functioning" children require less social support. According to the Centers for Disease Control and Prevention, 1 in 68 children are diagnosed with autism in the United States (1). Children with ASD require a specialized approach to their healthcare. Within a 1-year period, children with ASD require more visits to pediatrician and specialty care providers. These specialists include podiatrists, osteopathic therapists, speech therapists, occupational or social skills therapists, and neurologists (1). Therefore, an inter-professional approach to pediatric ASD is imperative to improve recognition and optimize treatment. Additionally, it is important for parents and physicians to recognize the early indicators of autism, which will be further discussed.

Early Recognition of Autism

Milestones

In order to gauge the progression of an infant's or toddler's cognition and physical development, physicians use developmental milestones. During the infancy stage of children with ASD, primitive reflexes that are normally inhibited by a certain age, persist. Furthermore, many primitive reflexes may fail to appear altogether (2). One such reflex found in Autistic children younger than 37 months, associated with toe walking, is retained Tonic Labyrinthine Reflex (TLR) in a supine position, seen in Figure 1 (3). This residual reflex normally involutes by the age of 4 months (3). If the TLR remains intact after 4 months, it can lead to poor posture and balance, as well as problems with spatial relation and vision (4).

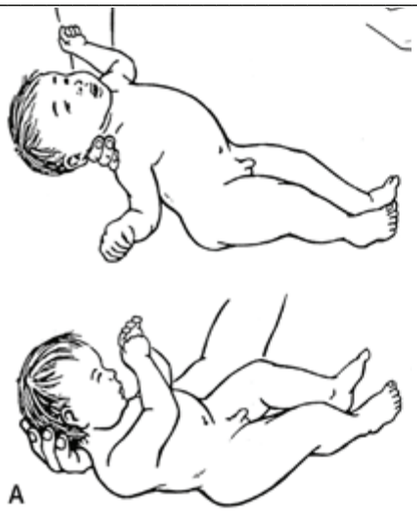

Figure 1- Tonic Labyrinthine Reflex- Infant in supine position with neck in hyperextension (stimulus) produces shoulder retraction and leg extension (Top). Infant with neck in flexion and in fetal position without stimulus (Bottom). Adapted from "Infant Growth and Development," by Johnson CP, Blasco PA., 1997, *Pediatrics in Review*, p. 224-42. (3)

Retention of the TLR could lead to several walking patterns later in life associated with autistic toddlers (4). These include abnormal coordination, varied stride length and bradykinesia (5). Dysfunction at the level of the cerebellum, brainstem, and frontal lobe may underlie motor abnormalities seen in ASD (6).

Traditionally, normal-developing toddlers (NT) start to independently walk at 12 months old compared to toddlers with autism (AT), who start to independently walk at 13 months old (7). However, the determining indicator while assessing toddlers for Autism is speech. AT who had delayed first word onset beyond 12 months, combined with delayed gait, had the strongest prediction of developing "lower functioning" autism (8).

Gait Attributes

The most notable characteristic of AT is toe-walking when compared to NT. Other features worth noting when performing a gait analysis on an AT include: a wide based gait, ataxic gait, posturing and clumsiness (7); however, these features are non-specific when evaluating a child for Autism and seen in other developmental disorders, such as Cerebral Palsy. Higher specificity for AT and gait was found utilizing the Walking Observational Study (WOS) and Positional Pattern for Symmetry During Walking (PPSW). The WOS compared arm movements (forearms parallel to the ground, arms held in asymmetric position, elbow in irregular pattern, forearms held rigidly, arm and hand flapping). Additionally, the WOS also compared foot movement (heel-toe pattern, tip toe pattern and out-toeing pattern), and general movements (waddling walk, lack of opposition pattern, stereotyped general movement). WOS was performed in a retrospective study with 55 participants. Children were divided into three groups AT (20 patients), NT (20) and children with developmental delays of mixed etiology (7). Children from ages 3-5 years old were videotaped and their gait was analyzed. It was noted that AT showed forearm rigidity during gait compared to toddlers without autism (7). Other features of AT include repetitive movements, such as arm-and-hand flapping/arm wave that were specific to AT as opposed to toddlers with other developmental disorders. Regarding foot movements, toe walking was the most characteristic feature of AT (7).

The PPSW measured body position during an 8-second frame and a half-second frame of gait in relation to an Eshkol-Wachman Movement Notation (EWMN). EWMN assumes each upper or lower limb segment is regarded as an axis, should be parallel in relation to the spine, and should be in symmetry with the contralateral limb up to 45 degrees of freedom. It was found that AT had an asymmetric pattern, defined as any limb with greater than 45 degrees of deviation from the spine. This feature was highly specific for AT compared to NT and toddlers with other developmental disorders, such as Cerebral Palsy (7). It has been proposed that this asymmetry could be caused by an atypical hemispheric asymmetry in brain connectivity (9). Podiatrists often encounter parents and caregivers that videotape their children walking. Therefore, evaluating gait utilizing the EWMN approach could be beneficial. While toe walking can be the first obvious sign of autism it can be nonspecific with other developmental disorders (7). Toe walking when paired with asymmetric pattern movement can rule out other disorders. Developmental milestones and gait dysfunction are important early indicators of autism and guide treatment options for osteopathic and podiatric physicians..

Treatment/Therapy

(Conservative) Osteopathic Approach to Treatment

Children with autism typically have an ataxic gait, commonly described as waddling in nature. The diminished musculature of the lumbar spine, abdominal core, and lower extremities offer poor stability and increased trunk swinging during ambulation. This results in somatic dysfunction that can be appreciated beyond the thoracic spine. These findings, paired with anatomical and physiologic pelvic discrepancies, and leg-length discrepancies, can be physically and emotionally demanding during ambulatory activities for patients.

Currently, occupational therapy paired with Osteopathic techniques are used on patients to correct somatic and physiologic dysfunctions, many of which improve their stability and balance when walking and standing. Techniques to be considered include osteopathic treatments of the lumbar, pelvic, and lower extremity regions respectively. While myofascial release and soft tissue techniques may benefit the aforementioned regions, there are specific treatments tailored to each region. Commonly used are articulatory techniques, which involve passive, direct-action, low-velocity, with moderate to high amplitude articulations used to carry a joint repeatedly through its restrictive barrier toward its full range of motion to increase free range movement. Muscle energy techniques involve a patient's active muscle contraction, used upon request, in a precisely controlled position and direction to counter the physician's established counterforce, with an end goal to increase the targeted joint's free range of motion as well.

In the lumbar region, rotational alignment, flexion/extension, and side bending components of the spine through articulatory and muscle energy techniques have proven beneficial in allowing well-balanced tension among bilateral paravertebral musculature. In the pelvis, articulatory and muscle energy techniques are used for the iliac and ischial bones to allow for appropriate hip swing, leg length accommodation, and to mitigate upper body swinging when walking and running (10). The three bones that comprise the pelvis are commonly the site of somatic dysfunction in relation to lower back and lower extremity dysfunction. Lower extremity variations, commonly involving leg-length discrepancies, benefit from the use of sequential heel lifts and integrative ambulatory therapy. This improves stridor, cadence, and overall postural balance during both standing and movement.

More rigorous studies are needed to validate the true efficacy of manipulation and integrative therapy in mitigating physical discrepancies in these children.

Podiatric Approach to Treatment

Conservative and surgical treatment options aim to improve ankle joint range of motion and facilitate heel strike in the contact phase of gait. Conservative interventions include calf stretching exercises, serial casting, orthoses, and adjunctive botulinum toxin injections (11). Exercises stretching the Achilles tendon involve passive or active dorsiflexion at the ankle with the knee extended, and then flexed. If stretching fails, plaster casting for two week periods, for as long as eight weeks, often yields positive results (11). Ankle-foot orthoses (AFO) aims to eliminate motion at the ankle and prevents gastrocnemius-soleus contractures from developing. Botulinum toxin injections into the superficial posterior leg compartment blocks acetylcholine release at the neuromuscular junction, inducing muscle paralysis, and allows the heel to reach the ground during gait. These injections are best used in conjunction with serial casting and stretching (12)[KN9] . If conservative measures fail to correct the deformity, surgical intervention may be indicated.

Figure 2- Serial casting with plaster to increase ankle joint dorsiflexion. Adapted from "Toe-walking in children younger than six years with cerebral palsy. The contribution of serial corrective casts.," by Cottalorda J, Gautheron V, Metton G, Charmet E, Chavrier Y. 2008. *J Bone Joint Surg Br*., Volume *82*, p. 541-44. (13).

While surgery is rarely indicated, a tendo-achilles lengthening (TAL) or gastrocnemius recession may be performed. If a gastrocnemius contracture is demonstrated following the Silverskiöld test, a gastrocnemius recession is preferred. A percutaneous TAL is performed when concomitant gastrocnemius and soleus contractures occur. A long-term follow-up study of pediatric toe-walkers treated with TAL or gastrocnemius recession not only showed improved ankle dorsiflexion in swing and stance, but decreased pelvic tilt, increased stride length, and decreased cadence (14). From a retrospective study, fifteen children suffering from toe-walking were treated with percutaneous TAL, then short leg cast for 4 weeks. Of the ten patients who could be contacted for follow-up, none reported recurrence or muscle weakness; however, two patients reported occasional Achilles tendonitis (15). Support for surgical management of toe-walking arises from improved ankle dorsiflexion, consistent outcomes, and greater parent satisfaction (16).

Conclusion

While toe-walking is the most specific lower limb finding in children with Autism, it is also associated with other neurodevelopmental disorders. Providers, such as podiatrists and osteopathic physicians, are essential in recognizing nuances in clinical presentation and differential diagnoses. With a growing awareness of this disorder amongst medical professions and the public, caregivers are inclined to seek out appropriate treatment. Therefore, it is beneficial for providers to recognize treatment methods, and indications for one choice of therapy over another. Although toe-walking may recur, the conservative and surgical measures at our disposal enhances the quality of life for patients as falls are decreased and stability is improved.

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Nutrition Therapy in Diabetes Mellitus Management

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Abstract

Without any method of intervention, complications of diabetes will affect the body on a systemic level. With respect to the lower extremity, morbidities related to the nervous system, vascular system, dermatologic system, and biomechanics are affected. Severe complications include Charcot neuroarthropathy and diabetic foot ulcers which can lead to lower extremity amputation (LEA), which is associated with a 39-68% five-year mortality rate. Diets with low glycemic index and high in natural fiber, protein, fruits, and vegetables, with reduced sugar assist in lowering the HbA1c in patients with Type 2 diabetes, and also aid in diabetes prevention. Implementation of a low carbohydrate or a fat-calorie restricted diet also aid in glycemic control, cardiovascular risk management, and other comorbidities associated with diabetes. The purpose of this article is to present a review of the current literature of nutrition therapies used in the management of diabetes mellitus.

Background

As of 2015, an estimated 30.3 million people in the United States suffer from diabetes, and 33% of the population are prediabetic (1). According to the World Health Organization, the number of people with diabetes has risen from 108 million in 1980 to 422 million in 2014. It continues to increase annually, and is estimated to be the 7th leading cause of death by 2030.

Among the diabetic population, 87.5% of adults were either overweight or obese. Other risk factors correlated to diabetes include smoking, physical inactivity, high blood pressure, and hyperlipidemia (1). Diabetic patient medical expenditure is 2.3 times higher than medical expenditure for people without diabetes, and is one of the leading causes of death in the U.S. (1). Having symptoms and adverse effects of diabetes affect many parts of the body, including the feet and eyes. As a method of prevention, it is often advised above any drug intervention that lifestyle choices are managed and proper checkups with a podiatrist and optometrist are involved. Our goal is to investigate nutrition therapy for individuals whom are at risk or are currently diagnosed with diabetes in order to educate the public and clinicians on conservative treatment methods.

Etiology

Diabetes is a general term for several possible underlying pathophysiologies including Type 1 Diabetes mellitus (DM1), Type 2 Diabetes mellitus (DM2). Diabetes insipidus, and gestational diabetes. A focus on diabetes mellitus will be discussed to target the specific pathophysiologies involved with nutrition. Diabetes mellitus is a disease in which there is abnormal carbohydrate metabolism due to a decrease in GLUT4 transporters in muscle cells, leading to elevated blood glucose levels and glycation of extracellular proteins. Glycated hemoglobin (HbA1c) serves as a laboratory marker for diabetic progression. As a result of low intracellular glucose, citric acid cycle intermediates are not broken down and energy production is limited. Therefore, ketogenesis is triggered. In this process, blood acidification (diabetic ketoacidosis) and hyperventilation occur. Any disruption in the relationship between the GLUT4 transporters and insulin can result in diabetes mellitus. DM1 is specifically due to failure of the pancreatic beta-cells producing insulin, which makes up 5% of the diabetic population (1). DM2 is specifically due to insulin resistance of the GLUT4 receptor to its insulin agonist, and may later involve insufficient insulin production from the pancreatic beta-cells. DM2 accounts for 90-95% of all diabetes cases (1).

Central obesity, also known as abdominal obesity, is closely associated to diabetes mellitus, amongst other diseases (2). Apart from elevated blood glucose levels and glycated HbA1c proteins, elevated levels of plasma leptin, tumor necrosis factor alpha, and non-esterified fatty acid levels also play a role in causing insulin resistance (2).

Diabetes and the Foot

Diabetic patients develop both macrovascular and microvascular diseases affecting multiple organs and regions of the body. One of the major morbidities of diabetic patients is the diabetic foot. The diabetic foot is more susceptible to peripheral neuropathy and ulcer development. One of the most important causes of the development, progression, and severity of neuropathy in a diabetic foot is the induction of the sorbitol pathway due to hyperglycemia. Although diabetic neuropathy is a diagnosis of exclusion, symptoms relating to defects in sensory, autonomic, and motor function are evident. The American Diabetes Association (ADA) recommends that all patients who are diagnosed with DM2 be screened for diabetic peripheral neuropathy upon diagnosis and patients diagnosed with DM1 be screened for diabetic peripheral neuropathy within 5 years[SX5] [BM6] of diagnosis (3). Thereafter, annual screenings for both DM1 and DM2 diagnosed patients is recommended. The Society for Vascular Surgery, the

American Podiatric Medical Association, and the Society for Vascular Medicine have collaborated to develop a clinical practice guideline (4). The guidelines focus on 5 major concerns of the diabetic foot: prevention of foot ulceration, offloading, diagnosis of osteomyelitis, wound care, and peripheral arterial disease (4).

One of the more severe consequences of diabetes is lower extremity amputation (LEA), which is frequently preceded by a foot ulceration (Image 1)(5). About 60% of these ulcers are primarily due to neuropathy (6). The five year mortality rate that follows a LEA is 39-68% (6). A study by Ortegon et al found that the frequency of LEA could be reduced by 45-89% by preventing the occurrence of diabetic foot ulcers (5). Most patients with diabetic foot ulcers also present with insulin resistance, central obesity, dyslipidemia and hypertension, all of which are associated with increased risk for cardiovascular disease (6). Many of these associated conditions may be prevented and managed with proper diet and exercise.

Image 1: Foot ulceration that can lead to lower extremity amputation. Adapted from Diabetes Lecture at Western University of Health Science by Dr. Jonathan Labovitz, DPM.

Another severe complication of diabetes is nerve damage. The symptoms of tingling, numbness, burning or pain spread from the tips of the toes or fingers gradually upward are signs that may lead to loss of sensation in the affected limbs and digestive issues such as nausea, vomiting, diarrhea or constipation. For men, neuropathy symptoms may lead to erectile dysfunction. Studies have shown that increased glycemic variability is a significant independent contributor to developing diabetic peripheral neuropathy in type 2 diabetic patients. (29)

When poor blood flow or nerve damage affect the feet, various foot complications arise. Cuts and blisters can cause serious infections that often heal poorly which may ultimately require toe, foot or leg amputation. Diabetic foot problems, which include lower extremity amputation (LEA), are major factors correlated with morbidity and mortality in diabetic patients. Thus, it is important to carefully evaluate patients at risk for diabetes to reduce the probability of any fatal complications to arise.

ADA Nutrition Therapy Guidelines

Success with nutrition therapy in diabetic patients depends on how well the nutrition plan is individualized. The healthcare professional must review diet preferences and goals with the patient, as well as review current eating habits (7). The American Diabetes Association (ADA) has developed nutrition practice guidelines for registered dietitians to guide patients for effective glycemic control (2). The goal of diabetes nutrition therapy is to promote a healthier diet which will allow for better control of glucose, blood pressure and lipid levels (7). One of the main goals of the ADA nutrition guidelines is portion control with an emphasis on nutrient dense foods (7, 8). The patient is to avoid sweetened beverages, processed foods, and foods high in saturated fats. It is recommended to incorporate more lean proteins into their diets, and eat more high fiber foods. Sodium intake should be limited to a maximum of 2,300 mg/day (7). The ADA does not recommend the use of minerals, supplements, or herbal based remedies in the control of diabetes. The general recommendations include maintenance of body weight goals, prevention of complications of diabetes, hemoglobin A1c <7%, blood pressure <140/80 mmHg, LDL cholesterol <100 mg/dL, triglycerides <150 mg/dL, HDL cholesterol >40 mg/dL for men, and HDL cholesterol >50 mg/dL for women (8).

Apart from nutrition therapy, the ADA recommends addressing other risk factors that may play a role in each patient's success, such as family history of diabetes, history of abuse or trauma, psychosocial factors, along with previous and current medication use.

Strategies for Diabetes Management

Management of diabetes is multifactorial. Apart from diet, other management styles should be taken into consideration.

Psychosocial Management

Studies support that handouts of reminders and lessons of self-monitoring of diet and exercise, behavioral goal setting, cognitive restructuring, assertive communication skills, and relapse prevention are all effective in the diabetes management process (9). A clinical psychologist may conduct individual support therapy sessions (9). The psychologist is able to educate the patient on the effects of medication on their behavior and provide them with basic mental health knowledge (9).

Exercise Management

An exercise plan allows patients to maintain muscle mass while reducing energy intake through their diets (10). A study by Francois et al. documented that there is a likelihood that DM1 patients will be physically inactive due to fear of severe hypoglycemia. Prevention of a hypoglycemic event can be achieved through proper preparation for exercising and reducing insulin dosing before exercising. One type of exercise modality used in the management of diabetic cardiovascular complications is high-intensity interval training (HIIT) (11, 12). HIIT may be described as a set number of minutes spent doing vigorous high-intensity training, followed by a set amount of minutes of a low-intensity recovery period, although specific definitions may vary slightly. A review of multiple studies found that HIIT helped improve glycemic control, blood pressure, and lipidemia levels in patients with type 2 diabetes mellitus (11[EO11]).

Nutritional Management

Different routes of nutritional therapy are considered when assigning a patient a nutrition regimen to follow. Some factors include the patient's personal and cultural beliefs, willingness and ability to make diet changes, the amount of monitoring and support available, and financial circumstances (7). A study showed that the use of a face to face support system in combination with a mobile health app lead to 5% more body-weight loss when compared with the app group alone (P=.06) (13). A survey study among clinicians identified the most popular apps used and recommended were MyFitnessPal, CalorieKing, Fitbit, Weight Watchers, SparkPeople, and Lose It! (14, 15).

Nutrition studies aim to normalize blood glucose levels with minimal use of diabetic medications. Two types of nutrition regimens have been consistently recommended; a low carbohydrate diet or a fat-calorie restricted diet. According to multiple studies, both therapy interventions are equally effective in improving HbA1c levels with the staple grain food being the primary type of carbohydrate utilized as compared to other carbohydrate sources such as processed grains, sugar filled drinks, and desserts with no nutritional value (16). Studies show that low glycemic index diets have significant improvement on the health status of diabetic patients without inducing hypoglycemic incidents (17). Low glycemic index foods such as oats, beans, lentils, and vegetables all contributed towards managing blood-glucose levels in the participants and there was a significant decrease in the HbA1c levels compared to the group of participants that were on the high glycemic index diet (17).

An example of a low carbohydrate diet includes the Dietary Approaches to Stop Hypertension (DASH) diet. The DASH diet is known for being rich in fruits, vegetables with the consumption of low fat dairy foods and a reduction in overall fat. Studies show DASH diet use correlates with significantly lowered systolic blood pressure compared with the control diet (−11.2 mm Hg; 95% confidence interval, −6.1 to −16.2 mm Hg; P<0.001) and the fruits/vegetables diet (−8.0 mm Hg; 95% confidence interval, −2.5 to −13.4 mm Hg; P<0.01) (18). A 3 year follow up study observed a significant decrease in body mass, systolic and diastolic blood pressure, body fat content, fasting glucose, insulin, and leptin compared to the control group ($p < 0.05$) (19). A study that followed tight management of ADA guidelines found a reduction of complication incidences with increased HbA1c (from 9.7 to 25.6%, $p < .0001$) but found no improvement with cardiovascular risk factors, such as blood pressure (from 89.7% to 87.4%, $p = 0.36$) (20). Diabetic patients are at a three-fold increased risk for coronary heart disease and stroke ($P < 0.001$) (21). The DASH diet also has been correlated with decreased cough in COPD patients. A DASH diet sample meal with a breakdown of nutritional serving size category, focus, and benefits are shown in Table 1.

An example of a fat-calorie restricted diet includes the Mediterranean diet. The Mediterranean diet is high in monounsaturated fats, fiber, fruits, nuts, protein and antioxidants, and low in meats and dairy products. A study conducted by Schroder observed a protective effect of the Mediterranean diet on the development of obesity and type 2 diabetes (22). It was shown that this particular diet helped in satiety due to the energy dense foods that are high in fiber and healthy fats which help in weight control, insulin resistance, and the prevention of pancreatic beta cell dysfunction (22). Another study observed an inverse relationship of the Mediterranean diet to cardiometabolic disorders ($p<0.001$) and overuse of pharmaceutical medications (23). Improvements in endothelial function with prediabetic and diabetic patients have also been correlated with Mediterranean diet consumption. A study recognized increases in vasodilation correlated with Mediterranean diet adherence with T2D patients [5.2 ± 0.4 at 1.5 years vs. 3.8 ± 0.4 at baseline; $p=0.04$] and prediabetic patients [4.9 ± 0.4 vs. 3.8 ± 0.4; $p=0.04$] (24). A Mediterranean diet sample meal with a breakdown of nutritional serving size category, focus, and benefits are shown in Figure 1.

Example Lunch Menu	Focus	Benefits
DASH Diet Sample: 4 cups spinach 1 sliced pear ½ cup canned mandarin oranges ⅓ cup sliced almonds 2 tbsp red wine vinaigrette 12 reduced sodium wheat crackers 1 cup fat free milk Snack: 1 cup fat free, low calorie yogurt	Rich in fruits, vegetables Low-fat dairy foods Reduced intake in overall fat	Improvement in cardiovascular risk and COPD symptoms Reduction in body fat content, fasting glucose, insulin, and leptin
Mediterranean Diet Sample 5 oz. salmon filet ¾ Tbsp olive oil 1 cup fennel bulb 1 cup whole wheat couscous 1 Tbsp walnuts Snack: Plum	Rich in monounsaturated fats, Fiber, Fruits, Nuts, Protein, Antioxidants Reduced intake of red meats and dairy products	Improvement in satiety, weight control, insulin resistance, endothelial function, and pancreatic beta dysfunction Reduction in cardiovascular risk and pharmaceutical medication dependence

Table 1 Breakdown of the DASH diet and the Mediterranean diet by nutritional serving size category, focus, and benefits.

Discussion

According to Spanakis and Golden 2014, combating diabetes involves a multi-level approach that includes economics, public health, healthcare systems, patients, providers, and community programs (25). As the numbers of people affected with diabetes worldwide continues to increase exponentially, various studies have been conducted and are currently being performed to analyze data, genetics, lifestyle, treatment, and possible cures for diabetes. It has been observed that groups with a support network, decreased intake of saturated fatty acids, increased exercise, increased dietary fiber, and reduced glycemic index of foods have greatly benefited by reducing body weight and controlling glucose levels.

According to Franz 2010, groups that changed their unhealthy lifestyle for a balanced nutritional regimen with an active lifestyle have greatly benefited towards diabetes control, and have reduced their risk of cardiovascular diseases (26). In the study conducted by Gray 2015, individuals with either type 1 or 2 diabetes showed improvement with their lifestyle management when specific goals are set (27). Some goals include participating in insulin education program using carbohydrate counting and meal planning, utilizing mobile applications to ultimately engage consistent carbohydrate intake according to the times of day, and planning meals based on portion control and wholesome food choices.

Following ADA recommended guidelines can help people diagnosed with diabetes achieve their goals. Additional recommendations of a low carbohydrate or fat-calorie restricted diet further benefits patients with the prevention of cardiovascular morbidities. Among the complications of diabetes, morbidity and mortality are heavily associated with cardiovascular disease (CVD) with hypertension and dyslipidemia as clear risk factors to screen and be cautious of (28).

It is recommended that further studies analyze the correlation of diabetes amongst different ethnic groups to find optimal prevention and treatment guidelines with a multidimensional emphasis on ethnicity and genetics, as well as an analysis on the accessibility of specific diets with respect to geographic and socioeconomic factors in patient populations.

Conclusion

Diabetes is a disease that is commonly associated with poor outcomes, thus, it is only appropriate to approach such a disease with proper attention. It is important to understand the disease affects multiple organs, regions, and systems of the body. With respect to the nutritional demands on the body, a primary goal is to combat the outcome of insulin resistance. Effective nutrition therapy can benefit those individuals whom are at risk or are currently diagnosed with diabetes. The current set of evidence-based literature can be used to educate the

public and clinicians on tools and options patients can take on managing their diabetes through nutrition.

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Diabetic Foot Care Within Hispanic Communities and the Role of Social and Cultural Influences

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Abstract:
It has been shown that type 2 diabetes mellitus has a genetic and environmental component. The focus of our study was to observe how lifestyle choices play a role in diabetes, particularly within the Hispanic community (1). In regards to health disparities, previous lower extremity studies have shown a correlation between lower socioeconomic standing with decreased foot health; however, previous studies have not taken into account cultural factors that are everyday variables in patients' lives (2). The study hypothesizes that certain aspects in the social history of the Hispanic community have negative impacts on their foot care and diabetes management. Surveys were conducted at Arrowhead Medical Center among 119 Hispanic individuals who were 18 years or older. In addition, surveys were translated into Spanish for non-English speaking respondents. Based on participant's answers, the effects of factors such as economic issues, social issues, and family involvement on diabetic foot care were observed. Diet was shown to be a leading factor with significant correlations between normal meals consisting of rice, beans, fast food, and sweet drinks and having increased blood glucose levels. Over 15% admit they had not changed their diet since being diagnosed with diabetes. Of the correspondents, 65% reported numbness in their feet and over 60% claimed to cut their own nails, which is advised against due to the increased risk of infection. Only 18% of respondents stated they would seek podiatric care if they suspected a foot infection. All these correlations and percentages demonstrate that more insight is needed to better understand the multifactorial approach to caring and educating the Hispanic population.

Introduction:

The Hispanic population is one of the fastest growing minorities within the United States. However, there has not been an overall improvement in reported health quality within this community. Mexican Americans, for example, suffer from disproportionately higher rates of type 2 diabetes and associated complications than the general population (3). Potential complications of this disease include kidney failure, cardiovascular disease, foot ulcers, retinal damage, and other chronic conditions. Aside from diabetes, Hispanic communities have higher rates of morbidity due to cardiovascular disease and obesity (4). These chronic conditions often progress to foot complications consisting of lack of nerve sensation from diabetes, poor circulation to the lower extremities from peripheral arterial disease, and foot pain from obesity (should we change it to just foot pain?). Thus, there is a need for close examination of the health disparities among the Hispanic community that have resulted in poorer health outcomes and foot-related conditions.

Examining the combined effect of social and cultural factors is significant in tailoring effective foot care treatment and management plans for Hispanic patients to reduce the risk of amputations. Podiatrist involvement is critical in managing these patients due to the strong correlation between diabetes and foot health. Evaluating the health disparities of Hispanics requires the consideration of social history and cultural aspects which play a role in reported foot health complications. When podiatrists consider these factors, this leads to increased cultural competence and ultimately better foot care management from both the healthcare professionals and the patients throughout their daily lives.

Previous research has shown that Hispanics are disproportionately affected with higher rates of lower limb amputation related to diabetes (5). In this study, the hypothesis was that the higher incidence rate could be due to the higher prevalence of vascular disease, neuropathy, and history of lower extremity complications; however, this hypothesis was not supported by the data and suggests that other variables are involved which requires further investigation.

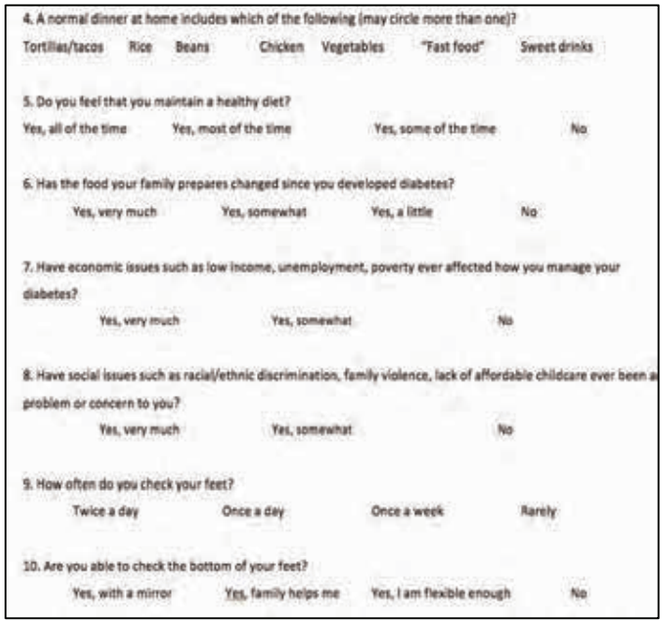
One of the hypotheses in this study is that social history and cultural factors play a significant role in Hispanics' reported foot care and diabetes management. The need to explore cultural and social history risk factors in health among Hispanics is imperative, and may provide some potentially effective management strategies to improve foot health and overall health outcomes. Social support is a critical component to the well-being and care of those with chronic illnesses. Social support can aid in stress management, balancing glucose levels, and help to encourage a low-fat diet to reach a healthy weight.

Methods:

Data was collected from Hispanic patients with diabetes within the podiatry clinic at Arrowhead Regional Medical Center in Colton, California. Surveys

were collected between June to August in both 2016 and 2017. A sample size of 119 Hispanic participants was used to gather data. Participants were selected if they were Hispanic and 20 years or older. All personal information was kept confidential and anonymous, adhering to the protection of the human subjects and respondents. This research study also received IRB (Institutional Review Board) approval from the Western University of Health Sciences. The participants were always instructed on what to expect with involvement in the research study including time commitment (less than 10 minutes), purpose of the study, and the right to withdraw from the study at any time. The study information and cover letter were written in English and then translated to Spanish. This study information and cover letter was utilized to help the respondents determine whether they would like to take the survey or not.

The survey was 2 pages long, consisting of 21 questions (See figure below). Surveys asked participants to answer questions about their demographics, past medical history, dietary habits, and diabetic care. The surveys were also translated into Spanish for non-English speaking respondents. The staff podiatrist examined each potential participant to identify any lower limb complications and risk factors related to diabetes such as past history of lower extremity pathology in ulcers, neuropathy, peripheral vascular disease, and foot pathologies/deformities. Some questions included "How often do you check your feet?", "Do you have numbness in your feet or ankles?" and "What color socks do you wear?". Diabetic patients are advised to wear white socks in case they suffer an injury, so that blood can be detected on the socks once removed. Information was also gathered either from the patient or their medical records regarding glucose levels and Hemoglobin A1C score. This information was then converted to numerical data so that the data could be analyzed using Statistical Package for the Social Sciences (SPSS) statistics software.


4. A normal dinner at home includes which of the following (may circle more than one)?

Tortillas/tacos Rice Beans Chicken Vegetables "Fast food" Sweet drinks

5. Do you feel that you maintain a healthy diet?

Yes, all of the time Yes, most of the time Yes, some of the time No

6. Has the food your family prepares changed since you developed diabetes?

Yes, very much Yes, somewhat Yes, a little No

7. Have economic issues such as low income, unemployment, poverty ever affected how you manage your diabetes?

Yes, very much Yes, somewhat No

8. Have social issues such as racial/ethnic discrimination, family violence, lack of affordable childcare ever been a problem or concern to you?

Yes, very much Yes, somewhat No

9. How often do you check your feet?

Twice a day Once a day Once a week Rarely

10. Are you able to check the bottom of your feet?

Yes, with a mirror Yes, family helps me Yes, I am flexible enough No

Figure 1. Section of the survey given to patients

Results:

There were 119 completed surveys. The average age is 58, with a mode of 63, and a range of 26-82. There were 67 women and 52 men respondents. After analyzing the data using SPSS (Statistical Package for the Social Sciences), we discovered several correlations that were significant. Figure 2 depicts how response items correlated with hemoglobin A1C levels specifically.

Response items correlated with HbA1C level	Pearson correlation (r)	p-value
Manage diabetes with insulin	0.248	0.016
Weight	-0.188	0.097
Last Glucose	0.489	0.00
Social Issues	-0.184	0.074
Vegetables	-0.198	0.055
Response items correlated with Glucose level		
Manage diabetes with diet	-0.185	0.062
Normal dinner at home includes rice	0.19	0.053
Normal dinner at home includes beans	0.181	0.065
Normal dinner at home includes fast food	0.188	0.055
Normal dinner at home includes sweet drinks	0.252	0.01
Feels they maintain a healthy diet	-0.310	0.01
Last HbA1C	0.489	0.00
Response items correlated with having an amputation		
Gender	-0.214	0.021
Normal dinner at home includes tortilla	-0.2	0.03
Family reminds them to check their feet	0.183	0.052
Have numbness	0.155	0.096
Have sore/ulcer	0.384	0.00
Response items correlated with having a sore or ulcer on feet		
Age	-0.188	0.043
Height	0.195	0.058
Rice	0.191	0.037
Social Issue	0.199	0.031
Can check their own feet	0.222	0.016
Have used traditional medicine on sore/ulcer	0.191	0.038
Had an amputation of their feet or toes	0.384	0.00

Figure 2. Table of significant correlations (P-values near <0.05) between variables. Values were calculated using SPSS software.

Looking at the second group in figure 2, response items were correlated with glucose levels, and we can see that drinking sweet drinks regularly is highly correlated with a high glucose level, with a p-value of 0.01. The average HbA1C was 7.86 and the average glucose was 163.77. We found that 30% of participants have had an ulcer, and 12% have had an amputation. The data suggests that 14% of participants eat fast food regularly, 15% regularly drink sweetened beverages, and 89% feel they have a healthy diet. In terms of foot care, 66% of participants have numbness in their feet, while 63% of participants cut their own toenails. We also found that 60% of participants say economic issues have affected their treatment of diabetes, and 28% say that social issues have affected their treatment. Less than half, 46%, of participants have family members that remind them to care for their feet.

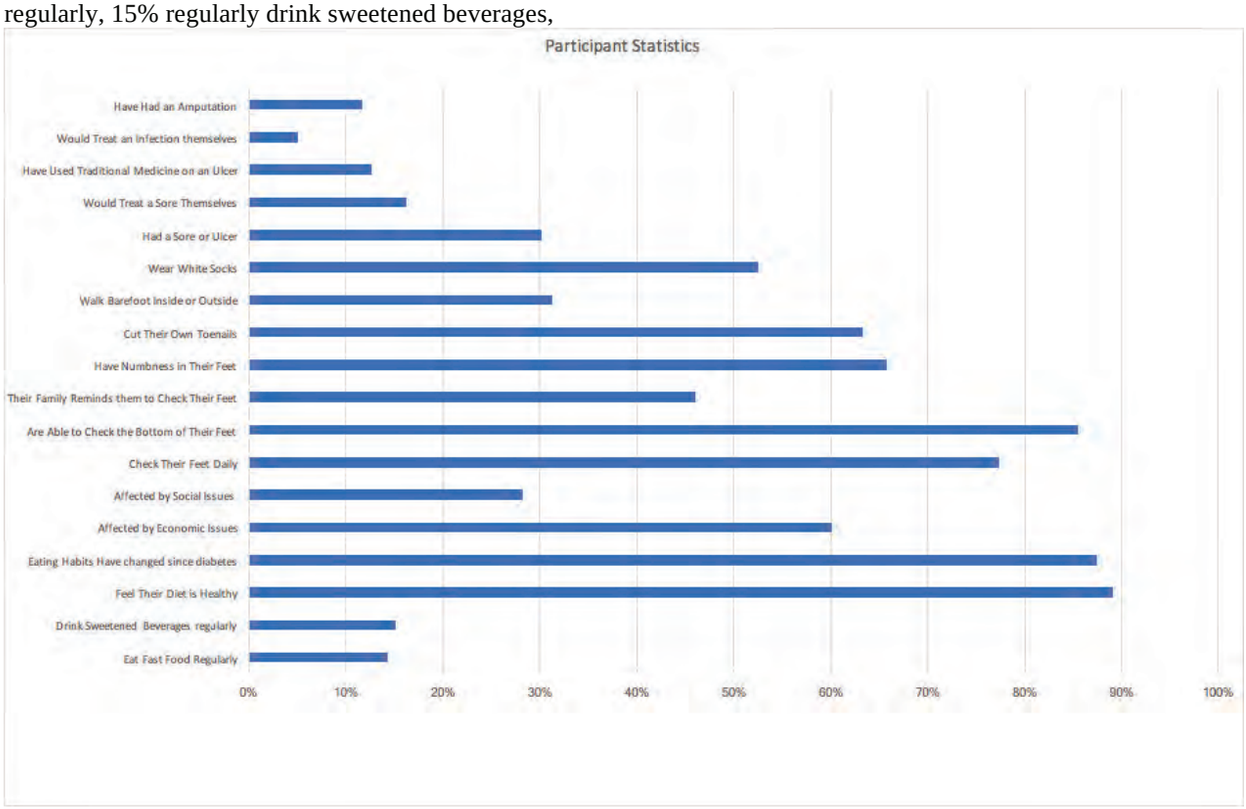


Figure 3. Graph depicting participant statistics based on the survey given.

Figure 3 is a chart showing the percentages of participant's responses on specific questions. Almost 90% of participants feel their diet is healthy, yet over 10% say they eat fast food regularly. Over half do not wear white socks even though it has been shown to help reduce infections and ulcers in those with neuropathy. Over 65% have numbness in their feet, 30% have had an ulcer, and 12% have had an amputation. Over 60% cut their own toenails, which is advised against when you have any numbness. Over 12% reported that they had not modified or changed their diet since being diagnosed with diabetes. Only 38% said they managed their diabetes with exercise. Outside of modern medicine, 14% of respondents said they used traditional herbs / supplements to manage their diabetes. Only 26% of patients say their family is very helpful at maintaining a healthy diet for diabetes. Also, 23% of the participants did not check their feet on a daily basis and that could be in part due to the fact that 53% of patients do not have family members that remind them to check their feet. Even though diabetics should never walk around barefoot, 31% claim to walk around barefoot at least some parts of the day. One of the most alarming findings was that only 18% claimed they would seek help from a podiatrist if they thought their foot was infected.

Discussion:

The data we collected and analyzed appears to further support our hypothesis that certain aspects of a Hispanic patient's social life likely have negative impacts on their management of their feet and diabetes. For example, foods that are commonly eaten in a Hispanic community were shown to be correlated with glucose levels. As shown in Figure 2, normal dinners that include rice, beans, and sweet drinks all show positive correlations with glucose level, where a high glucose level is an indicator of worsening health. Our

data also suggested that there is a negative correlation with patient's eating vegetables and the patient's HbA1C level. This data correlation makes sense with more vegetables leading to better-controlled sugar levels. However, it is important when educating the patient to give specific instructions as to what their diet should consist of. Just stating to "eat more vegetables" may not prove to be beneficial to the patient. Instead, healthcare providers should focus on what types of vegetables and why they are critical to the patient's health. Patients should be educated on low glycemic foods that will help maintain weight loss. It should be explained that lower glycemic foods help you feel fuller longer because they are absorbed slower from the intestines into the bloodstream. Another result from the survey demonstrated that meals at home that involved rice positively correlated with having an ulcer on the patient's feet. Patient education regarding carbohydrates can center around how those that are high in fiber such as beans and flax, or whole grains such as buckwheat are better options, especially for a patient with diabetes. With these variables in mind, we can note the importance that a Hispanic diet plays in the long-term health of these patients.

Correlations in the data support the overall validity of this study. Positive correlations with low P-values, such as with having an amputation of feet or toes with having a sore or ulcer on feet showcases items that should be expected. It is shown with the positive correlation with "manage diabetes with insulin" with HbA1C level with a P-value of 0.016. Unfortunately, along with the correlations that were expected, there also came correlations that were expected to be significant but were not. Much of the data showed P-values too high to consider significant, which meant that many of the questions asked on the survey were not as influential as expected.

A major factor that may have influenced this study was the way in which questions on the survey itself may have been interpreted differently due to lack of specificity. For example, question number four enquires what a "normal dinner at home" would include, but it is never specified what "normal" means. This leaves the interpretation up to the patient, which could differ depending on each patient's perspective. This could potentially lead to inconsistent data. Another limitation is that the study was conducted in a single medical center, making it more difficult to generalize results to other patient populations.

Conclusion:

Based on participants' answers, it can be demonstrated that factors such as economic issues, social issues and family involvement play a significant role in the management of diabetes in the Hispanic population. It can also be noted that diabetes management affected by social issues correlates with having a foot sore/ulcer; these wounds can often lead to amputation. The variables attributing to the higher amputation risk could be due to the differences in access to care, patient education, patient compliance, self-care management, and cultural issues. Diet plays an important role, as there are significant correlations between meals consisting of rice, beans, fast food and sweet drinks with having a higher last glucose level. Also noted was the correlation between "last glucose level" and "management of diabetes with diet" with an r-value of -0.185 and a p-value of 0.062. All of this potentially indicating that having a poorly managed diet can correlate with higher glucose levels.

Data suggests that more insight is needed to better understand the multifactorial approach to caring and educating this population. Future studies can include more participants from various locations to address issues with generalizability noted in our study. Our study also suffered from correlations that were not significant, but this may also be addressed with a larger number of participants. With more significant data, we can better educate patients in the Hispanic community. A possible first step is recognizing that a disparity in treatment may exist and can be due to social and cultural trends within the Hispanic community. Clinicians and healthcare providers need to improve education of patients and their families with special focus on the Hispanic community. Providers have come a long way in bringing awareness to the general population about diabetes but there is still drastic improvements that need to be made in educating the Hispanic community.

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Qualitative Analysis of Risk Factors and Injuries in Ballet Dancers

Tyler Rodericks, MS-2 and Bryanna Vesely, MS-2

Abstract

It has been found that ballet dancers have high rates of injury. While the specific types of injuries most commonly occurring in ballet dancers have been characterized, there is limited research seeking to characterize specific risk factors and preventative measures associated with injury. This study sought to identify risk factors and preventative measures for ballet injuries by holding focus groups comprised of pre-professional ballet dancers. The subjects were presented with discussion topics designed to promote an exploration of potential risks and preventative measures associated with the injuries or lack of injuries they had experienced. Transcripts from these focus groups were coded into ten major themes. The themes internal pressure, external pressure and ballet milestones were found to be most associated with increased incidence of injury in ballet dancers. The themes of seeking treatment, treatment compliance, targeted treatment and return to dance were mostly associated with risk factors impacting full recovery. The themes non-dance activities, equipment and partner dances were associated with a mixed distribution of risk factors and preventative measures. A better understanding of these factors, as well as the specific movements and practices of ballet could enable doctors to better tailor treatment plans for their ballet patients. The purpose is to optimize recovery and prevent future injuries and help bridge the communication and compliance barriers in medical treatment (1).

Introduction

Many forms of dance share elements of their various movements and techniques, but these are nuanced and implemented in different ways across various disciplines. While the stresses placed on the body may vary across the disciplines, lower extremity injuries are common with the most prevalent consisting of bone stress and chronic injuries (2, 3). The high prevalence of lower extremity injuries in ballet dancers can be attributable to the unique foot and ankle motions a ballerina performs such as going en pointe (Figure 1), whereby a ballet dancer rapidly transitions from weight-bearing dorsiflexion to weight-bearing plantar flexion on the tip of their toes (4). Foot and ankle injuries account for over half of the injuries in ballet dancers because of the strains of ballet techniques put on the lower extremity (5).

Figure 1. A ballet dancer en pointe where there is maximum weight-bearing plantar flexion. Adapted from the Lower Extremity Review (4)

Ballet dancers particularly experience injuries at a rate of approximately 1.1 injuries per year (6). Ballet dancers are exposed to high forces and constant physical stress, with repeated impact over extensive periods of time (7). While the most common injuries that develop secondary to ballet are lower back pain, hamstring strain, and ankle tendinopathy, foot and ankle injuries involving ankle sprains, tendinitis, stress fractures, sesamoid injuries, and ankle impingement injuries are also common (3, 6, 8, 9). Ballet is particularly stressful on the forefoot, midfoot, and hindfoot and has a lifetime injury incidence of 90% (10). Previous studies have explored possible stresses that are predictive of lower back and hip injuries in ballet and found a decreased incidence of injury corresponding with more experience in ballet dancers (3, 11). However, there's insufficient qualitative research to address risks and preventative measures for injury in ballet dancers.

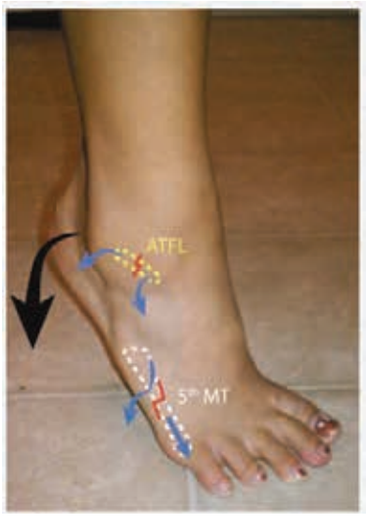

Figure 2. This movement increases the risk for anterior talofibular ligament sprains (yellow dashed line) and spiral fractures of the fifth metatarsal shaft (white dashed line), also known as the dancer's fracture. The red zigzags are the common locations of injury. Adapted from the Lower Extremity Review (4)

As a result, risk and preventative factors associated with the development of foot and ankle injuries for ballet dancers have yet to be characterized, and specific modalities by which these injuries are typically acquired and could be prevented are unknown. A better understanding of the musculoskeletal stresses in ballet that are commonly experienced in the development of foot and ankle injuries would enable physicians to better treat injuries that ballet dancers experience, which may result in faster recovery and reduced economic loss to ballet dancers, schools, and companies. Understanding risk factors that predispose such injuries would also enable ballet companies and physicians alike to give valuable insight into good preventative practices by which dancers may be able to continue practicing their art with fewer injury-related interruptions.

Methods

The study was initiated by contacting ballet studios and ballet teams to recruit participants. Recruitment targeted young adults, 18-24 years old, who have danced for at least 4 years. Although prior injury was not a requirement for participation, most of the participants had experienced dance related injuries. Would it be possible to specify what injuries- were there similar injuries? different?] Each group was comprised of 4-6 participants and was scheduled to last between 45 and 60 minutes. Consent forms, demographic info, and a preliminary survey were completed by participants prior to the start of each focus group (Figure 1). Facilitators utilized a set of pre-established questions to stimulate discussion about potential risks and preventions.

The focus groups were held over Skype, recorded via QuickTime software, and saved with encryption and password protection. The recordings were transcribed without personally identifiable information, and the transcriptions were independently coded by two researchers. Eight original themes were used for coding quotes. These consisted of internal pressure, external pressure, ballet milestones, seeking treatment, treatment compliance, targeted treatment, return to dance and non-dance activities. Two emergent themes associated with injury, equipment and partner dances, were also added during the coding process. Transcriptions were each coded Independently by two different researchers and then compared for agreement. Disparities in coding decisions were resolved by a third researcher. Quotes in each theme were analyzed for shared risks and preventative factors that could be specifically identified.

# participants	9
gender	100% female
ethnicity	100% white (non-Hispanic)
Average age	22.11 years old
Average age starting dance	4.61 years old
Average length of dancing	17.17 years
Average age of starting pointe	11.56 years old

Figure 3. Demographics

Discussion

To date, ten main themes have been identified in focus group transcripts. Three of the themes, internal pressures, external pressures, and ballet milestones, influence the incidence of injury. Internal pressure is the stress the dancer places on themselves that increases the risk of them to be injured. This includes the dancer pushing their body beyond its capacity, as seen with flexibility. This theme also includes feeling pressure to not rest and overwork themselves. The next theme, external pressure, is how the dancer perceives external pressures. In the focus groups, parental pressure, team pressure, and pressure from the instructor have all influenced the participants to overwork and therefore increase their risk for injury. Next, ballet milestones are large moments in a dancer's life that they work towards. These milestones, such as going on pointe too early, can increase the dancer's risk for injury. However, proper preventative care such as taking demi-pointe to strengthen muscles before going on pointe can help prevent injuries. These three themes are comprised of primarily intangible risk factors and preventative measures, but risk factors appear to predominate.

The next four themes are related to recovery and the risk of re-injury. These include seeking treatment, treatment compliance, targeted treatment, and return to dance. Preventative measures appear to predominate within these themes. Seeking treatment includes how long it took for the dancer to go to a medical professional. In the focus groups, a trend that emerged is that the dancers often hid the injury so they would not have to take time off dancing. Many times, they did not seek treatment until the injury had progressed or their parents or instructors made them. Seeking treatment earlier may have prevented the injury from progressing and is a possible subject for medical professions to educate their dancing patients. Previous studies have shown that dancers have a high threshold

for pain that also might lead to them seeking treatment later (12).

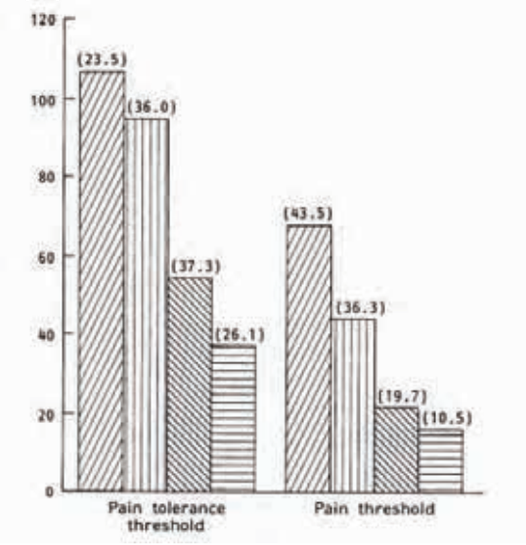

Figure 4. Mean pain and pain tolerance thresholds in seconds for male and female dancers and non-dancers. From left to right: Dancers (male), dancers (female), non-dancers (male), non dancers (female) Adapted from the British Journal of Sports Medicine (12)

Treatment compliance is whether the dancers followed the treatment their provider gave them. Many of the dancers were noncompliant and did not want to take time away from dancing in fear of falling behind. The motto of dancing through pain was shared amongst focus group participants. Targeted treatment is when the health care professional tailored the treatment to the dancer. There was a mixed distribution of participants who had received targeted treatments. For those who did receive treatment that was targeted toward ballet dancers, they found it helpful to have someone understand the mechanics of their movements. They were less inclined to ignore medical advice when the treatment was tailored to their sport. Those who did not receive targeted treatment thought they would have taken medical advice more seriously if they did. Other studies support the idea that there are communication barriers between physicians and dancers in the current way that dancers are treated which can lead to adverse effects on dancer's health (1).

Lastly, return to dance is how quickly the dancers returned to dancing and to what extent they returned to their former regimens. Some dancers returned to ballet at full intensity rather than easing back slowly. It was suggested that if they had received a plan for how to gradually return to dance it might have increased treatment compliance and reduced the rate of re-injury.

The final three pre-coded themes are non-dance activities, equipment, and partner dance which relate to pre-professional ballet dancer schedules, environment they perform and practice, and reliance on their partner. These themes contain a mixed distribution of risk factors and preventative measures. Non-dance activities include what the dancers did on their days off. Some dancers in the focus group participated in sports or exercises on their days off that may have strengthened their muscles and prevented them from getting injured while others might have increased their risk of getting injured by not allowing their bodies to rest. Equipment includes props, shoes, and the environment that the dancers perform and practice with. Some of the participants brought up that during performances on non-dance floors, they would subsequently notice the impact it had had on their joints. Also, having pointe shoes that are overused and worn out could put dancers at additional risk for foot and ankle injuries. Previous studies have also explored the impact of wardrobes and equipment that could not accommodate conventional preventative treatments for the foot and ankle, such as ankle wraps and braces (4). The theme of partner dance emerged in the first two focus groups. Participants explained that sometimes practicing new moves with a partner might be a form of injury prevention while other times not being fully coordinated with their partner could increase their risk for injury.

To this date, only one company was used in the study. This as well as the small sample size limits the conclusions of the study and creates bias. As the study progresses, more focus groups will be conducted with different companies to help broaden the demographics and account for different geographic locations.

Conclusion

While previous studies have found ballet dancers to be at high risk for injury, there has been limited research aimed at identifying specific risk factors and preventative measures (1, 5, 6). The various factors found could provide valuable insight for instructors, dancers, and physicians alike in the promotion of preventative practices by which dancers may be able to continue practicing their art with fewer injury-related interruptions. Follow up studies are still needed to quantitatively investigate the significance of the specific risk factors and preventative measures identified herein. A better understanding of these risk factors could enable physicians to more successfully tailor their treatment plans for improved outcomes in ballet dancers.

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Barefoot Running: A Review

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Abstract

Minimalist running shoe gear has gained an increasing amount of popularity amongst long distance and novice runners. However, there has been a resurgence of barefoot running that has been popularized amongst the running community. This review will analyze the biomechanics associated with each running style based upon foot strike pattern. Additionally, this report will briefly address the major injuries accompanying each running method. Literature has supported that barefoot running may help to decrease the rate of tibial stress fractures, patellar-femoral pain, Achilles tendinopathy and plantar fasciitis, despite many variable factors involving training and individual biomechanics. Podiatrists must account for these factors when advising patients on shoe gear options.

Introduction

Running has evolved from a basic means of transportation to an essential skill needed across various sports and the sport of running itself. Physicians have also advocated that running promotes a healthy lifestyle and overall wellness. As health professionals continue to advise their patients to take up a more active lifestyle, it is also the health care provider's responsibility to be familiar with the best supportive shoe gear. This has become increasingly difficult with the growing popularity of various types of minimalist shoe gear options appearing on the market and trends such as barefoot running. Many patients are ill-informed about whether barefoot running is beneficial in preventing injury and enhancing athletic performance (1). The following will be a comprehensive review on the biomechanics of barefoot running, including a review of strike patterns of both barefoot and shoe gear running. As well as a review of variables that are altered with barefoot running that have been previously studied.

Different Methods of Running

Runners can generally be categorized into three different foot strikes: rearfoot, midfoot or forefoot. Rearfoot Strike (RFS) is defined as the heel contacting the ground upon initial impact. RFS is a common running technique favored by runners who use shoe gear. Midfoot Strike (MFS) is defined as the midtarsal bones or mid-arch coming into initial contact with the surface, as seen in Figure 1 (2). During the contact phase of gait, it allows the foot to be in alignment with the hip (1). Forefoot Strike (FFS) is defined as the ground initially coming into contact with the head of the fifth and fourth metatarsal heads (3). FFS running tends to be favored for barefoot runners, and is advocated for and featured on major websites such as Runner's World. Within the running community this running pattern has been coined a "minimalist" running style (4). It is well accepted that when running in modern running shoes, at least 75% of distance runners run with a RFS, 24% of runners land with a MFS, and 1% run with a FFS (5).

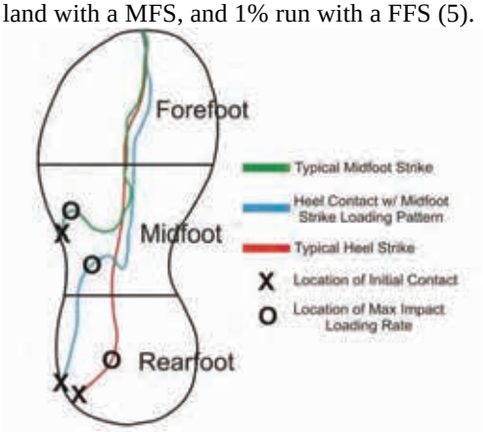

Figure 1- Area of foot receiving contact with the ground in Midfoot Strikers (MFS) (2). Adapted from "Run Blogger" by Peter Larson, Copyright [2018] by Run Blogger Media. Adapted with permission.

Comparison of Running Styles

Biomechanical Forces:

RFS running absorbs about 2-3 times an individual's body weight, which allows the foot to be planted on the ground while the body continues to be carried over the knee joint (1). In MFS the impact of force across the hip, knee and ankle joint is considerably less due to the large surface area needed to disperse the load over the midfoot (1). MFS have been associated with an increased dorsiflexion at the ankle joint and decreased knee flexion (6). FFS running is associated with increased flexion at the knee and greater plantar flexion at the ankle joint, which incorporates the help of the plantar fascia to act as a shock absorber during running (1). As a result, this causes the ankle joint to bear more force while decreasing the force across the knee joint (1). FFS are sometimes connected with a reduction in stride length and impact, as shock is distributed across the ankle, knee, hip and spine, as well as an increase in

proprioceptive feedback while contacting the ground (3).

Most commonly in the favored FFS approach amongst barefoot runners, a higher initial maximum impact can be attributed to an increase in plantar flexion at the ankle joint from the gastrocnemius and a low muscle activity of the tibialis anterior based on an EMG study (7]). When comparing FFS to RFS, RFS demonstrated a higher vertical load, as can be seen in Figure-2 (6). An increase of muscle activity by the thigh extensor muscles (vastus medialis, vastus lateralis, rectus femoris) immediately after impact has suggested a more vertical posture of the average barefoot runner when compared to an EMG study of shoe gear runners (7). Despite this initial high impact force that barefoot FFS receive, the overall vertical impact force is much lower compared to a shoe gear runner utilizing RFS technique.

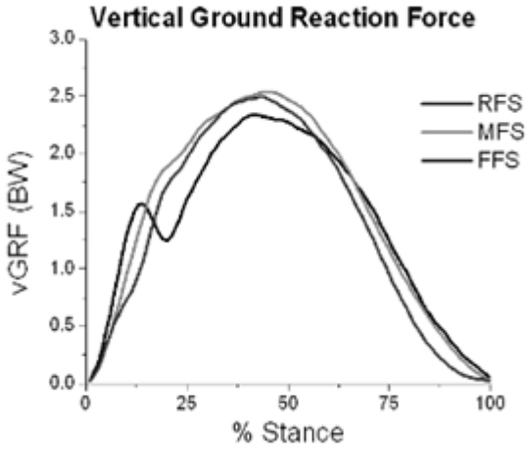

Figure 2- Increase in ground reaction forces as seen in RFS and MFS (6). Adapted from "Biomechanical Differences of Foot-Strike Patterns During Running: A Systematic Review With Meta-analysis," by Almeida MO, Davis IS, Lopes AD. 2015, *J Orthop Sports Phys Ther*, *40*, p. 755. Adapted with permission.

Braking:

Braking is regarded biomechanically when the heel strikes the ground, the body decelerates abruptly, causing the body to come to a temporary dead stop (7). It has been proposed that since shoes are not involved in barefoot running, the time it takes for the foot to contact the ground is shorter, which may lead to a quicker response time (7). Until recently, it has been proposed that superficial cutaneous nerves have been attributed to a shorter braking time. However, in a recent study by Thompson and Hoffman, it was also found that sensory proprioception found at the superficial cutaneous level did not influence changes in musculoskeletal compensation or positions at the ankle joint in barefoot runners (8). It has been proposed that mechanical feedback at the subcutaneous and deep dermal layer at the level of the ankle joint and at the calcaneal fat pad have been attributed to changes in the gait cycle of barefoot runners (8).

Injury

The overall incidence of running related injuries is estimated to be between 19.4% and 79.3% annually (9). The knee is the most common site of running injuries, followed by the lower leg, foot, and thigh. Patellofemoral pain, iliotibial band syndrome, tibial stress syndrome/fractures, plantar fasciitis, and Achilles tendinitis are typically among the most common injuries reported (5). Numerous etiologies can explain injuries in runners: age, gender, BMI, foot type, flexibility, terrain, distance, pace, running experience, previous injury, and various other medical and lifestyle factors such as alcohol use, smoking, and cross training can all contribute to running injuries (7).

RFS is associated with an increased load to the muscles of the anterior compartment of the lower leg, due to the dorsiflexed ankle positioning at heel strike. This can result in hypertrophy of these muscles and increased pressures in the anterior compartment and lead to chronic exertional compartment syndrome (5). RFS runners experience a higher vertical load, due to the foot striking perpendicularly to the ground. This has been linked to a higher incidence of injuries including tibial stress fractures and plantar fasciitis (6).

In comparison, FFS distributes the center of mass anteriorly leading to an increased flexion of the knee and plantar flexion at the ankle at the contact phase of gait (1). By doing so it decreases the amount of load on the knee joint and incorporates the help of the plantar fascia to act as an elastic shock absorber (1). FFS is associated with increased dorsiflexion velocities during the eccentric phase of gait at the ankle joint (1). This may result in greater strain and strain rate to the Achilles tendon from initial contact phase to toe off. However, FFS has been shown to be strengthen and stretch the Achilles tendon in some individuals (1). Additionally, landing on the ball of the foot as seen in FFS, especially if pronounced, will likely increase the direct force to the metatarsal heads, which can lead to stress fractures (5). This might be attributed to a smaller surface area that receives high initial vertical impact load.

Variable/Injury	Changes associated with injury in published literature	Changes associated with Barefoot Running	Theoretical implication	Summary and potential clinical outcomes
Stress fractures of the tibia	- Increased hip adduction - Increased rearfoot eversion - Increased free moment - Increased impact peak - Increased ground reaction force	- Unknown - Increased rearfoot eversion - Unknown - Decreased impact peak in some runners - Decreased ground reaction force in some runners	- Unknown - Increased risk - Unknown - Reduced risk - Reduced risk	Potential to reduce risk of tibial stress fractures, but only if impact forces are lower, may depend on other factors. Clinical case series suggests increased risk early during adaptation.
Stress fractures of the metatarsals	- Increased peak pressure under metatarsal heads - Earlier peak rearfoot eversion - Increased forefoot loading	- Increased peak pressure under metatarsal heads Decreased peak pressure heel, midfoot and hallux - Unknown - Increased forefoot loading	- Increased risk - Unknown - Unknown	Barefoot running may increase risk of metatarsal stress fractures as greater application of force for both initial contact and propulsion is experienced.
Patellofemoral pain	- Increased impact peak - Increased eccentric load on knee - Poor gluteal strength - Hamstring inflexibility	- Decreased impact peak - Unknown for barefoot but concise forefoot strike may decrease eccentric load - Unknown - Unknown	- Decreased risk - Decreased risk - Unknown - Unknown	Barefoot running may reduce forces experienced by the knee

Variable/Injury	Changes associated with injury in published literature	Changes associated with Barefoot Running	Theoretical implication	Summary and potential clinical outcomes
Achilles tendinopathy	- Increased rearfoot eversion - Increased ankle dorsiflexion at impact - Decreased leg abduction - Decreased knee range of motion - Decreased tibialis anterior, gluteus medius, and rectus femoris activity - Early Pronation	- Increased rearfoot eversion - Increased ankle plantarflexion at impact - Unknown - Decreased knee flexion at ground contact - Increased gastrocnemius activity - Unknown	- Increased risk - Decreased risk - Unknown - Increased risk - Unknown - Unknown	Barefoot running may result in greater eccentric loading on the ankle. Chronic high velocity eccentric loading during running may increase the risk of injury. However, eccentric loading may be beneficial in relieving Achilles tendinopathy if controlled.
Plantar fasciitis	- Increased vertical ground reaction forces - Increased loading rates - Lower medial longitudinal arch - Increased forefoot pronation - Decreased ankle dorsiflexion range of motion at impact	- Decreased ground reactive force in some runners, significantly increased in some - Decreased loading rates in some runners, increased in others - Raised medial longitudinal arch - Unknown - Decreased ankle dorsiflexion range of motion at impact	- Risk dependent on individual response to barefoot running - Beneficial - Decreased risk - Unknown	Barefoot running may aid in attenuating the associated risk factors. However, these beneficial changes may be acquired only after habitation to barefoot running in some individuals.

Table 1- Biomechanical Risk Factors Associated with Running Related Injuries and Potential Clinical Implications Barefoot Running May Pose (1). Adapted from "Barefoot running: an evaluation of current hypothesis, future research and clinical applications," by Tam N, Astephen wilson JL, Noakes TD, Tucker R., 2014, *Br J Sports Med*, *48*, p.352. Adapted with permission.

With the increased trend towards barefoot running and FFS, more time has been dedicated toward studying its effects. While FFS possibly predisposes the runner to certain injuries, some studies have begun to show the reduction of tibial stress fractures, patellofemoral pain, Achilles tendinopathy, and plantar fasciitis in barefoot runners, as seen in Table-1. As suggested previously, the reduced stride length as seen in FFS results in lower loads experienced by the body, which may protect the runner from impact-related injuries (5). In one study of mid and long-distance collegiate runners, the injury records of 36 rearfoot strikers and 16 forefoot strikers were analyzed. It was reported that rearfoot strikers were 2.5 times more likely than forefoot strikers to obtain a mild or moderate running-related injury. It was also shown that hip pain, knee pain, low back pain, tibial stress injuries, plantar fasciitis, and stress fractures (excluding metatarsal bones) were 2.7 times more likely to occur in rearfoot strikers (5).

Conclusion

Barefoot running is not a new development, however, it has only recently been reestablished as a feasible method of running. There remains much to be studied to determine whether it is a safer and more effective way to run because the resurgence of barefoot running has occurred mostly within the past decade, especially among track athletes and Olympians. Some studies have shown that it is possible to change from a RFS to a FFS with minimal time and practice requirements, however more research must be done to demonstrate the true impact of changing strike method (10). Additionally, studies have shown mild to moderate evidence to support the change to a FFS and barefoot running. To be able to undeniably support barefoot running, controlled trials must be conducted to establish greater evidence that barefoot running is indeed everything it is thought to be.

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Physiological Benefits of Periodized Aerobic Training

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Abstract

This article explores and summarizes the benefits and possible applications of periodized aerobic training. For many years, the health community has accepted that exercise is one of the key interventions prescribed to patients facing diseases such as obesity, cardiovascular disease, dyslipidemia and diabetes. Physicians regularly recommend exercise, however many physicians and health care workers do not direct patients to the best protocols for exercise programs. Whether due to ease, familiarity, or lack of knowledge of current literature, many patients are told to do cardiovascular training in a manner such as "jog, bike, or swim for 30 minutes a day". These suggestions will make the patient more cardiovascular fit, however this organization is nowhere near as productive as periodized aerobic training. This periodization involves specifically designed increases and decreases in volume and intensity, timed specifically to optimize the general stress response and adaptation. This article with discuss the physiologic benefits of aerobic training and will summarize periodization of training and its benefits to exercising individuals.

Introduction

For many centuries, health and physical activity have been a staple of cultures around the world. In the days of the ancient Greeks, advancements in technology, art, literature, and philosophy were accompanied by a desire to perfect the human body through exercise and physical competitions. In today's advanced world, however, even with much more knowledge and research in health and exercise, physical activity and aerobic health has taken a back seat. Obesity is becoming the norm in America, with 36.5% of the adult us population being obese (1). With this increase comes a host of other complications, such as cardiovascular disease, increased cancer risk, and increased risk of diabetes and associated complications including peripheral neuropathy and risk of ulcers and amputations. These risks of obesity and poor cardiovascular health are well established and discussed across health professionals and lay citizens alike. Aerobic exercise has been shown to have profound benefits that work to combat the aforementioned risks. Evidence of the benefits of aerobic exercise include improvement of blood pressure and vascular flow (2), decreases in cardiovascular risk and improvement of diabetes control and inflammatory markers (3, 4).

Any intervention to combat these diseases begins with lifestyle change, including exercise. Health care providers prescribe exercise as a first line treatment regularly, but the prescription often merely suggests exercises in a vague and unorganized prescription. Providers are familiar with the profound benefits aerobic exercise can have on patients, but their prescriptions for exercise are nowhere as detailed as their prescriptions for medications. When giving a patient a medication, the provider writes for a specific dose, how to take it, and for how long. When giving a patient an exercise prescription however, the prescription is often along the lines of "try to exercise more" or "try to walk, run, or bike." This is falling far short of the specificity of care patients deserve.

A major concern of patients, as well as practitioners, is the lack of experience or knowledge in designing and implementing an appropriate and effective aerobic exercise program. This paper will discuss physiological responses that training induces as well as the modern, scientific methods for aerobic training in order to better prepare doctors, therapists, and trainers to appropriately prescribe a beneficial and detail exercise protocol increase the aerobic health in their patients.

Respiratory Adaption

With aerobic work, the body requires oxygen. Efficiency in the lungs and pulmonary system is a key component of aerobic fitness. Although usually not the limiting factor in endurance performance because the lungs are naturally very effective at getting O_2 into the body, the lungs need to operate at an appropriate level in order to deliver O_2 to the blood stream as well as exhale CO_2, a metabolic waste product of aerobic work which also contributes to acid buffering. Breathing rate and breathing depth are controlled by neural pathways and chemoreceptors that respond to pH changes in the blood and CO_2 content. At rest, a minute ventilation of about 6 l/min (tidal volume of 0.5 l/breath at a rate of 12-15 breaths/min) is sufficient to supply the body's low oxygen requirement. However during exercise, the lungs need to bring in up to 150L of O_2 every minute in elite athletes in order to meet demand (untrained individuals only experience minute ventilation at about half that) (5). At high intensity exercise, the lungs are bringing in about 2-3 liters of air per breath, utilizing a much higher percentage of the lungs vital capacity. Training can help increase the lungs efficiency to these levels, allowing prolonged duration of exercise at a given intensity. Studies by Khosravi et al. and Ozdal et al. showed that eight weeks of endurance training can

improve respiratory factors that will assist with ventilator efficiency. Both studies saw significant increases in vital capacity, forced vital capacity, and maximal voluntary ventilation, suggesting that inspiratory (diaphragm, external intercostals, scalenes) and expiratory muscles (internal intercostals and abdominals) are better able to move air in and out of the lungs (6, 7). Obstructive lung diseases such as asthma can decrease the efficiency of the lungs due to inflammation of the airways. Some have raised concerns that since exercise induces release of pro-inflammatory molecules, that prolonged elevation of these molecules due to training could have a negative effect. However, studies have shown that even though these inflammatory markers are elevated in the lungs as a result of training, there is no noticeable impact of lung efficiency and function (8). Respiratory function sees slight benefits as a result of aerobic training, but the real benefit in terms of increased performance begins with improvements in how the body extracts the O_2 from the lungs.

Cardiovascular Adaptation

The cardiovascular system plays a vital role in O_2 delivery to working tissue, and therefore plays an integral part in aerobic exercise. Oxygen in the lungs needs to get to the working tissue. The cells responsible for this job are the red blood cells (RBCs). Red blood cells flow through the blood plasma and contain an important protein complex called hemoglobin (Hb), which binds to oxygen and allows for transport throughout the vascular system, delivering it to the working muscle tissue. The hemoglobin protein is structured as to allow for very efficient O_2 binding where the partial pressure of O_2 is high, like at the level of the lungs (PO_2 about 100mmHg), but also allows for O_2 release from Hb at areas where there is a low partial pressure of O_2, such as working muscle (PO_2 about 40mmHg). This relationship, signified by the oxygen-hemoglobin dissociation curve, allows adjustable Hb saturation that is key in O_2 carrying and delivery. There are many regulators of Hb's affinity to O_2, such as temperature, pH, and Co2 levels. When cells undergo aerobic metabolism they produce a by-product called 2,3-diphosphoglycerate (2,3-DPG) that also has an allosteric effect of Hb. When there is a lot of 2,3-DPG present (when an person is exercising) the oxygen-hemoglobin dissociation curve shifts to the right allowing for better dissociation and delivery of O_2 to tissues. Trained people with high aerobic fitness exhibit a higher production of 2,3-DPG, which, along with other factors, result in a large shift of the dissociation curve that signifies a more efficient O_2 delivery system (9).

Another observation is that with trained athletes, the RBCs in their system are on average, younger than that of an untrained individual. This is due to stress on the RBCs as they are repeatedly rushed through the vasculature. This wears down the cell until it dies. RBC death in turn stimulates erythropoiesis, and the creation of new RBCs leading to a higher rate of RBC turnover. These new blood cells are more flexible and pliable, which allows them to better slide through capillaries to deliver O2 to tissues.

It has been well known in the world of endurance sports that increasing the amount of Hb in the blood can have a notable positive impact on endurance performance. This was shown by a study that reinfused blood into cross country skiers, greatly increasing the amount of Hb in the blood and improving performance (10). The amount of RBCs and Hb in blood is usually measured indirectly by hematocrit (Hct), which is the ratio of red blood cells in the blood to plasma. One would assume that an increase in Hb and RBCs in the blood would result in a higher Hct, and this is true, but what is observed in trained athletes is that they have Hct that is actually lowered (44-49%) (11). This is due to the athletes increase in blood plasma volume as a response to training, functionally diluting the RBCs. A decreased hematocrit helps decrease the viscosity of the blood, allowing for easier flow through the arteries and veins, and decreases the effects of sweat loss during exercise.

Outside of adaptations to the blood itself, alterations in heart function and control also prove to be beneficial adaptations to endurance training. Cardiac output (CO) is one of the key factors in determining VO_2, the amount of oxygen that can be utilized by the body. CO is a measurement of the amount of blood that is pumped by the heart every minute. It is comprised of two variables: the heart rate (beats per minute) and stroke volume (volume of blood pumped per beat). Altering these two variables, and thereby the CO, has a large effect on aerobic capability. As with any other muscle, the heart becomes stronger as an adaptation to the progressive stress of training. Studies show that with training, the heart, specifically the left ventricle, hypertrophies and becomes stronger. This response is heightened with an increase in the intensity of the training (12). This will result in a higher stroke volume, as the heart can pump more blood with each stroke. Improved stroke volume will also affect heart rate. As a result of training, since the stroke volume of the heart increases, the heart rate of the athlete decreases for any given CO. With this, the trained persons heart rate is lower at any given work rate than those who are untrained. This is a result of more "vagus control" or parasympathetic influence on heart rate. With this adapted heart, the cardiac muscle can work at higher rates, but with this increase work capacity also comes increased need for oxygen. As a response to this increased demand, the capillaries that supply the heart

tissue with blood grow to further vascularize the tissue. This increases the capillary density surrounding the heart as much as 57%, allowing more blood flow to the area (13).

Within the systemic portion of the vasculature, there are adaptations as well. Capillary density around working muscle tissue also increases in response to training, much in the same way it does with cardiac muscle. The capillary network in the muscle tissue can be increased as much as 30% (13). By increasing the amount of capillary access to the skeletal muscle, it allows for better extraction of O_2. This increases the a-vO_2 difference. A-vO_2 difference is a measurement of the amount of O_2 in the blood in the arteriole prior to engaging with the muscle tissue and the amount of O_2 in the venous blood after gas exchange in the capillaries. With training, this extraction can moderately increase. Since VO_2, a main indicator of aerobic capacity, is equal to the CO x a-vO_2 difference, the increase in both will overall contribute to an increased ability to take in and utilize O_2. With a better cardiovascular system, the body is able to deliver more blood to the working tissues.

Muscle Tissue Adaptation

Many of the more profound changes that are observed in response to training are seen in the skeletal muscle tissue. Human skeletal muscle differentiates into three different fiber types. Type IIx muscle fibers, or fast twitch fibers, obtain their energy through mostly anaerobic energy systems. They generate a lot of force for a short duration and can hypertrophy when trained with resistance training. Type I muscle fibers, or slow twitch fibers, can better utilize aerobic energy systems due to their increased mitochondrial density. They cannot generate as much force as trained type II muscle, but fatigue as a much slower rate. Type IIa muscle fibers are a hybrid type of fiber that has some properties of both fast twitch and slow twitch fibers. These fibers allow for larger force production then type I fibers, but do not fatigue as quickly as type IIx fibers. Many factors can help identify a fiber type, such as the amount of mitochondria, type of myosin heavy chain protein, vascularization, oxidative and glycolytic capacity, glycogen storage capacity and innervation of a type of motor neuron. Aerobic athletes utilize their type I and type IIa muscle fibers more then their type IIx. Aerobic training therefor can increase the efficiency of type I and type IIa fibers. One study by Fry et al. examined fiber type specific responses to 12 weeks of endurance training by utilizing muscle biopsy techniques to identify theses changes. With endurance training, the group observed that there was a decrease in overall type IIx fibers, and an increase in type IIa fibers. This of course would assist in time to fatigue of the muscle. There was also observed hypertrophy (muscle growth) in type I and type II muscle. Another interesting observation concerned the satellite cell activity of the muscle fibers. Satellite cells are quiescent cells (non activated), on the periphery of the muscle cells. They can be stimulated by trauma or stress and activated to increasing the amount of myonuclei in a cell which will allow for an increased regulation and production of the necessary proteins involved in muscle function, such as myosin, actin, titin, etc. Satellite cell activation and myonuclear addition to the existing muscle cells was only observed in type I muscle fibers (14). The inclusion of more myonuclei would indicate more metabolic work being done by that fiber, and one can see how this adaptation would be beneficial in supporting the muscle cells used most for endurance activity.

One regulator of muscle type changes is the PCG-1α transcription coactivtor. A transcription coactivator is a molecule that assists with the increase expresses of a gene or several genes. PCG-1α in this case helps up-regulate the expression of several genes involved in muscle metabolism such as increased oxidative myosin. (15). PCG-1α also has regulatory involvement in the expression of genes coding for mitochondrial proteins and enzymes.

With extended periods of training (greater than 15 weeks) enzymes such as malate dehydrogenase, citrate synthase and pyruvate dehydrogenase, which are enzymes key to the citric acid cycle have been shown to increase in the mitochondria (30%, 26%, 21% respectively) (16). With increased levels of these enzymes, the citric acid cycle is more efficient, producing more electron carriers at a higher rate, contributing to the rate of ATP production. Other enzymes involved in the electron transport chain (such as cytochrome c, an electron carrier), have also been recorded to increase with prolonged training (17, 16).

All of these previously discussed adaptations help produce ATP from energy substrates (carbohydrates, fats, and proteins). The body being the ever-adaptive specimen it is, also changes to help better bring in and store the vital molecules needed for metabolism. Muscles can utilize several different pathways to convert nutrients to energy. Glycogen is a branched polymer of glucose molecules that can be stored in the muscle tissue itself or in the liver for later breakdown and utilization. Circulating blood glucose is also a convenient source and is the second method of choice for muscle to obtain nutrients. The glucose in the blood stream can be transported into the cell in one of two ways. At rest, the hormone insulin interacts with receptors on the cell surface, causing a cascade of molecular events that result in a trans-membrane channel called a GLUT-4 channel to move to the surface of the cell to allow glucose to pass through and into the cell. During exercise, insulin levels are low, but the intercellular calcium levels are high, due to repeated

muscle contraction, causing the GLUT-4 transporters to move to the cell membrane to allow for the increased uptake of blood glucose into the muscle cell independent of insulin. Trained athletes have developed a higher number of GLUT-4 transporters (up to a 30% increase) as to better increase the uptake of blood glucose (16). One can see what benefits this can provide to a patient with diabetes who suffers the consequences of chronic elevated blood glucose.

During aerobic exercise, the body will also draw upon another source of energy besides glucose. This substrate is fat or fatty acids. Fat provides energy in abundance as it contains 9 kcal/gram, while glucose only provides 4kcal/gram. While fat does provide a greater amount of energy, it is a culprit when it comes to obesity and all its complications. Using the bodies fats then as fuel would be an ideal advantage of aerobic exercise. With training, people shift the percentage of energy that they draw from sugars and fats, where the trained individual will utilize a higher percentage of fats at any given work intensity then the untrained person. This has been shown in Perry et al.'s study where they observed a significant increase in fat oxidation at 60% of the subjects VO2 peak (16). In summary, a trained individual will be better able to store and use glucose for the muscles energy needs as well as be better able to utilize fat oxidation for their energy demands, i.e. "burning the fat".

Periodization of Exercise Protocols

In order to improve aerobic fitness, many strategies and techniques designed to cause these desired adaptations have evolved into a variety of training methods, most of which stem from the idea of the general adaptation syndrome (18). Hans Selye proposed that the body can change its homeostatic levels, that is its "normal conditions", in response to repeated stressors on the body, thereby creating an adaptation that results in a new homeostasis. This theory proposes a three-phase response to a stressor. The first stage is an alarm phase, in which the body has an acute response to the stressor placed on it. During the alarm phase, the body sees a lower resistance to stress. The second phase is the resistance phase, in which the body will respond and resist the stress applied to it. If the stressor continues, or if over trained, then the body enters an exhaustion phase, where resistance to stress declines, while if trained appropriately, the body will continue to gain resistance as an adaptation to the stress (Figure 1). The idea behind training is to repeatedly apply stress to the body, dosed and timed appropriately so that the next stressor is applied during the resistance phase of response. This will create an accumulation of repeated resistance responses that, over time, allows the body's systems to adapt to better respond to stress. Training can be designed to stress certain systems of the body in different ways, and at different times so that each system can obtain the desired response. The complexity of such a strategy was furthered with the idea of periodized training, proposed by Matveyev in the 1960's.

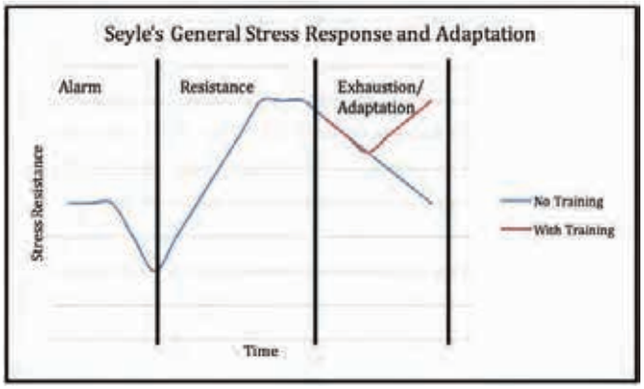

Figure 1: Seyle's General Stress Response. Illustrates the alarm phase, resistance phase and exhaustion or adaptation phase.

Periodized training involves a detailed, long-term approach to designing workouts that fit together to reach a desired fitness level (19). Athletes and patients alike commonly practice a linear and constant training program, by either working at the same volume or intensity every day, doing the same types of workouts every training session, or not scheduling training sessions that allow for recovery and adaptation. This is common place in the prescription of exercise given by health providers today. Many times, the suggestions are to exercise for a certain amount daily or some other suggestion of aerobic exercise that is consistent and nonvarying. While the common appeal of this prescription would be simplicity, the research discussed in this paper suggests this type of fitness program design is in fact inferior to a periodized approach. Periodized training programs alter the training frequency, volume, and intensity of workouts to allow the body to optimally respond to stressors. Training intensities or volumes that are too low fall into a category of undertraining and do not stress the body enough to allow for high degrees of adaptation. Contrasting undertraining is overtraining, where the stressors are too intense, too long, or too frequent for the body and often results in staleness, a decrease in performance, a drop in the level of adaptive response to the training, and injury or reinjury. Optimal training falls into a range of acute overload in a training program that adequately stresses the body, but then allows for recovery and optimal adaptation. Adopting such an approach would lead to greater and more quickly obtained aerobic fitness in patients.

Traditional periodization splits training into different cycles. These cycles are the microcycle, which is the smallest cycle, the mesocycle, which is comprised of several microcycles, and the macrocycle, which is comprised of several mesocycles. The macrocycle is the largest and least specific portion of a periodized training program. Macrocycles can range from several months to years. The macrocycle is composed of smaller mesocycles, which are usually a few weeks in time (3-8 weeks). The mesocycles are further broken down into microcycles, which is typically a week worth of exercise prescription. The microcyle schedule will describe the weekly activates in terms of they types or modes of workouts, describing the volume and intensity of each workout. To help the patient progress optimally though their fitness goals, the mesocycles and the microcyles both are organized in a progressive manner, shifting intensity and balancing volume as to allow for optimal adaptation (19).

For example, with a 4 week mesocycle, the first microcyle (1 week) will be at moderate volume and low to moderate intensity, the second will be at higher volume and moderate intensity, the third will be at moderate volume and high intensity, while the forth will be at low volume and high intensity. This type of organization allows for the variety of stressors, while giving time for compensation to the acute stress placed on the body. Typically these cycles avoid drastically increasing volume and intensity at the same time, which can often place too large a stress on the body and can lead to detraining or injury. This type of organization is even present within the microcycle, where each day of the week is adjusted for a progression of both volume and intensity with scheduled recovery to avoid overtraining. The desired outcome of this organization is to have an undulating exercise load (comprised of volume and intensity) that shows a long term increase in aerobic ability and fitness. This progressive increase in training load will induce compensatory responses by the body but also has adequate variance to allow for recovery and faster adaptation without overtraining. An example of a 12-week macrocycle with 3, 4 week mesocycles is shown in Figure 2.

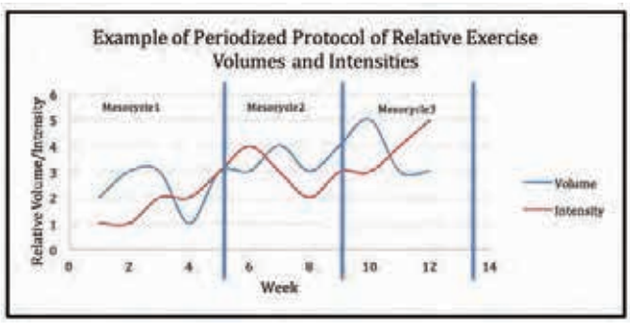

Figure 2: Example of Periodized Protocol of Relative Exercise Volumes and Intensities: This figure shows a 12-week macrocycle of training, split into three mesocycles each consisting of 4 one week long microcycles. Mesocycles and microcycles both will have undulating levels of intensity and volume of training, in order to allow for optimal levels of adaptation and recovery.

One study, by Suarez et al., examined the effect of periodization in a four-week mesocycle. In this study, one group of participants trained with a constant workload throughout the four weeks. The other group exercised with different increments of intensity varying over the four weeks, an example of a periodized mesocycle. The periodized group showed a significant decrease in the VO_2 (an indirect measurement commonly used in physiology to estimate level of aerobic work) at ventalatory threshold, an adaptation that is beneficial for aerobic performance, where the constant loaded group did not. The group concluded that "periodisated programmes obtain equal or higher adaptations with lower training volumes than non-periodisated programmes" (20). This is a profound finding: that a person trying to increase their aerobic fitness can do so more efficiently even at lower training volumes, by using periodization.

A common method of varying training intensities and volumes in a periodized training program is the utilization of high intensity interval training (HIIT). Interval training consists of repeated, high intensity bouts of exercise, intermixed with a low intensity rest period. Protocols range from 1 minute on-1 minute off, to 5 to 10 minutes on- 2 to minutes off, with varying intensities between 85-100% of an athletes VO_2 max. Many studies have shown that interval training is effective in improving physiological indicators of aerobic performance such as VO_2 max, time to exhaustion, ventilatory thresholds, OBLA (onset of blood lactate accumulation above 4mmol/l), increased aerobic enzymes, capillary density, power output, and fat and carbohydrate metabolism. (21,22,23,24,25,13,16,26).

Beyond traditional periodization, other types of periodized schedules have been examined, including undulating or nonlinear periodization and block

periodization. Undulating periodization follows a similar plan to traditional periodized schedules but with more drastic variations in intensity within and between meso- and microcycles. Blocked periodization organizes its mesocycles or microcycles into very specific types of training and training loads. An example would be a two-week stint of extremely high intensity activity, followed by very light activity for two weeks in order to sufficiently rest and recover. The intensities and volume of work done in these different blocks usually contrast greatly and one does not see the progressive increase or decrease approach that would be recommended for a traditional periodization strategy. A study by Ronnestad et al. examined the effects of a block like periodized program for cyclist compared to a more traditional periodized schedule. In this study, the block group started with one week of five HIIT sessions followed by three weeks of only one HIIT session a week, where the traditional group had four weeks of two HIIT sessions a week. At the end of the four weeks of training the block group showed increases in VO_2 max and peak power output compared to pre-training, where the traditional group saw no changes in these variables. The group summarizes their findings, concluding that "block periodization of training provides superior adaptations to traditional organization during a 4-week endurance training period, despite similar training volume and intensity" (27).

Other Considerations and Future Research

Selecting the right type of plan to use depends on a variety of factors. Starting fitness level should be a consideration when determining the prescription of exercise, as one activity can be strenuous for some, but not for others. Safety should also be a concern, particularly with rehabilitation exercise prescription. Time available to the patient or athlete as well as personal preference of activity are also important factors. Even with the best fitness protocol, adherence is key to improving fitness. Research in adherence of these protocols vs traditional nonperiodized training could give insight into possible long-term advantages that periodization can have for lifestyle and health benefits.

Another area of future research that could see lots of potential benefit would include exploring the application of a periodized training schedule to cardiac rehabilitation patients. HIIT training has already been shown to be beneficial, safe, and shows good adherence in cardiac rehabilitation patients (28). These protocols, however, do not periodize the training schedules, instead having their patients perform the same intensity, dose, and duration of training every week. With research showing increased benefit and adaption of aerobic fitness in healthy populations, it raises the question of if there would be more benefit to cardiac rehabilitation patients if they are rehabilitated with a periodized training schedule. The study of the application of periodized exercise on long-term benefits in other areas such as diabetes management, and physical rehabilitation could continue to yield superior results to traditional exercise protocols, and further research will need to be done to explore these questions.

Summary

Improving cardiovascular fitness requires the body to make adaptations in the performance of the heart, vasculature, lungs and end-organ tissues. These adaptations do not come about on their own; the body requires training to stimulate change. Over the years, training styles have varied greatly, but now with more scientifically supported experimental data, some styles of training have become favored in that they increase the relative improvements of athletes, compared to other training schemes. Periodized training is one such method that uses an organized schedule of training that undulates intensity and volume to allow for more optimal adaptations. As such, there is no "golden standard" of training, as new methods are constantly developing, which aim to improve the body's aerobic fitness. That is the job of the practitioner; someone to examine the literature, determine the adaptions that they wish to impose in the patient, and then design a personalized training program to try and produce adaptations that lead to better results. Periodized training, as well as the body's physiological responses to aerobic training, proves to be a beneficial exercise prescription that can be of use to physicians in clinical practice.

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Sleepless Legs: Fibromyalgia and Restless Leg Syndrome

Jin Lee, OMS-2

Abstract

Due to the similarities shared between fibromyalgia and restless leg syndrome, it may be possible for an inexperienced physician to misdiagnose one for the other. Both are chronic pain disorders that commonly involve the lower extremity, as seen in their association with periodic leg movements in sleep. Comparing the diagnostic criteria show an obvious distinction, but the diagnoses of one does not exclude the absence of the other, which can further complicate a clinical presentation that may already be crowded with other comorbidities. Checking for the presence of tender points and paying close attention to the pain descriptors chosen by the patients can assist in this distinction. This is important because the two share key differences in their pattern of neurotransmitter imbalance, which has implications on the pharmaceutical prescription. There are also non-pharmacological options that may provide additional benefit.

Introduction

Fibromyalgia (FM) is characterized by the persistence of generalized pain in multiple regions of the body, which tends to be more severe in situations of immobility. Six out of the 18 tender points classically associated with FM are located along the greater trochanter, upper gluteal region and the knees. Many of these tender points in FM overlap with sites of entheses, where tendons insert into bone, in those diagnosed with a spondyloarthritis [2]. Another study (2015) identified that among those diagnosed with ankylosing spondylitis (AS), classified under spondyloarthritis, nearly a third of them had restless leg syndrome (RLS) [3]. Restless leg syndrome is characterized by an urge to move and/or the experience of unpleasant sensations in situations of immobility. The results of this 2015 study is in accordance with a cross-sectional study (2010) that found a significantly higher prevalence of RLS in those diagnosed with FM [1]. The purpose of this article is to compare and review the clinical presentation, diagnosis, and pharmacological treatment options for FM and RLS, while highlighting common pain descriptors, their link to periodic leg movements in sleep (PLMS), and their response to counterstrain, one of the modalities used in osteopathic manipulative treatment (OMT).

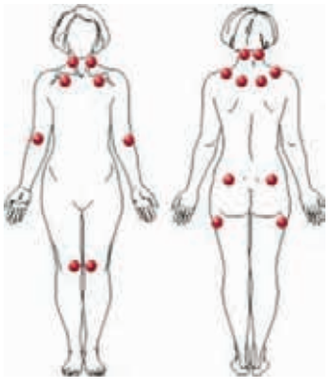

Figure 1. Classic tender points in fibromyalgia

Clinical Presentation

Some of the clinical patterns that FM and RLS share include a higher prevalence among females, cases of early presentation in the pediatric population, and the common involvement of the lower extremity. Although there is overlap in the descriptors chosen for the unpleasant sensations that these patients feel, which is not always pain, there are notable differences between the two groups.

Tender points

Unlike RLS, FM is classically associated with 18 tender points. Six of them are located along the greater trochanter, upper gluteal region and medially just above the knees (Figure 1). It should be noted that a recent descriptive study (2017), using a visual analogue scale to subjectively evaluate pain in FM patients, confirmed the classic tender point on the knee as well as a more generalized pattern that involved the ankle and various aspects of their foot [6]. If this is true, then differentiating between FM and RLS, the later not being strictly associated with tender points, may not always be so straight forward.

Pain descriptors

A comparison study (1986) between FM patients and rheumatoid arthritis (RA) patients, using the McGill pain questionnaire (MPQ), identified that both groups chose aching (82%) as one of the fitting descriptors. Some of the next most common descriptors include exhausting, nagging, hurting, sore, shooting and radiating in the FM group and stiff and moving in the RA group. Although less than the RA group, it is worthwhile to note that 48% of the FM patients also identified stiff and moving as fitting descriptors [4].

In contrast, a study (2012) that provided the MPQ to RLS patients identified that more than 50% of them chose tingling, jumping and nagging as fitting

descriptors. Other common MPQ words chosen by more than 40% were tiring and annoying. Unlike the FM study (1986), this RLS study also reported other words and phrases that came up spontaneously or via prompt from a list of RLS descriptors outside of the MPQ. More than 10% spontaneously used the words irritating, painful, crawling, uncomfortable and discomfort. When prompted, 88% chose restless and 50-70% chose uncomfortable, twitchy, unpleasant, irritating and nagging [5].

FM	Similar	RLS
Aching Sore Shooting Radiating Stiff Moving	Annoying Nagging Exhausting/Tiring Hurting/Painful Miserable/Uncomfortable	Restless Tingling Jumping Twitchy Fidgety Crawling

Table 1. Common pain descriptors

Diagnosis

The latest revision (2016) of the FM diagnostic criteria by the *American College of Rheumatology* requires high enough scores on the widespread pain index (WPI), the symptom severity scale (SSS) and the presence of generalized pain in 4 out of 5 regions for at least 3 months. The WPI has the patient identify the number and locations of tender points, while the SSS determines the severity based on the level of fatigue and other common symptoms. The patient must have a WPI ≥ 7 and SSS score ≥ 5, or a WPI of 4-6 and SSS score ≥ 9 [7]. Any patient that meets these criteria can be diagnosed with FM even alongside another overlapping diagnosis.

In contrast, the diagnostic criteria of RLS are based on the presence of an urge to move and/or unpleasant sensations that begin or worsen in situations of immobility [8], such as when sitting in class or before sleep.

Sleep

The research explaining the link between chronic pain and sleep deprivation is growing, and this link has been confirmed by a meta-analysis (2015) on the effect that sleep deprivation has on pain perception [9]. The persistence of unpleasant sensations in the absence of motion, which can be said for both RLS and FM, makes falling asleep a nightly challenge for these patients.

Periodic leg movements in sleep

Adult FM patients report having a hard time falling sleep, repeatedly waking up early, and feeling unrefreshed [13, 14]. Some FM patients may experience periodic leg movements in sleep (PLMS), but this association with PLMS is much stronger among RLS patients [15]. It certainly helps to explain why RLS patients might have a predilection for descriptors like jumping, twitchy, and fidgety. One sleep study (2000) identified that a significant number of adolescents (9-18 years old) diagnosed with juvenile fibromyalgia (JF) exhibited PLMS [14]. PLMS is just one of many overlaps shared by FM and RLS patients. It should be noted that the evidence is unclear on how many FM and JF patients with PLMS would also qualify for a RLS diagnosis.

Neurotransmitters

Patients with FM have been associated with insufficient levels of gamma-aminobutyric acid (GABA) [19], an inhibitory neurotransmitter that has been shown to inhibit noradrenergic neurons in the brains of sleeping rats [10]. Research on the pathophysiology of FM has identified several areas in the brainstem, including the nucleus raphe magnus [12], an area involved in serotonin release and pain modulation. In comparison, the research on RLS pathophysiology has identified links to spinal cord defects and the dopaminergic pathway [16].

Treatment

The pharmacological therapies that have been shown to provide symptomatic relief for some FM and RLS patients are notably different, and reflect the difference in their pathophysiology.

Antiepileptics/antidepressants

The pharmacological agents used in the treatment of FM varies depending on the symptom being targeted. Local anesthetics have been recommended for peripheral pain, antiepileptics for central sensitization, and GABA agonists for sleep disturbances [19]. Antidepressants can be used for negative effects, like depression, or central sensitization. Central sensitization is a blanket term that refers to a persistent state of heightened nociceptive activity due to a dysfunction(s) in the nervous system. Antiepileptics and antidepressants, which can be used for the symptomatic relief of central sensitization in FM, involve GABAergic and serotonergic responses respectively. GABA is a neurotransmitter with a role in reducing neuronal excitability and serotonin is a neurotransmitter that has been linked to sleep regulation [11].

Opioids

For patients with RLS, opioids have been shown to provide symptomatic relief and may improve sleep

quality by reducing PLMS [20]. One study (2007) that looked into the augmentation of RLS through long-term Tramadol use, reported worsening of RLS symptoms at higher dosages of Tramadol [21]. Tramadol has opioidergic properties, but it also blocks the reuptake of serotonin and NE. It is speculated that this increase in serotonin and NE activity may have negative effects on RLS symptoms [22].

Counterstrain

In consideration of non-pharmacological treatment options, which is part of the treatment recommendation for FM patients [19], we will look at counterstrain. Counterstrain, one of the modalities in OMT, aims to relieve musculoskeletal pain by guiding the patient away from the barrier of restriction and holding them in a passive position for 90 seconds. It is theorized that this passive positioning helps to reset muscle spindle activity and relieve abnormal neuromuscular activity [23]. A randomized pilot project (2002) involving FM patients [17] and a single-blind randomized control trial (2012) with RLS patients [18] both reported significant subjective improvements in the groups that received counterstrain in addition to the standard mode of care. It is interesting to note that counterstain was effective even in the RLS study (2012) because the technique of counterstain is centered around the alleviation of tender points. It should also be noted that in the FM study, the osteopath was permitted to use other OMT modalities, such as myofascial release and soft tissue, at his/her discretion so the results from this 2002 study cannot be entirely attributed to counterstrain.

Conclusion

Comparing the common pain descriptors among FM and RLS patients helps to delineate some of the qualitative differences between the two, while comparing the diagnostic criteria reveals that the musculoskeletal symptoms of RLS are not quantified as it is in the diagnosis of FM. However, due to the many comorbidities that FM and RLS can present with and the many overlaps in clinical presentation, extrapolating the correct diagnosis and determining the correct target for treatment in these patients may pose a challenge. Paying attention to their pain descriptors and isolating the key descriptors from those that are vague may help in this distinction, especially in cases where pain follows a generalized pattern with an indefinite presence of tender points. Among the myriad of ways that FM and RLS patients can present, sleep disturbances and fatigue are two of the more common comorbidities suffered by both groups. PLMS has been observed in both groups, but is more common among RLS patients. It can be speculated that this difference in PLMS prevalence likely has connection to the differences in pathophysiology, something that is reflected in the results of pharmacological therapies. The key neurotransmitter that is deficient in RLS is dopamine, while the levels of NE, serotonin and GABA tend to be low in FM patients. The results of providing counterstain in conjunction with pharmacological agents that reset these neurotransmitter imbalances appear promising for both groups, but the evidence is scant and further research using counterstain is needed.

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A Place for Podiatric Medicine in Fracture Liaison Services

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Abstract

Fragility fractures are often the first physical manifestation of osteoporosis, and as such any patient sustaining a low-trauma fracture should be worked up for systemic medical causes. Unfortunately, up to 90% of patients presenting with this condition are not assessed further. If, however, osteoporosis is diagnosed, patients can begin medical therapy to prevent fracture recurrence. This review examined the impact of Fracture Liaison Services (FLS) on patients with fragility fractures. FLS are programs implemented by healthcare systems to identify at-risk patients and bridge the care gap between fracture treatment and treatment of osteoporosis. In addition to assessing patient outcomes, this paper sought to determine a podiatrist's role in these programs. Patients who followed up in FLS programs had significantly lower incidence of recurrent fractures compared to those with similar fractures who opted to follow up with primary care physicians (4.1% vs. 19.7% respectively, $P<0.01$) over 2-4 years, and a reduction in mortality by 35% (HR 0.65) over a 2 year follow up. There was also a large number (over 50%) of patients with radiographic evidence of osteopenia with a foot fracture never screened for osteoporosis. It is recommended to continue implementing FLS programs in healthcare systems. FLS offers a timely and cost-effective tool to screen at risk patients and offer them appropriate treatment. As experts in lower extremity pathology, podiatrists can detect osteoporosis by picking up early signs on plain film radiographs. Incorporating podiatrists into FLS programs can prevent fractures and reduce recurrences, healthcare costs, and mortality.

Introduction

When a new fracture presents to the emergency department, it is sent for in-patient evaluation by orthopedics/trauma or referred to an outpatient fracture clinic for follow up (2). In many cases, this alone may be adequate management. Other cases however, require further work-up as the patient may be suffering from an underlying condition that puts them at greater risk for fracture. Although there are numerous metabolic bone disorders, osteoporosis has been identified as the most common condition, affecting nearly 1 in 3 women and 1 in 5 men over the age of 50 years (1). Osteoporosis has multiple complex etiologies and is unfortunately overlooked and undertreated across the world, especially in the acute setting (3). To address this issue, coordinator-based secondary fracture prevention services are being incorporated into healthcare systems to diagnose and treat osteoporotic patients. They have been coined the term *Fracture Liaison Services* (FLS).

While this new model of care is being utilized by orthopedic departments across Europe, Canada, Australia, Asia, and the United States of America, it has not yet been formally described in the podiatric literature. The purpose of this review is to report evidence on beneficial effects of FLS and evaluate how its application to podiatry might improve healthcare outcomes and lower financial burdens in an increasingly osteoporotic population.

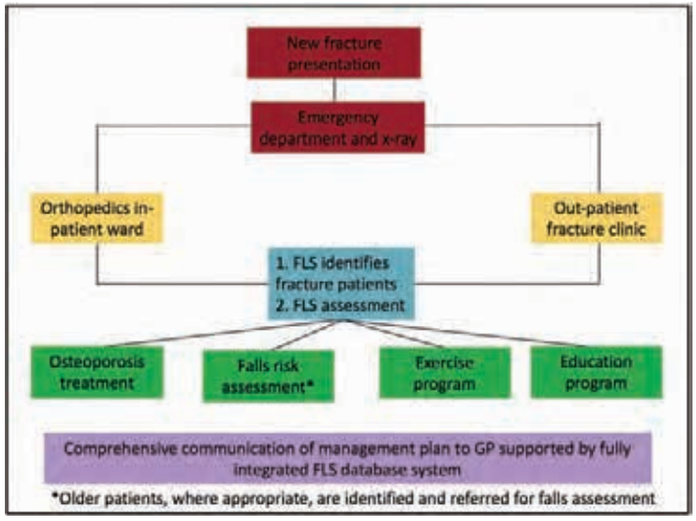

Figure 1: Sequence of care for a patient with a fracture in an FLS program. Adapted from www.capturethefracture.org by Kimberly Pham

Background

Fracture liaison services are designed to close the care gap for fracture patients. Despite conventional and effective treatment options for osteoporosis, studies show that only about 10% of women with fragility fractures actually receive pharmacological therapy (2). The gap refers to the remainder of patients who are never offered a screening or treatment plan for management of osteoporosis after presenting with a fracture (2, 3). Programs successful in addressing this gap have a dedicated coordinator who acts as the link

between the orthopedic team, osteoporosis prevention and falls services, the primary care provider, and the patient. In addition to a liaison, there must be access to bone mineral density testing, osteoporosis education, and a fracture registry and database. Healthcare providers involved will have clearly defined roles and a "medical champion" is identified to head the project (19). This term was coined by Marsh et. al. in 2011 and is ideally an orthopedic surgeon, endocrinologist, or other bone metabolism specialist who will be responsible for reviewing each case (4).

It is currently reported that patients presenting with a non-vertebral fracture are twice as likely to suffer a subsequent fracture when compared to those without a fracture (5). Table 1 lists additional risk factors associated with osteoporosis and fragility fractures (17). Subsequent fractures are associated with a higher morbidity and mortality which increases burden on healthcare systems (6-10). A successful FLS will reduce the recurrence of fragility fractures by identifying at-risk patients and providing the appropriate management for underlying bone pathology. Emerging literature suggests that these services significantly reduce this risk, although the level of evidence is low thus far due to the limited number of studies available (4).

Table 1 Risk factors for osteoporosis and fragility fractures

Major risk factors

- Personal history of fracture as adult
- History of fragility fracture in first-degree relative
- Low body weight (<127 lbs.)
- Current tobacco use
- Use of corticosteroids >3 months

Minor risk factors

- Impaired vision
- Estrogen deficiency at <45 years old
- Dementia
- Poor health/frailty
- Recent falls
- Low calcium
- Low physical activity
- Alcohol consumption >2 drinks/day

Table 1: Adapted from Labovitz et. al (2007)

Impact

Recent studies have proven to show a reduction of recurrent fractures, a reduction in overall mortality, and cost-effectiveness of these services (4). In a prospective controlled observational study, patients who followed up with FLS, had significantly lower incidence of recurrent fractures compared to those with similar fractures who opted to follow up with primary care physicians (4.1 vs. 19.7% respectively, P<0.01) (11). Reduced secondary fracture risk leads to a reduction in mortality and healthcare costs. In a study conducted in the Netherlands, patients who followed up with FLS had a reduction in mortality by 35% over a 2 year follow up (11). These results may be secondary to better post-fracture care. Improved coordination within a multi-disciplinary team may help discover comorbidities and causes of osteoporosis.

Although the benefit to patients is evident, barriers exist when it comes to implementing these programs into healthcare systems. These mainly surround uncertainty about their cost-effectiveness. There have been several economic evaluations of these programs that report FLS to be cost saving if at least 350 fracture patients are managed annually (9). Analysis conducted alongside one study reported that for every 100 patients managed, 6 recurrent fractures would be prevented (13). This led to an overall savings of $250,000 and quality-adjusted life years (QALY) gained (13). FLS has been shown to be cost-saving compared to conventional fracture treatment.

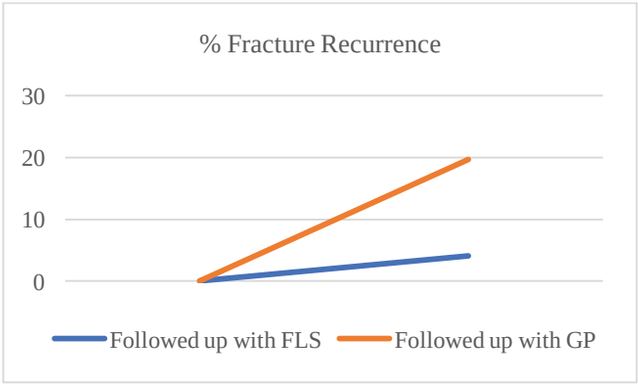

Figure 2:
Individuals who followed up with their fracture in a fracture liaison program had a recurrence risk of 4.1% (blue line). Individuals who followed up with their fracture with a general practitioner had a recurrence risk 19.7% (orange line)

Fractures in Podiatry

It has been well established that incorporation of a podiatrist into a general medical practice or specialty practice such as orthopedic surgery is cost-effective (14). In addition to saving money, podiatrists are essential in diabetic foot care and limb salvage, reducing amputation rates by 45-85% (15). They are often the first provider to identify a patient's diabetes, peripheral arterial disease, and many other systemic conditions that may first present in the lower extemity. Osteoporosis is a clinically silent disease, with the first major manifestation usually being a low-trauma "fragility" fracture. As the population of podiatric

patients leans more and more toward elderly, diabetic, and overweight individuals, risk factors for fragility fractures are highly prevalent. With 10% of all fractures occurring in the foot, podiatrists cannot afford to miss an underlying systemic pathology as a clinical clue to the fracture (16). At-risk patients should be referred for bone mineral density testing and followed up with the appropriate treatment. In addition to preventing future fractures, it is important to recognize the underlying condition as it will influence the surgeon's treatment modalities and affect outcomes and rehabilitation potential (17).

PubMed, EMBASE, Cochrane Library, and Google Scholar were systematically searched using the keywords *fragility, fracture, podiatry, liaison, foot,* and *ankle* to identify meta-analyses or systematic reviews touching on the utilization of podiatric services in FLS. Surprisingly, very limited information was found on this topic. One study however, recognized that findings of osteopenia or fracture of the foot are predictive of low bone density, and are often not evaluated. In this study, over 50% of the participants with radiographic evidence of osteopenia, fracture, or both, were not evaluated by the clinician for risk factors of low bone mass or referred for dual x-ray absorptiometry scanning (18). While treating a fracture takes precedence in the acute scenario, underlying osteoporosis should not be ignored.

Incorporating Podiatry

Podiatrists can make significant contributions to FLS programs. As experts in foot and ankle pathology, they typically read a higher volume of lower extremity radiographs than any other specialist. Radiographic findings such as cortical thinning and prominent trabeculations in the metatarsals may be subtle and overlooked by a general practitioner (20). A podiatrist is trained to identify such distinctions that suggest osteopenia and can lead to better preventative care. Although fragility fractures are the first clinical manifestations of osteoporosis, by the time they occur it may be late in the disease process. Thus, by the time an osteoporotic patient presents with a fracture and the diagnosis is made, they are at significantly greater risk for fracture recurrence. A podiatrist who screens patients for signs of osteopenia on plain film radiographs he or she may have ordered for plantar fasciitis, may make a life-saving referral.

Implementing an FLS program can be difficult. Healthcare systems may be resistant due to their own financial constraints. They must be convinced that it will improve patient outcomes and eliminate unnecessary spending. The easiest and most powerful way of doing this is through audit (19). If the audit identifies a disproportionate use of resources or a complete lack of intervention, it proves to be cost-effective and installing a program is easily recommended. A multi-disciplinary team can then be established. Table 2 illustrates the steps in implementing such a program, and table 3 gives a general idea of who should be involved in the program. If a podiatrist is included in this program, each at-risk patient that presents will be evaluated and, if warranted, referred for additional screening. In the same way that orthopedic departments are utilizing this service to reduce fracture recurrence and create better patient outcomes, podiatrists can take advantage as well. Fracture liaison services offer a convenient and systematic tool that podiatrists can use to provide better care for their patients.

Table 2 Steps in implementation
1. Get the idea onto the provider's agenda
2. Create the service development team, headed by a champion
3. Secure access to post fracture patients
4. Estimate the workload and resources needed
5. Define the role of the coordinator
6. Engage with the local planning machinery
7. Start prospective data collection
8. Initiate the service and develop it iteratively

Table 2: Steps that should be taken in order to implement a fracture liaison service into a healthcare system.
Adapted from Marsh, et al. (2011)

Table 3 A typical multi-disciplinary working group for osteoporosis service development
1. Lead clinician/local champion
2. Secondary care clinicians—consultant orthopedic surgeon, consultant radiologist, consultant in care of the elderly medicine
3. Nurse specialists / nurse practitioners (if appointed)
4. Primary care clinicians
5. Patient representatives
6. Allied health professionals—physiotherapists
7. Public health consultants
8. Service manager
9. Community pharmacists
10. Prescribing management team member

Table 3: Multi-disciplinary team involved in administrating a fracture liaison service.
Adapted from Marsh, et al. (2011)

Discussion

This literature review was performed to investigate how fracture liaison services can impact a population, and how a podiatrist may prove to be a valuable asset in these programs. After a thorough assessment, it is recommended that healthcare systems

continue incorporating these programs as they have a positive impact on patient outcomes, as well as hospital and patient finances (12, 13). Patients who followed up with FLS had significantly lower risk of recurrent fractures (4.1 vs. 19.7%, P<0.01) when compared to those following up with primary care, and mortality was lowered by 35% (11, 12). These findings are of great interest but may also be due to better post-fracture care from a proactive multi-disciplinary team, as well as better patient adherence to treatment regimens in such an environment. Future studies with homogeneous design and longer follow up periods are required to better understand how a population can benefit from these services.

It is recommended that podiatric services be included in the next development of an FLS program. Podiatrists often obtain plain film radiographs to evaluate their patient's foot and ankle conditions and can easily pick up signs of osteopenia, whether they are treating a fracture or another pathology. A patient should not have to suffer a fragility fracture in order to bring to their physician's attention that they are suffering from osteoporosis. Earlier detection is possible. In the case of a foot or ankle fracture, it is important that the podiatrist treating the condition has access to the right resources and can make the appropriate referral for BMD testing and a full work up if indicated, in order to best serve his or her patient.

Conclusion

FLS programs have demonstrated the potential to significantly reduce post-fracture mortality, fracture recurrence rates, and associated healthcare costs (11-13). Studies have shown that the majority of patients presenting with a new fracture are not offered screening or treatment for osteoporosis (2). This is something that can be changed by improved multi-disciplinary care. As a podiatrist in today's growing population of patients with advanced age and other comorbidities, it is important to evaluate any underlying condition behind a fracture and consider further work-up and referral. Podiatrists may even be able to add another level of prevention by detecting at risk patients earlier than if they were to present to the emergency department with a fragility fracture. FLS offers a timely and cost-effective tool to screen at risk patients and offer them appropriate treatment. The incorporation of podiatry into these programs may result in better patient outcomes and reduced financial burden on healthcare systems.

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Calcific Uremic Arteriolopathy: Diagnosis and Treatment

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Abstract

Calciphylaxis is a very lethal disease process characterized by the calcification of small and medium sized vessels. It commonly manifests in the foot and ankle as painful, non-ulcerating subcutaneous plaques. As the prevalence of calciphylaxis is quite low, the pathogenesis is poorly understood and may be linked to overexpression of osteogenic markers. Imaging studies can be used to aid in diagnosis, however biopsy remains the gold standard. The purpose of this article is to be able to recognize and identify clinical manifestations and characteristics of calciphylaxis to aid in the diagnosis and treatment of this rare disease.

Introduction

Calciphylaxis is a rare and serious disease characterized by the calcification of small and medium sized vessels. While only affecting about 4 percent of the population, it is extremely lethal with a one year mortality rate around 46 percent (1,2,3). Calciphylaxis occurs in many populations but predominates in patients suffering from end stage renal disease (ESRD), although ESRD is not required to procure calciphylaxis (4,5). Calcific uremic arteriolopathy is a term used to describe a subset of calciphylaxis patients suffering from ESRD, however this article will not focus on this subpopulation. It is important for foot and ankle specialists to be aware of the disease process because it most commonly manifests in the foot and ankle. The purpose of this article is to be able to recognize and identify clinical manifestations and characteristics of calciphylaxis to aid in the diagnosis of this rare disease.

Pathophysiology

As the prevalence of calciphylaxis is quite low, the pathogenesis is poorly understood. There are many theories as to what causes calciphylaxis. Previously, it was thought that just abnormally high calcium-phosphorus products were causing calciphylaxis through calcification. However, recent research is discovering that this process is not a passive process but an active cellular process. Increased calcium-phosphorus levels lead to overexpression of osteogenic markers in human smooth muscle cells predisposing patients to calcification. Bone morphogenetic protein-4 (BMP-4), a prevalent marker among calciphylaxis lesions, is a powerful stimulator for bone repair and development and thought to encourage calcification of vessels (6). Calcification of vessels ultimately leads to ischemia of underlying tissue, due to arteriolar narrowing from endothelial damage.

Risk Factors

With the poorly understood mechanism of the disease coupled with low prevalence it is difficult to assess why particular patients get this disease. There are a number of risk factors that correlate with calciphylaxis including hyperphosphatemia, obesity, protein C and S deficiencies, hypercalcemia, ESRD, female, Caucasian, patients on dialysis, medications and diabetes mellitus. Warfarin alone has been shown to be a significant risk factor. In a study looking at 2234 dialysis patients, those who developed calciphylaxis were found to be on warfarin (7,8).

Clinical Manifestations and Diagnostic tools

Although rare, it is important to be able to recognize calciphylaxis clinically as it can be detrimental to a patient's life. Most common presenting symptoms include painful, non-ulcerating subcutaneous plaques, or necrosis that may progress to ischemic ulcers with eschars(9). A retrospective review found that 60% of patients had lesions on their legs, 23% on the abdomen and 9% on the buttock (10). Less commonly patients may present without necrotic skin lesions, and complain of painful proximal muscle weakness, likely from the underlying ischemic pathophysiology of the disease (11).

Figure 1. Skin necrosis of a patient with calciphylaxis. Adapted from UpToDate. (6)

Once clinically suspicious, a diagnosis of calciphylaxis is made based on a skin biopsy. A histological study of the necrotic lesions, demonstrated in figure 2, would show dermal arterial calcification, subintimal fibrosis, and thrombotic occlusion. Kossa and Alizarin red stains are necessary to identify microcalcifications of the tissue (12). If a biopsy is

performed, a 4 to 5 mm deep punch biopsy of the lateral margins is preferred over an excisional biopsy. Often times a biopsy can be contraindicated due to an active infection of the lesions which may lead to new lesions, bleeding, or ulcerations. Laboratory values can be used to raise clinical suspicion of the disease to warrant further work up. An increase in the calcium phosphate product, calcium, phosphorus, and parathyroid hormone levels can be indicative of the disease (13).

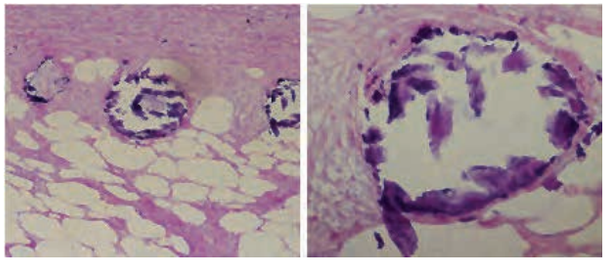

Figure 2. Microscopic imaging of characteristic arterial calcification in a patient with calciphylaxis adapted from UpToDate (20)

Imaging studies are not used to confirm calciphylaxis because they are often inconclusive in patients with strong clinical suspicion of calciphylaxis. However, a study conducted by Bonchak et.al found that in conjunction with laboratory and histopathological findings, radiographic findings could serve an important diagnostic role. Radiographic findings from 9 of 10 patients diagnosed with a skin biopsy were noted to have vascular calcifications in the underlying soft tissue, as seen in figure 3 (14). Thus, when diagnosing a patient with calciphylaxis it is important to utilize all diagnostic modalities in order to ensure an accurate diagnosis, and initiate the proper treatment.

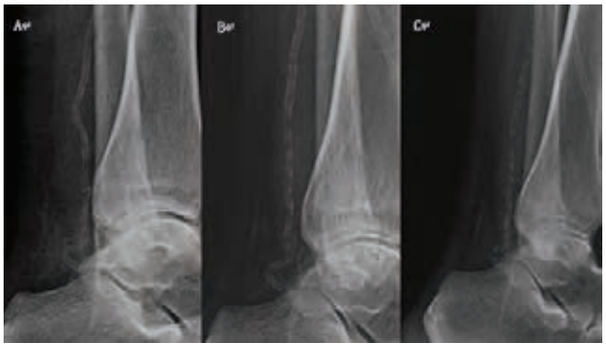

Figure 3. Radiographic image of the lower extremity demonstrating vascular calcifications in the underlying soft tissue adapted from AJKD (15).

Treatment

There is no definitive treatment or cure for calciphylaxis, however, a multi-intervention strategy has been reported help 6 of 7 patients completely recover (16,17). Sodium thiosulfate (STS), a chelating agent, is used invariably in helping treat calciphylaxis. STS is used across all patients including patients on hemodialysis and peritoneal dialysis (10,16,18,19). Local wound care and pain management are other important aspects of treatment. Nonsurgical debridement and wound care is the preferred method except if there is infected tissue, then surgical debridement is indicated. As the pain is quite severe in these patients, opiates are generally used to make the patients comfortable (1). Treating abnormal levels of calcium, phosphorus and parathyroid hormone are important as well. It is important to use non calcium based phosphate binders such as Sevelamer Carbonate or Lanthanum Carbonate as calcium-based binders will increase rate of vascular calcification (20,21,22). Cinacalcet as opposed to vitamin D analogs should be used in the case of hyperparathyroidism as the former decreases both PTH and calcium (23,24,25). As mentioned above warfarin is a significant risk in patients with calciphylaxis and should be assessed if the risks outweigh the benefits for discontinuing it. Hyperbaric oxygen therapy has shown promising results with 58 percent of 46 patients improving and the majority completely healing (26).

Conclusion

It is very important to not overlook the symptoms associated with calciphylaxis because it may delay treatment and ultimately lead to death. Calciphylaxis is more commonly found in patients with hyperphosphatemia, obesity, protein C & S deficiencies, female, Caucasian, patients on dialysis, medications and diabetes. The disease exhibits painful subcutaneous plaques which can lead to eschars and ulcerations. Although biopsy is currently used to diagnose calciphylaxis, it is often contraindicated due to infected lesions, thus laboratory and imaging modalities can be used in conjunction to support this diagnosis. Treatment regiments are a case by case basis with some studies showing extremely promising results. With emerging research and physician education calciphylaxis will become a more manageable disease with a better prognosis.

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Low Dislocation Rate in High-Risk Patients Observed Using Cobalt Chrome and Dual Mobility Heads

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Abstract

According to recent Medicare data, dislocation of total hip arthroplasty (THA) is the leading cause of failure that results in revision. Dislocation also accounts for up to 35% of failed hip revisions. Basic science equations for drop-out distance and impingement free range of motion dictate that larger heads are more stable. The consensus of orthopedic literature shows lower dislocation rates with increasing head size. The lowest dislocation rates are observed using large cobalt chrome heads at anatomic size. THA with anatomic head size using a dual mobility head design was studied to determine the dislocation rate in a cohort that included high-risk patients. It is hypothesized that in a cohort that includes high-risk patients, the low dislocation rate seen in primary THA with cobalt chrome heads will be mirrored in those who receive dual mobility heads. This study evaluated 367 patients (425 primary THAs) who had THA performed by a single surgeon. Each patient had a total hip arthroplasty using anatomic head size defined by head size 6mm smaller than the outer diameter of the cup. A cobalt chromium head was used in 322 patients (375 hips). A dual mobility head design was used in 45 patients (50 hips). Every operation was performed using a minimally invasive posterior approach and computer navigation for cup position and limb length. The rapid recovery postoperative protocol eliminated traditional hip precautions. All dislocations and revisions for dislocation were reported. Failure of the hip replacement operation was defined by revision surgery, radiographic failure, or any hip rated as poor by patient self-assessment. The cohort that received large cobalt chromium heads had a dislocation rate of 1.2% and the rate of revision for dislocation was 0.6%. This cohort included 32% high-risk patients. There were no dislocations or revisions in the 45 patients (50 hips) who had a dual mobility head design. This cohort included 18% high-risk patients. The low dislocation rate reported in this high-risk patient population is the result of two prosthetic designs that have the greatest drop out distance and impingement free range of motion available on the market today. This design is equally effective in preventing dislocation using both cobalt chromium and dual mobility heads.

Introduction:

Total hip arthroplasty is one of the most successful orthopedic surgeries performed today. It is a procedure that helps patients with chronic pain return to a pain-free lifestyle with improved quality. Although most THAs are very successful, complications may still arise with one of the most devastating of those being a dislocation. Dislocation rates after a primary THA are usually 2-5% depending on the institution. Dislocation after a primary THA can lead to subsequent reduction, another operation, re-dislocation and even death in some cases. This is not to mention the financial burden placed on the patients and the health care system with the cost of revision due to dislocation being cited as high as 150% (1). According to recent Medicare data, dislocation of total hip arthroplasty (THA) is the leading cause of failure that leads to revision. Dislocation also accounts for up to 35% of failed hip revisions. Primary risk factors for dislocation after a primary THA include patient age, surgical approach, component malposition, and design of the prosthesis.

Basic science equations for drop-out distance and impingement free range of motion dictate that larger heads are more stable (Figure 1). Based on this math, it is justified to assume that the placement of a femoral head implant should be the same size as the femoral head that was removed from the patient. Thus far, the results in orthopedic literature regarding this topic has been mixed with results showing either lower dislocation rates with increasing head size or no difference in dislocation rate. As seen in Table 2, Goel et al found that with increased use of femoral heads greater than 32mm, six-month dislocation rates decreased. At the Mayo Clinic in 2005, it was also found that a larger head size resulted in lower dislocation rates (3). In orthopedics today, however, a 32mm cup is considered large where the average femoral head size is closer to 42mm for females and 49mm for males (4). The concern with using larger head sizes has been the production of polyethylene wear debris and osteolysis which could lead to revision (5). There are also many implants on the market which are designed to reduce dislocation rates. Theoretically the design of a dual mobility cup should minimize prosthetic cup impingement and increase range of motion before dislocation (1). The dual mobility design consists of a metallic shell with a mobile insert (Figure 2). This design was introduced in 1975 with increased use in the late 1990s with the main reservation indicated for osteolysis and cup loosening. Although the metal-on-polyethylene design has become increasingly popular, another option for surgeons is to use metal-on-metal (MoM) implants. However, less and less surgeons

are opting to use MoM implants because of the possibility of debris, such as cobalt or chromium ions, being released with implant wear that can cause soft tissue changes (6). In this study of hip replacement patients, it is expected that anatomic head size is the main factor preventing post-operative dislocation to the point that even bearing surface does not make a difference.

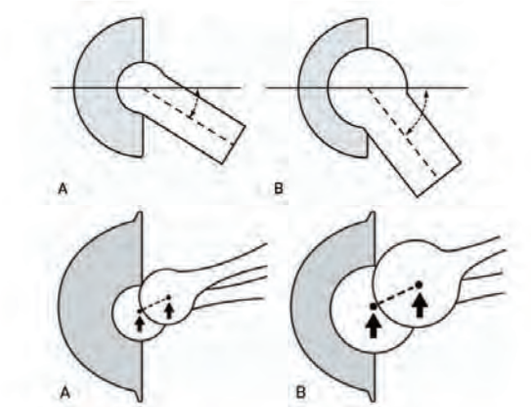

Figure 1. Large femoral heads provide a larger dropout distance and larger impingement free range of motion that a small femoral head. Adapted from Hip & Pelvis. Cho et al 2016.

Figure 2. Cobalt chromium cup design (left) and dual mobility cup (right). Adapted from Earl's View.

Table 1: The six-month dislocation rate has decreased from 1997 to 2011 with the increasing use of femoral heads larger than 32mm. Adapted from The Journal of Arthroplasty. Goel et al 2014.

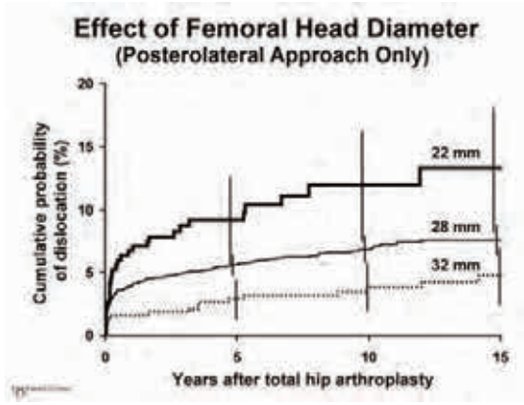

Table 2: The probability of dislocation decreases with increasing femoral head diameter. Adapted from the Journal of Bone and Joint Surgery. Berry et al 2005.

Methods and Materials:

This was a retrospective cohort study. The surgeon has been using femoral head implants near anatomic size for many years, and this study is simply a snapshot of one year's worth of patients. During this year both cobalt chromium and dual mobility cups were utilized. This study cohort includes 367 patients (425 primary THAs) who had THA by a single surgeon in 2014. Each patient had a THA using anatomic head size defined by a head size 6mm smaller than the outer diameter of the cup. A cobalt chromium head was used in 322 patients (375 hips). A dual mobility head design was used in 45 patients (50 hips).

Every operation was performed using a minimally invasive posterior approach and computer navigation for cup position and limb length. The rapid recovery postoperative protocol which includes the initiation of mobilization and physical therapy as soon as the patient was implemented for all patients which eliminated traditional hip precautions. These precautions include crossing of the legs or ankles while sitting, standing, or lying down, avoiding flexion at the hips past 90 degrees, avoiding getting into a car from a curb, and sleeping on the side of the hip that received the operation.

The patients were qualified as high risk if they had at least any one of the following: cognitive impairment/history of drug abuse, gluteus medius impairment, damaged greater trochanter or pelvis, previous surgery, and morbid obesity. In the patients who received the cobalt chrome implant, 31.8% were considered high-risk, while 17.7% of those who received the dual mobility design were considered high risk.

The patients have been routinely followed for one to two years. All dislocations and revisions for dislocation were reported with failure of the hip replacement operation being defined by revision surgery, radiographic failure as seen on chart review, or any hip rated as poor by patient self-assessment during follow up appointments.

Results:
Failure of THA was defined by dislocation, revision for any reason, poor patient assessment of the surgery, or radiographic evidence of failure. In the cohort where a cobalt chromium head was placed, four of the 375 hips dislocated (1.2%) and two (0.6%) were revised. In the group with dual mobility design, there were zero dislocations and none of the patients underwent subsequent revision.

Discussion:
In this study, the effect of femoral head diameter on the risk of dislocation was evaluated while considering if the bearing material of the implanted cup made a difference. High-risk patients were also taken into consideration since they are more likely to dislocate post-THA total hip arthroplasty. Overall, it was found that there were zero dislocations or revisions in the cohort of patients with the dual mobility design and only 1.2% of patients that experienced dislocation in the cohort of patients with the cobalt chromium design. The dislocation rates for both groups were below the national average for dislocation after THA. Current literature proposes that more than half of the dislocations occur within the first three months following surgery with more than three quarters taking place within one year. Therefore, it can be expected that the dislocation and revision rates reported now are unlikely to increase significantly with time. This study further confirms in conjunction with other researchers that larger femoral head sizes reduce dislocation rates. This study further expanded on that notion by showing that the anatomic head size dislocation rates are low if not completely eliminated even with differing bearing surfaces and with a cohort that includes high-risk patients.

The major weakness of the study was the relatively small number of subjects. The strength of this study was the inclusion of patients considered high risk. In future experiments, these results could be combined with patient data from earlier years within the surgeon's practice to evaluate if the results vary with a larger patient population. The data should be expounded to consider gender and age matching as well as matching for an equal number of head designs used for a prospective study. Other implant designs should be studied as well along with continued studies on the dual mobility design as the research regarding its efficacy is still limited.

Conclusion:
In conclusion, Medicare data has shown that dislocation after a primary total hip arthroplasty is the number one cause of failure leading to revision. A dislocation after a THA is a safety issue for patients, a time burden, and a financial burden for all parties involved. With this knowledge, we have set out to build on the existing fund of knowledge within orthopedic research to solve the problem of dislocation.

The average anatomic femoral head size in a female is around 42mm while in it a male it is 49mm. However, for many years within the orthopedic joint replacement specialty, it is commonplace to replace heads with implants of 22mm, 28mm, 32mm in size. The placement of larger heads for a total hip arthroplasty has been considered by some a risk due to the debris that can be produced and the wear of the implant, but the number one feared complication of a THA is dislocation. Multiple studies including this one have shown that the placement of femoral heads closer to anatomic size reduces dislocation rates compared to the use of smaller heads. Furthermore, this study showed in a small cohort that if a large femoral head is utilized, dislocation rates can be reduced even in patients with a higher risk of dislocation, regardless of the bearing surface of the implant.

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Case Report: Bizarre Parosteal Osteochondromatous Proliferation, otherwise known as Nora's Lesion

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Abstract

Bizarre Parosteal Osteochondromatous Proliferation, also known as Nora's Lesion, is a rare osseous lesion that continues to remain frequently ill-defined, misdiagnosed, and mistreated. The clinical presentation can include mildly painful deformity which commonly affects tubular bones of the hands and feet, although it has been reported in the skull and mandible as well. Nora's lesion often occurs in middle-aged patients and may be a result of repetitive trauma. Nora's lesion has been frequently misdiagnosed as an osteochondroma; therefore, it is important to differentiate between the two as the mainstay of treatment can differ.

Introduction

Nora's lesion or "Bizarre Parosteal Osteochondromatous Proliferation" (BPOP) is a rare osseous lesion first described in a case report by Nora et al in 1983 on 35 patients. Due to its rare presentation and therefore scarcity of reports throughout literature, it's pathology remains ill-defined and as a result, it is frequently misdiagnosed and mistreated.

Nora's lesion is most commonly found in patients in their 3rd and 4th decade of life and it affects both genders equally. Trauma is purported to play a role in the formation of the lesion; however, this is not always confirmed. The clinical presentation can include mildly painful deformity more commonly affecting the long tubular bones of the hands and feet (i.e.: metatarsals, phalanges) and rarely the mandible.

The etiology of Nora's lesion remains unknown. This condition affects male and female patients equally and is most common in the third or fourth decade of life, but can occur in patients at all ages. This condition has a predilection for the hands, as they are affected four times more often than the feet. Nora's lesions have been reported mostly in the long bones but are also documented in the skull, mandible and sesamoids (1). Predisposing factors include an association with trauma (2).

Case Report

A 30-year-old previously healthy female patient presented with an enlarging mass localized to the left second digit for approximately 1 year. The patient had an unremarkable medical history. She claimed her symptoms started after she stubbed her toe twice over a short period of time. She initially presented to an outside hospital where radiographs were taken. The patient was then diagnosed with a fracture of the proximal phalanx. She was treated conservatively in a postoperative shoe to allow the fracture to heal. However, the patient continued to have toe pain. She decided to seek a second opinion at Olive View Medical Center podiatry clinic, where she presented after stubbing her toe a third time.

On physical exam, the second digit was grossly enlarged at the base of the proximal phalanx of the second digit with a large firm palpable bony mass that extended into the second interspace. There were no associated open lesions or drainage. No erythema, hyperpigmentation, or warmth noted to left second digit. The prominence was mildly painful on palpation.

The interpretation of the patient's radiographs revealed a possible bizarre parosteal osteochondromatous proliferation, also known as a Nora's Lesion. Most benign bone tumors are recognizable from characteristic features that allow diagnosis with plain radiographs. Generally, it is considered unnecessary to pursue advanced imaging and invasive diagnostic studies on benign lesions.

However, given the patient's history of repetitive trauma and continued pain, more advanced diagnostic imaging techniques were necessary. An MRI exhibited an exophytic mass extending off the lateral aspect of the proximal phalanx of the second digit with continuity between the medullary cavity of the phalanx and the mass. The mass had characteristics most consistent with a pedunculated osteochondroma.

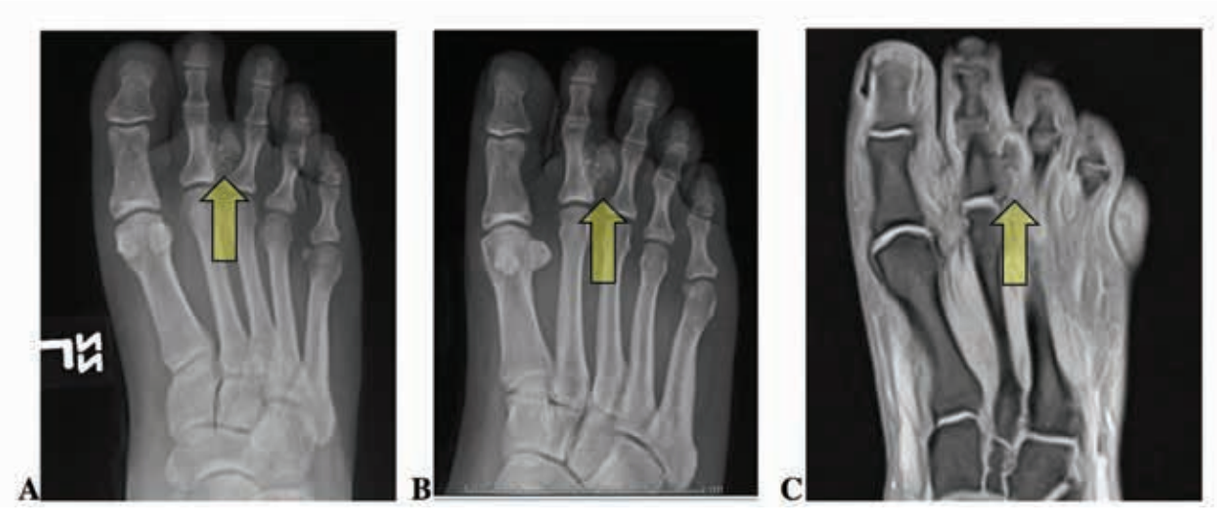

Figure 1 (A,B): Radiographs of the patient's left foot showing bizarre parosteal osteochondromatous proliferation arising from the lateral cortex of the proximal phalanx of the left second toe. (C) T2 weighted MRI of left foot showing a bony, exophytic mass extending off the lateral aspect of the proximal phalanx of the second toe. There is continuity between the medullary cavity of the phalanx and the mass, which is often more consistent with an osteochondroma.

The patient underwent an excisional biopsy of the osseous tumor, and the incision was closed without complications.

Figure 2: Intra-operative image of Nora's lesion excision

The lesion was sent to pathology for histological analysis. The histopathology report showed lamellar bone with areas of enchondral ossification and fibrous tissue. The diagnosis was initially read as osteochondroma. However, given that the intraoperative features and radiographs were not typical for osteochondroma, the pathology team was re-consulted for additional review. Based on clinical and radiographic findings, along with the histopathology report, it was concluded that the tumor was consistent with a Nora's lesion.

The postoperative course consisted of non-weight bearing in a posterior splint and crutches. Sutures were removed at two weeks without incident and the patient was advised to begin weight bearing as tolerated in a CAM boot.

Histology:

In this case, the initial diagnosis was interpreted as osteochondroma, and as aforementioned this is a common misdiagnosis of Nora's lesions. This often occurs due to commonalities between the two conditions including a well-circumscribed mass of bone with overlying cartilaginous cap. Nora's lesion can be differentiated from osteochondroma histologically in that osteochondroma features strictly hyaline cartilage along the margins of the cartilage cap, while Nora's lesion may contain reactive cartilage as well (3).

Typical histological findings in Nora's lesions include the bizarre enlargement of chondrocytes in cartilaginous tissue, proliferation of spindle cells and hypercellularity of cartilage (4). The superficial cartilage cap features highly cellular fibrocartilaginous tissue (1). Furthermore, histological evaluation also demonstrates increased cartilage cellularity, new osseous calcification, and fibrous vascular tissue loosely arranged around trabeculae (1,3,5). Cells can be variable in size with mild chondrocyte changes including binucleation and nuclear enlargement (1,3). Spindle-shaped or stellate cells and granulation-like tissue can be observed in random arrangements throughout the cartilage (1,3,4,6). The cells present in BPOP do not demonstrate atypia or abnormal mitoses (1). Abundant fibrocartilage and myxoid tissue may be observed as

well. Increased endochondral ossification with irregular organization of bone trabeculae stains highly basophilic with hematoxylin and eosin stain, eliciting the common name “blue bone”, which is indicative of incomplete endochondral ossification (1,3,6).

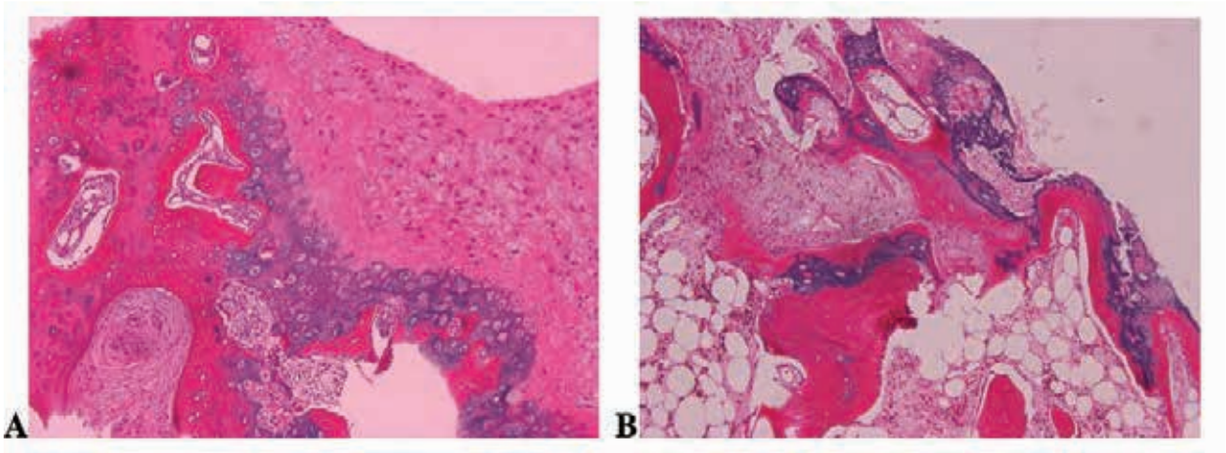

Figure 3 (A, B): Histology report described lamellar bone with areas of endochondral ossification and fibrous tissue

Discussion

Nora’s Lesion is frequently misdiagnosed as osteochondroma, as was initially suspected in this case. Therefore, it is important to differentiate between the two as the mainstay of treatment differs. BPOP are reported to have high recurrence rates (20-55%), which differs from that of osteochondroma, which has a recurrence rate of 5.8% (7). This suggests alternate pathophysiologies between BPOP and osteochondroma. A study pertaining to gene expression comparing BPOP and osteochondroma showed that there is differential expression of the TGF-beta receptor, BMP and Wnt signaling pathways, in addition to differences in growth factors and extracellular matrix components (8).

Imaging plays an important role in distinguishing Nora’s lesion from more common bone lesions. There are key differences between BPOP and osteochondroma when assessed through imaging modalities including MRI and CT scan. An osteochondroma has a central region of continuity with the underlying bone marrow, whereas a Nora’s lesion does not - it arises directly from the cortical surface of the underlying bone (8,9).

Treatment:

Conservative treatment in general is considered inadequate. Excisional biopsy is typically indicated, particularly when associated with mild pain or decrease in function. During surgical excision, pseudocapsule and periosteal tissue must be adequately removed (5). En bloc resection is recommended with subsequent decortication in order to decrease the chances of recurrence (4).

Conclusion:

This case is a classic example of a Nora’s lesion diagnosis. As is common with this condition, the patient was initially suspected to have an osteochondroma due to physical examination and radiographic evaluation. MRI and histologic findings aided in the correct diagnosis, with findings most consistent with BPOP. Excisional biopsy was performed in this patient, as is recommended as the standard of care for a Nora’s lesion. Although Nora’s lesion is uncommon, it is important for physicians to be able to recognize this pathology in clinical practice and determine appropriate treatment.

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Case Study: Presentation of Chilblains in a Young Female Patient

Mohammad Waqas Choudhery, OMS -2

Abstract

Chilblains is an acrally located cutaneous lesion that occurs with exposure to cold temperatures. Chilblains is classified into primary and secondary forms. The primary form cannot be clinically distinguished from the secondary form; however, it is not associated with any underlying conditions. The secondary form is associated with underlying conditions including cryopathies and lupus erythematosus. Histopathology does not aid in distinguishing between the two forms of Chilblains. This article will raise awareness of Chilblains by presenting an unusual case seen in a young female patient.

Introduction

Chilblains or Pernio is a skin disorder that results from cold exposure. The word "chilblains" is derived from the Old English words "chill" and "blegen" (sore). It is a localized cutaneous inflammatory lesion that may be erythematous or purplish in color (1). Ulceration and blisters may develop with symptoms of burning or pruritus.

Chilblains primarily occurs in young women between the ages of 15 and 30 years, but can occur in other age groups (2). Factors that may predispose to chilblains include tight clothing, poor circulation, female gender, exposure to cold, anorexia nervosa, low body mass index, systemic lupus erythematosus, and rheumatoid arthritis (3). Chilblains may be primary (idiopathic) or secondary to an underlying condition, such as cryopathies and lupus erythematosus. Acute chilblains usually presents several hours after cold exposure and resolves within a few days to weeks, whereas chronic cases last longer and are associated with repeated cold exposure. Typical lesion locations include the dorsal site of distal phalanges of the fingers and toes. However, the lesions can also appear on the nose and ears.

The differential diagnoses for chilblains includes Raynaud's phenomenon, vasculitis, SLE, Aicardi-Goutières syndrome, and emboli. These include examples of disorders that may be mistaken for Chilblains. They present similarly and have a predilection for acral areas.

Case Presentation

A 15-year-old Hispanic female, active in soccer, presented in late February of 2011 reporting that one month prior she suddenly developed itching in the toes of both feet. This was followed by purple/black discoloration of the toes (Figure 1). When compared with other classic presentations of Chilblains, the appearance of the toes was quite similar (Figure 2). There were multiple erythematous papules that occurred gradually over the course of two weeks on both feet. She denied any trauma or pain in her toes. She was a competitive soccer player and had been playing in the cold rain for many consecutive days prior to the development of these symptoms. The patient's medical history included exercise-induced asthma and chronic headaches. She was using Albuterol and Amitriptyline 30 mg daily for her headaches.

The patient's toes were cold to the touch and the purple skin at the base of the hallux toenails were not tender to palpation. There was no presence of ulceration or blisters.

The results of her laboratory findings were normal for CBC, ANA, CH50, and cryoglobulins. A cold agglutinins titer was elevated (1:80). Patient refused a skin biopsy as it would interfere with her soccer schedule. The patient had many risk factors for a classic Chilblains case.

Figure 1 - Adapted from (Pediatrics Consultant Live)

Figure 2 - Adapted from (Foot & Ankle Specialists of the Mid-Atlantic)

Histopathology

In Chilblains, histologic sections of the dermis demonstrate superficial and deep perivascular lymphocytic infiltrate (Figure 3). There may also be an increased number of eosinophils in the infiltrate of early lesions (Figure 4).

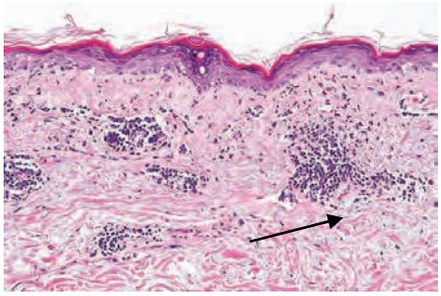

Figure 3 - Adapted from (Luciano Schiazza MD)

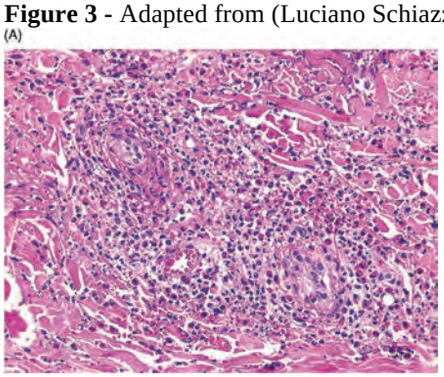

Figure 4 - Adapted from (DermNet NZ)

Discussion

Chilblains presents as cold-induced inflammatory cutaneous lesions. It is commonly mistaken as vasculitis or an embolic event. The exact pathophysiology of Chilblains is poorly understood, but is related to patient and environmental factors. The presentation is described as a vasculopathy leading to microvascular injury. Patients with Chilblains have prolonged exposure to the cold causing cold-induced vasoconstriction and subsequent hypoxemia and inflammatory response (4). This is an abnormal vascular response to cold exposure and may be a possible cause of formation of skin lesions. Idiopathic chilblains can be distinguished from secondary chilblains by the presence of vessel wall and dermal edema (5). Idiopathic chilblains is typically reported during the cold season of winter to early spring, but can also arise due to cold exposure. The lesions that manifest after cold exposure are erythematous or purple lesions that may be associated with pruritus. Chilblains lesions often present bilaterally and symmetrically on hands or feet (4). The results of laboratory findings of idiopathic chilblains are usually normal. The laboratory findings in this patient's case were normal, other than an elevated cold agglutinins titer (1:80).

Chilblain lesions can be associated with underlying conditions, which is why it is important to use diagnostic studies to screen patients with clinical and histologic features. Idiopathic Chilblains has no characteristic histopathologic features that confirm the diagnosis. It is therefore a diagnosis of exclusion, in which a skin biopsy can be used to exclude the presence of other underlying conditions.

The diagnosis of Chilblains is made clinically based on the appearance of erythematous skin lesions following cold exposure. Skin biopsies and laboratory investigations can be used to rule out other medical conditions.

The treatment of chilblains involves both conservative and pharmacological measures. Conservative treatment involves keeping the affected areas warm, avoiding rapid temperature changes, and smoking cessation (8). Pharmacological measures include the use of Nifedipine, a calcium channel blocker that can help facilitate healing in some patients due to its vasodilating properties (6). By inhibiting calcium influx through voltage-dependent channels, vascular smooth muscle intracellular calcium stores are limited and thus depend on extracellular calcium influx for contraction (7). Nifedipine inhibits this mechanism and subsequently produces arterial vasodilation and decreased peripheral vascular resistance. In Chilblains there are cold-induced vasospasms, which is why Nifedipine proves to be effective in order to counteract the vasoconstriction.

Conclusion

The patient in this case was diagnosed with idiopathic Chilblains. The patient was instructed to avoid the cold and keep her feet warm and dry. Following this conservative treatment, the lesions greatly improved. The patient never followed up since her initial presentation as the condition never reoccurred due to the precautions she took in cold weather. Chilblains can affect any patient demographic, especially patients with poor circulation to their extremities. However, with timely diagnosis and appropriate care, the condition is manageable.

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Case Study: Nursing Self Care Plan for an Ankle Fracture

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Abstract

Ankle fractures are very common, and will require either non-surgical or surgical treatment. However, many patients mistake a fractured ankle for a sprained or twisted ankle, which can cause serious consequences if the ankle heals improperly. The literature related to fractured ankle self-care plans is rare or unclear. A case study is presented with data obtained through experiences related by the patient, patient's medical records, health care professionals' reports, and literature reviews of associated nursing knowledge. Specific nursing interventions include education regarding diet and supplement administration, and monitoring home exercises as recommended by the inter-professional team made up of podiatrists, orthopedic surgeons, and physical therapists. The patient's motivation can be increased to seek information to carry out self-care behaviors to improve well-being during the healing process through collaborative nursing self-care plans involving the patient's preferences, needs, and cultural values.

Introduction

Patient-centered nursing care may help individuals gain the necessary knowledge to make informed health decisions. Identifying practices that optimize healing and function would help nurses educate and promote patient's independence in overcoming the challenges of the activities of daily living (ADLs). Creating positive outcomes and well-being is important. This case study of a patient who suffered an ankle fracture will enable nurses and other health care professionals to see how concepts from nutrition, physical activities, and cultural values into the health self-care plan can enhance patient's life during the process of ankle healing. Several of the principles can be transferred to a variety of other situations which make the following information applicable.

Case Description

A 58- year-old Chinese female was admitted to the Emergency Department (ED) due to a broken left ankle from an unintentional fall. The chief complaint was pain in the left ankle and the inability to stand on the leg. She had pre-hypertension along with a family history of hypertension and was taking valsartan (160 mg) and hydrochlorothiazide (12.5 mg) P.O. QD. She had an allergy to diclofenac, as evidenced by an itchy red rash. She was alert and oriented. Vital signs included a temperature of 99^0 Fahrenheit, heart rate of 80 beats per minute, respiratory rate of 25 breaths per minute, blood pressure of 135/88 mmHg, and pain rated 9/10, which was characterized as sharp and throbbing. She lived alone and had never had a fracture previously. She had been working part-time in the home care field as a Certified Nursing Assistant (CNA). After diagnostic x-rays and observation, she was referred to an outpatient orthopedic practice.

Two different orthopedic surgeons recommended an open reduction internal fixation using a metal plate and screws. However, the patient refused to accept that surgery was the only option because she was afraid her health insurance would not cover the procedure and she could not afford to pay for it. Patient stated she looked at her leg and saw a large amount of swelling, two "blood blisters" and bruising down to the toes (Figure 1). Her ankle was extremely tender to touch. She thought surgery would cause more injury. She received no explanations related to the surgery in words she could understand. Due to the respect given to those in authority, which is strong in Chinese culture, she did not ask further questions. External compression with a cast was applied and she went home with immobilization for two months. No surgery was scheduled. Once the leg was casted, the patient no longer complained of pain.

Figure 1. Left ankle bruise and edema, 1 week after the injury

A few days later, she was still worried she might not have made the right decision by refusing surgery. Talking to several friends who have had fractured extremities previously, she was told it would take longer to heal without surgery. This reinforced her previous decision because time was not an issue and x-rays did not show misalignment. Two months later, radiographs showed the ankle bones were in good alignment and forming a bony callus (Figure 2). She practiced physical therapies every day because the cast

was removed. In addition to bed exercises, she also did manual massages from the ankle area towards the heart. This skill is derived from Chinese acupressure and improves circulation. After teaching, she did it effectively. She learned Tai Chi exercises and took a brisk walk 30 minutes after dinner daily. The patient followed a healthy diet as well. At 11 months after the injury, her left ankle demonstrated appropriate alignment and was completely healed (Figure 3). Therefore, she determined that taking care of herself at home without surgery was the correct decision for her.

Figure 2. Left ankle x-ray with Mortise view, two months after the injury occurred. The ankle bones in alignment (Talo-crural angle is normally between 75 and 87 degrees) with formation of bony callus.

Figure 3. Left ankle x-rays taken 11 months after the injury. Appropriate alignment and fracture deformity of the left fibula has healed (red arrowhead).

Literature shows that manual therapy on the affected ankle and soft tissues combined with proprioceptive and strengthening exercises greatly improve the treatment of pain and ankle injuries (1). Tai Chi is also a good example for long-term exercise on the joints, which is focused on coordination and balance (2). In addition to a healthy diet, supplementation with calcium and vitamin D_3 combination are helpful for bone healing (3).

Challenges of ADLs Associated with Fractured Ankle

Since patients with fractures lose the ability of normal mobile function. A deliberate action or behavior must be developed to keep the patient physically and psychologically healthy at home and accomplish daily activities successfully and safely. Before engaging ADLs, these patients have to investigate different options to make wise decisions. Nurses provide the information and teaching to motivate the patient care for themselves and achieve the best health outcomes. Medical professionals, such as nurses, help increase motivation for appropriate action through incorporating principles from patient's own culture, personal preferences, and values to create care plans.

The major problem these patients will encounter is decreased physical mobility. To adapt to this physical immobility, teaching should include elevation of ankle above the level of the heart while sitting or lying in bed to decrease edema and increase circulation (4) improving healing; instruct regarding non-weight bearing until cast is removed (5,6) and make sure the patient has been taught proper use of crutches because fractured ankles require approximately 6 to 8 weeks for soft tissues to heal; teach appropriate gastrocnemius stretching with joint mobilization or range of motion exercises to prevent stiffness and enhance stability (7); teach about foods rich in calcium, protein, and vitamin D_3 to enhance tissue and bone repair (3). In the Chinese culture, common foods which are high in calcium, protein, and vitamin D_3 are fried baby fish with peanuts, salmon head soup, baby fish yam leaf soup, simmered pig's feet, tofu, broccoli, kale salad, and fortified soy milk.

Regular exercise such as a brisk walk is key to the maintenance of stretching and strengthening muscles after immobilization (12). It also prevents weight gain and avoids increasing the burden on the joints. This patient's doctor recommended 500 mg calcium and 10,000 IU vitamin D_3 per day for 8 weeks as well as exposure to the sunlight for 15 minutes daily to help accelerate and fortify soft callus formation. Many people tend to neglect these common and easy interventions because fractured ankles are not life-threatening.

Another related problem is safety. An increased risk of falling may be related to the home environment which may include stairs, liquid spills, rugs, dim lighting, or slippery tiles. After assessment of fall risk at home, nursing education should focus on demonstration of safe cooking, showering, and dressing activities of daily living if the patient lives alone (8).

The patient with fractured ankle can be taught to use a bath chair, walker, and toilet for tripod balance to accomplish the ADLs; discussion of home hazards and instruction about anti-fall protective devices such as installing grab bars in the bathroom, which can reduce fall hazards (9). Encourage the patient to avoid area rugs, pets, and keep a cell phone in their pocket at all times; instruction to dangle prior to getting up slowly and verbalize proper medication usage, supplements, and side effects. Within two minutes of changing position from supine to standing, systolic blood pressure drops ≥20mm Hg or diastolic blood pressure drops ≥10mm Hg, which is associated with increased risk of falls (10). Orthostatic hypotension is a risk due to anti-hypertensive medications and diuretics, which can also cause dizziness. The patient should be told to take valsartan every day and avoid drug-drug interaction such as NSAIDs when she had a pain. She should take Tylenol instead of Advil.

Implications for Nursing Practice

Ankle fractures are the most common injury of the lower extremities in all age groups, particularly post-menopausal women with osteoporosis by a reduction in bone mineral density and leading to a high risk of fractures by falls (11). A fracture occurs when the ankle suddenly rolls inward or outward. Soft tissues are damaged and inflammation occurs rapidly. Patients tend to mistake a fractured ankle for a sprain or twist. This lack of knowledge may delay care, prolong healing, and cause poor outcomes. Nonpharmacological treatments can help improve patient's outcome when used properly.

Nurses play a vital role in providing affordable and high-quality home care to meet the needs of patients with a fracture. Nursing collaboration has the potential to improve quality and access to home care for individuals, especially those who live alone. Many costs associated with fractured ankles are not covered by health insurance, such as lost wages due to inability to work, transportation costs, food delivery, continuing physical therapy, supplements, and alternative medicine. All increase out-of-pocket cost affecting individuals and families (13). Early functional return can get these patients back to work and reduce overall costs.

Conclusion

The home care plan focused on patient's own preferences, values, and needs. In this case study, nursing care plans included patient teaching based upon her needs, motivating, and enabling her to do self-care. Cultural factors, such as the relationship between doctors and the patient and alternative therapies such as massage and Tai Chi were considered. Inter-professional collaboration could include the nurse, pharmacist, dietitian, physical therapist, and doctor. Safety was a major factor incorporated in the nursing care plans. A crucial role of the nurse is patient education but the entire inter-professional team is needed to help patients gain all the necessary knowledge to carry out self-care solving daily problems and improving quality of life in a cost-effective manner.

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Case Report: An Orthotic Approach to Childhood Cerebral Palsy Gait

Kevin N. Nguyen, MS-3 and Trevor Takeyama, MS-3

Abstract

Cerebral Palsy is a non-progressive upper motor neuron (UMN) disorder that classically presents with spasticity, dystonia, or athetosis. The etiologic events are thought to occur in the early phases of fetal and infant cerebral development. In the lower extremity, the disorder causes muscle contractures and a resultant "scissoring" gait. This case report presents a 6-year-old male with cerebral palsy complaining of right foot pain, weakness, and uncoordinated gait. The patient was casted for custom orthotics and instructed to continue physical and occupational therapy. At 1-month follow-up, the patient had a significant improvement in gait, reduction in pain, and increase in stability and comfort during activity. Due to the absence of contractures, UMN deficits and the ability of orthotics to help regain a normal gait, a diagnosis of cerebral palsy is less likely.

Introduction

Cerebral Palsy (CP) is a permanent non-progressive UMN disability that is thought to occur in individuals with perinatal insult. These can be due to a low birth weight, chorioamnionitis, neonatal encephalopathy, or maternal respiratory tract or genitourinary infections. Classically, a patient will present with muscle spasticity, dystonia, hypotonia, or athetosis. These motor delays and abnormalities are the first and most apparent signs of a developmental disorder. CP affects roughly 3 in every 1000 births (1,2). Spastic CP is the most common form of this disorder which encompasses 75% of all cases. This form of CP involves contractures of the lower extremity adductors, gastrocnemius, and semitendinosus muscles leading to a characteristic "scissoring" gait (3). This "scissoring" type of gait is due to the ankle equinus secondary to contracted gastrocnemius, adducted leg from contracted adductors, and flexed knee from the contracted semitendinosus.

Previous studies have shown that there are conservative treatments available to aid in the correction of these muscle contractures. Such treatments include passive stretching, physical and occupational therapy, and orthotics (2,4). These non-operative active therapies aid to relax and lengthen tight muscles and tendons, whereas orthotics aim to correct any biomechanical deformities originating from the foot. By changing the way these soft tissue structures behave, it is possible to correct an abnormal gait associated with CP.

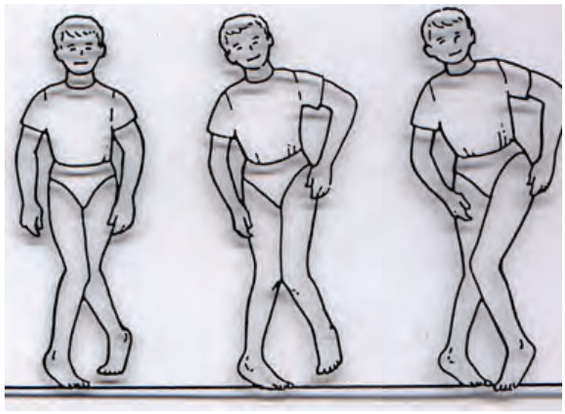

Figure 1. Scissoring gait. Flexed knees due to contracted gastrocnemius. Adducted legs due to contracted adductor muscles. Ankle equinus bringing foot plantigrade. Adapted from (HSP Research Foundation).

Case Report

History of Present Illness

The patient was seen over a 9-month period starting from March 2017 to December 2017. At the initial encounter, the patient was a 6-year-old male complaining of mild 4/10 pain on the inside of his right foot, weakness, and uncoordinated gait. He had associated stiffness in the morning and difficulty getting out of bed, which required assistance. The pain occurred with different shoes, but the patient admitted that a new pair of shoes alleviated some of the pain. He was able to participate in baseball with minimal pain to his feet but admitted to having difficulty riding his bicycle. The patient was diagnosed with CP by a neurologist at birth when his parents noticed a delay in crawling, walking, and mobility challenges on his right side. The mobility issue and stiffness of his right side caused him to have some problems writing. The patient and his mother admitted he had a lack of coordination during gait and bicycle riding, though it did not limit his gross motor function when he played sports. He rarely endured falls,

but his mother felt that his overall function was limited due to weakness and pain in his feet. The patient was undergoing physical and occupational therapy, never tried orthotics and did not have any upper extremity limitations.

The patient had a medical history consistent with CP and attention deficit hyperactivity disorder for which he was prescribed Lisdexamfetamine 20 mg PO QAM. He denied having any other medical conditions or allergies. He had no social history regarding tobacco, alcohol, illicit drug use, and sexual activity. His review of systems was unremarkable, except that the patient admitted to positive right-sided weakness and foot pain as noted in the history of present illness. There was no pertinent family history or surgical history.

Initial Physical Exam

At the initial visit, the physical exam findings were as follows: the patient was alert and oriented, pleasant, cooperative, and well-developed without distress. There were no dermatological or vascular findings. Musculoskeletal exam showed bilateral pes planus foot type, which was fully flexible, as demonstrated by correction with the Hubscher maneuver. There was pain on palpation to the right medial arch, muscle strength 5/5 in all 4 planes bilaterally, and valgus resting calcaneal stance position bilaterally. Ankle dorsiflexion was 95 degrees with knee extended and 100 degrees with knees flexed bilaterally. External hip rotation with knee flexed was 90 degrees and 60 degrees extended bilaterally, and internal hip rotation was 75 degrees bilaterally. Forefoot-to-rearfoot relationship was in valgus bilaterally, and the calcaneus was displaced laterally on the right greater than the left. There were no limb length discrepancies noted.

On gait exam, there was a decreased arm swing, delayed midstance resupination, no toe-off, everted angle of gait to the right, no Achilles contracture, pronation throughout gait, and noted genu valgum.

On neurological exam, the right patellar deep tendon reflex was 3/4 on the right and 2/4 on the left upper extremity triceps reflexes were 2/4 bilaterally. Negative Romberg and Babinski signs.

Assessment and Plan

At initial visit, the 6-year-old male CP patient had right foot medial arch pain likely secondary to flexible bilateral pes planus. There was a discussion with him and his mother about the use of orthotics as conservative treatment. It was recommended that he continue physical and occupational therapy and follow up in the clinic to be casted for custom orthotics.

Second visit – September 2017

The patient followed up with complaints of increased 8/10 right foot pain greatest with activity. Walking for over an hour increased his pain to the point where he wanted to rest or be carried by his parents.

On physical exam, there was normal ankle range of motion without pain or crepitus bilaterally. Maximally pronated feet were seen while weight bearing with a laterally displaced calcaneus bilaterally. No contractures or spasticity was noted in the lower extremities, including the adductors and hamstrings. Gait exam showed maximally everted feet with little resupination and increased angle and base of gait.

These findings suggested that the previous history of CP was not likely a definitive diagnosis and the patient would be in need for custom orthotics to continue to participate with his desired activities. The patient and his mother agreed with the plan of care for custom orthotics with a deep heel cup for greater support and to prevent pronation.

Final Visit – December 2017

At the final visit, the patient reported his pain level reduced to 1/10 and his pain with prolonged walking and activity had significantly improved after wearing the orthotics. He related that he wore the orthotics every day without any pain or discomfort, and was able to walk and run better without the fear of tripping or falling. Since the use of the orthotics, the complaint of pain decreased, and his physical therapist mentioned his gait had significantly improved.

On gait exam, the patient was seen to have a normal angle and base of gait with orthotics. He was able to resupinate with toe-off instead of being maximally pronated through the stance phase of gait and rolled off the medial border of the forefoot bilaterally. His cadence and stride length were also seen to have increased with the orthotics.

With the improvement of stability, coordination, and pain with wearing orthotics, the patient's mother was advised that without any contractures and the ability for the orthotics to help him regain a normal gait pattern, it was very unlikely that the patient has CP. The patient was instructed to follow-up in 1 year or if there is a change in 1 full shoe size to be recasted for new orthotics.

Discussion

Spastic CP is a motor disorder involving injury to the pyramidal system. This type of CP is defined as a "velocity dependent resistance to stretch." While injury occurs in the developing brain, the symptoms are usually treated at the muscular level. Muscles of spastic CP patients often develop contractures, which limit range of motion. Ultrasonographic measurements have shown that muscle length in CP patients are not only

shortened, but have reduced volumes up to 50% (3). Normally, as a child grows, bone elongates and muscles respond to the stretch by increasing the number of sarcomeres. Serial sarcomere studies of CP patients have shown to be altered in comparison with typical developing muscles (3,5). This is one factor that can lead to contracted muscles. Another factor that can influence muscle stiffness is the amount of collagen in the extracellular matrix of myocytes. Collagen is a structural protein with little elasticity that is found in connective tissue. Gracilis, a leg adductor, and semitendinosus, a knee flexor, have increased stiffness and collagen content in spastic CP patients (6). The increase in collagen content of these muscles creates a less elastic and more rigid muscle.

Ankle equinus results from a contracted gastrocnemius or Achilles tendon, causing an increased pressure shift from the hindfoot to the forefoot (4). If there were contractures of the gracilis and semitendinosus, the leg length would thereby shorten and an ankle equinus could develop as a biomechanical compensation to get the foot to the ground (plantigrade). Knee flexion caused by a contracted semitendinosus and hamstring complex, an adducted leg caused by a contracted gracilis, and ankle equinus from a contracted gastrocnemius can lead to the classic "scissoring" gait pattern seen in CP patients (7).

On physical exam, the patient was not seen to have any ankle equinus with the ability to dorsiflex both his ankles to 95 degrees with his knees extended. There were also no signs of increased knee flexion or adductor contraction. Genu valgum was seen in the patient, but that is a normal finding given the patient's age (8). With these collective findings, the probability of this patient having CP was less likely from a podiatric standpoint.

The patient presented with both an everted resting calcaneal stance position and collapsed medial arch bilaterally upon physical examination. After ruling out CP as an etiology for his presentation, the painful symptoms were likely due to a pes planus deformity. Pes planus is a condition in which the medial arch of the foot is flattened, which often causes excessive pronation of the foot with forefoot abduction and rearfoot eversion (9). Patients with pes planus often present with medial arch pain especially during prolonged standing or activity due to increased weight bearing force on the medial column of the foot (10). Pes planus is divided into two types: flexible or rigid (9). It was determined our patient presented with flexible pes planus. The Hubscher maneuver was used to examine and evaluate the flexibility of the patient's pes planus deformity by dorsiflexing the hallux while weight bearing and arch formation was noted bilaterally.

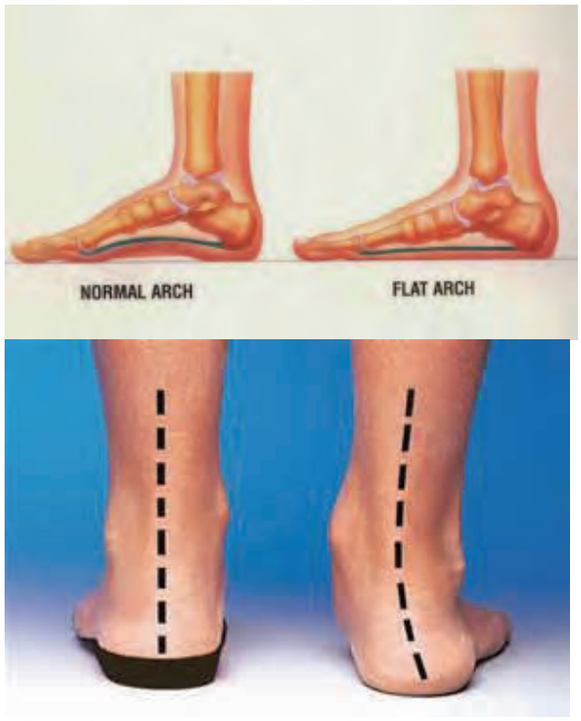

Figure 2. Pes planus foot type. Showing flattened medial longitudinal arch and everted resting calcaneal stance position. Adapted from (Special Tests – Orthopedic Testing Procedure) and (Team Athletic Mentors).

Custom foot orthotics are frequently prescribed and used in the management for flexible pes planus in children (11,12). The goals of orthotics are to reduce abnormal motion of the foot and align the subtalar joint into a neutral position (10). A medial flange is often used as an orthotic modification to increase the height of the medial side of the orthotic, encouraging more supination. A deep heel cup modification is also often added to prevent excessive calcaneal eversion or pronatory forces and allow for more stability of the foot (9,10).

In our patient, symptoms were significantly improved with the use of custom orthotics. There was significant improvement in pain from the correction of the rearfoot deformity, which allowed for a change in forces and reduced heel eversion. Treatment for children with flat feet is typically straightforward because their feet are more flexible due to ligamentous laxity and lack of neuromuscular control (10,11). Children typically have excessive rearfoot valgus and minimal arch height when weight bearing, which were both noted in our patient (10). The added stability to the foot allowed for proper alignment of the joints and reduction in pain.

With foot pain, an abnormal gait that could be corrected with custom molded orthotics, and the

absence of gastrocnemius, adductor, and hamstring contracture; it is less likely CP affects this patient. It is also worth noting that a positive Babinski sign is seen in 75% of spastic CP patients (14). The patient had negative Babinski and Romberg signs which would make the presence of an upper motor neuron lesion unlikely (15). These findings further support the idea that the patient does not have CP.

Additional questions that could have been asked are if the diagnosing neurologist had magnetic resonance imaging done of the patient's brain. This is a recommendation of the American Academy of Neurology for diagnosing CP in suspected patients (1). It may also be helpful to know if the patient had a normal birth, as preterm births are more likely to be associated with CP (2). The answers to these questions would help to further make a definitive diagnosis on the patient's CP status. This case report sheds light on the similarities between a disabling condition such as cerebral palsy as a diagnosis of concern versus pes planovalgus and not only informs the public of plan of care for such an instance, but also the influence a provider has on the lives of patients.

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Hyperbaric Oxygen Therapy in Ulcer Treatment of Chronic Wounds

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Abstract

Hyperbaric oxygen therapy is the combination of elevated air pressure and supplemental 100% oxygen. This therapy has shown efficacy in wound reduction, vascular insufficiency improvement, and amputation prevention. A few common indications are infection of skin or bone that causes tissue necrosis, skin grafts under risk of failure, and non-healing wounds which includes diabetic foot ulcers. As this therapeutic method becomes more readily available across the country, it is a recommended tool for consideration in wound management.

Introduction

Chronic wounds of the foot affect approximately 6.5 million patients in the United States. With increasing costs of healthcare and inflation, the incidences of comorbidities such as diabetes, cancer and the inevitable fate of aging, this issue is not likely to subside in the near future (1). Among the various treatment options available for wound management, hyperbaric oxygen therapy (HBOT) will be under review. The objective is to investigate the effects of HBOT in ulcer management.

Hyperbaric Oxygen Therapy (HBOT)

Hyperbaric Oxygen Therapy is a non-invasive treatment that involves the patient positioned within a chamber that reaches pressures up to 3 atmospheres (ATM); whereas, normal air pressure at sea level is 1 ATM. The available chambers; illustrated by figure 1, are monoplace or multiplace hyperbaric chambers, that have the capacity to hold a single patient or multiple patients at a time respectively (2). Additional to the pressurized chamber, the patient receives 100% oxygen, either directly from the chamber as in the monoplace chamber or from a tight fitting facemask, endotracheal tube or hood as in the multiplace chamber (2,3). The typical regimen consists of 90 -120 minute sessions, 5 days a week at 2.4 ATM for 33 sessions or more as determined by the patient's healing (3,4).

Figure 1 - Monoplace Hyperbaric Chamber holds the capacity for a single patient to undergo HBOT (left), Multiplace Hyperbaric Chamber holds the capacity for multiple patients to undergo HBOT(right)

The combination of increased pressure and oxygen supplementation results in physiological changes within the body that have shown benefits for wound healing. The most evident quantifiable change is an elevation of oxygen saturation. Under normal conditions blood plasma usually has 3 mL/L of oxygen, whereas when a patient undergoes HBOT their plasma oxygen concentrations reach up to 60 mL/L (3). The elevated plasma oxygen saturation aids in the delivery of oxygen to ischemic tissues. This benefit is highly desired due to injured tissues requiring more oxygen to survive (4). The down-regulation of proteases and free radicals release is a physiological response resulting in decreased vasoconstriction, edema and cellular damage. Other effects of HBOT that assist in wound healing are angiogenesis within ischemic tissues, collagen synthesis, bacteriostatic properties against organisms that produce alpha exotoxins, Ex. *Clostridum spp.* and potentiation of select antibiotics such as Aminoglycosides and quinolones (3,4).

Epidemiology, Pathogenesis, and Clinical Manifestations of Chronic Ulcers

Clinicians are recommended to consider all aspects of patient care. Considering not only socio-economic capabilities but also understanding that ulcers vary in epidemiology, pathogenesis, and clinical manifestations. Careful considerations must be made regarding wound care management with respect to age, location of ulcer, and etiology.

The most common ulcer in the foot is the diabetic foot ulcer. The diabetic foot ulcer arises from a combination of peripheral neuropathy and repetitive microtrauma. The ulcers heal 60-80% of the time with about 10-15% failing to heal (5). Diabetic foot ulcers are the most common cause of lower extremity amputation. The amputation rate of diabetic foot ulcers can range from 5-25% (5).

A general summary of the most common forms of ulcers are listed below in Table 1. Vulnerabilities identified in the patient's condition should be criticized to determine if the patient is eligible for Hyperbaric Oxygen Therapy (HBOT). Indications and contraindications will be discussed below.

Table 1: Epidemiology, Pathogenesis, and Clinical Manifestations of Common Ulcers of the Foot (6, 7, 8, 9)

Pressure Ulcer	**Epidemiology:** Acute hospitalizations, long term institutional care, nursing homes, improper shoe wear	**Pathogenesis:** Intermittent pressure against hard surface and/or trauma/shear force disrupts blood vessels between bone and skin and can also cause a break in skin barrier.	**Clinical Manifestations:** Location near osseous prominences, fibrotic with necrotic eschar, deep probing to bone, surrounding periwound erythema.
Venous Ulcer	**Epidemiology:** Venous insufficiency or venous hypertension by dysfunctional calf muscle or incompetent venous valves	**Pathogenesis:** Deep Venous Thrombosis and/or venous valvular insufficiency prevents proper return of blood to heart, causing deoxygenated blood to be pooled in the lower extremities with the help of gravity.	**Clinical Manifestations:** Location near medial and lateral malleoli, surrounding dermatitis, periwound erythema, scaling, weeping, crusting, intense pruritus.
Diabetic Foot Ulcer	**Epidemiology:** Diabetes, polyneuropathy from chronic alcoholism, arsenic poisoning, local neuropathy from Herpes zoster, Hansen's disease	**Pathogenesis:** Non-ischemic foot ulcer from foot deformities possibly secondary to peripheral neuropathy.	**Clinical Manifestations:** Location in regions of repeated trauma. Commonly, the plantar aspects of the metatarsal heads or dorsal Interphalangeal joints with overgrown hyperkeratotic lesions, undermined borders, with a lack of sensation upon monofilament.
Malignancy/ radiation induced cutaneous Ulcer	**Epidemiology:** Basal/ squamous cell carcinoma, soft tissue sarcoma, radiation treatment	**Pathogenesis:** Elevated expression of proto-oncogenes or radiation can cause malignant transformation → increased tissue stress and excessive granulation	**Clinical Manifestations:** Periwound erythema, scaling, weeping, crusting, surrounding dermatitis, medial and lateral malleoli, like venous ulcers

Ischemic Ulcer	**Epidemiology:** Progressive peripheral vascular disease, arterial embolization, Raynaud's disease, history of claudication	**Pathogenesis:** Atherosclerosis or vascular insufficiency with diabetes prevents proper oxygenation of issues in the foot, rendering tissue vulnerable to ischemia.	**Clinical Manifestations:** Location between toes, tips of toes, phalangeal heads or lateral malleolus, regions of repetitive trauma, even sharp demarcated and punched-out wound margins, pale/gray or yellow wound bed, necrosis or cellulitis w/ dry necrotic eschar, minimal exudate, blanched or purpuric periwound, and pain localized to ulcer.
Hypertensive Ulcer	**Epidemiology:** Arterial hypertension, diabetes	**Pathogenesis:** Medial calcification that obliterates the small arterioles → reduced tissue perfusion leads to ischemia and ulcer	**Clinical Manifestations:** bilateral, supramalleolar of anterolateral, Achilles tendon, perceptible pulses, pain localized to ulcer

Indications

Hyperbaric oxygen has fourteen approved indications as outlined by the Undersea and Hyperbaric Medical Society [10], along with a few off-label uses. Some approved uses include: Anemia, severe brain abscess, burn, crush injury, sudden gangrene, infection of skin or bone that causes tissue necrosis, skin grafts under the risk of failure, and non-healing wounds which includes diabetic foot ulcers. Off-label uses that have yet to be proven efficacious are autism, stroke, and ADHD.[3] Additionally, HBOT also has been known to attenuate neuroinflammation.[11]

Diabetic patients in particular have an increased risk for ulcer development and delayed wound healing which subjects them to an increased risk of infection and gangrene. Hyperbaric oxygen has sped up healing in complex wounds such as: diabetic foot ulcers, leg ulcers, irradiated wounds, wound fistulas, ischemic wounds, refractory chronic wounds and wounds that have failed to heal within six months by about 47% in 10 treatments.[12] Diabetic ulcers with soft tissue infections; classified as Wagner grade 3 as referenced in Table 2, that have not responded to conventional therapy for at least 30 days are highly indicated for HBOT use.[3] The therapeutic benefit is theorized to address the comorbidities associated with diabetes; such as, vascular compromise, neuropathy or infection, either acute or chronic. The soft tissue infections found in Wagner grade 3 ulcers are typically mixed infections of both aerobic and anaerobic microorganisms. The increased oxygen saturation suppresses the anaerobic microbial growth and improves bactericidal action of leukocytes.[2] If the patient develops gangrene, HBOT not only suppresses the anaerobic Clostridial organisms but also halts the production of **α** toxin, which aids the body to rapidly clear the infection.[2]

Table 2: Wagner Classification system [13]

Grade	Description
0	No open lesions; may have deformity or cellulitis
1	Superficial diabetic ulcer (partial or full thickness)
2	Ulcer extension to ligament, tendon, or deep fascia without abscess or osteomyelitis
3	Deep ulcer with abscess, osteomyelitis, or joint sepsis
4	Gangrene localized to portion of forefoot or heel
5	Extensive gangrenous involvement of the entire foot

Contraindications and Complications:

HBOT is contraindicated in conditions where there has been physical injury to normally closed air-filled spaces. In particular, pre-existing conditions involving the lungs and ears are of the most concern. Patient's with a pre-existing pneumothorax are highly contraindicated to undergo HBOT due to the likelihood of the patient rapidly progressing to a tension pneumothorax or death. Additional conditions needed to be screened for before the patient undergoes treatment are signs of pulmonary blebs, emphysema with CO_2 retention, sinusitis, seizures, pregnancy, implanted devices such as pacemakers, claustrophobia, along with

medications the patient is taking. Specific medications that are contraindicated for ulcer management in junction with HBOT are Disulfiram, Bleomycin, Cis-platinum and Sulfamylon. These medications can cause oxygen toxicity, interstitial pneumonitis and impaired wound healing respectively.[3] The final noteworthy contraindication that should be screened for is if the patient is undergoing radiation therapy for cancer treatment, due to an increased risk for delayed wound healing. It has been noted, this patient population has up to a five-fold increased risk for delayed healing compared to other patients with complex wounds.[12]

Possible complications are pneumothoraces, rupture of small vessels, damage to the inner, middle or external ear canals, temporary nearsightedness (myopia), oxygen seizures, convulsions, pulmonary edema and hemorrhage. Additionally there is risk for fires within the chamber along with explosion.[3,14] If precautions are made and patients thoroughly screened complications are rare.

Hyperbaric oxygen therapy for wound size reduction

Hyperbaric oxygen therapy has been shown in clinical trials to reduce the size of ulcers in complex wounds. According to Opasanon et. al, the maximal amount of wound size reduction occurred after the initial 10 treatments, by 47%.[12] Patients with diabetic ulcers treated with hyperbaric oxygen; compared to standard therapy, experienced significant reduction in wound area size.[15] Venous ulcers have also shown significant decrease in ulcer size, documented after 6 weeks with treatment.[16] In regards to primary arterial ulcers, patients experienced an increase in healing rates and ulcer size reduction.[17] Overall, venous and arterial ulcers have demonstrated the best outcomes with greater reduction in wound size. However, treatment of diabetic ulcers with this approach should not be overlooked.

Hyperbaric Oxygen Therapy Efficacy in Decreasing Adverse Events

HBOT has also shown demonstrated a decreased incidence of adverse events. Specifically studies involving diabetic foot ulcers or arterial ulcers saw a reduction in amputations.[16,17] Additionally there is evidence of reduced rates of fatalities and hypoglycemia in comparison to patients without hyperbaric oxygen therapy. The study by Magnus Londahl resulted in one death out of thirty-eight patients who went through the hyperbaric oxygen therapy in contrast to three deaths in the thirty-seven patient placebo group. Hypoglycemia occurred in four patients in the placebo group compared to only two patients in the trial group.[18]

Conclusion

HBOT is a non-invasive treatment option with few contraindications and rare complications. This treatment modality has many uses and has shown efficacy in decreasing healing times of chronic wounds such as non-healing ulcers and does this by aiding in treating other potential underlying issues that may be delaying their healing such as infection, arterial insufficiency or anemia. In primary non-healing ulcers healing rates increased with hyperbaric oxygen therapy after standard therapy had been performed.[17] Patients with diabetes did not see an increase in healing after hyperbaric oxygen therapy. However a reduction is ulcer size was observed and therefore beneficial for this patient population.[15] With this information in mind HBOT should be considered as a treatment modality in patients with delayed wound healing with or without comorbidities to decrease the risk of adverse events such as amputation.

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A Student-Friendly Guide for the Selection of Wound Care Dressings for the Foot and Ankle

By Ricardo Navarrete Jr, MS-3 and Lant Abernathy, MS-3

Abstract

Wound care is a challenging and dynamic field in podiatry. Choosing what dressings to use for the myriad of wounds that can present is also a challenging feat. Many factors can contribute to what dressing is used, whether it be venous or diabetic in nature, with excessive drainage or little drainage, for necrotic and non-necrotic tissue. This review article serves to summarize and examine what dressings to be used for indicated situations.

Introduction

As a podiatric student in training, the distinction and selection of appropriate wound care dressings can be often difficult to navigate through due to the extensive array and ongoing production of new of dressing types. The importance of dressing application to foot or ankle wounds is imperative in providing optimal wound healing. Chronic wounds also pose a significant management challenge to healthcare professionals. Successful wound management requires an understanding of the healing process, type and status of the wound, and knowledge of the properties of the various available dressings. Although the ultimate goal in most cases is quick healing, one must remember that a healing wound is a dynamic process requiring a series of adaptive smaller goals as the wound progresses through the repair process. The practitioner should be able to select dressings best suited depending on the various stages of wound healing, type of wound, location, size, drainage, infection along with several other factors.

When recognizing the importance of applying appropriate wound dressings, there seems to be limited availability of student references and resources in providing a simple guide to select the right type of dressing.

Dressings are only one aspect of managing a wound. Equally important offloading strategies, debridement techniques, and medications that provide the necessary integrated wound care approach to management, will not be discussed. Prevention of specific diabetic foot ulcers is not discussed, but rather a general review of foot and ankle wounds will be covered. The cost benefit associated with the clinical selection process also will not be discussed, as it adds another dimension in prescribing the "best" dressing for a wound which in turn strays from optimal theoretical management. The assumption of adequate debridement preparation and general wound care up to application of a dressing will be implied.

Acute wounds can be considered less of concern as they normally heal in a sequential and timely manner in four major phases: coagulation, inflammation, proliferation, and remodeling. Chronic wounds are said to be halted in one of the major phases of wound healing. This creates an impairment of the usual stepwise progression of a healing wound and falls into the ongoing cycle of a non-healing wound. The Journal of Biomedicine review article on wound dressings list factors that attribute to the ideal wound dressing based on its ability to:

"a) provide or maintain moist environment. b) enhance epidermal migration. c) promote angiogenesis and connective tissue synthesis d) allow gas exchange between wounded tissue and environment e) maintain appropriate tissue temperature to improve the blood flow to the wound bed and enhances epidermal migration f) provide protection against bacterial infection and g) should be non-adherent to the wound and easy to remove after healing h) must provide debridement action to enhance leukocytes migration and support the accumulation of enzyme and i) must be sterile, non-toxic and non-allergic." It is up to clinician's experience and preference on selecting between these types of dressings as they should be tailored based on fundamental wound characteristics.

Dressings are designed to be in direct contact with the wound, which is different from a bandage that holds the dressing in place. A dressing applied to a wound optimizes the amount of moisture to the wound bed which promotes a clean and protected ideal environment and therefore allows healing and prevention of issues like infection (3). This guide concentrates on detailing each of the seven most commonly used wound dressings and the selection process given the nature and presentation of a wound. The seven types of dressings most encountered are: hydrocolloid, hydrogel, alginate, collagen, foam, transparent, and cloth.

An adequate application of a wound dressing may consist of a primary, secondary, and tertiary dressing, dressing adjuncts (i.e. saline, tape and or topical agents), and includes the duration and frequency of dressing change. Wound etiology, location, drainage level, infection, and necrosis are several of the various factors that will be discussed when evaluating a wound and prescribing a dressing. The primary dressing is directly

in contact with the wound and skin surfaces. It serves to protect, prevent further contamination, and hold or administer medication like gels/creams. Most primary dressings are non-adherent. Secondary dressing covers the primary dressing. This provides padding to cushion and support the wound (i.e. protect bony prominences). Tertiary dressings serve to affix the primary and secondary dressing. They protect the previously mentioned bandaging, hold complete dressing in place, and make the application look aesthetically pleasing. Duration and frequency of dressing changes are another important aspect of wound management; however, it will not be discussed extensively. Wound etiology, location, drainage level, infection, and necrosis are several of the various factors that are considered when evaluating a wound especially in the setting of prescribing a dressing.

Hydrocolloid Dressings

Hydrocolloid dressings are composed of a polyethene film or foam that has integrated compounds/chemicals, such as gelatin or carboxymethylcellulose, that absorbs water from wound exudate which forms a gel layer (1). The resulting moist environment is favorable for the body's natural enzymes to work as well as stimulate angiogenesis, fibrinolysis, and epithelialization (1). Hydrocolloid dressings create a water-tight seal around the wound, so that no exogenous material may enter the wound. The dressing is also self-adhesive, requiring no further taping (1).

Hydrocolloid is indicated for a variety of different wounds such as venous ulcers, pressure ulcers, and even burns. Evidence suggests that the use of hydrocolloid dressings for diabetic foot wounds is negligible, with either a benefit or disadvantage over other dressings (2). The thickness of wound can be partial to full thickness, such as a Wagner stage 1 and 2, or specifically in diabetic foot wounds a UT Texas 1A and 1B. The wound can have low to moderate drainage. High drainage will result in inadequate adherence of the dressing to the skin and will result in a failed gel-formation and water-tight seal. Hydrocolloid dressings are not indicated in wounds with infection, as it creates a natural barrier for the bacteria to proliferate in. It is also not indicated in wounds with sinus tracts as sinus tracts need to be packed with material.

Hydrogel

Hydrogel dressings are composed of a gel matrix that has 90% water distributed through it (3). The dressing works to keep the wound moist by assisting in the exchange of salts and discharge from the wound site with the moisture in the gel. It also creates an environment to advance autolytic debridement, epithelialization, and granulation (3). A barrier can be created between the wound and penetrating bacteria and oxygen, preventing infection of the wound. In addition, hydrogels also have cooling properties which may ultimately help with inflammation and pain (3).

There are three main types of hydrogels that are used in wound care. The first is sheet hydrogels, which are composed of a thin mesh that has the gel suspended within it. There is hardly any skin damage with these meshes since they become congruent with the skin, using no adhesion (3). Disadvantage is that it can be easily dislodged, by knocking the dressing off while trying to rehydrate the wound with saline. The second is impregnated hydrogel which is a gel that is dispersed on a vehicle such as gauze. This dressing can be used to fill wounds that are deep to eliminate dead space. Finally, there is the amorphous hydrogel that is very viscous and can be administered directly onto the wound to penetrate fissures, tunnels, and other hard to reach areas of the wound. These 3 types of hydrogels often require an accessory dressing in order to keep the primary dressing in place (3).

Hydrogel dressings are very versatile since it is mostly composed of water and no other provocative chemicals. As far as thickness of skin the dressing can be used for partial to full thickness wounds. This would be indicated in Wagner stages 1 and 2 as well as in diabetic foot ulcers in UT Texas grade 0 and 1, stages A, B, and C. Unlike other dressings, hydrogels can be used in infected wounds. Hydrogels can also be used in minor burns as well as skin reactions to radiation exposure. Contraindications to hydrogels are extensive exudative discharge (i.e. venous ulcers) and full thickness burns.

Alginate

Alginate dressings are usually constructed of salt fibers formed from plants/seaweed that allow absorption of discharge (blood, serous drainage, sanguineous drainage, etc.) into the dressing (6). One single dressings can absorb a voluminous amount of water/discharge exiting from wounds. Since the alginate dressing absorbs water, it also acts as a moisturizer which keeps the wound moist. This moisture contributes to the body's natural wound healing process of autolytic debridement, angiogenesis, and epithelialization (6). The dressing can also form to wound shapes, making this dressing very versatile in challenging/hard-to-reach areas of the body and/or foot and ankle, as well as oddly shaped wounds (6).

Alginate dressings are primarily used for wounds with moderate to large amounts of exudate (6). These include venous ulcers, decubitus ulcers, arterial ulcers, diabetic foot ulcers, and neuropathic ulcers. Thus, if a wound is xerotic and/or not producing exudate then alginate dressings are contraindicated. Alginates can be used to treat partial thickness to full thickness wounds. There is little evidence to suggest it should be used in

necrotic wounds since necrotic wounds need excess moisture in order to heal.

Collagen

Collagen dressings are scaffolds that help cells (fibroblasts, myofibroblasts, macrophages, etc.) integrate into the matrix to promote wound healing (6). These collagen dressings originate from animal sources such as bovine or swine. As stated above it helps with the natural wound healing process with autolytic debridement, angiogenesis, and epithelialization (6).

Collagen dressings have no specific indication which make it a very functional and well-rounded dressing. All ulcers and wounds are applicable to this type of dressing. As far as depth goes, it can be used in partial to full thickness wounds. It can be used in heavy/moderate exudative wounds, necrotic wounds, and 1st to 2nd degree burns. Skin grafts are also good candidates for collagen dressings, in that the collagen dressing can provide extra scaffolding in addition to the skin graft that allows wound healing. Chronic wounds are also applicable, in that the collagen dressing can fundamentally initiate the wound to end the inflammatory phase and enter into the proliferative phase. Contraindications to collagen dressings are dry eschar wounds a 3rd degree burns (6).

Foam Dressings

Foam dressings are generally synthesized out of a polyurethane material that serves as a type of moisture retentive dressing designed to accommodate fluid. Therefore, foams create a favorable healing environment facilitating granulation and epithelialization. They work by allowing water vapor to enter by the means of a hydrophilic surface, however also keeping contaminants out. These can be applied to partial or full thickness wounds that have moderate drainage. Foams are also useful as a primary or even secondary layer as they can also apply bulk and padding to the wound bed around bony prominences. One may use foams on decubitus ulcers to prevent further friction and pressure on the wound. The outer layer may be waterproof or hydrophobic and many are available in various sizes and shapes. Some have adhesive tape, or boarders, around the edges for easier application. Due to the hydrophilic component, foam may over dry the wound, and thus will need a saline soak. Thus, wounds that have minimal to no exudate will not have a great therapeutic effect. Contrary, if a wound is producing heavy exudate this can over saturate foam creating macerated tissue surrounding the skin, and a dressing that may need extra secondary dressing to reinforce the foam. Another disadvantage to foams is the requirement of more frequent changes compared to alginates and which also accommodate less wound exudate. Foams cannot be used on sinus tracts or dry eschars, however can be used on infected wounds. Additionally, these dressings may be associated with malodorous discharge similar to what can be seen in hydrocolloids. In all, foam dressings are appropriate choice for acute or chronic partial/full thickness wounds with large exudates and good for chronic venous stasis ulcers and deep cavity wounds (4)

Film Dressing

An effective yet lesser known solution is the transparent film dressing. These are manufactured as a thin sheet of colorless material, generally an elastic polyurethane and impermeable to bacteria and contaminants. They are available in a wide variety of shapes and sizes to conform to different wounds. One may be able to see the wound healing process, draining material, and overall appearance. Transparent dressings are generally indicated in superficial wounds with minimal to no exudate producing wounds. They can provide protection and secure other dressings acting as a secondary dressing. They are gas and moisture permeable, which may be used for delicate and minimally exudative wounds. However, they do not contain any absorptive properties so any extra fluid collection in this dressing can cause periwound maceration. Another disadvantage is the potential damage to new epidermis that or uninvolved skin done by the adhesive portion of the dressing when removing. Therefore, patients with fragile skin, including the elderly or patients with cutaneous atrophy, should decrease the frequency of dressing changes or avoid films altogether. An advantage can be seen in its flexible material, by conforming to wounds in difficult-to-apply areas. Overall, film dressings are used for acute partial/full thickness wounds with minimal exudates. It can be also used for non-draining primarily closed wounds. Other applications are used for for catheter sites, first- and second-degree burns, incision sites, IV sites, grade 1 decubitus ulcers, and graft donor sites.

Cloth Dressing

Historically, dressings were typically made of cloth. They still remain one of the most commonly used dressings often used to protect open wounds or areas of broken skin. These types of dressings are constructed from an open-weave fabric, usually cotton, rayon, polyester, or a combination of these fibers. Traditional gauze dressings function as an absorbent, breathable and protective pad for a wound. Today, gauze dressings offer a variety of options—woven or nonwoven, sterile or nonsterile, plain or impregnated, adherent or non-adherent, and fenestrated (perforated or with slits)—and is available in various sizes, shapes, and thicknesses. Woven gauze is commonly used which consist of a loose, open weave, allowing fluids from wounds to be absorbed into the fibers – wicked away. Woven gauze is

usually fine or coarse cotton mesh, depending on thread count. Fine mesh cotton gauze is often used for packing, such as a normal wet to moist dressing. Coarse mesh cotton gauze, such as normal wet to dry dressing is used for non-selective debridement. When it comes to packing for a wound, use a single gauze strip or roll to fill deep ulcers as opposed to multiple single gauze dressings (2×2s or 4×4s) because retained gauze in the ulcer bed can serve as a source of infection. It is contraindicated to cut woven gauze and place into a wound due to the potential of loose fibers becoming lost in the wound itself, this could delay healing. Nonwoven gauze contains fibers pressed together to resemble a weave, providing improved wicking and greater absorbent capacity. Compared to woven, this type of gauze has the benefit of leaving less loose fibers behind in a wound when removed. Most of nonwoven gauze is made of polyester, rayon or an assortment of these fibers and are stronger, bulkier and softer versus woven pads. Gauze dressings can also be found to have different types, including impregnated, wrapping and sponge/pad. One may use different types of gauze depending on what layer of dressing the clinician is applying. Impregnated dressings have a coating or have been saturated with some kind of medicine or pharmaceutical material, useful for primary layers. Wrapping gauze can be used for a tertiary layer for securement, padding, and protection. These dressings may include cotton, elastic, or a nylon and rubber mix, and have a fluff dried with crinkle-weave pattern. Gauze pads or sponges is a gauze folded or prefabricated into a square, these are useful for overlaying another dressing as a secondary layer. Overall, gauze can be used for cleansing, packing, scrubbing, covering, and securing in a variety of wounds. Closely woven gauze is best for extra strength or greater protection, while open or loose weave is better for absorbency or drainage.

Agents used for Infected Wounds

There are three main types of antimicrobial agents that should be used in patients with infected wounds. These include silver, iodine compounds, and sodium hypochlorite. These agents can be impregnated in any of the dressings described above, or directly applied to the wound. All of these agents are bactericidal, fungicidal, virucidal, and sometimes sporicidal.

Silver has been used since the 19th century, well before the discovery of any Penicillins or other antimicrobial agents. Since silver is positively charged, it works by binding to negatively charged entities on the bacterial cell membrane and wall which ultimately creates lysis of the bacterium (4). This classifies silver as bactericidal and is broad spectrum against gram positive and negative microbes. Additionally, it can regulate extracellular proteins as well inflammatory markers for chemotaxis of excessive of macrophages and neutrophils (4).

Silver is used as a bactericidal agent in sterile dressings for infected wounds, but is primarily used in 1st and 3rd degree burns (4). Silver should not be used with any exogenous debridement enzymes, as the silver ions could interfere with the activity of these debridement agents. Contraindications include 3rd degree burns and, although very rare, any patient that suffers from metal hypersensitivity (4).

Iodine/Iodophores are one of two Halogen-releasing agents. There are two main Iodine/Iodophore containing compounds, povidone-iodine and cadexomer. Iodine was used as early as the 19th century and was used in WW1 by Alexander Fleming to decrease gas gangrene in patients (5). The mechanism of action is unknown, but it is proposed that the iodine penetrates the cell and binds to essential proteins inhibiting them causing the microbe to die (5). Providone-iodine should be used on wounds that have frequent dressing changes as well as low exudate emitting from the wound (5). Contraindications include any issue with the thyroid as well as medications that could tamper with thyroid function (5).

Chlorine releasing agents (CRA) are the other of the two Halogen-releasing agents (5). Sodium hypochlorite, basically bleach, has been the most widely known and used CRA for wound dressings. Like the Iodophore/iodine compounds, the mechanism of action is unknown. It is postulated that since CRAs are highly oxidative agents that can disrupt normal cellular function, causing cell death (5).

Conclusion

This article serves as a guide for the beginning clinician as they start to navigate and encounter patients. The tables provided below are intended to convey and simplify characteristics when choosing a wound dressing given etiology of wound. With the correct dressing in the right situation will facilitate the body's natural wound healing process, as well as prevent infection. It is important for the student to understand how to properly assess an ulcer as well as determining which dressing and agent is indicated. Improper selection and application of the wound dressing may hinder the wound healing process, create an environment more vulnerable to infection, and potentially worsen the wound. As seen throughout this document there are various dressings for similar wounds. In summary, one should remember the ultimate characteristics and goal of wound healing.

Table 1. Quick Glance at Dressing Categories and Uses					
Category	**Description & *example names***	**Indications**	**Contra-indications**	**Advantages/ Disadvantages**	**Layer**
Hydrocolloid  Adapted from "Health Products for you"	Gelatin, pectin or carboxymethylcellulose in an adhesive base - regular or thin wafers, paste or granules *Tegasorb, Tegaderm, Nu-derm, Bioclusive*	Partial/full thickness, uninfected minimal drainage	Heavy Exudate, Wounds with tunneling/sinus tracts, Infection	Adv: Facilitates hydrolysis, barrier to bacteria, and controls odor	Primary
Hydrogel  Adapted from "kikgel"	Gel forming materials, like glycerin, copolymer & humectants - gel, gauze, wafer or gel sheet *Elasto-gel, Tegagel sheet, Vigilon gel sheet*	Partial/full thickness, infected wounds (with Abx agent) minor burns,	Heavy Exudate Wounds, Full thickness burns, macerated tissue	Adv: Facilitates hydrolysis, cooling effect, deep wounds, tunneling or undermining	Primary
Alginate  Adapted from "Medetec"	Moisture Layer, very absorbent *AlgiDERM,*	Partial/full thickness wounds, Moderate to high drainage wounds, infected	Xerotic wounds, allergy to alginic acid	Adv: Hemostatic, fills deep cavities, tunneling or undermining	Primary
Collagen  Adapted from "Bdh"	Scaffolding for cells to grow in *Promogram, Fibracol*	partial/full thickness, chronic wounds, moderate to heavy drainage, 1st/2nd degree burns, infection	Dry eschar wounds, 3rd degree burn wounds	Adv: Bacteriostatic, skin grafts, facilitates new skin development Ddv: unusual odor. Application may be difficult	Primary
Foam  Adapted from "Helios Wound solutions"	Foamed polyurethane polymer, hydrophilic, adherent/non-adherent - wafers, pillows, composite dressing *PolyMeb, Hydrosorb, Reston*	Partial /full thickness moderate to heavy drainage,	Dry or minimal drainage	Adv: Provides padding, accommodate tubes, used under compression Ddv: desiccate if no exudate from the wound, maceration if too much exudate	Primary or Secondary

Film  Adapted from "Medline"	Polyurethane, membrane film - self adherent, semipermeable *Tegaderm, Opsite, Bioclusive*	Partial thickness, surgical incision, minor burns,	Moderate to heavy drainage	Adv: Protects from friction, barrier to bacteria Ddv: epidermal stripping on removal, maceration if too much exudate	Primary or Secondary
Cloth  Adapted from "Costal orthopedics"	Cotton, rayon, polyester, or a combination. Woven/non-woven, sterile/non-sterile, plain/impregnated, adherent/non-adherent and fenestrated-Gauze pads, sponges.	Partial/full thickness, burns, minimal to heavy drainage, infected or non-infected	Can leave behind fibers and or residue, painful or cause trauma when removed	Cleans, packs, scrubs, covers, and secures. Closely woven = extra strength or protection. Open/loose weave = absorbency	Primary, Secondary or Tertiary

Table 2. Example Dressing Prescription Given Wound Etiology

Wound Type	Primary	Secondary	Tertiary
Diabetic Foot Ulcer (None to minimal drainage)	1. Hydrogel 2. Non-adherent 3. Collagen	1. Gauze 2. Gauze 3. Non-adherent	1. Roll Gauze 2. Roll Gauze 3. Roll Gauze
Diabetic Foot Ulcer (moderate to heavy drainage)	1. Collagen 2. Collagen 3. Alginate	1. Foam 2. Adherent 3. Foam	1. Roll Gauze 2. Bordered foam 3. Roll Gauze
Diabetic Foot Ulcer (Infected)	1. Gauze (antimicrobial agent) 2. Non-adherent 3. Alginate	1. Gauze pad 2. Foam 3. Foam	1. Roll Gauze 2. Roll Gauze 3. Roll Gauze
Ischemic Ulcer (dry gangrene/necrotic)	1. Gauze (iodine)	1. Gauze	1. Roll Gauze
Venous Leg Ulcer (None to minimal drainage)	1. Collagen 2. Collagen 3. Non-adherent	1. Bordered foam 2. Non-adherent 3. Gauze	1. N/A 2. Multilayer compression 3. Multilayer compression
Venous Leg Ulcer (Moderate to heavy drainage)	1. Alginate 2. Alginate 3. Non-adherent	1. Gauze/ABD 2. Non-adherent 3. Gauze/ABD	1.Multilayer compression 2.Multilayer compression 3.Multilayer compression
Pressure Ulcer (decubitus)	1. Hydrocolloid 2. Bordered foam 3. Gauze	1. N/A 2. N/A 3. Film	1. N/A 2. N/A 3. N/A
Post-Surgical	1. Gauze 2. Non-adherent 3. Film	1. Bordered foam 2. Gauze 3. N/A	1.N/A 2. Roll Gauze 3. N/A

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The Role of Piscine Acellular Dermal Matrix (ADM) in Wound Care

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Abstract

Acellular dermal matrix (ADM) is a biologic that is frequently used as a treatment for chronic and acute skin wounds. Given its ability to be used as a skin substitute, ADM is an expanding field of study, with various experiments regarding its potential use and efficacy. Although commonly derived from mammalian sources, such as humans, bovine and equestrian animals, Atlantic cod is now a burgeoning source for piscine ADM. Piscine ADM has a lower economic and ecologic burden than its predecessors, while still offering anti-inflammatory and analgesic properties that other biologics may not have. The aim is to investigate what advancements piscine ADM can offer and its role for lower extremity wound care.

Introduction

Skin accounts for one-tenth of the human body and is one of the largest organs of vertebrates (1). Damage to this major organ, such as burns, trauma, or surgery has considerable ramifications. Engineered skin substitutes are being extolled as a prospective source of treatment for acute and chronic skin wounds. Tissue engineering is an emergent field aimed at producing new biological substances for replacing diseased or damaged organs and tissues. In order to attain such a goal, a source of cells is required along with an artificial extracellular matrix (ECM), to act as a supportive medium for cells. Acellular dermal matrix (ADM) is a biologic material composed of only extracellular matrix. ADM currently have a wide range of clinical indication including plastic surgery, reconstruction, and wound care (2). Historically sourced from humans, pigs, cows, and horses, ADM now sees a future in fish, specifically Atlantic cod (Figure 1). Omega-3 Wound (Kerecis, Iceland, Reykjavik) is the first piscine ADM on the market.

Figure 1: *Kerecis Omega3 Wound (adapted Parshley (3))*

Virion & Prion

Atlantic cod (Gadus morhua) and humans have little to no risk for cross-transmission of viral or prion diseases. The theory is that the environmental conditions for fish pathogens differ significantly from that of humans and would therefore not pose the same risk as land-dwelling mammals (4). Mammalian-derived ADMs must undergo an extensive 'viral inactivation' process to prophylactically rid possible viral or prion contaminants. The process of 'viral inactivation' removes all soluble components from the tissue, which includes lipids, elastins, hyaluronic acid and other beneficial elements to wound healing. Acellular fish dermal matrix having little to no risk of viral or prion disease are not subject to the same extent of sterilization, allowing the preservation of bioactive material such as omega-3 fatty acids (5).

Omega-3 Polyunsaturated Fatty Acid Anti-inflammatory Properties

Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are omega-3 fats. These compounds are precursors to specialized pro-resolving mediators (SPM).[2] SPMs include resolvin and related compounds such as protectins and maresins; all of which have been shown to inhibit neutrophil infiltration in animal models as well as downregulate inflammatory messengers. For example, resolvin D1 inhibits IL-1B production and protectin D1 inhibits TNF and IL-1B (6). Additionally, EPA and DHA, upon incorporation into the cell membrane, displace and reduce arachidonic acid, the main precursor to inflammatory peptides. This provides EPA and DHA with augmented anti-inflammatory potential (Figure 2) (6).

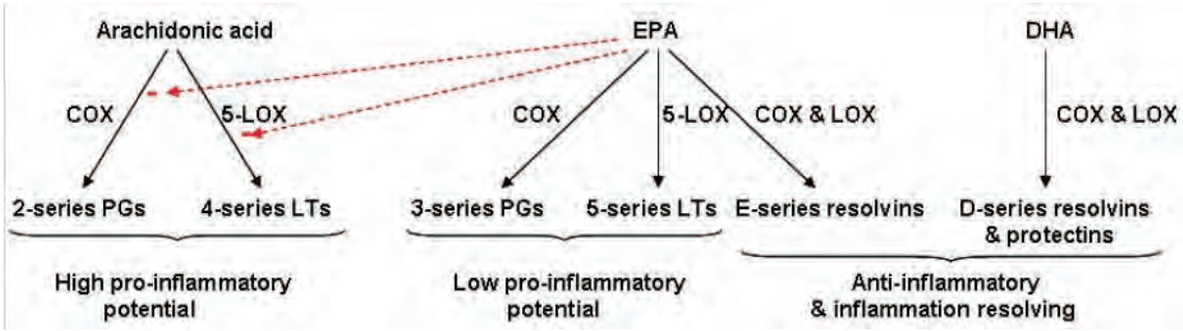

Figure 2*: General end products overview of arachidonic acid, EPA, and DHA as well as their associated propensity as pro-inflammatory products (adapted from Calder, Wounds International (5))*

Role in Chronic Wounds
Metalloproteinases (MMPs) are found in excess of chronic wounds and are protease enzymes that preferentially break down proteins found in the ECM. Although MMPs have a function to remove damaged proteins in the acute setting, prolonged exposure leads to impaired healing and eventually a chronic wound (7). EPA and DHA's effect on the inflammation cascade blunts the effects of MMPs, allowing reversion of chronic wounds back into a more acute state (8).

In a study conducted by Yang, 18 subjects were selected who met the criteria of a 'hard to heal' wound, as defined by full thickness and >20 cm^3 or present for at least 52 weeks, were given a trial of the Omega3 Wound piscine ADM. These patients suffered from comorbidities commonly seen in the podiatric profession such as venous insufficiency, diabetes and peripheral arterial disease. After 5 weeks of weekly application, there was a 40% decrease in surface area and a 48% decrease in depth. Three of the 18 ulcers closed by the end of the 5-week period (8).

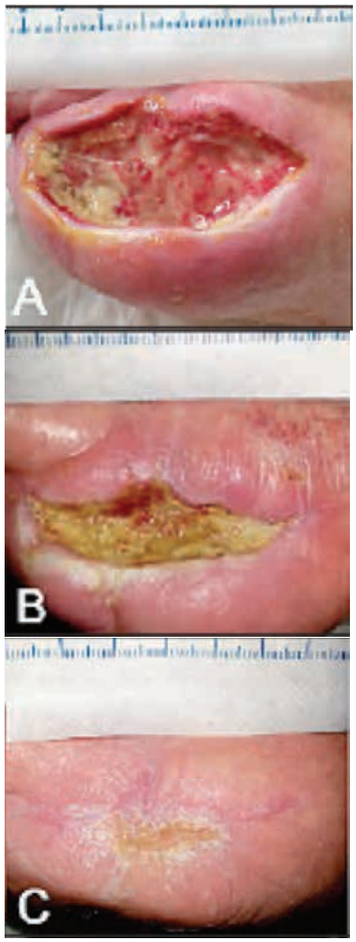

Figure 3*: Progression of wound healing with Kerecis Omega3. A-C show appearance of wound (A: prior to treatment, B: under treatment, C: healed wound) (adapted from Trinh, Phlebologie (9))*

Analgesic Properties
Omega-3 fatty acids' anti-inflammatory effects have been shown to clinically reduce the number of NSAIDs required by individuals when put on a high enough dose (6). Similarly, Trinh et al. followed 5 patients with diabetes mellitus and complicated wounds in the lower limb with exposed bony segment treated with piscine

acellular dermal matrices and found decreased intake of opioids (9).

Omega-3 fatty acids may also block pain neuron voltage-gated sodium channels (VGSCs) that are integral in initiating neuropathic pain. In a case series published in 2010, Ko et al. followed five patients with diagnoses ranging from cervical radiculopathy, thoracic outlet syndrome, fibromyalgia, carpal tunnel syndrome, and burn injury on a high dose of omega-3 fish oil (2400-7200 mg/day of EPA-DHA). The patients were followed for 19 months and the neuropathic pain was both subjectively and objectively diminished (10).

Autoimmunity

Baldursson et al. examined the use of fish skin ADM compared to porcine SIS (small intestine submucosa) ADM on 81 volunteers post infliction of a 4 mm full thickness wound on their forearms. Autoimmune assays were performed for all 40 individuals in the active arm examining RF, ANA, ENA, anti-dsDNA, ANCA, anti-CCP, anticollagen I and II. Of the 40 individuals, 4 individuals were positive for ANA prior to the piscine ADM application and the same 4 remained ANA positive after completion of the study. All 4 individuals were tested for extractable nuclear antigen antibodies (ENA) and were found to be negative. Seven individuals had elevations in Anti-C I and two in Anti-C II on Day 0, these findings persisted post-trial with negligible changes in amount. The authors suggest no potential for piscine ADM to trigger seroconversion of autoantibodies (11).

Microstructure

Although fish and human epidermal tissue have similar composition, the microstructure of the two is quite different. Generally, fish epidermis is more of a 'mucous' system than a 'keratinized' system. When examined under scanning electron microscope, piscine ADM was found to be highly porous compared to human amnion/chorion membrane grafts (dHACM). Furthermore, the contrast is amplified in both the diameter and depth of pores. A study published in 2017 estimated pores in fish ADM to be as numerous as 16.7 per 100μm^2, 16.1μm in diameter, and at a depth of 450μm. dHACM measured 1.7/100 μm^2, 1.3 μm, and 20.1 μm. The significant differences aid in explaining another phenomenon observed in the same study: fibroblast infiltration. The larger dimensions as the authors hypothesized allows for cells to migrate into the graft. Hematoxylin and eosin staining revealed that fibroblasts remodeled the fish skin graft as they migrated through the graft; however, in dHACM, the fibroblast formed a layer on top with minimal interaction with the graft. This contributed to a statistically significant increase in 3-dimensional ingrowth with the piscine ADM (3)

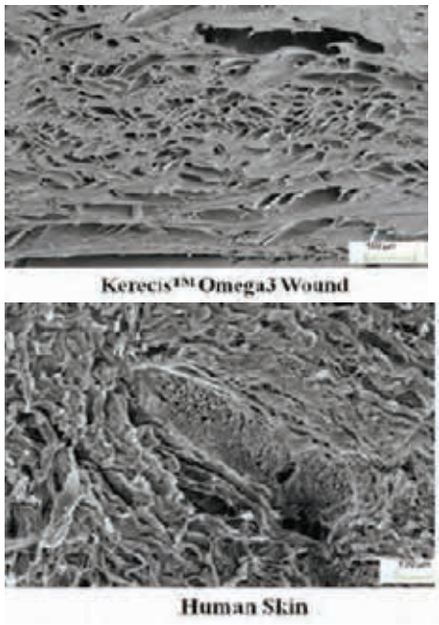

Figure 4: *Scanning electron microscopy images of fish skin (left) and human skin (right) reveals the differences in porosity as well as pore dimensions. (adapted from Magnusson, Today's Wound Clinic (4))*

Anti-Microbial Properties

In comparison to mammalian skin, piscine skin expresses a variety of antimicrobial peptides that contribute to its innate defense system. These peptides include hepcidin, defensin-like peptide, apolipoproteins, and hepcidin, many of which persists after sterilization (11). Piscine ADM have a clinically examined antimicrobial window of 48-72 hours (5).

Environment and Religious Neutrality

Under FDA guidelines, livestock with the intent of graft harvest, cannot be sourced from a herd earmarked for the commercial use. Consequently, production of livestock for graft harvest is a separate entity and such animals are bred in genetically altered and isolated herds. These animals, reared for graft harvest are disposed of after the acquirement of the biological product (12,13). Atlantic cod skin is collected from schools destined for consumption, minimizing the environmental footprint and may be the more economically viable option.

There is controversy surrounding animal-derived products originating from religious doctrine. For example, Hindus and Sikhs are not permitted to use swine and bovine products unless in dire situation (14).

Fish lack the religious opposition and may be the more ethically appropriate alternative to patients.

Discussion

Wounds are common practice for most podiatric physicians and proves to be a time and labor intensive endeavor. Many patients are afflicted with chronic, non-healing ulcers as a result of poorly controlled diabetes, peripheral arterial disease, or a variety of other comorbidities. Patients undergo extended periods of treatment to no avail. Creating a clear void in addressing chronic wounds. Currently, there are no products of bioengineered skin that can mimic the anatomy, physiology, stability or appearance of undamaged skin. Since its introduction in 1994, acellular dermal matrices have been the forefront of wound care. ADMs are acellular bio-material that functions as a natural platform for fibroblasts and endothelial cells. Composed of purely extracellular matrix, ADMs are historically derived from mammalian tissues. Common sources include pigs, cows, horses, and humans. ADMs mode of action has been heavily based on the researched on porcine-derived small intestinal submucosa (SIS) wound matrix. Proposed hypotheses of function include scaffold ability, fibroblasts receptors, angiogenesis stimulation, chemoattractant for endothelial cells, and the presence and protection of growth factors (15).

Omega-3 Wound (Kerecis, Iceland, Reykjavik) is the newest ADM to the market. Harvested from Atlantic cod in the Icelandic seas, Omega-3 Wound is a piscine ADM that is structurally unique and functionally advantageous. Harboring less zoonotic pathogens, piscine ADM undergo a less extensive sterilization preserving bioactive material. Fatty acids such as DHA and EPA have been extensively researched, with incredibly positive conclusion that these omega-3 fatty acids have not only immunomodulatory functions but also analgesic properties. The porous structure of the cod dermis provides adequate room and structure for fibroblast proliferation and remodeling (16). Contraindications to Omega-3 wound or other piscine derived ADM include known fish allergies or sensitivity to fish materials.

Conclusion

Piscine ADM is a competitive biologic, given its lack of autoimmune inducers along with immunomodulatory and analgesic benefits. The use of piscine ADM as a graft material is promising, despite few studies on efficacy. More studies on the use of piscine ADM for chronic and recurrent ulcers such as neuropathic or venous stasis ulcers would be beneficial, as ulcerations render a patient susceptible to infections and possible subsequent amputations. More research regarding piscine ADM and the breadth of benefits and consequences are required before it becomes a widely used product.

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Diabetic Foot Ulcers: A Review of Acellular Bioengineered Tissue Grafts

Samta Batra, MS-1

Abstract:

A chronic wound may encounter difficulty healing due to a variety of factors, including the presence of systemic diseases, lack of tissue growth factors, or inefficient fibroblasts. Technological developments have allowed bioengineered skin grafts to successfully avoid these growth impediments when treating wounds such as diabetic foot ulcers. The grafts have been designed to include biological mediators which can promote biological processes such as thrombus, scar formation, and matrix synthesis. In this review, two separate studies observed the healing progress of ulcers when treated with a human reticular acellular dermal matrix and a fetal bovine dermal matrix.

Introduction:

Diabetes is known to cause peripheral neuropathy and negatively impact blood circulation (1). Due to lack of neuronal sensation, diabetic patients are incapable of recognizing excessive pressure exerted on various areas of the foot (1). They can be unaware of deepening wounds that become exposed as the superficial skin layers degenerate when there is continued contact with the ground (1). The poorly maintained vascular system fails to deliver a sufficient amount of oxygen and nutrients needed for the wounds to heal appropriately (1). Untreated diabetic foot ulcers (DFUs) are clinically important because they can increase requiring a patient's lower limb amputation risk (1).

Recent developments have allowed newly designed skin substitutes to be used alongside standard care in order to increase the healing rate of DFU (2). The current standard of treating DFUs includes using preventive measures to maintain healthy glucose levels, utilizing appropriate footwear to reduce pressure on the wound, and consistently assessing and monitoring the vascular status (3). DFU's can also be treated for by dampening the wound with saline-infused dressings, debriding hyperkeratotitc lesions, and prescribing antibiotics if patient presents with comorbidities (3). With conservative treatments, wounds will undergo blood coagulation, vascularization, fibroblast and endothelial cell production, and granulation tissue development as part of the healing process (4). Traditional grafts, such as the allograft featured in Figure 1, are processed to include elements such as glycerol, and become a skin-like fabric that can be applied to the new host (5). There has been a shift towards utilizing tissue engineered grafts for chronic wound healings due to the potential for the release of growth factors, which allows for rapid and successful ulcer healing. Grafts can be cellular or acellular, allogenic or autologous, derived from humans or other animals, and have varying compositions of fibroblasts, keratinocytes, and epidermal cells. The purpose of this article is to present two types of bioengineered acellular tissue grafts, and the physiological interaction between grafts and DFUs (3).

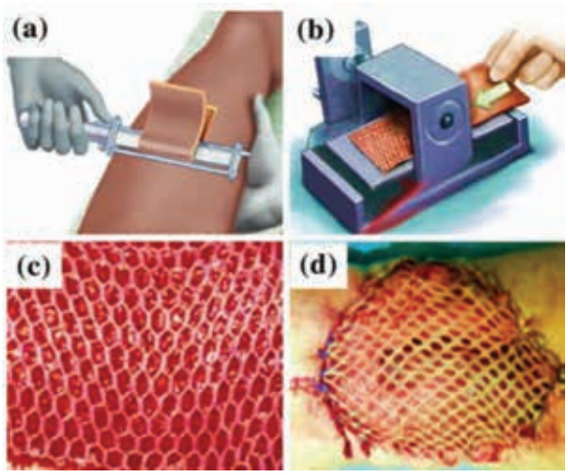

Figure 1: The creation of a traditional skin allograft taken from a cadaver, adapted from Progress in Biomaterials (5).

Pathophysiology

DFUs consist of fibroblasts that do not migrate as widely or interact with growth factors as efficiently as fibroblasts in typical, non-diabetic wounds do (3). The cellular elements required to promote reepithelization do not function optimally (6). Consequently, the extracellular matrix in DFUs becomes a specialized region, which researchers believe has the capacity to improve the cellular functions, especially in chronic non-healing wounds (6). The skin substitutes used for DFUs can range according to their composition, which are generally categorized depending on the presence of cellular matrices (6). Bioengineered tissue grafts are considered to be successful if they can promote the healing process by releasing cytokines, providing established scaffolding, promoting angiogenesis, and incorporating into the host without any complications (6).

Skin substitutes are created in order to introduce a new matrix with or without living cells, that has the

capability to immediately restore the regeneration process (7). Depending on the brand, acellular dermal matrices can be enhanced by adjusting the relative composition of the elastin, collagen, fibroblasts, and keratinocytes within the framework (7).

Treatment

Current Research Regarding HR-ADM Allografts

In 2016, the International Wound Journal published a prospective randomized study by Zelen *et. al*, analyzing the healing rates of chronic DFUs in patients treated with human reticular acellular human dermal matrix (HR-ADM) grafts (8). The DFUs of those within the control group receiving only treatment with standard of care (SOC), were then compared to the healing rate of the 20 subjects who received HR-ADM allografts in addition to SOC (8). After 6 weeks, 65% of the HR-ADM group's wounds were closed compared to the 5% of those within the SOC only group (8). At 12 weeks, 80% of the HR-ADM group's wounds had healed, while 20% of the SOC only group's ulcers had closed (8). There was a statistically significant difference between the percentage of the wounds closed between the HR-ADM and the SOC only group at both the 6 week mark, which has a p-value of 0.00028, and at the 12 week mark, which had a p-value of 0.00036(8). The mean time of healing for the HR-ADM group was 28 days, compared to the SOC group's 41 days, at the 6 week mark, and 40 days, compared to the SOC group's 77 days, at the 12 week mark (8).

The advantages of the HR-ADM graft include the flexible and consistent reticular structure which maintains and promotes dermal functions such as granulation, matrix formation, and blood vessel formation (7). The fibroblast and endothelial cell-based graft, consisting primarily of collagen and elastin, is capable of performing vitally critical roles of such as cell mobility and attachment (7). Since the graft has been created from deeper layers of the dermis, the cells will share a similar architectural foundation when adapting to the patient's skin (7). The glycosaminoglycans and hyaluronic acid also support the HR-ADM's extracellular matrix's ability to immediately react to incoming stimuli, and appropriately release growth factors (7). Consequently, HR-ADM grafts are being considered as serious competitors for wound repair upon successful integration into host cells.

Current Research Regarding PriMatrix Allografts

Published by Advances in Skin & Wound Care in 2014, a prospective multicentric study was conducted by Kavros *et. al* which assessed the healing capabilities of the PriMatrix, a fetal bovine acellular matrix (9). For 12 weeks, 46 subjects participated for the complete duration of this multicenter study (9). Each subject received an average of 2.0 ± 1.4 applications of the PriMatrix to their ulcer, and around 76% of the subjects' wounds had recovered by the end of the study (9). The average wound area still declined by 71.4% for those subjects whose ulcers were not considered to have healed completely (9).

The PriMatrix allograft has gained attention because studies have demonstrated that it can successfully regenerate tissue over both tendon and bone. The bioengineered matrix has also been recognized for healing full thickness wounds that are not restricted to diabetic ulcers (2). The presence of type I and III collagen allows PriMatrix grafts to regulate cell proliferation, scaffold regeneration and decreased scar development (8) Upon application, the scaffolding of the graft immediately attaches to the blood cells and interacts with localized growth factors (9). There have been, however, reports of allergic reactions occurring in some the subjects (9). Since PriMatrix grafts have demonstrated success, studies have promoted this as another source of therapy for patients with DFUs (9).

Conclusion:

Diabetic patients with foot ulcers can experience significant changes since untreated wounds can cause the patient to experience difficulty walking and potentially increase risk for an amputation. To obtain the greatest healing potential, early assessment is crucial when ensuring that off-loaded wounds be treated as quickly as possible. The commercial market has produced dermal matrices such as Alloderm, which does not rely on immunogenic cells, and Dermagraft, which is derived from neonatal fibroblast cells (4). Within the studies presented, the authors concluded that HR-ADM grafts have shown to decrease the time needed for DFU's to heal when provided with standard care (8). The authors also concluded that PriMatrix grafts can be successfully utilized in conjunction with the standard treatment plan for patients with diabetic foot ulcers (9). For future studies, follow up with the patients a year after the study has concluded in order to recognize any complications or adverse effects would be beneficial. Another suggestion would be to compare the results within each study based on factors such as type of shoes used during the treatment, type of diabetes, and previous exposure to surgical debridement. Although the recovery will be rapid and more predictable, there are concerns regarding the expense, when compared to standard care dressings and allergic reactions. Certain grafts, such as Integra, can cause the accumulation of fluid and create an environment prone to infection (4). Overall, each graft has a unique combination of factors promoting the vasculature, growth, and basal membrane development within the wound. Future studies have the potential to recognize the relationships between environmental factors, such as obesity, age and post-operative wound maintenance, and the healing progression of the graft-treated wound. Advancements in bioengineered grafts

can improve the healing rates and decrease the wound area rapidly when incorporated with standard care techniques.

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The Effects of Human Amnion Membrane on Wound Healing: A Systematic Review

Elnaz Hamedani, MS-1 and Bryanna Vesely, MS-2

Abstract

Wound management is a critical component of podiatric care, as chronic wounds affect millions of patients annually and create a financial burden on the healthcare industry. In an effort to decrease the frequency of chronic wounds in the patient population, physicians have started using human amnion membrane in wound dressings to promote faster healing. This systematic review examines the various studies that have used human amnion membrane in wound management to determine the overall efficacy of this treatment for diabetic and chronic wounds. Recent studies have shown that human amnion membrane promotes healing in pressure ulcers and chronic diabetic wounds. Human amnion membrane was applied to wound dressings in micronized, granulated, or sheet form. Although recent studies have shown that human amnion membrane promotes wound healing in diabetic and chronic wounds, these studies focus on small sample sizes. Additionally, these studies vary in the form of human amnion membrane that is used. Future studies should be done on larger patient populations, and it would be beneficial to investigate if the different forms of human amnion membrane have any impact on efficacy.

Introduction

Wound healing is a vital process composed of a sequence of regulated events to repair damaged skin. Wound healing consists of four phases: hemostasis, inflammation, epithelialization, and remodeling. After the onset of injury, hemostasis begins when the coagulation cascade uses thrombin to create a fibrin mesh and turn the recruited platelets into a stable clot. In the second phase, neutrophils and monocytes remove pathogens and foreign material followed by macrophages to secrete growth factors, cytokines, and phagocytose debris. The epithelialization or proliferation phase begins to fill the tissue with new collagen and ground substance produced by fibroblasts. Lastly, in the remodeling or maturation stage the collagen is reorganized, the vascular network regresses, and the wound hopefully returns to its pre-injury state (1). The pathophysiology of wound healing is depicted in Figure 1 below. Because of the intricacy of these phases, patients with underlying illnesses such as diabetes and heart disease are susceptible to complications while completing the steps in this pathway.

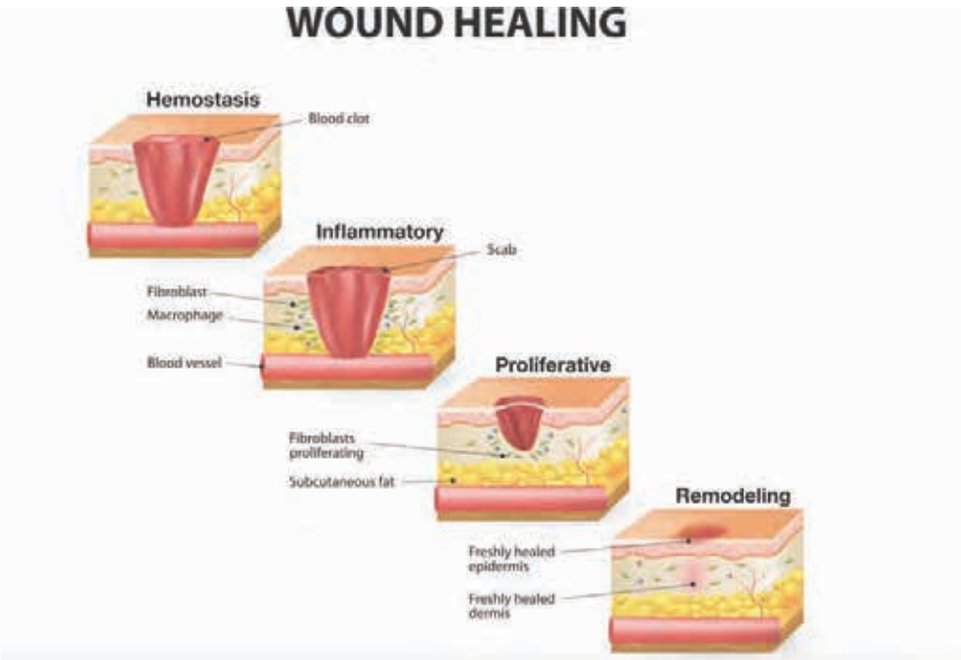

Figure 1. Pathophysiology of the four stages of wound healing adapted from Shield Healthcare (1).

For wound healing to be successful, there must be adequate oxygen supply, nutrition, and proper regulation of the wound healing factors. Due to the complex nature of wound healing, underlying health conditions may prevent wound healing and lead to the development of chronic wounds. As defined by Medicare, a chronic non-healing wound is a "wound that does not heal by at least 50% after receiving basic wound care for 30 days (2)." The number of patients impacted by chronic wounds is growing yearly from 6.5 million, and is mostly caused by the increase of chronic diseases, such as diabetes, which impair these pathways. Chronic wounds drain the economy by costing the medical system over $25 billion per year, with a single diabetic ulcer costing up to $50,000 (3). Aside from the financial burden, poor healing wounds can cause a variety of health issues for patients ranging from outpatient surgeries to amputations and infections. To help manage wound healing, physicians and researchers have sought to find ways to help increase the speed and efficiency of healing. This article examines the various uses of human amnion membrane in wound healing, and compares recent case studies to determine if human amnion membrane is a viable solution for effectively treating wounds.

Human Amnion Membranes

Amniotic membrane is the innermost layer of the placenta composed of the thick basement membrane and an avascular stromal matrix. Amniotic membrane is no stranger to the medical community as it has been used for ophthalmologic procedures since the 1940s, however it has recently been introduced to the field of wound healing. In ophthalmology, it was first used by De Rotth for conjunctiva reconstruction and cornea infections due to its similar composition to the conjunctiva (4). Recently, research has been conducted on the additional impact of amniotic membranes and their prospective effects on healing.

With chronic wounds, allogenic and autologous split thickness skin grafts are a common treatment used among physicians. In split thickness skin grafts, the skin is integrated into the final tissue which makes it subject to various complications such as infection and rejection. Amniotic fluid however does not permanently integrate into the final skin tissue. Instead it secretes growth factors necessary for regeneration and angiogenesis. Amniotic fluid is immunoprivileged, meaning it can tolerate antigens without creating an immune response. Because amniotic fluid is from an earlier point in development than mesenchymal stem cells, it is less likely to be rejected, yet it still has a high proliferation capacity, multipotency, and immunomodulatory activity (5).

Recent Studies of Human Amnion Membrane

In a 2016 research study with 25 patients who all had chronic leg ulcers, it was investigated to see if amniotic membrane would promote tissue reconstruction instead of scar tissue. All participants had chronic leg ulcers for over 3 months without active infections, diabetes, a history of smoking, hypertension, or any medical conditions. The patients were separated into a control group with 11 patients treated with conventional wound dressing, consisting of Vaseline application and gauze dressing, which was changed daily for 8 weeks, and a study group with 14 patients who had amniotic membrane placed on the ulcer. The amniotic membrane was placed on the ulcer, followed by an application of Vaseline and a gauze dressing. The healing rate, detection of ulcer size, pain assessment and images were taken on days 0, 4, 14, 21, 30, 45, and 60. The results for the control group had no ulcer size reduction and no improvement in pain. Whereas, in the study group all 14 ulcers had complete healing. Of these, 13 of 14 had healthy granulation, and 11 of 14 had pain improvement. This study concluded that wound healing can be improved by using amniotic membrane versus the conventional wound dressing (6).

Since the concept that amniotic membrane induces epithelization in wounds was already established, another research study was conducted to understand the effects of amniotic membranes on chronic wounds. This study, conducted in 2014, used keratinocytes to examine how amniotic membranes affect different signaling pathways and regulatory genes (7). It was found that amniotic membrane impacted Smad2 and Smad3 TGFB-induced phosphorylation. TGFB can arrest the cell cycle by stopping cells from going into the G1/S phase transition which is contraindicative when trying to rebuild damaged epithelial tissue. However, in the presence of amniotic membrane, TGFB is inhibited, preventing cell cycle arrest (7). Amniotic membrane also has an impact on TGFB1 by promoting myofibroblast differentiation at wound sites which is necessary for wound healing. In addition, amniotic membrane increased c-Jun protein expression at the wound border which is required for the progression of the cell cycle through the G1 phase, allowing the cells to replicate and rebuild the damaged area (7).

In a randomized clinical trial conducted from 2012 to 2013, the healing of pressure ulcers treated with cryopreserved human amniotic membrane allograft versus traditional treatment was compared. All 24 patients in the trial needed split-thickness skin grafts for the pressure ulcers. The patients were divided into two groups; the amnion group and a control group which was treated with local Dilantin powder application, a phenytoin sodium commonly used for wound healing. Healing time was recorded for both groups. Complete healing took place in the amnion group with 75% of the

patients while it took place with 0 patients in the control group. Decrease wound discharge, a sign of early response to healing, began significantly earlier in the amnion group versus the control group. Healing time was 20 days in the amnion group versus 54 days in the control group. All in all, this study supports that amnion therapy is an effective method to increase healing in pressure ulcers (8).

A 2013 prospective study by Werber et. al observed the effects of amniotic membrane in chronic diabetic wounds of the foot (9). In this study, amniotic membrane was granulated and applied to fill openings in soft tissue and bone (9). Over the course of the study, 18 out of the 20 chronic wounds treated had healed within 12 weeks (9). Similarly, in a 2016 case review by Hawkins, amnion membranes were used for diabetic ulcers in three patients (10). Human amnion membranes were dehydrated and micronized before being applied to diabetic foot ulcers post debridement (10). After one month of treatment, which consisted of weekly micronized human amnion membrane dressings, all three patients reported healed diabetic foot ulcers. Figure 2 shows the results of wound healing in one of Hawkins' patients after one month of micronized dehydrated amniotic membrane treatment. Hawkins reported that at the 6-month follow-up, there was no re-ulceration in any of the three patients.

Figure 2. Diabetic ulcer after two weekly applications of human amnion membrane as mentioned in the Hawkins case study. Adapted from Wounds (10).

While Hawkins used micronized human amnion membranes, other studies have used flat sheets of amnion membrane in the wound dressing. A 2017 retrospective cohort study by Lullove examined the effects of dehydrated human amnion membrane in 20 patients who had a variety of diabetic foot ulcers, venous leg ulcers, and autoimmune wounds (11). Unlike the weekly application of human amnion membrane in the Hawkins study, Lullove applied human amnion membrane to the ulcer dressing biweekly. Of these 20 patients, the mean healing period for all three ulcer types was 9.2 weeks (11). In this study, the use of dehydrated human amnion membrane closed foot ulcers without any adverse effects noted to date (11).

In a 2016 retrospective case study by Rosenblum, the use of dehydrated amniotic membrane was assessed for diabetic foot ulcers (12). After placement of an amnion membrane allograft, the wound was monitored every 1 to 2 weeks, with mean closure by 9.2 weeks (12). An example of one of Rosenblum's case patients can be seen in Figure 3, which shows the progression of amnion membrane allograft treatment in a diabetic foot ulcer. While these studies showcase the benefits of dehydrated human amnion membrane in wound healing, larger cohort studies are needed to validate these case study results.

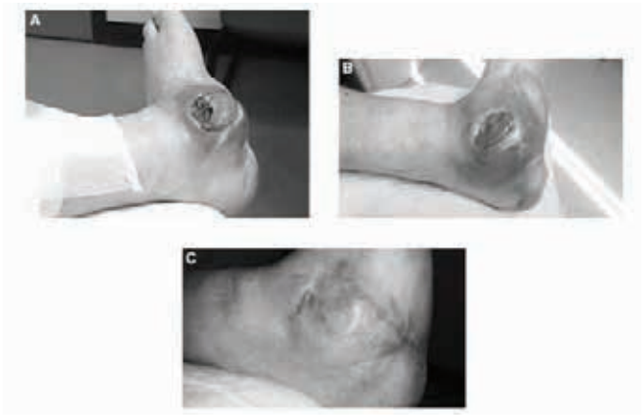

Figure 3. Diabetic foot ulcer prior to amnion membrane allograft (A); 10 days after initial amnion membrane allograft application (B); final results after diabetic ulcer healed following amnion membrane allograft (C). Adapted from Journal of the American Podiatric Medical Association (12).

Conclusion

Amniotic membrane has been extensively used in ophthalmology to aid in surgery and wound care. More recently, human amnion membrane has been used as a wound dressing for podiatric wounds. Although these studies have shown the benefits of using human amnion membrane, further investigation is needed, preferably with larger cohorts, to determine how other underlying factors influence the use of amnion membrane. While human amnion membrane has been shown to improve wound healing, the availability of this treatment should also be considered. The average cost

of human amnion membrane varies from $400 to $4,000 based on the size of the membrane (13). The high cost of this treatment might not make this a feasible option for all patients who have chronic wounds. Future research can also delve into the efficacy of human amnion membrane and how it is affected by patient history, duration of treatment, and how often the amnion membrane is applied to the wound (12). These studies also did not disclose the exact location of the wounds, which would be beneficial in determining if the location of an ulcer positively or negatively influences healing time. Additionally, although human amnion membrane has been used in various patient case studies, these studies have used different forms of the membrane. It would be beneficial to determine if efficacy varies whether it is applied in a micronized, granulated, or sheet form. Future studies in the use of human amnion membrane can also focus on how the processing of amnion membrane affects the efficacy of the treatment.

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Painful Diabetic Neuropathy Treatments: A Recent Literature Review

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Abstract
Painful diabetic neuropathy (PDN) is a complication of diabetes that leads to debilitating symptoms which reduces patients' quality of life. Management is based on glycemic control, risk factor management, and symptom treatment. Treatment options for pain have remained unsatisfactory with needed room for improvement. This article discusses recent literature concerning treatments targeting symptomatic control for PDN.

Introduction
In 2015, an estimated that 30.3 million Americans, or 9.4% of the adult US population, were living with diabetes. Additionally, 84.1 million, or 33.9% of the adult US population, had prediabetes (1). Painful diabetic neuropathy affects 10-20% of all diabetics, or 40 to 50% of all diabetics with neuropathy, with up to 39% untreated (2). Prevalence of painful diabetic neuropathy (PDN) will continue to increase as the diabetes epidemic grows (3).

Symptoms of PDN are commonly described as but not limited to burning, stabbing, and/or dull pain. PDN's painful and debilitating symptoms lead to a diminished quality of life and frustration to patients. Providing effective management for PDN has remained difficult, which highlights the need to develop more efficacious treatments. Recent randomized controlled trials (RCTs) and meta-analyses have been providing evidence for effective treatment methods, and evidence against treatment methods that are proving to be less effective. Research on efficacious treatment options for PDN has also remained difficult, with most RCTs yielding unsatisfactory results (4).

Current research on PDN management is also inadequately implemented in the clinical setting. Bringing awareness to current research concerning management and maximizing efficaciousness of treatment options is needed to improve patient outcomes. The goal of this review is to discuss recent literature concerning emerging PDN treatments, focusing on articles that indicate change to current clinical management.

Prevention
Preventing PDN is dependent on adequately controlling diabetes. Prolonged hyperglycemia causes nerve damage, leading to hyperexcitable pain pathways (5). Delaying onset and progression of neuropathy is dependent on proper control of blood glucose, with CL Martin et al. demonstrating a 64% risk reduction of diabetic neuropathy with intensive therapy for glycemic control (6). Even once diagnosed with PDN, proper glycemic control halts its progression (7). Maintaining a proper Hba1c should remain a priority to minimize the progression of PDN. Although slight improvements in vascular risk factors such as dyslipidemia, hypertension, smoking, and high BMI are associated with a significantly lower risk of the onset of diabetic neuropathy, there is no literature measuring the effects of such vascular risk factors using diabetic neuropathy or painful diabetic neuropathy as a primary outcome (8). Such a study would provide useful information that can guide clinicians with targeted lifestyle modification recommendations.

Current Guidelines
A systematic review by The American Academy of Neurology (AAN) published guidelines in 2011 for the treatment of diabetic neuropathy. Pregabalin was regarded as an effective method of treatment (Level A) (9).

Treatments designated as probably effective (Level B): Gabapentin, Sodium valproate, Amitriptyline, Duloxetine, Venlafaxine, Dextromethrophan, Morphine, Oxycodone, Tramadol, Capsaicin, Isosorbide dinitrate, and percutaneous electrical nerve stimulation for three to four weeks. Lidocaine was possibly effective.

Treatments designated as "probably not effective" include: oxcarbazepine, lamotrigine, lacosamide, clonidine, pentoxifylline, mexiletine, magnetic field treatment, low-intensity laser therapy, and Reiki therapy.

Table 1: Summary of Recommendations	
	Recommended drug /dose
Level A	Pregabalin, 300-600 mg/d
Level B	Gabapentin, 900-3,600 mg/d
	Duloxetine, 60-120 mg/d
	Morphine sulfate, titrated to 120mg/d
	Tramadol, 210 mg/d
	Oxycodone, mean 37mg/d, max 120mg/d
	Capsaicin, 0.075% QID

Table 1: Summary of recommendations (adapted from American Academy of Neurology)

Pharmacological studies

Capsaicin was originally thought to decrease pain by depleting substance P (11). More recently, it was found that capsaicin attenuates cutaneous hypersensitivity and reduces pain by defunctionalizing nociceptor fibers (12). One large benefit of capsaicin's mechanism is limited systemic absorption leading to less adverse effects than systemic drugs. A 2017 network meta-analysis (NMA) by van Noorten F et al. assessed the efficacy of 8% capsaicin patch compared to commonly used oral treatments for PDN (13). This is the first large magnitude meta-analysis to include capsaicin patch as a treatment option. The NMA included 25 RCTs, and found capsaicin 8% cutaneous patch to be as efficacious (greater than 50% pain reduction) than pregabalin, gabapentin, and duloxetine. Cumulative rankings found capsaicin patch to rank 2nd or 3rd for overall efficacy outcomes. Capsaicin patch also had significantly less adverse effects as compared to the systemic oral agents. The findings of this NMA warrant further RCTs to determine the long-term effectiveness of the capsaicin patch, and increased awareness is needed of this low risk, affordable, and effective treatment option.

There is one RCT currently in progress, Pain Improvement With Novel Combination Analgesic Regimens (PAIN-CARE) that is comparing the treatment combination of pregabalin and the antioxidant alpha-lipoic acid (ALA) against pregabalin and ALA alone (14). It is an approved treatment option for neuropathic pain in Germany but not elsewhere. ALA is thought to be effective for neuropathic pain due to its antioxidant properties, which protects micro and macrovascular complications (15). Recently, ALA has also been found to selectively inhibit neuronal calcium T-type channels, leading to decreased sensitivity to pain (16). A 2012 meta-analysis by Mijnhout et al. found intravenous ALA administration leads to clinically significant reduction of neuropathic pain (17). However, evidence for ALA through the oral route at 600mg or more provided inconclusive evidence. PAIN-CARE will answer the question if whether oral ALA and pregabalin is superior to pregabalin alone. Although the trial is not specific to painful diabetic neuropathy, the study will use adults with neuropathic pain. ALA is the only non-sedating agent proven effective against neuropathic pain, and the researchers hypothesize that using one non-sedating agent in conjunction with pregabalin will be safer and more effective than pregabalin alone. If their hypothesis is valid, patients may benefit from decreased systemic effects instead of relying solely on pregabalin. Participant recruitment commenced in September 2017.

One potential treatment option for PDN, Botulinum Toxin-A (BTX-A), is not part of the AAN's recommendations. A 2015 meta-analysis of two studies using BTX-A versus placebo injections for neuropathic pain by Lakhan SE et al. found statistically significant improvement of minimum change in pain (18). Significant minimum change in pain is commonly described as 1.3 visual analogue score (VAS) point improvement, with 2.0 VAS point improvement described as clinically significant (19,20). This meta-analysis found a change of pain of -1.96 VAS points. In one pilot study included in the meta-analysis, Yuan et al. used 4 U of BTX-A per site, total of 50 units, to the dorsum of each foot on 20 patients (21). This approach resulted in 44.4% of the BTX-A group experiencing a reduction of pain within 3 months, significantly higher than the placebo group. In another study, Ghasemi et al. used 8 to 10 U per site in 40 patients (22). The result was a decrease in neuropathic pain score and Douler Neuropathhique 4 score. There were no statistically significant adverse effects. The authors of the meta-analysis recommend large-scale studies using BTX-A for treatment of PDN to further determine efficacy. BTX-A may potentially have a place for adjunctive treatment for PDN.

One method of treating PDN is considering comorbid conditions and creating a management plan that addresses PDN and the comorbid condition. For example, it is common clinical practice for patients with depression to typically receive a SSRI, or patients with anxiety to receive an anticonvulsant. A systematic review published in 2017 suggested that phenotyping of pain may lead to more precise management and improved patient outcomes (23). Out of seven thoroughly reviewed RCTs, four suggested benefit to treating according to phenotype or comorbidities, and three RTCs provided weak evidence or evidence against treating PDN based on comorbidities.

This meta-analysis resulted in three main results: "First, paroxysmal pain had a better response to pregabalin;

Second, the preservation of thermal sensation or nociception anticipated a positive response to the topical treatment of pain; and, third, after a failure to duloxetine (60 mg/day), the patients with evoked pain or severe deep pain had a better response to association of duloxetine/pregabalin while those with paresthesia/dysesthesia benefited from duloxetine monotherapy (120 mg/day)" (23). However, since scientific evidence of stratifying PDN treatment by comorbidities is lacking in studies, guidelines have not incorporated this concept. Treating PDN according to comorbidities still requires more studies to determine efficacy of the treatment approach. Finding success of this comorbidity-based approach may further personalize treatment and decrease empiric medication use.

Opioids

It is also important to take note of studies that have found treatments to be weakly effective or inconclusive. Recent studies have been dismissive of the efficacy of opioids for the treatment of PDN, despite the AAN's classification of morphine, oxycodone, and tramadol as "probably effective". Studies that examine opioid efficacy in treatment of PDN hold an important role in potentially decreasing unnecessary opioid use and contributing to the improvement of the opioid crisis in the U.S.

A 2017 systematic review of studies compared morphine with placebo for neuropathic pain (24). Selection criteria included randomized double-blinded trials of two weeks or longer. Five randomized, double-blinded, cross over studies, involving 236 patients was used for data. Moderate improvement of pain was experienced by 63% of those who received morphine, and 36% of those who received placebo. The authors concluded insufficient evidence to support or refute morphine's efficacy in any neuropathic pain condition.

A review published in 2016 assessed the efficacy of oxycodone for neuropathic pain (25). The review used five randomized, double-blinded studies, reporting on 687 participants, 637 of who had PDN and 50 with postherpetic neuralgia. All studies compared oxycodone against placebo. The results provided only very low quality evidence of oxycodone's value of treating PDN or postherpetic neuralgia. In three studies used in the review, 44% of participants treated by oxycodone and 27% of those taking placebo experienced moderate benefit of at least 30% pain relief (NNT 5.7). Additionally, 86% of subjects treated by oxycodone experienced adverse effects, compared with 63% for those taking placebo. With a high number needed to treat and high rate of adverse effects, the role of oxycodone as a treatment agent for PDN should be reconsidered.

Finally, a review on tramadol for neuropathic pain in 2017 identified 6 randomized, double-blind studies involving 438 patients (26). The studies were not specific to PDN, but also included neuropathic pain patients due to cancer, cancer treatment, postherpetic neuralgia, and polyneuropathy. Exclusion criteria included those with other significant comorbidities or causes of pain. Tramadol induced pain relief in 70/132 (53%), and 40/133 (30%) had pain relief with placebo (NNT 4.4). Rate of adverse events were higher with Tramadol (58%) than with placebo (34%). The authors concluded only low or very low quality evidence of benefit from tramadol due to inadequate studies with elevated risk of bias. Again, more comprehensive large scale RCTs are needed to determine the efficacy of tramadol for neuropathic pain, including PDN.

Non-pharmacological studies

Emotional distress is a common occurrence among patients with PDN, with one study by Selvarajah et al. finding a prevalence of 51.4% in its 142 patient sample (27). The 2014 study discussed the importance of recognizing the psychosocial aspect of pain management in PDN. Continued recognition and identification of contributors of emotional distress may improve outcomes for PDN, as chronic PDN is a complex experience comprised of the pain itself, along with the psychosocial consequences. Due to this complexity of sensory pain +/- psychosocial difficulties, a holistic approach consisting of more than pharmacological treatments are required for optimal management.

A recent 2017 randomized trial published in the Clinical Diabetes journal used mindfulness-based stress reduction (MBSR) as a treatment intervention for pharmacologically optimized patients with painful diabetic neuropathy (28). MBSR courses focuses on promoting mindfulness exercises to become more self-aware as a witness to their situation, allowing objective self-assessments leading to self-regulated improved response to pain (29). The study resulted in patients with decreased pain intensity, pain catastrophizing, depression, and perceived stress when compared to standard care. A significant shortcoming of this study was a treatment arm of only 30 participants. In a meta-analysis of MBSR for chronic pain, quality points were assigned for an n value equal to or greater than 50 (30). Further RCTs on MBSR can benefit from including a larger sample size, preferably of over 50. Still, patient referral to a qualified community MBSR program can be utilized as an effective low risk tool that can be incorporated in patient management.

A 2017 study published in the Journal of Nursing Scholarship examined the effect of aromatherapy massage in patients with PDN (31). Aromatherapy's analgesic effects are believed to be related due to the following: the volatile compounds of essential oils stimulating pleasure centers in the brain; analgesic components in the essential oils affecting dopamine, serotonin, and norepinephrine receptor sites in the brain; healing touch of skin contact; and the rate of essential oil absorption is increased with massage (32). The study consisted of 21 patients receiving aromatherapy massage 3 times a week for 4 weeks, and 25 patients receiving standard care. Coconut oil was used as carrier oil, along with the essential oils: rosemary, geranium, lavender, eucalyptus, and chamomile. The study found a statistically significant decrease in neuropathic pain, and statistically significant increase in quality of life after a minimum four weeks of intervention. Further studies may contribute supporting evidence for aromatherapy as a treatment option for PDN by including a larger sample size and comparing those who received aromatherapy against patients who received massage with unscented oil as a control arm. Although more research is needed to determine its efficacy, aromatherapy massage may be utilized as a low risk and well tolerated treatment option that can be added on to PDN management.

Conclusion

Recent research has continued to model management for PDN and will continually do so, which has been driven by unsatisfactory treatment and an enlarging population affected by PDN. There are recent promising studies of low cost and low risk treatment modalities that have emerged. Capsaicin patch, ALA, and BTX-A carry potential for a greater role in management of PDN, all while avoiding systemic adverse effects. Especially when considering the growing argument against the use of opioids, alternative methods of managing pain will become increasingly meaningful. Treatment targeted according to accompanying conditions with PDN may also hold value without addition of new medications. Lastly, studies regarding safe alternative adjunctive methods such as MBSR and aromatherapy massage may be of some value in management of PDN.

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High-Top and Low-Top Shoe Design Effects on Preventing Ankle Sprains

By Rohan Thamby, MS-3, Steven Cooperman, MS-2

Abstract

Ankle sprains are among the most common type of sports injuries; of these injuries, inversion sprains are the most common. Throughout the years, there have been many innovations made to shoes in order to combat these injuries, including high top and low top modifications to shoes. The purpose of this literature review it to attempt to determine what protective intrinsic and extrinsic factors aid in prevention of ankle sprains. After reviewing several articles, it was determined that the extrinsic differences, such as high versus low top shows, in determining incidence of ankle sprain injury is currently undetermined. Despite the efforts in the reviewed articles, it is inconclusive whether or not high top shoes make any difference in ankle sprain injuries versus low top shoes. Based on current data available in these studies, further research is required in this topic.

Introduction

Ankle sprains are some of the most common injuries in basketball athletes, accounting for as many as 3.85 occurrences per 1,000 athletic events (1). With such a commonplace injury, there is a significant amount of resources utilized for recovery and rehabilitation. Ankle sprains related to basketball usually occur with excessive inversion and plantarflexion of the foot which leads to damage of the anterior talofibular ligament and/or the calcaneofibular ligament. There are several intrinsic risk factors that contribute to ankle injury such as: muscle imbalance, poor flexibility, unstable postural sway, irregular ankle mobility, poor proprioception, and previous injury (2). However, with the upswing in production and sales of performance products and accessories, there is a great deal of attention placed on the extrinsic factors that may play a role in ankle injuries such as taping, braces, and footwear.

Ankle tape and braces have been proven to be effective in reducing ankle inversion and therefore reducing the susceptibility for ankle injury (3). Regarding footwear, there is conflicting evidence as to the effectiveness of high-top versus low-top basketball shoes. Due to the increasing popularity of the low-top basketball shoe, there is a greater need to determine the risks and benefits of this shoe design. The purpose of this literature review is to discuss the latest studies regarding high-top, low-top shoes, and other innovations for these shoes on preventing ankle sprains.

High-Top and Low-Top Shoe Effects

In a study performed by Ricard, Schulties, and Saret, the effects of high-top and low-top shoes on ankle inversion were examined (4). The high-top and low-top shoes used in the study were Reebok Turf Rat Hi and Reebok Turf Rat Lo football shoes respectively. The study was conducted using 20 male subjects with no history of lower extremity injury in the last 6 months that limited activity for more than 2 days. The patients were placed on an inversion platform (Figure 1), and filmed at 60Hz while the platform was quickly inverted to 35° on the right ankle (Figure 2). There were 5 separate trials run for each subject in both high-top and low-top shoes, resulting in 10 total trials per subject. This film was then analyzed using motion analysis techniques where three metrics were measured: amount of inversion, average rate of inversion, and maximum rate of inversion. The data from each patient, throughout the multiple trials was then compared to determine if there was a significant difference between high-top and low-top shoes based on these three metrics.

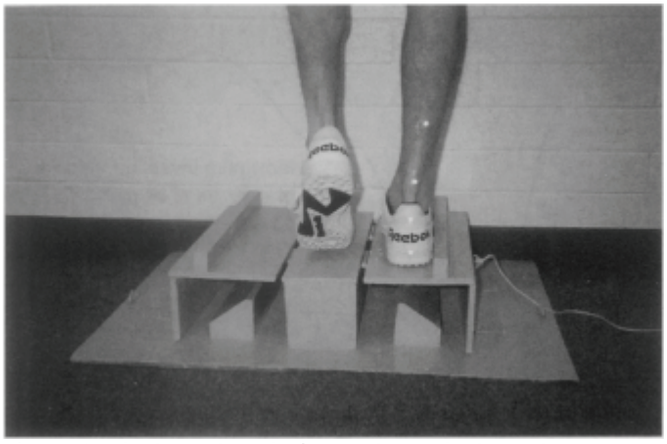

Figure 1. The inversion platform prior to the inversion of the right side

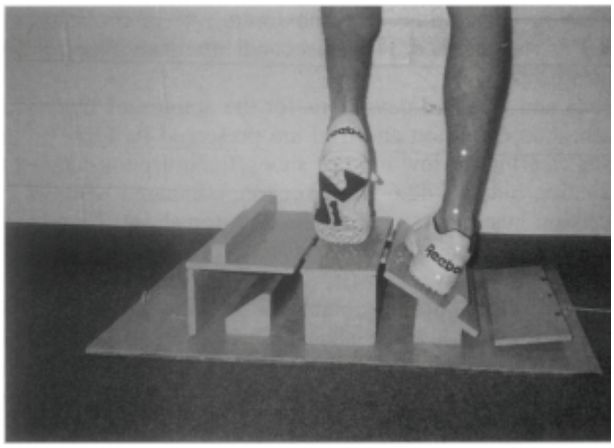

Figure 2. The inversion platform after the right side is inverted to 35°

Upon analysis of the results of the trials for the three metrics the high-top shoes reduced them all by a statistically significant amount when compared with the low-top shoes. The average inversion for the low-top shoes was 42.6°, while in the high-top shoes the subjects inverted an average of 38.1°, a 4.5° difference. The next metric, the average rate of inversion, also favored the high-top shoes; the high-top shoes averaged an inversion rate of 305.2 ± 19.7 °/s, while the low-top shoes averaged an inversion rate of 378.2 ± 33.2 °/s. This results in the high-top shoe reducing the average rate of inversion by 73 °/s in relation to the low-top shoes. The final metric analyzed was the maximum rate of inversion which, again, favored the high-top shoes. The maximum rate of inversion for the high-top shoe throughout the five trials averaged out to be 409.8 ± 59.3 °/s, while the low-top shoes averaged 509.9 ± 90.9 °/s over the five trials.

This particular study showed that the high-top shoes do have the potential to provide some benefits in preventing ankle inversion injuries in relation to the low-top shoes. This study supported the previous findings of Garrick and Requa, who, in a 1973 survey of 2562 basketball players-games, found that the lowest rates of ankle injuries were among the athletes who wore high-top shoes with taped ankles (5). During that same study, it was also shown that the highest rates of ankle injury occurred amongst the athletes who wore low-top shoes without ankle tape (5). This study hypothesized that one of the main contributing factors to the decreased incidence of injury, outside of the reduction in amount of inversion, was the slowing the speed of inversion of the foot. It was proposed by Vaes, et al in a 1998 study that slowing down the rate of inversion allows time for the muscular protection of the ankle joint to be activated (5). This was well demonstrated in the study by the way the inversion platform was used. The patients stood on the platform placing all of their weight on their right foot and were directed to look forward, the platform then dropped to 35° inversion at random intervals throughout the 10 trials (5 for high tops and 5 for low tops). This measurement technique prevented the subjects from bracing for the inversion, muscle guarding, by prematurely activating their muscular protection. By utilizing this technique the study was able to test the functionality of the high-top versus the low-top shoe, while taking out as much of the intrinsic muscle protection as possible. In regards to this metric, the high-top shoes were shown to reduce the rate of ankle inversion which according to the Vaes, et al study, should reduce the incident of ankle injury.

Cushioned Column Systems

During this period of testing, another factor for shoe height and preventing ankle sprains came to light. In 2008 a study performed by Curtis, et al aimed to determine the effect of shoes with cushioned column systems under the heel on reducing lateral ankle sprains (6). With the continued development of new cushioning systems such as Nike Zoom Air, Nike Lunarlon, and Adidas Boost, this was an important variable to consider. If cushioning was able to provide significant reduction of lateral ankle sprains, then shoe height would not need to be considered as strongly. These cushioning systems have been designed to amplify protection, support, and energy return, it was important to consider just how accurate these claims were. This study focused on creating surveys for collegiate level athletic trainers that asked 11 questions ranging from age, sex, prophylactic measures used, degree of sprain, and what type of shoe was worn. Any ankle injury that led to missing at least one day of activity was classified as an ankle sprain.

The study recorded 230 (141 male and 89 female) collegiate basketball players and was conducted during the 2005-2006 collegiate basketball regular season. Based on these results there was no difference in ankle sprain incidence between shoes that did have a cushioned column system versus shoes that lacked a cushioned column system. One outcome that was observed was that cushioned column systems that contributed to increased shoe heel height were actually more susceptible to ankle inversions (7). Some proposed reasons for this susceptibility were the lack of muscle recruitment and less stability, but further testing was not done to confirm these reasons. This study was significant in shifting the conversation back to mainly high-top vs low-top shoes only despite what advertisements regarding cushioned column systems have shown.

Inversion Kinematics and Muscle Activation

While the function of high-top shoes in preventing ankle sprains has been studied since the 1980s, there has been considerable debate over these results. Several studies have pointed out that high-top shoes definitively decreased the amount and rate of ankle inversion which decreases the risk of ankle sprains (2,4). When conducting studies from an epidemiological viewpoint, there seems to be no significant differences between high-top shoes and low-top shoes (8). In 2014, a study conducted by Fu, et al went in a different route and focused on ankle inversion kinematics and pre-landing electromyography (EMG) activation of ankle everter muscles (8). This study postulated that because earlier onsets and larger amplitudes of pre-landing EMG activity are essential to stiffening the muscles (in preparation for the landing and contact portion of foot movement), then sufficient pre-landing EMG activity should be a mechanism to protect ligament integrity during excessive and sudden changes in motion (8,9). Shoe designs can vary in ankle collar properties and these differences can provide different proprioceptive inputs and different neuromuscular responses which could lead to a better understanding of the collar height effect (8).

This study focused on 13 healthy male students with low-top and high-top forms of basketball shoes with identical midsoles and outsoles. They were then placed in four conditions: 15° of inversion, 30° inversion, combined 25° inversion plus 10° plantarflexion, and a combined 25° inversion plus 20° plantarflexion. The participants were instructed to hang from an overhead bar with heels 40 cm from a tiltable platform that could induce ankle inversion and/or plantarflexion (8). There were 5 successful trials of each condition performed with a 2 minute period of rest between each trial (8). Ankle inversion kinematics and EMG data of the tibialis anterior (TA), peroneus longus (PL), and peroneus brevis (PB) muscles were measured simultaneously with an eight camera motion analysis system (8). Some key kinematic variables of interest that were noted were: the ankle inversion angle at contact, the maximum ankle inversion angle, the time to maximum ankle inversion angle, and the ankle inversion range of motion (ROM), and the maximum ankle inversion angular velocity (8). For the amplitude of pre-landing muscle activity, the mean amplitude of the integrated EMG from the 50 ms prior to initial contact ($aEMG_{pre}$) was calculated in each of the four conditions (9).

The study found that as far as ankle inversion kinematics, there were no significant shoe effects on the maximum ankle inversion angle, the ankle inversion ROM, and the maximum ankle inversion angular velocity during landing on an inverted, or a combined inverted and plantarflexed surface between high-top and low-top basketball shoes (8). The increased height provided by a high-top basketball shoe therefore did not provide an increase in ankle stability based on the variables measured.

When measuring muscle activation, the onset time of TA ($F = 4.486$, $p = 0.047$) and PB ($F = 4.476$, $p = 0.048$) activity were significantly later when wearing high-top shoes compared to low-top shoes during the 15° inversion condition[10]. In the other three conditions however, there was no significant difference between low-tops and high-tops (8). The $aEMG_{pre}$ when wearing high-top shoes was significantly lower compared to low-top shoes in both the 15 inversion and the combined 25 inversion plus 20 plantarflexion conditions for the TA and especially the PL (37.2% decrease) and PB (31.0% decrease) (8). This showcased that the shoe partially influenced the timing and amplitude of the muscles tested before touchdown in landing movements. These findings showed preliminary evidence that wearing high-top shoes in certain conditions can give delayed pre-activation timing and decreased amplitude of everter muscle activity which can negatively affect the ability to evaluate, establish, and maintain ankle stability.

These results showed that an increased amount of $aEMG_{pre}$ and onset time while wearing low-top basketball shoes could provide increased proprioceptive feel leading to a more stable reaction to certain foot movements. Other factors such as vision and cognitive influences such as feeling more secure and safe could be reasons why these measured variables were affected during this study (8). Unfortunately, a severe limitation to this study was the small sample size used in this study. Despite the numerous tests performed on each subject, increasing the sample size for future studies would be an ideal manner to confirm the results from this study.

Conclusion

There are many intrinsic factors that affect the stability of the ankle during athletic activity but the extrinsic effects, including those of footwear, are still being studied. The studies that have been discussed have shown that there are some benefits to wearing high-top shoes in order to prevent ankle injuries. However, preliminary testing suggests that high-top shoes preventing ankle inversion might not be as helpful in preventing ankle sprains as previously thought. In the current state, much of the extrinsic effects of footwear on the incidence and prevention of ankle injury is still unknown. There is still a great deal of work to be done in order to determine the true efficacy of not only high-top and low-top shoes, but of athletic footwear in general. Future studies focusing more on muscle activation and inversion kinematics could play a role in determining the extent to which a type of shoe

aids our body to adapt in athletic events. Also, future studies involving more subjects with multiple types of high-top and low-top shoes would be ideal to answer the current debate. With an increasingly active population it is important that these studies continue to be conducted to prevent foot and ankle injuries.

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Current Literature on Management of Diabetic Ankle Fractures

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Abstract:
Ankle fractures are an extremely common and potentially debilitating lower extremity injury. These injuries are quite complicated when sustained by the diabetic patient population. With the understanding of decreased healing potential, we reviewed current recommendations on postoperative care, surgical construct, and weightbearing, as well as current recommendations in the treatment of complications such as infection, malunion, Charcot, and skin/wound dehiscence. The goal of this literature review is to discuss current recommendations on management of these fractures as well as management of the complications associated with these injuries in the diabetic population.

Introduction:

Diabetes mellitus is a prevalent disease that has been on the rise the last several years. In 2011, the Centers for Disease Control and Prevention, as well as the American Diabetes Association published the National Diabetes Fact sheet which estimated 25.8 million people, or 8.3% of the US population have either type I or II diabetes mellitus (1). Due to the prevalence of diabetes in our day and age it is imperative the treating physician be aware of the risk factors which are associated with these patients. It is also important for professionals to be aware of the effects of diabetes on fracture healing and fracture management. Ankle fractures are one of the most common fractures affecting our country currently, accounting for 9% of all fractures in adults. Diabetes-related bone disease has been linked with underlying hormonal, immune, and genetic pathways (2). Along with molecular changes of bone, chronically elevated glucose levels can have a detrimental effect. These factors cannot be ignored when managing a diabetic fracture.

It is well documented, patients with diabetes mellitus have demonstrated higher complication rates due to many different risk factors, such as polyneuropathy, nephropathy, peripheral vascular disease, and impaired immune response (3,4). Prevalent complications of diabetic ankle fracture include amputation, infection, mal/delayed/nonunion, Charcot collapse, and wound problems (3,5). Compared to nondiabetics and diabetic patients without these comorbidities, diabetics with neuropathy or vasculopathy are at greater risk of complication (4). Considering that both diabetes and ankle fractures are increasing in incidence and that 30-day postoperative rates of complications are now often used as a marker of quality care, it is essential that providers are aware and prepared for the unique risks and complications of diabetic ankle fracture management (6,7,8). The purpose of this literature review is to discuss complications, risk factors and recommendations of management in ankle fractures sustained by diabetic patients.

Materials and Methods:

The WesternU Pumerantz Library database was utilized for keyword searches and review of abstracts and full-text articles. Keyword searches included combinations of the following terms: “Ankle”; “Fracture”; “Arthropathy”; “Fixation”; “Internal”; “External”; “Hybrid”; “Combination”; “Operation”; “Surgical”; “Post-Op”; “Diabetic”; “Diabetes”; “Mellitus”; “Peripheral”; “Sensation”; “Joint”; “Protective”; “Complication”; “Infection”; “Wound”; “Malunion”; “Delayed”; “Union”; “Nonunion”; “Charcot”; “Hardware”; “Amputation”.

Discussion:

Treatment

The literature reports a high risk for complications in diabetic ankle fractures (3,4,9). When initially managed non-surgically, diabetic patients with dislocated/unstable ankle fractures have a disproportionally high rate of complications, up to between 66%-75%, with nearly 4-15.5:1 times more likely odds of finding a complication in a patient positive for neuropathy (10-16). Furthermore, in a study by Rosenbaum et. al., when eventually treated surgically, patients had a 100% complication rate compared to 12.5% in those who were primarily treated surgically (17).

Given the extremely high complication rate in unstable ankle fractures, recent literature recommends primary surgical fixation (4,10,13,18). However, patients with neuropathy or vasculopathy when treated primarily with open reduction internal fixation still have significant post-operative soft-tissue and osseous complications (4,18). Therefore, in this subset, careful soft-tissue management as well as stable, rigid internal fixation are crucial to obtaining a good outcome (4).

Several small uncontrolled series have recommended augmented internal fixation for the treatment of neuropathic patients with acute ankle fractures (Figure 2) (3,5,19,20). The most recent literature review on ankle fractures in diabetic patients reports that "diabetic patients with ankle fractures achieve better outcomes with additional fixation" (10,19). While there are a multitude of combination approaches, there is inconclusive data on which combination is best (3,13,21,22,23,24). Combination approaches generally combine ORIF with some form of internal fixation arthrodesis, often across multiple joints (i.e. trans-articular fixation using large Steinmann pins or screws, intramedullary rods, etc.) and/or additional fixation (i.e. external fixation, additional screws/syndesmotic screws, intramedullary fibular Kirschner-wires, rigid locking plates, or tendoachilles lengthening etc.) (10,19).

Figure 1: An example of augmented internal fixation with increased syndesmotic fixation.

Post-Op Care

It has also been shown that weightbearing timing is another variable that can create risk of complication in the diabetic population. It is suggested, the post-operative non-weightbearing period should be increased two- to threefold compared to that of the non-diabetic patient (10,12,18,25,26). Prolonged periods of non-weight bearing should also be considered in diabetic patients with displaced fractures (17).

Complications and Prevention

Amputation, which often follows infection, is a serious risk in the diabetic patient. The rate of amputation in diabetic patients after an ankle fracture can reach ≤42%, with mortality of 11% (11,27,28). Lower extremity amputation in diabetic patients is associated with peripheral neuropathy, peripheral vascular disease, foot ulcers, former amputation, and treatment with insulin (29). A study by SooHoo et. al. concluded that ankle fractures in diabetics have a greater rate of amputation and infection (30). In patients with increased risk of amputation due to peripheral neuropathy, use of additional fixation, in a study by Jani et. al., reduced major complications, including amputation (13%) by 5-18% compared to previous studies (19).

Infection, which can lead to sepsis and death in addition to amputation is also considered a major complication. The infection rates for diabetic patients with ankle fractures can reach 60% (27). In a study by Blotter et. al. infectious complications occurred in 24% of diabetic ankle fractures treated with ORIF; 42.9% of these infections required amputation (31) Strict control of HgA1c may reduce the risk of post-operative infections. Wukich et. al.'s study demonstrated an association between HgA1c ≥8% and surgical site infection (32). Dronge et. al. assert HgA1c levels <7% are associated with a decrease in infectious complications (33). Furthermore, vacuum-assisted closure is more likely to decrease the surgical site infection rate after ankle surgery in diabetics than standard moist wound care (34).

Figure 2: Ankle malpositioning after nonunion and hardware failure.

Mal/delayed/nonunion is a significant risk of diabetic ankle surgery (Fig. 1). McCormack and Leith observed a 71.4% incidence of asymptomatic nonunion in diabetics with displaced ankle fractures (11). A study by Shibuya et. al, showed that 1 in 4 diabetic patients will have at least one bone healing complication (13).

Osseous complications, are associated with peripheral neuropathy, increased surgery duration, Hgb A1c levels >7%, and vasculopathy (4,13). Out of all these risk factors, peripheral neuropathy is the most significant, being associated with 50% of all bone healing complications (13). This may be explained by the results of several animal and bench studies reporting that neuropathy leads to a malfunction of bone metabolism (13). In these patients with neuropathy or vasculopathy, rigid internal fixation and attempts to limit operative time is essential to reducing bad outcomes (4,13). Especially considering that for every additional 10 minutes of surgery, the odds of a bone healing complication are increased by a factor of 15% (13).

Regarding post-operative care and nonoperative management of ankle fractures, prolonged non-weight-bearing and subsequently protected weight-bearing are recommended in patients with diabetes (4). The traditional rehabilitation protocol recommends at least 6 to 8 weeks of non-weight bearing. Yet, in a study by Bazarov et. al. only 2.1% of patients had bone healing lesions after ≤2 weeks of non-weightbearing, which may be explained by the specific patient subset (35).

Charcot collapse, the hypertrophic, destructive neuroarthropathy, is a serious complication that is usually incited by a subtle injury to a neuropathic ankle which triggers a cascade of foot/ankle joint instability and collapse (36,37,38). Charcot collapse most commonly occurs following non-surgical treatment of displaced ankle fractures (28). In a study by Holmes et. al. up to 72.5% of patients with delayed treatment developed Charcot changes (39). In a retrospective review of isolated diabetic ankle fractures treated primarily with open reduction internal fixation by Blotter et. al. only 9.5% of patients suffered from post-operative Charcot collapse (31). 50% of patients reported trauma as a precipitating event to development of Charcot complications, nevertheless post-operative Charcot collapse may also be explained by the progression of a primary Charcot Neuroarthropathy that was previously undiagnosed (4,28).

The literature stresses the importance of early diagnosis to prevent the severe deformity complications of treatment delay (4,5). Early Charcot clinically presents as an erythematous, warm, edematous joint, which is often misdiagnosed as infection (4). A 2017 study by Richman et. al. reviewing treatment of hindfoot and ankle Charcot patients, recognize high limb salvage rates in patients treated with retrograde intramedullary nails or external fixation, however both techniques are far from perfect and often result in complications requiring revision (23,40-46). Given its high morbidity and treatment challenges, Charcot collapse is a feared complication.

Wound and skin-related problems are the most frequent complications after an ankle fracture (27). In a study by Miller et. al. 1.25% of primarily non-diabetic ankle fractures treated with ORIF had wound complications requiring further debridement (16). A history of diabetes, especially with peripheral neuropathy or vasculopathy, was associated with increased risk of soft-tissue complications (4,16). In diabetics with peripheral neuropathy who've lost protective sensation this risk increases seven-fold (4,47,48). Wukich and Kline insist that careful soft-tissue management as well as stable, rigid internal fixation are crucial to reducing wound complications in patients with significant risk factors, such as neuropathy or vasculopathy (4). Furthermore, diabetic patients should be warned by their surgeon of this increased risk to encourage patient compliance (4,16). Additionally, prolonged surgical procedures and high serum glucose levels are associated with the presence of postoperative blisters (27). Therefore, limiting operating time and HgA1c control may reduce wound complications.

Conclusion:

This study reviews the current literature on management of diabetic ankle fractures, including risk factors, complications and preventions. Pre-operatively physicians should alert diabetic patients with neuropathy, vasculopathy, and/or HgA1c ≥ 7% of their increased risk of complications. Furthermore, treatment with ORIF, which can be supplemented with additional fixation in complicated diabetics, should not be delayed, especially with displaced fractures. Perioperatively careful soft-tissue management, reduced operative time, and vacuum-assisted closure may reduce the risk of complications. Post-operatively physicians should monitor for signs of infection and Charcot collapse, such as erythema, warmth, and edema. Additionally, physicians should be aware that diabetics have an increased risk of amputation, wound problems, and bone healing complications. In conclusion, ankle fractures are an extremely common injury with high risk for morbidity in the diabetic population. We aim to provide physicians with a comprehensive resource on current treatment recommendations as well as management of the complications associated with these injuries in the diabetic population.

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A Review of Adult ACL Injury Treatment: Is Surgical Reconstruction Superior to Conservative Treatments?

J. Taylor Adams OMS-1, Ryne Jenkins OMS-1

Abstract

For the last 40 years, physicians and other health care professionals have debated the necessity of surgical reconstruction of the Anterior Cruciate Ligament (ACL) post injury. To attempt and answer this question, a systematic literature review of all available random controlled trials and meta-analysis comparing conservative versus surgical treatment for ACL tears was performed. Seven studies were analyzed and six demonstrated no statistical difference in patient function and subjective satisfaction for patients who underwent conservative versus surgical treatment. Study results showed that conservative treatment methods are recommended for patients with a mild ACL injury and patients who perform non-strenuous or low impact recreational activities. In contrast, surgical reconstruction remains recommended for patients seeking to return to strenuous athletic activities in relatively less time due to the increased stability of the knee joint.

Background

The anterior cruciate ligament (ACL) is one of the major stabilizing ligaments of the knee joint, and is commonly injured by young, active adults usually due to abnormal pivoting or twisting of the knee that place intense stress on the ACL (1,2). The ACL connects the tibia to the femur and functions to prevent forward slipping of the tibia on the femur and hyperextension of the knee. Tearing of the ACL results in instability of the knee with weight bearing or pivoting. ACL tears also increases the risk of secondary complications such as meniscal tearing and the development of more severe osteoarthritis (3,4,5).

This type of injury is commonly treated with surgical reconstruction of the ACL by removing the ruptured ligament and grafting in a tendon from nearby structures (6). However, in recent years more studies have been published that challenge this traditional model of resorting to surgery and demonstrate that similar results of patient satisfaction and function can be achieved via conservative treatment methods alone (6,7,8). Conservative treatment methods can include extensive rehabilitation and physical therapy, neuromuscular training exercises and functional bracing (9). This review focuses on comparing and summarizing the results of a review and multiple studies assessing the outcomes of surgical versus conservative interventions for patients with ACL tears in an attempt to determine if one treatment method is superior.

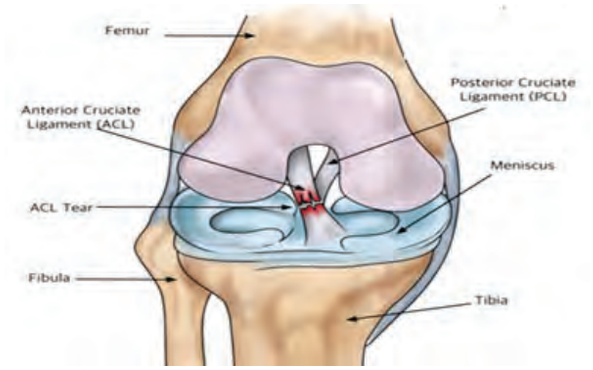

Figure 6: Depiction of an anterior cruciate ligament tear; (Adapted from KRV Physiotherapy)

Selection Criteria

A systematic literature review of studies published from January 1998 to January 2018 comparing surgical and conservative treatment of ACL injuries was performed. Studies were drawn from the Cochrane Database, PubMed and Google Scholar using the following search terms: ACL tear, conservative ACL treatment, surgical vs conservative ACL treatment and ACL injury repair. Inclusion criteria consisted of any trial or previous review that assessed the outcomes of surgical reconstruction versus conservative treatment in adult patients with an ACL injury. Surgical repair was characterized as any type of surgical reconstruction that repaired the ACL. Conservative treatment was defined as any rehabilitation program other than surgical repair. Studies without direct comparison between a surgical reconstruction cohort and a conservative treatment cohort were excluded. Studies focusing on pediatric patients were excluded. Studies were screened independently by two authors through literature searches. Seven studies were selected for inclusion in our review.

Results

Seven studies assessing patient outcomes following surgical reconstruction versus conservative treatment met criteria during the study period. Six of those studies demonstrated that there was no statistical difference in patient function and subjective satisfaction for those who received conservative versus surgical treatment (3,4,11,12,13,14). The seventh study indicated that surgical repair is most effective for return to strenuous physical activity in a shorter time (15).

In 2010, Frobell et al. analyzed early surgical reconstruction with structured rehabilitation versus structured rehabilitation alone and optional delayed surgery. During the course of the study, 61 patients underwent early surgical repair. Of the 59 patients assigned to rehabilitation plus optional delayed ACL reconstruction, 23 underwent delayed ACL reconstruction, while the other 36 received rehabilitation alone. The primary endpoint of the study demonstrated that there were no significant differences between patient groups in the Knee Injury and Osteoarthritis Outcome Score 4 (KOOS-4) from baseline to two years post-intervention. There were no significant differences between groups for any patient-reported secondary outcomes at two years, including knee-related outcomes, health status and return to preinjury activity level (11). A secondary study using the same sample population continued patient follow up for five years. By year five, 30 (51%) patients assigned to optional delayed surgery had reconstruction surgery. This study corresponded with the results of the previous study demonstrating that there was no significant difference in the KOOS-4 score from baseline to 5 years between the group assigned to rehabilitation plus early ACL reconstruction and the group assigned to rehabilitation plus optional delayed ACL reconstruction (3).

In 2017, Kovalak et al. evaluated 43 patients with ACL tears who underwent post-surgery closed kinetic chain strength training after ACL reconstruction and 39 patients who only underwent neuromuscular training as part of a conservative treatment. No statistical difference was observed between the groups for any of the parameters evaluated, including assessment of subjective knee function, one-leg hop test, assessment of joint position sense, muscle strength, and the health profile. This suggests that patients may not need surgical reconstruction to return to their activities of daily living prior to injury as compared to those undergoing surgery.

Another study was conducted evaluating long term outcomes of ACL reconstruction versus conservative treatment that included 11 years of follow up. There were 109 patients (60 reconstructions and 49 conservatively treated) that were evaluated based on clinical, radiological and internationally accepted knee-scores (Tegner, IKDC, Kellgren and Lawrence). Physical activity levels were similar in both groups during the follow-up period ($p = 0.16$). The study also demonstrated significantly better knee-stability ($p = 0.008$) for patients undergoing surgical reconstruction. However, Kellgren and Lawrence scores showed more osteoarthritis (Grade II or higher) following ACL reconstruction (42% vs. 25%) (4).

Dawson et al. conducted a retrospective review in 2016 of 63 patients, 40 undergoing ACL reconstruction and 23 undergoing conservative treatments. Patients were administered questionnaires used to assess general and knee-specific function. There were no statistically significant differences in the outcomes measured. The majority of patients stated that, if given the option, they would proceed with the same treatment in the event their previously uninjured leg became injured. The study suggested that conservative treatment can allow similar function and satisfaction to those who elect to have surgical reconstruction (13).

In 2016, Monk et al. performed a systematic review of one study evaluating the benefits of conservative versus surgical treatments for patients with a torn ACL. The study they selected was a randomized clinical trial that placed 121 patients into either the surgical reconstruction or conservative treatment with optional delayed surgery cohorts. After evaluating the quality and validity of the study, they determined that there was no significant difference in subjective patient ratings using the KOOS-4 from baseline to two and five years with a 95% confidence interval. They concluded that the ability for patients receiving conservative treatment to elect to have surgery at a later date may have affected the outcome of the original study and suggested that further randomized clinical trials be performed to test for differences in outcome between the two treatment types for ACL injury.

While the previous studies showed support of conservative treatment for ACL injuries, a 2017 study focusing on conservative treatment for baseball players showed poor patient satisfaction after receiving conservative methods of treatment. Forty-two patients with ACL injuries underwent conservative treatment throughout the season and ACL reconstruction was performed following the season ending. Of the 42 patients, 38 of them (91%) returned to competition after conservative treatment. Those same 38 patients experienced their knee giving way, of whom 36 (95%) stated that fear of their knee giving way hampered their performance. At the time of ACL reconstruction, 9 patients had chondral injuries and 22 patients had

meniscus injuries which may be secondary injuries due to knee instability throughout the season (15). As previously mentioned, an 11-year follow-up study showed surgical reconstruction provided significantly better knee stability than conservative treatment ($p = 0.008$) (4). Another 2-year follow-up study also demonstrated greater knee stability for those undergoing reconstructive surgery when combined with extensive neuromuscular training and physical therapy, rather than conservative treatment alone (10).

Discussion

Six of the seven studies reviewed concluded that there were no statistically significant differences between cohorts when comparing surgical versus conservative treatment of ACL injuries. Every study attempted to screen for patients that had unilateral injuries and no prior knee surgeries. They matched patients in control and intervention groups in order to improve generalizability by controlling for race, gender, age and level of activity. In all of the studies, conservative treatment was accompanied by optional delayed surgery, meaning that in all but one study, patients from the conservative treatment group 'opted out' and joined the surgical group, which reduced sample size in those variable groups. Despite this outcome the data showed no statistically significant differences between treatment groups. Additionally, in two of the studies, patients reported higher subjective satisfaction after receiving conservative treatments as compared to those who received ACL reconstruction surgery, when measuring pain and subjective return to function (4,10). This is a relevant finding due to the increasing role of patient choice in determining treatment options. Further studies should continue to explore satisfaction levels of patients after experiencing ACL injuries and treatment.

While six of the seven studies supported conservative treatment as an equal means to surgical treatment for ACL tears, the final study of athletes strongly disagreed with these previous results. Based on the author's own observation, the patient's pre-injury opinions on surgical versus non-surgical treatment options might have affected the outcome of conservative treatment; regardless, the study showed 95% of the 42 patients believed the conservative treatment hampered their competitive performance (15). Based upon these results and two studies demonstrating better knee stability for patients undergoing surgery, it does appear that surgical reconstruction could be beneficial for those seeking to return to strenuous athletic activities within a shorter time-frame. The instability felt by these patients may be explained by the excessive anterior posterior translation and tibial rotation associated with the rupture of the ACL (16). Excess movement felt in the knee was most likely amplified with the pivoting, jumping, running and contact associated with sports causing the athletes to feel unstable. However, this study did not continue to follow patients further than their return to full athletic competition at 13.8 ± 7.6 weeks whereas other studies reevaluated patient function at two and five years. It would be beneficial in future studies to see if patients have similar concerns following a full athletic season after surgical reconstruction, or at the same two and five-year marks following either treatment method.

Conclusion

Overall, this review found that across six of the seven studies including a total of 527 patients, no significant differences were found in the outcomes of surgical versus conservative interventions. The quality of evidence for our review was moderate. Six of the studies included are at risk of bias because clinicians and participants were not blinded to their treatment. Six of the studies did not control for injury severity and therefore may introduce bias due to expected outcomes. Additionally, all of the studies we reviewed used varying rating methods (i.e. KOOS-4) to determine treatment outcome and patient satisfaction. In future studies, internal validity could be improved by screening for patients with injuries of similar severity and randomly assigning treatments instead of allowing patients to elect initially. However, all studies included in this review indicate that conservative treatment is a viable option for many patients. Following an ACL tear, patients should be presented with all practical options for treatment and rehabilitation that pertain to their situation. For those patients with a mild ACL injury and those who perform non-strenuous or low impact recreational activities, conservative treatment methods may be more beneficial to the individual because it is possible to return to pre-injury activity without the additional costs and risks associated with surgery. These types of treatments include but are not limited to: physical therapy, neuromuscular training, functional bracing and corticosteroid injections. In contrast, surgical reconstruction remains recommended for patients seeking to return to strenuous athletic activities in relatively less time because of the increased stability of the knee joint. This subject warrants further investigation into the comparison and improvement of conservative treatments, such as: which combinations of therapies are most successful at treating mild ACL tears, the number of therapy visits required to allow patient to return prior activity, and what populations benefit most from conservative treatment.

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Laceration Repair and the Lower Extremity

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Abstract

Laceration and traumatic injuries are common reason for patient to seek emergent medical help. Given the high incidence of these injuries to the lower extremity, all podiatrists should be prepared to efficiently repair acute injury. This paper seeks to examine the literature to determine the best course of action for podiatrists to care for laceration patients in the emergency department setting.

Introduction

Each year in the United States, millions of people seek medical help from emergency department visits. In 2013, there were approximately 130.4 million visits to emergency departments (1). The incidence of patients presenting for lower extremity injury has been reported at 14.6%. Approximately 8% of lower extremity visits are for injuries classified as lacerations, with 66% occurring below the knee (2), the podiatric physician should be prepared and knowledgeable regarding appropriate care for lacerations, including the unique anatomic considerations and standards of the community regarding the most pertinent and recent information available. The purpose of this paper is to provide an overview of the considerations regarding repair and goals of laceration repair.

Patient Evaluation

While achieving control of bleeding is the first thing any physician must do when encountering a trauma patient, taking a thorough history is essential to optimize outcomes. It is important to determine the patient's tetanus vaccination status and the mechanism of injury. Obtaining information regarding the patients' tetanus toxoid vaccination status combined with assessment of the wound itself and understanding how the injury happened will allow the practitioner to make the best decision regarding the need for further tetanus toxoid or tetanus immunoglobulin (Figure 1) (3). Patients with wounds that are not considered minor and are not clean (i.e., including but not limited to visible contamination, animal bites, puncture wounds, gunshot wounds, machinery wounds, etc.), with fewer than three prior doses of tetanus toxoid (DTap, Tdap or Td, TT) should receive both tetanus toxoid and tetanus immunoglobulin. The tetanus immunoglobulin directly provides the antitoxin, ensuring protection even if an immune response has not yet occurred (4).

Table 1: Basic Tetanus Prophylaxis Guidelines (3)

	Clean, minor wound		**All other wounds**	
History of tetanus vaccination (DT, DTaP, Tdap, or Td)	Tetanus toxoid	Tetanus Ig	Tetanus toxoid	Tetanus Ig
Unknown or <3 doses	Yes	No	Yes	Yes
≥3 doses	No, if >10 years since last dose	No	No, if >5 years since last dose	No

The patient should be asked about any allergies, including iodine, latex, adhesive, anesthetics, and antibiotics to avoid potentially harmful reactions (3). Assessing the patient's overall health status is also important to understanding the risk for infection and impediments to healing. Diabetes mellitus, immunosuppression (e.g., HIV, chemotherapy, corticosteroid use), extremes of age, and poor blood flow increase infection risk (5, 6).

Care of lacerations based on time interval between injury and presentation have been debated. A study published in Emergency Medicine Journal in 2014 found no association with infection for injuries occurring less than six hours or more than twelve hours before presentation and that a "golden period" for safe wound closure by primary intention based on delay in time of presentation does not exist with improved technology and routine decontamination[6].

A physical exam for a patient presenting with a laceration should include evaluation for any local signs of infection as well as a baseline exam of neurovascular status, tendon or bone involvement because these types of wounds may require specialty consult and acute surgical management to maintain functionality[7].

Presence of infection may also be appropriately treated

by delayed primary closure or healing by secondary intention; closure of a contaminated wound or one with local signs of infection can precipitate anaerobic infection[7].
Wound evaluation is a critical step to proper management of laceration injuries. Visible contamination and foreign matter is a significant risk factor for developing infection; copious irrigation with sterile saline or tap water before primary closure is essential and will wash away foreign matter and dilute bacterial concentration (3, 8). Using 50-100 mL of sterile saline per centimeter of laceration length is recommended, but this should be adjusted based on characteristics and degree of contamination (7). Large wounds (>5 cm), wounds with stellate shape, jagged edges, and injury deeper than subcutaneous tissue are at increased risk of becoming infected (5, 6). Careful examination of the laceration should determine severity, involvement of bone, muscle, nerves, and blood vessels. Extensive damage may require vascular or plastic surgery consults. Foreign bodies should be removed using forceps, using caution near blood vessels, nerves, and joints. Debridement of devitalized tissue is important to reduce risk for infection (3).

Preparation for Closure and Material Selection
When removing local hair before closure shaving techniques should not be used, instead the surrounding hair should be clipped as to avoid introducing hair into the wound (3). Use of injectable local anesthetics such as 1% lidocaine or 0.25% bupivacaine is acceptable for small wounds, although larger wounds may require a regional block or general anesthesia (3). Epinephrine may be used in conjunction with local anesthetics to promote hemostasis or if higher doses are desired, but should be used with caution in the digits because of the vasoconstrictive properties of epinephrine (3, 7).
Topical anesthetics may also be used. Lidocaine-adrenaline-tetracaine (LAT) has been proven to be an effective alternative to local injections of anesthetic with lesser hypersensitivity and systemic risks associated with its predecessor tetracaine-adrenaline-cocaine (TAC) solutions (7,9). This makes topical anesthesia an excellent option for repair of simple lacerations in pediatrics as well as anxious adults. The primary drawback to LAT gel is the short duration of efficacy (9). It is important to note that not all topical preparations are suitable for use in open wounds, for example, EMLA cream (eutectic lidocaine-prilocaine), Ametop gel (tetracaine), and Instillagel (lidocaine) are only suitable for intact skin (9).
It is important for the physician to consider what materials they wish to use to close the lacerated tissue. Many options are currently on the market for use in skin closure including tissue adhesives, surgical strips, staples, and traditional sutures which are available in absorbable and non-absorbable varieties.

Tissue adhesive such as Dermabond (2-octylcyanoacrylate) and LiquiBand (butylcyanoacrylate) are typically used in lieu of epidermal sutures and the application is painless, simple, and faster than traditional suturing. They are effective because they belong to the family of cyanoacrylates which polymerize with moisture on the skin, giving them their adhesive properties (10). Patients may also prefer this method of closure because water avoidance is unnecessary once dried (10). An additional benefit to using tissue adhesive is the patient will not need to have sutures removed later on (3, 10). Despite these favorable properties, tissue adhesive should only be used on perfectly approximated wounds, with skin edges in direct apposition under low tension because the low tensile strength of such products (3). Bleeding tissue may cause the epithelial wound edge separation and the possibility that the adhesive seeps between wound edge and inhibits healing exists (10). Tissue adhesives should not be used in patients at risk for delayed wound healing, complex wounds, on mucosal surfaces, or tissues that maintain moisture (intertriginous areas) (3). Tissue adhesives cost more than sutures, but this expense may be obfuscated by the unneeded return visit and fast application time (3, 10). Proper application of tissue adhesive involves approximating the skin edges and applying the adhesive over a dry wound, overlapping the skin by approximately 5 mm. Multiple applications will give more effective results and full tensile strength is achieved after 2.5 minutes (3). Ointments may remove tissue adhesive and the patient and physician should not use antibiotic ointments or petrolatum ointment (3).

Surgical strips (SteriStrips) may be used on wounds if deep, buried sutures have been placed (10). Use of this type of closure product typically requires the laceration to be a simple, well approximated wound in a low tension area (3, 10). Adhesive adjuncts such as tincture of benzoin and Mastisol can be applied to dry skin to assist in maintaining application the surgical strip to the skin, but irritation and local inflammatory reactions may occur with these products (10). Although typically placed perpendicular to the wound edges, different techniques of applying surgical strips have been suggested, including placing the strips parallel to the wound edge to reduce blistering and shear forces and placing the strips diagonally in a zigzag pattern to more uniformly distribute tension (11). Following the removal of sutures, it is recommended that wounds are supported by skin taping (3).
Skin staples made from stainless steel have been used reliably in the closure of high tension wounds while providing good wound eversion with low reactivity and

risk (10). Outcomes related to wound discharge, dehiscence, necrosis and allergic reaction with staple use has been shown to be equivalent to other closure methods (12). Despite this, according to a meta-analysis by BMJ, infection risk, previously thought to be lower, has been shown to be increased with staple use (12). The same meta-analysis noted lower limb and upper limb surgical and trauma patients were not differentiated in the studies assessing outcomes of staple use in limbs. Staples cost more than sutures but are a quicker method for closure. Wounds must be carefully selected and have adequate soft tissue to provide a seat for the staple which makes the knee, pretibial area and foot inadequate for staple closure (12).

Sutures have a long-proven history of effectiveness in laceration and wound closure. Sutures come in absorbable and non-absorbable varieties, monofilament, braided or twisted multifilament configurations, and may be coated with antibiotics. Absorbable sutures degrade via proteolysis (natural) or hydrolysis (synthetic) and have been used to close deep, multiple layer lacerations, to close dead spaces, and approximate wound edges before epidermal closure with non-absorbable sutures, surgical strips, or tissue adhesives (3,10). The rate of absorption, which typically begins with gradual decrease in tensile strength before decreases in suture mass, can be affected by patient factors including malnourishment/protein deficiency, infection and type of tissue (10). Some sutures are available with triclosan antibiotic coating, which has been proven effective against the most common pathogens, but currently there is no high-level evidence suggesting reduced surgical site infection rates (10). Selected suture size should be the smallest caliber to maintain wound strength, low tension wounds can be closed with smaller sutures (10). Most commonly used on the extremities are 4-0 and 5-0 sutures (3). Optimal cosmetic results can be achieved using the finest suture appropriate for the patient and the wound (3).

Selection of suture material should account for the patient's anticipated healing time and potential for infection regarding how long the suture maintains its tensile strength. Among other factors to consider is the elasticity of the suture. Elasticity is important when anticipating tissue swelling (10). The ideal suture would have low reactivity, high tensile strength, slow absorption, and good knot security. For this reason, the preferred absorbable sutures are polyglactin 910 (Vicryl), poliglecaprone 25 (Monocryl), polyglycolic acid (Dexon), and polydioxanone (PDS) (10). Many of these same sutures are becoming more popular for epidermal closure in addition to subcutaneous closure, replacing non-absorbable sutures. However, many physicians still use non-absorbable sutures regularly with excellent results. The most popular non-absorbable sutures are nylon (Ethicon) and polypropylene (Prolene) (10).

Table 2: Non-exhaustive list of sutures and selected characteristics (10)

	Configuration	Tensile Strength	Strength Retention; Complete absorption	Tissue Reactivity	Knot Strength
Selected Absorbable Sutures					
Polyglactic 910 (Vicryl)	Multifilament	Quite High	50% at 21 days; 42 days	Low-intermediate	Good
Poliglecaprone 25 (Monocryl)	Monofilament	Quite High	50-60% at 7 days, 20-30% at 14 days; 91-119 days	Very low	Good
Polydioxanone (PDS)	Monofilament	High	35% (4-0), 60% (3-0) at 42 days; 183-238 days	Low	Poor
Polyglycolic acid (Dexon)	Multifilament, braided	Intermediate	20% at 21 days; 90-110 days	Low-intermediate	Good
Selected Non-absorbable Sutures					
Nylon (Ethilon)	Monofilament	High	Non-absorbable	Low	Fair
Polypropylene (Prolene)	Monofilament	High	Non-absorbable	Low	Poor

Suture Techniques

Ideal closure technique would reduce wound tension, provide adequate hemostasis, and be executed quickly leaving the skin edges well-coapted with appropriate eversion. Excessive wound tension can lead to separation of skin edges and widening of the scar (10). Multi-layer closure of deep lacerations and surgical incisions provides optimal cosmetic results (3). Suture techniques may include running or interrupted stitches and a variety of different types of stitch, the best technique to use varies depending on a number of factors including practitioner's individual skill, skin characteristics, and location of the defect (10). Lower extremity wounds are commonly high tension and high stress from daily activity, for this reason simple interrupted or running stiches and horizontal mattress sutures are commonly used (10). The horizontal mattress suture is also useful for fragile or atrophic tissue (3). Deep tension-relieving sutures can be used to eliminate surface tension prior to closure. Undue wound tension can lead to separation of skin edges and widening of the scar (10). Proper technique involves the needle piercing the skin at a 90 degree angle and following the curve of the needle to create eversion of skin edges. Eversion compensates for eventual retraction of the scar during healing (3).

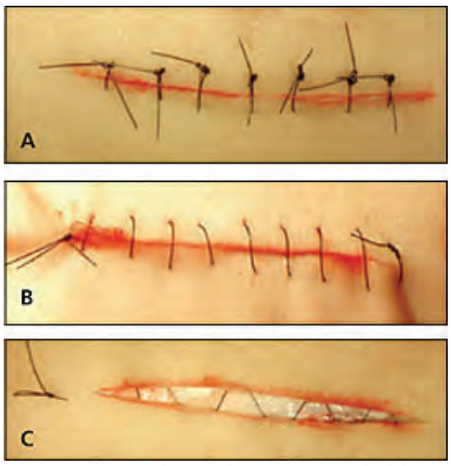


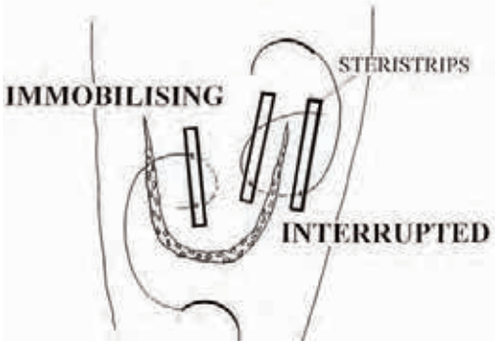
Figure 1: A) Simple interrupted. B) Simple running. C) Subcutaneous running. (3)

Often trauma leaves a stellate-shaped injury with corners that may be difficult to navigate. To manage this type of injury, the physician should employ a half-buried mattress suture which involves burying the suture in the subcuticular tissue of the apex of the flap to avoid compromising blood supply and risking tissue necrosis (3).

Pretibial lacerations are more likely to develop tissue necrosis and have delayed healing times. This is particularly true in the elderly, those with friable skin tissue, and injuries resulting in stellate-shaped wounds. This can result in lower quality of life and eventual skin grafts for these individuals. A technique combining use of surgical strips and simple sutures has been shown to reduce healing time than using either techniques individually. The essence of this method is simple, suturing through a steristrip to immobilize the skin flap followed by placing simple sutures through surgical strips placed parallel to the lacerated skin edge. This reinforces the suture and disperses the tension on the skin and has also been used elsewhere in the body on thin or atrophic skin (13).

A.

B.



C.

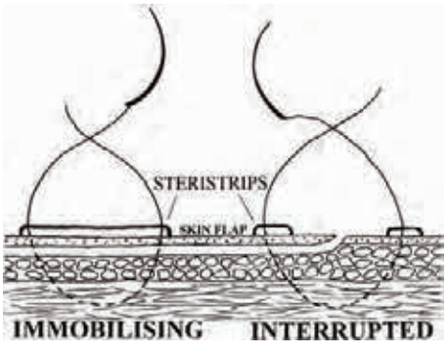


Figure 2: (A,B,C): Stellate-shaped pretbial laceration repaired with simple interrupted sutures through Steristrips to disperse tension. Also present are flap immobilizing sutures using the same technique (10).

Reinforced suturing using surgical strips for pretibial lacerations and atrophic skin.

Nail bed injuries are a special consideration for podiatric physicians. Approximately 50% of nail bed injuries have an associated fracture of the distal phalanx (14). Trauma presenting with subungual hematoma greater than 50% of the nail bed necessitates evacuation of the un-clotted blood, typically performed by trephination of the nail plate using an 18 gauge needle. Lacerations may require direct visualization and accordingly, avulsing the nail may be required. Given the proximity of the nail bed to the distal phalanx, osteomyelitis as a result of trauma is a serious possibility (14). Repair of nail bed lacerations may use 6-0 or 7-0 non-absorbable sutures (14), but tissue adhesives have been shown to be an effective alternative (15).

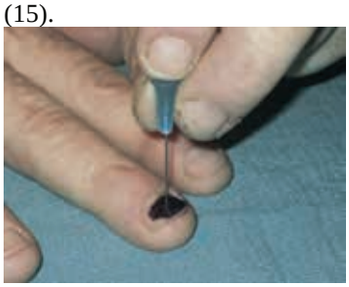


Figure 3: Example of trephining a subungual hematoma using a drilling technique with a 23 gauge needle (19).

Antibiotics and Follow-Up Care

Antibiotics in complex lacerations, animal bites (feline bites may be of particular concern), open fractures, bone or tendon involvement, and penetrating trauma has been recommended whereas simple uncomplicated lacerations have not been proven to necessitate prophylactic antibiotics, but may benefit from topical antibiotics (16). Judicious use of antibiotics is recommended given emerging antibiotic resistant organisms and to avoid possible side effects, including *Clostridium difficile* infection (17).

Regardless of technique used for closure, follow-up care is similar. Patients should be instructed to keep the wound clean and dry. Timing of suture removal is dependent on patient factors as well as location of the wound. Removal of sutures from leg or foot lacerations at 10-14 days post-injury is appropriate, but the thick skin of the sole of the foot may require sutures to be intact for up to 14-21 days (3).

Scarring has a unique consideration for podiatrists because large scars may not only be unsightly to a patient, but they may be uncomfortable in shoes or while walking, especially if on the plantar surface of the foot. Hypertrophic scarring usually occurs 4-8 weeks following infection, wound closure with excessive tension (and thus are more likely to appear in high tension areas of the body), or other trauma. Hypertrophic scars may gradually regress over the course of a few years (18). Keloids differ in that they may develop years after injuries and appear as shiny, hyperpigmented, nodular growths with telangiectasias. Keloids are more likely to develop in dark-skinned individuals and tend to be associated with family history of such cicatrices and are inclined toward recurrence (18). Multiple strategies exist to treat keloids and hypertrophic scars, including laser therapy, radiotherapy, cryotherapy, corticosteroid injections, and surgical revision but prevention of occurrence may have better outcomes for the patient than any treatment option currently available. Pressure therapy, silicone gel sheets, and flavonoids have all been proposed and used with some degree of success in prophylaxis (18).

Conclusion

It is important in the emergency department to consider the goals of management for any situation. For lacerations, the primary goals of the practitioner should initially include hemostasis, restoration and preservation of function, and avoiding infection. Recognizing the anatomic details of the lower extremity and using different strategies appropriate to the situation and to the patient for a quick, minimally painful experience is not an underrated aspect of care. Acceptable cosmetic results are critical to patient satisfaction, likewise with minimal missed school or work time. Given the volume of visits to the emergency department each year, it is essential for podiatrists and emergency physicians alike to have a well-rounded and knowledgeable skillset regarding lower extremity trauma and lacerations.

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Review of Induced Membrane Technique in Large Osseous Defects of the Foot

Ankurpreet Gill, MS-4

Abstract

In 1986, AC Masquelet invented a two-stage technique to heal large osseous bone defects in diaphyseal bones of the lower extremity. Since its development, the technique has undergone continuous adjustments to optimize patient outcome. Overall, it has proven successful in achieving union rates in a large variety of cases. The technique has recently been used extraneously to heal osseous defects in the foot. The purpose of this study is to describe Masquelet's technique, perform a review of current literature regarding the technique, and to consolidate and examine case reports utilizing the technique in the foot. The first stage of the technique involves radical debridement and placement of a cement spacer at the site of osseous insult. The spacer induces the formation of a surrounding membrane that resembles synovial epithelium and contains biological healing factors. The second stage requires careful removal of the spacer and filling of the membrane-surrounded void with bone graft. Eventually bony union is achieved, which allows for weight bearing. In a pub-med based search, there were five documented instances of the technique's use in the foot with favorable outcomes in all patients. While preliminary reports are promising, large scale investigative research to assess the technique's reliability is required for its widespread acceptance of use in the foot.

Introduction

In 1986, French orthopedic trauma surgeon A.C. Masquelet described a technique that could aid in the regeneration of bone within large osseous defects in the long bones of the leg. This technique utilizes a two-stage method in which a cement spacer is first filled into the bony defect causing a vascularized membrane to form around it. Weeks later, the cement spacer is removed while bone graft is inserted into the induced membrane and allowed to incorporate and form healthy new bone. This technique can be used in defects up to 25 cm and has gained popularity in the treatment of extensive osteomyelitis, septic non-unions, post-traumatic defe

cts, and bone tumors (1).

Due to its recent increase in popularity, the technique has been repurposed to aid in the treatment of defects in other bones in the upper extremity, clavicle, and foot (2). To date there is no article that has consolidated the reports relevant to podiatric practice.

Induced Membrane "Masquelet" Technique

The staged technique of regenerating bone within a large osseous gap takes patience and diligence by both doctor and patient.

Stage 1

The technique's most widespread indication is in the setting of unstable or infected bone, thus the importance of radical debridement cannot be understated. Persistent infection can undermine healing and increase the need for revisional surgeries. Therefore, it is generally advised to take an aggressive approach and perform an extensive debridement of both bone and nonviable soft tissue (Figure 1). This approach is further supported by the fact that the technique is suited for very large defects, diminishing concern for excessive debridement at the defect site.

A polymethylmethacrylate (PMMA) cement spacer is then inserted into the defect and left in for about 6-8 weeks, while the limb is stabilized by external fixation. For optimal outcome the spacer should be molded to intramedullary bone as well as over the edges of cortical bone (4). The purpose of the spacer is to cause a foreign body inflammatory response that causes formation of granulation tissue encapsulating the spacer that eventually neovascularizes (5). Histologically, the membrane resembles a synovial epithelium that contains a high concentration of VEGF and TGFβ1 while also secreting BMP-2. These factors have been shown to express pleiotropic effects on bone formation including osteoinduction, angiogenesis, and stromal cell differentiation (6).

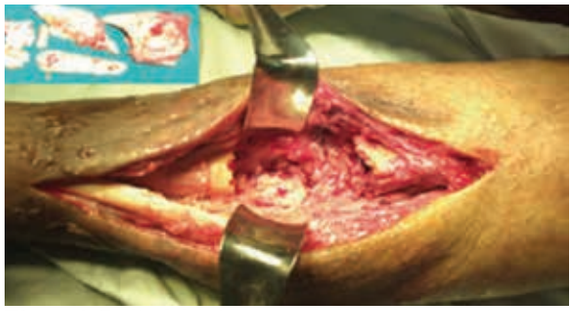

Figure 1. Radical debridement of affected bone performed, and defect prepared for insertion of cement spacer. (Image adapted from Barakat & Ayman, 2015)

Stage 2

Prior to removal of the spacer, eradication of infection must be reaffirmed via inflammatory markers

(CRP and ESR) and completion of antibiotic course. If doubt remains, tissue biopsy from the questionable site can be sent for culture and pathology (7). The spacer must then be removed carefully by placing a single longitudinal incision through the induced membrane (Figure 2). If removal of the entire spacer without damaging the membrane is impossible, it is reasonable to cleave the spacer into many pieces with an osteotome or saw and remove the pieces sequentially (3).

At this point the medullary cavities on each end are cleaned and curetted to facilitate graft integration. The membrane is then filled with bone graft and stabilized by external or internal fixation until bony union and consolidation is noted radiographically. Currently the widely accepted gold standard for graft choice is morcellized cancellous bone harvested from iliac crests (8). It is noted however, that other authors have used intramedullary reamer-aspirated graft combined with cancellous allograft and reported acceptable results (3,9).

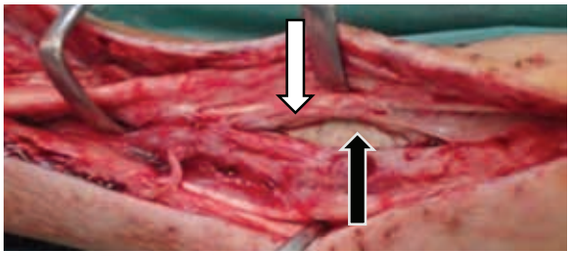

Figure 2. The newly formed induced membrane (white arrow) is incised. Cement spacer (black arrow) is noted remaining within the defect. (Image adapted from Giannoudis et al., 2011)

Current Literature

General Application

The extent to which this technique is used is minimal given the rarity of critical sized bone defects. However, there has been a relative abundance of literature reported regarding its use. Morelli and colleagues recently performed the first ever systematic review of studies that observed the technique (10). After implementing strict inclusion criteria, 17 articles (427 patients) were included in the analysis. They reported an overall 89.7% union rate and infection eradication in 91.1% of patients, although 7.7% of these cases required additional procedures to achieve union. Given the technique is in its early stages, the authors admitted there remains a significant amount of variability to the way the technique is employed, thus adding numerous confounding variables to the study. Regardless, they make the claim that the technique remains advantageous for the treatment of large bone defects (>20 cm) (10).

Aurégan, et al. also performed a systematic review of the technique utilized in the pediatric population. Of the 69 total patients (mean age 10) included in their study, they found that the rate of bony union achieved was only 58% but raised to 87% when considering revisional surgeries (11). The authors admit that although the rate of eventual union is acceptable, further interpretation of the data precipitates risk factors within the pediatric population that may serve as red flags for using this technique. Specifically, they indicate reserving caution for boys, malignant bone tumors, femoral defect with wide resection, and unstable fixation. These patients were observed to have increased rates of non-union, lysis, or fracture when using the technique (11).

Since its creation, the technique has evolved and gained technical complexity. Now it has reached the point where clinical data indicates validity as a therapeutic option in the patients with large osseous bone defects (1,2 10). Aurégan and Bégué published a review of experimental and clinical experiences outlining these technical advances and their underlying support. Guidelines are given regarding what type of defects respond optimally, fixation preference, timing of stages, and graft choices (12).

Podiatric Application

Induced membrane technique was originally designed with a predilection for long bone diaphyseal defects, but Pelissier and colleagues opened the doors to its use in the foot by utilizing it on a large midfoot defect in 2002 (13). They published a case report on a 71-year-old overweight, diabetic patient who was involved in a hunting accident. The incident obliterated the first two metatarsals of the left foot. The patient was placed in an external fixator for 4 months while the technique was performed, and bony consolidation was noted at 9 months with full resumption to daily activities and hunting. Despite the outcome, the author outlines regrets regarding the approach to this patient due to technical errors as well as stating that longitudinal tension forces along metatarsals made this a poor candidate in comparison to the classic tibial defect patient. The fact that bony consolidation was achieved and full weight bearing status restored in spite of these regrets is a testament to the tolerance of the technique and ultimately its reliability (13).

In 2009, Huffman, Harris, and Suk treated a 26-year-old male that suffered a gunshot wound which comminuted his first metatarsal, medial cuneiform, and navicular (14). An antibiotic impregnated spacer was inserted into the remaining defect after necessary repeat debridement (Figure 3). The author emphasizes that the use of the spacer not only provides prophylaxis against infection but also helps maintain medial column length through membrane induction stage. The membrane was later prepared and packed with reamer-irrigator-aspirator harvested intramedullary graft from the femur and secured into place with a locking bridge plate spanning from the 1st metatarsal to the calcaneus. At 1 year follow

up the patient was weight bearing in custom molded shoes (14).

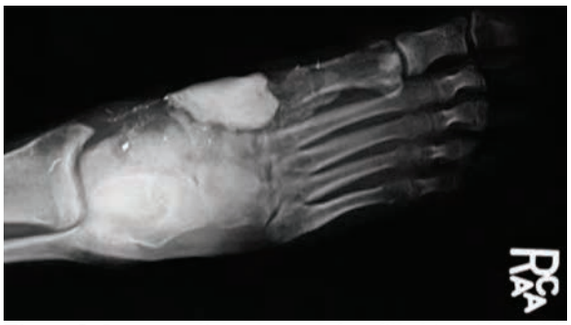

Figure 3. Large medial column defect filled in with antibiotic impregnated PMMA spacer. (Image adapted from Huffman, 2009)

Within the same year Largey, et al. reported treatment of a 24-year-old motorcycle injury that resulted in 90% loss of the medial cuneiform. The induced membrane technique in conjunction with a saphenous cross-leg flap for soft tissue coverage was performed. By 19 months later, the patient showed radiographic and CT scan evidence of bony consolidation of the graft with intercuneiform arthrodesis and metatarsocuneiform pseudoarthrodesis. The patient returned to full range of motion to the ankle and talocalcaneal joints but developed compensatory hypermobility of the talonavicular joint. A full return to preoperative level of work was noted with mild pain during strenuous or forced activity (15).

Makridis, et al. reported use of the technique in 2013 when a 53-year-old male presented with a 5 cm defect in the first metatarsal. Within 5 months of treatment the foot revealed radiographic evidence of osseous healing at the 1st metatarsal defect. At 18 months follow up the patient related no pain and was participating in activities of daily living (16).

The use of the technique broke new ground in 2015 when Mak, Stern, and Assal used it to treat an osteomyelitic midfoot in a patient with Charcot diabetic neuropathy. This patient, at age 50 with a HgA1c of 13.9% had developed a large plantar midfoot ulcer that resulted in deep infection of the bone and required urgent debridement and removal of the second and third cuneiform and cuboid bone. With extensive soft tissue debridement, antibiotic therapy and implementation of an antibiotic impregnated spacer, infection resolved in the patient – later reaffirmed with labs and cultures. A second, new cement spacer later replaced the previous one for membrane induction and was stabilized via medial column beaming (17).

Figure 4. (Left) Cement spacer in midfoot defect for membrane induction. (Right) Graft integration and cortical appearance 25 months post-operatively. (Image adapted from Mak et al., 2015)

Six weeks later, further reconstruction using lateral column and hindfoot fixation was added to reinforce the stable construct around the defect. The spacer was carefully removed, and the membrane protected defect was packed with autologous cortico-cancellous struts of iliac crest graft. The remaining gaps were packed with morcellized graft and a TAL was performed to reduce midfoot pressure. At 12 weeks the patient progressed to partial weight bearing in a CROW boot and at 24 weeks was able to fully weight bear in custom molded shoes with rocker bottom modification. At two years postoperatively, the radiographs demonstrated graft union and no sign of infection (Figure 4) while maintaining a plantigrade and ulcer-free foot (17). Considering the morbidity and mortality accompanied by amputations in the diabetic population, it is imperative to find new ways to sidestep that seemingly inevitable step. This case report, the first of its kind, takes advantage of the induced membrane's ability to vascularize a graft and prevent its resorption and in doing so adds to the physician's narrow arsenal of limb salvage options.

Conclusion

The potential for this technique to be utilized extensively in the podiatric profession is present, thus warranting this review. However, the current pool of data remains extremely shallow, rendering a formal systematic review impossible. With the small sample size of published cases available, it is apparent that this technique – once reserved for application solely in diaphyseal long bones – may also be used successfully in varying bones of the foot. Recent literature revealed reliability of the technique in diaphyseal long bone application with a union rate close to 90%. This has

encouraged modern use of the technique in the foot for patients requiring extensive reconstruction with notable success. Further large-scale investigative research regarding this technique in the foot is needed to replicate the foundation of support that exists in current literature for its application in long-bone diaphyseal defects.

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Editor's note -
This article was originally published in the 2017 Extremitas edition, but a misprint occurred and the last page was not included. The completed article is as follows:

Limitations of Ad Hoc Interpreters on Patient Understanding and Compliance in Diabetic Foot Care

Dana Brems, MS-3, Marcela Orellana, MS-3, David Shofler, DPM and Janelle Green, DPM

Abstract:
When there is a language barrier between healthcare providers and their patients, medical interpreters are used. These might be trained professionals or untrained "ad hoc" individuals. Oftentimes, when ad hoc interpreters such as family members are used, the podiatric physician's instructions to a patient are lost in translation. Studies have found that professional medical interpreters are more accurate than ad hoc interpreters in the general practitioner setting. However, there is limited literature on how ad hoc interpreters convey terminology used specific to diabetic foot care. Language specific to diabetic foot evaluation includes words that describe pain and sensation of the feet, anatomy of the foot, and self-care instructions. These uncommonly used words and phrases might be difficult for an untrained interpreter to accurately relay. In our study, we will look at how often and to what severity common podiatric phrases are misinterpreted by untrained individuals.

Introduction and Purpose:
Proper diabetic patient education is essential in reducing the risk of an injury that can lead to ulcer formation[1]. The prevalence of diabetes among the Latino population in the United States is high (3). Lavery et al found that Mexican-Americans have a greater risk of amputation than non-Hispanic whites (8). Although the exact reason for this disparity remains unclear, there is a possibility that lack of patient understanding based on language could play a role (4).

Ideally, Limited English Proficient (LEP) patients are seen by a language concordant provider. Studies have shown that this increases compliance and self-care activities(3), like those needed for diabetic foot care. However, many providers cannot communicate with their LEP patients in Spanish, and rely on interpreters who could be either licensed professionals, or ad hoc interpreters (10). An ad hoc interpreter is any untrained individual, usually a family member in a medical setting, that provides interpretation services (2).

Our study compared the effectiveness of ad hoc interpreters with regards to delivering podiatric medical information to diabetic patients. We surveyed twenty-one untrained bilingual individuals at a local health fair. The subjects underwent an English to Spanish interpretation test with a total of 30 phrases. There were a series of 10 phrases used by podiatrists at screening visits, 10 instructions given to diabetic patients about adequate foot care, and 10 instructions about wound care. We sought to evaluate if there is significant error in the content of a message conveyed the ad hoc interpreter in the setting of diabetic foot care.

Materials and Methods:

Our interpretation test was given to twenty-one bilingual volunteer subjects at the Pomona "Relay for Life" health fair in June 2016. Our inclusion criteria included subjects over the age of 18 who consider themselves bilingual. All subjects were informed that they would be recorded and agreed to participate in the survey and verbal test.

Before we conducted our verbal interpretation tests, we asked our subjects to fill out a short survey on paper.

Pre-Test Survey

1. Age
2. Do you consider yourself bilingual in English and Spanish? (Yes/ No)
3. Do you interpret medical information for a family member?
o Yes, about once a year
o Yes, a few times a year
o Yes, about once a month
o Yes, a few times a month
o No
4. What is the highest level of education you have completed?
o None
o Elementary school
o Middle school
o High school/ GED

o Some college
o College (B.A/B.S)
o Graduate school
5. Where did you go to school?
o The U.S.
o Outside the U.S.
o Both
6. Do you have diabetes?
o Yes
o No
o Unknown

Verbal Interpretation Test

We conducted an English-to-Spanish verbal interpretation test that consisted of common questions and instructions that a podiatric physician would ask a patient. The test was given via the researcher speaking a series of English phrases, and asking the volunteer to interpret them into Spanish. If needed, the phrase could be repeated, but not re-worded. The responses were spoken into a microphone and saved for later evaluation.

Error Evaluation

We evaluated the voice recordings for accuracy by transcribing participant responses and comparing them to a master translation done by an American Translators Association (ATA) certified language consultant. We quantified how many mistakes were made, and whether the mistake was an omission, addition, substitution, or false fluency. Additionally, we compared the clinical significance of these mistakes based on whether the mistakes affected the meaning of the conveyed message, and could potentially affect the patient's outcome. Finally, we tallied which words and short phrases were most frequently misinterpreted.

Verbal Test English Script

The following are the scripts for the verbal interpretation test. The script was drafted by investigators Orellana and Brems, then edited by multiple licensed medical interpreters. The edits were made to include words and phrases most often used by podiatrists. Additionally, common false cognates and words which only loosely translate to Spanish were added.

Foot Evaluation Case
1. When did your foot pain start? Was it sudden or gradual?
2. What makes it better? What makes it worse?
3. Can you describe the pain?
4. Is the pain dull or sharp?
5. Is there a burning, tingling, or pins and needles sensation?
6. Do you have that feeling on both feet?
7. Does the pain radiate anywhere else?
8. In a scale of 1 to 10, how severe is your pain?
9. What is your A1C level currently?
10. Record your glucose levels daily.

Diabetic Foot Care instructions
1. Keep your blood sugar levels in check to prevent neuropathy.
2. Neuropathy is nerve damage, and cannot be reversed once it occurs.
3. You are at a higher risk for developing foot ulcers.
4. Inspect feet daily. Be consistent.
5. Check in between the toes looking for redness or discoloration.
6. If you cannot see your feet, use a mirror or ask a family member to inspect them for you.
7. Wear shoes that fit properly.
8. Fit the longest toe, which might be the 2nd toe instead of the 1st.
9. Have your vision checked yearly to ensure that you can see your feet.
10. Don't walk barefoot because you'd be at higher risk of injury.

Wound Care
1. It is normal to see a small amount of blood on you bandages while the wound heals.
2. Remove your bandage daily and replace with clean ones.
3. Moisten the new bandage, without soaking it.
4. Place this wet bandage on the top of your foot, then wrap a dry one all the way around it.
5. Keep weight off the wound while it heals.
6. To prevent infection, don't get your foot wet when you shower.
7. Wash your foot with sterile water and saline. Pat your foot dry.
8. Look for signs of infection such as pain, redness, warmth, or pus.
9. If you notice these signs of infection, go to the nearest emergency room.
10. You will be provided a machine called wound vac to help the healing process.

Verbal Test Spanish Script

The following is the ATA certified Spanish translation of our script. The audio recordings of our subjects were graded against it.

Evaluación de los pies

1. ¿Cuándo inició su dolor en los pies? ¿Fue repentino o gradual?
2. ¿Qué le ayuda a mejorar? ¿Qué lo hace empeorar?
3. ¿Puede usted describir su dolor?
4. ¿El dolor es punzante o sordo?
5. ¿Existe una sensación de quemadura, hormigueo o de agujas y alfileres?
6. ¿Siente esa sensación en ambos pies?
7. ¿El dolor se extiende a cualquier otra parte?
8. En una escala del 1 al 10, ¿cuán severo es su dolor?
9. ¿Cuál es su nivel de A1C actualmente?
10. Registre el nivel de azúcar (glucosa) en su sangre diariamente.

Instrucciones para el cuidado de los pies de un diabético
1. Mantenga sus niveles de azúcar en la sangre controlados para prevenir la neuropatía.
2. La neuropatía es un daño en los nervios, que no puede revertirse si ha ocurrido.
3. Usted estará bajo un mayor riesgo de desarrollar úlceras en los pies.
4. Inspeccione sus pies todos los días. Sea constante.
5. Revise entre los dedos de sus pies que no haya enrojecimiento o descoloración.
6. Si usted no puede mirar sus pies, use un espejo o pida a algún familiar que los inspeccione.
7. Use zapatos que le ajusten apropiadamente.
8. Ajuste de acuerdo al dedo más largo de su pie, que podría ser el 2º en vez del 1º.
9. Sométase a un examen de la vista cada año, para asegurar que usted podrá mirar sus pies.
10. No camine descalzo, pues usted corre un mayor riesgo de lesionarse.

Cuidado de lesiones
1. Es normal ver una pequeña cantidad de sangre en sus vendajes mientras las heridas cierran.
2. Retire su vendaje diariamente, y reemplácelo con uno limpio.
3. Humedezca el nuevo vendaje, sin llegar a empaparlo.
4. Coloque este vendaje húmedo en la parte superior de su pie, y luego envuélvalo completamente con uno seco.
5. No aplique peso sobre la lesión hasta que haya sanado.
6. No moje su pie cuando se bañe, a fin de prevenir infecciones.
7. Lave su pie con agua estéril y salina. Seque su pie con pequeñas palmadas.
8. Busque señales de infección, tales como dolor, enrojecimiento, calor o pus.
9. Si observa estas señales de infección, acuda a la sala de emergencias más cercana.
10. Se le proporcionará una máquina llamada “Wound Vac”, que le ayudará con el proceso de curación.

Results

We initially surveyed twenty-one bilingual subjects, two of whom were eliminated from our data for being unable to complete the test. The average age of our remaining participants was 35. The majority completed “some college”, and all but one received some formal education in the United States. Only one of our participants had diabetes. Over half of our subjects interpret for family members once or more than once a month. (Figure 1)

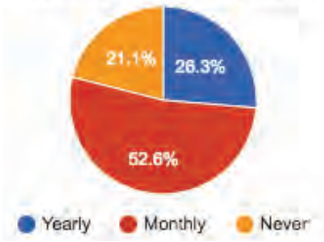

Figure 1 *- Ad Hoc Interpreting Frequency Distribution*

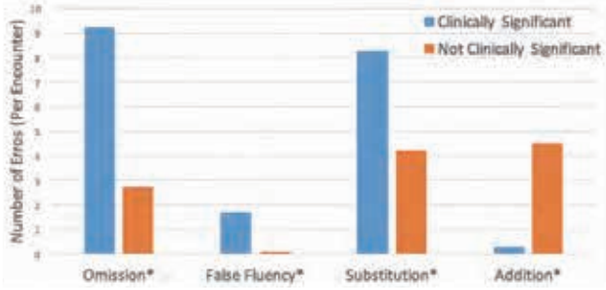

Figure 2 *- Average Number of Clinically Significant Errors*

Figure 2 demonstrates the average proportion of errors being clinically significant (CS). For example, the proportion of CS errors of addition is very low. Furthermore, one can see that omission has a high proportion of CS errors, therefore is a serious error of ad hocs. The average number of errors per encounter was 32, and the range was 10-84. 63% of the errors were clinically significant.

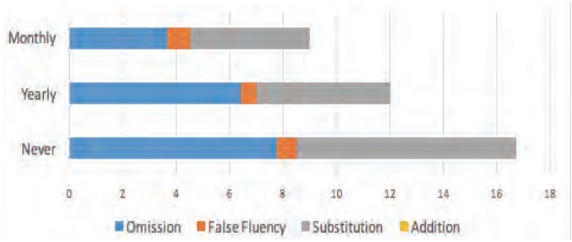

Figure 3a *– Foot Evaluation Case - Clinically Significant Errors*

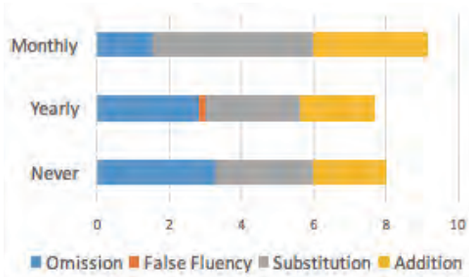

Figure 3b *– Foot Evaluation Case – Not Clinically Significant Errors*

On average, the frequent interpreters made fewer clinically significant errors during a general foot evaluation than those who had never interpreted for family members. (Figure 4a)

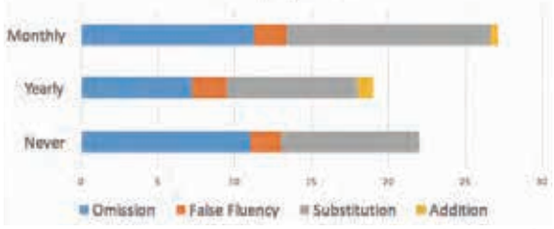

Figure 4a *– Diabetic Foot Case - Clinically Significant Errors*

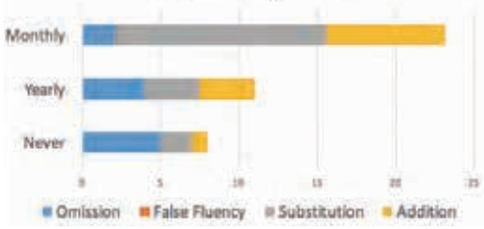

Figure 4b *– Diabetic Foot Case – Not Clinically Significant Errors*

On average, the frequent interpreters made more errors in the diabetic foot encounter, but the errors were more likely to not be clinically significant. (Figure 5b)

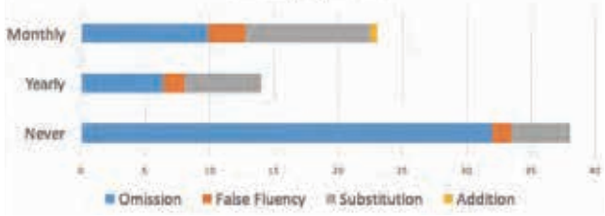

Figure 5a *– Wound Care Case - Clinically Significant Errors*

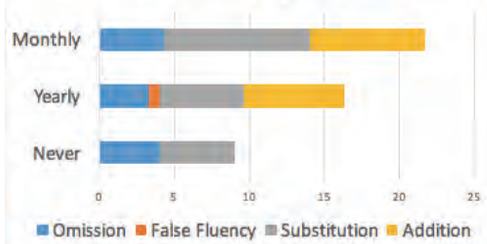

Figure 5b *– Wound Care Case – Not Clinically Significant Errors*

Overall, the highest numbers of errors were made in the wound care case. (Figure 6a)

Omission	False Fluency	Substitution
Warmth*	Redness*	"to help the healing process"
Pain*	Saline*	Bandages**
"while it heals"	To prevent*	Sharp**
"pat dry" / "a dry one"	Neuropathy**	Dull**
Currently*		Gradual*
Tingling*		(to keep) in check*
Pins & needles*		Higher risk*
Be consistent*		
Foot ulcer*		

Table 1 *– Commonly Misinterpreted Words and Phrases*
*Misinterpreted by over 50% of our subjects
**Misinterpreted by over 90% of our subjects

Discussion

Overall, we found that ad hoc interpreters, usually family members of the patient, consistently make errors. Virtually all of our interpreters made multiple errors that could be considered clinically significant, with an average of 32 errors per participant, per encounter. This demonstrates the need for professionally licensed interpreters in the podiatric medical setting, even if a bilingual family member is present.

Our data analysis demonstrates that podiatrists cannot assume how well an ad hoc will interpret based on his or

her education or experience. We found that there was no correlation between education level and interpretation accuracy. Furthermore, although ad hocs who interpret for family members made fewer false fluency and omission errors than those who do not, they still made a similar number of CS errors of omission. Conversely, those who interpret monthly for family members had higher rates of CS addition errors than those who do so less frequently. One possible reason is that ad hocs who frequently interpret for family members have experience working with doctors, and may add potentially incorrect comments based on their pre-existing knowledge. Further studies are needed to assess the reason behind this finding.

It is important to mention that most of the clinically significant errors were due to words or phrases that are not necessarily medical jargon. We noticed that words that describe the quality of pain, such as “dull” and “sharp”, were often substituted for words that describe the severity of pain. Knowing the quality of pain is important in any patient encounter, particularly for diabetic patients who may develop neuropathy. Providers can improve the quality of interpretation by using descriptive terms or pictorials when discussing quality of pain.

Furthermore, we noticed that words at the ends of long phrases were often omitted. To prevent these omission errors, we suggest speaking in short phrases when using an interpreter, whether trained or ad hoc.

Conclusion

Understanding physician instructions is critical to diabetic foot care. Our study shows that untrained interpreters are insufficient to accurately interpret for the healthcare provider, therefore we emphasize the need for trained interpreters to best necessitate patient understanding and manage patient health. Future studies are needed to evaluate the use of concise terms to describe pain when using ad hoc interpreters. Specifically, these studies should find replacements for commonly misinterpreted words. This research could also be expanded and applied to other fields of medicine.

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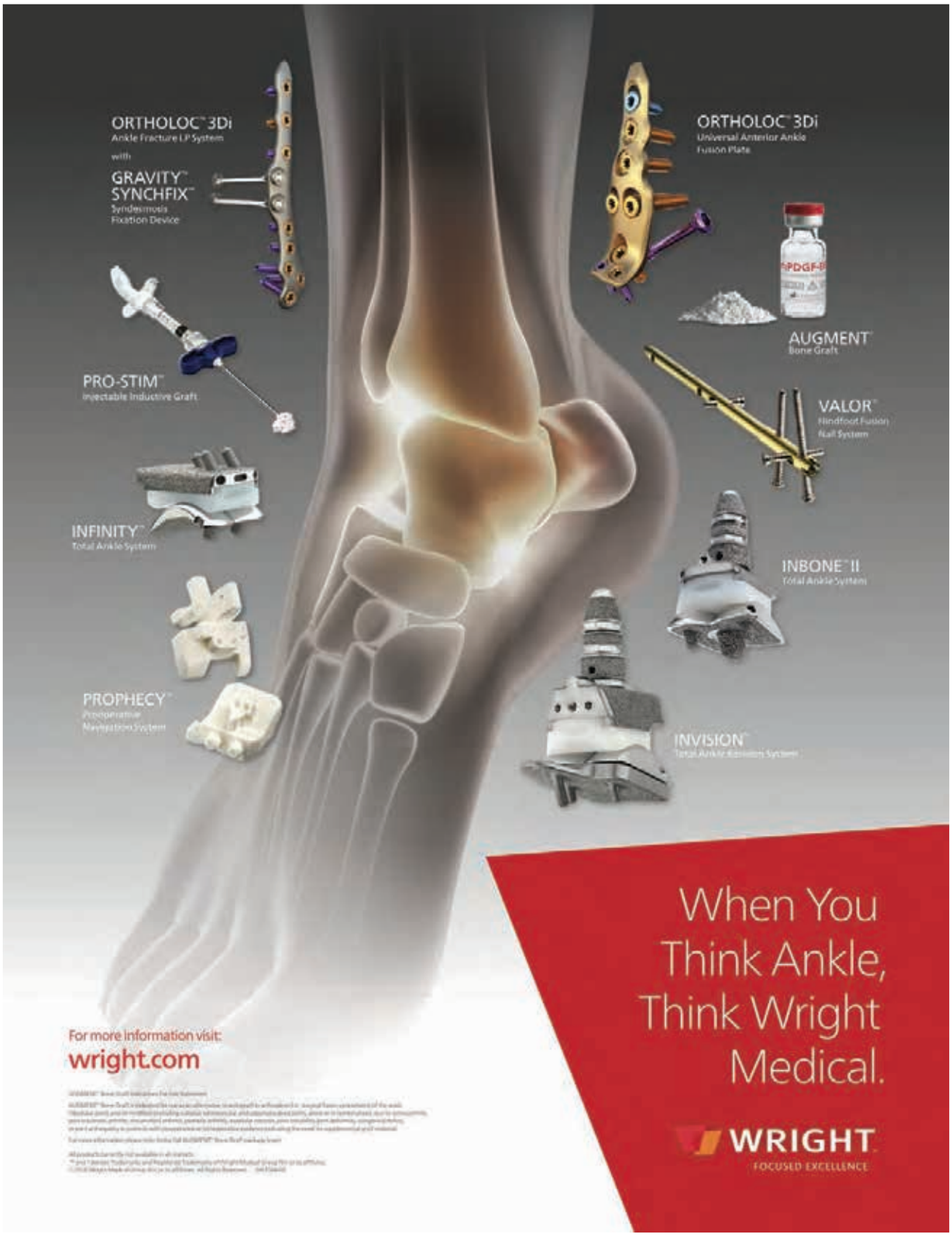
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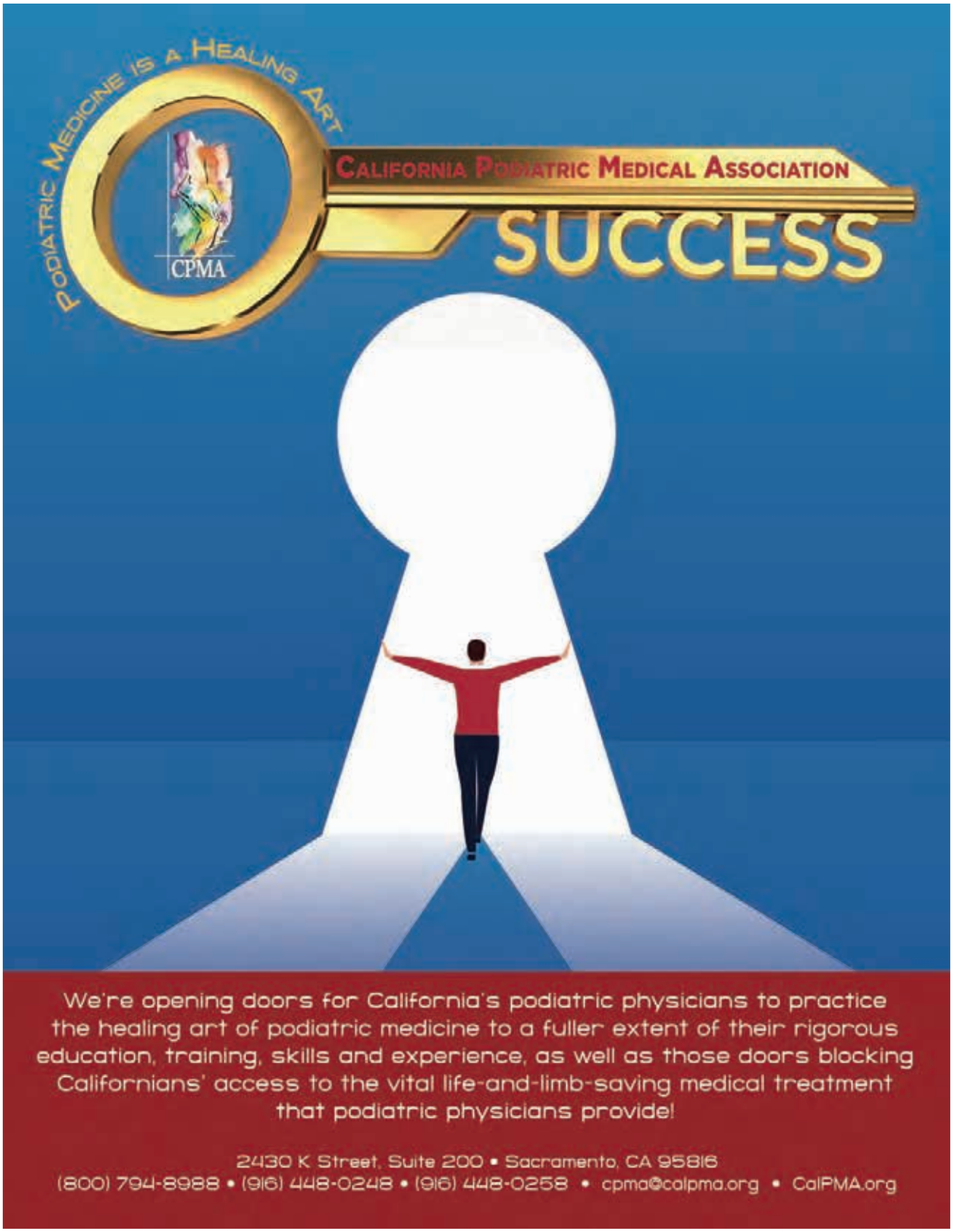
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