President's Message

Laurel Daniels Abbruzzese, PT, EdD

Greetings PASIG members! As physical therapists dedicated to serving the performing arts community, we are all familiar with the phrase, "The show must go on!" It is a saying used to encourage people to keep doing what they are doing even if they are experiencing difficulties and things are not going as planned. For many performing artists, "the show" met its match in the form of COVID-19.

On March 12th, Broadway went dark in New York City, and in an effort to protect public health, traveling off-Broadway shows, music concerts, gigs, and festivals have been cancelled all across the country. Major ballet companies have cancelled their spring seasons.

Collegiate dancers are finishing out their semesters taking class in their homes, using chairs and bed rails as ballet barres. Summer dance intensives are being cancelled or offered virtually. "Drawn to Life" by Cirque du Soleil® & Disney, which has been preparing all year, was forced into quarantine 4 days before its scheduled opening this past March. It was heartbreaking for all of their performers and the health care team that had to be let go without a return-to-work date.

It is the first week of May as I write this letter and the future remains uncertain. Social distancing is still a priority and reopen dates for most across the country have yet to be announced. For some of our performing arts therapists affiliated with larger teach-

(Continued on page 175)

Hello AOPT Foot and Ankle SIG members!

We write this newsletter in the midst of widespread stay-at-home orders across the country. Social-distancing, home-schooling, synchronous and asynchronous learning, telehealth, and personal protective equipment have all become a norm in our vocabulary, and lives. In this time of constant shuffling and re-shuffling of plans and priorities, it is a bit difficult to write about the FASIG initiatives for the year. But, in the midst of change there is also excitement. It is nice to have the time to move some of our planned tasks ahead and exciting to see how the "new-normal" may expand how we do things in the future. Highlights for a few of the FASIG initiatives are included below. The FASIG would also like to recognize the wonderful contribution of Dr. Kimberly Veirs, MPT, PhD, ATC, who submitted the manuscript titled, *Multi-Segment Assessment of Ankle and Foot Kinematics during Relevé Barefoot Demi-Pointe and En Pointe* for this edition of *OP*. This study provides a wonderful example of shared interest between the FASIG and the Performing Arts SIG and an opportunity to promote a greater understanding of multi-segment foot motion in dancers—a group with truly amazing feet!

- The American Orthopaedic Foot and Ankle Society (AOFAS) Annual Meeting is planned for September 9-12 at the San Antonio Convention Center. This is an example of plans that remain in flux. The FASIG continues to work with the AOFAS planning committee to develop high-level foot and ankle programming. This remains an exciting opportunity because this year the content may be delivered

(Continued on page 179)

Multi-Segment Assessment of Ankle and Foot Kinematics during *Relevé* Barefoot and *En Pointe*

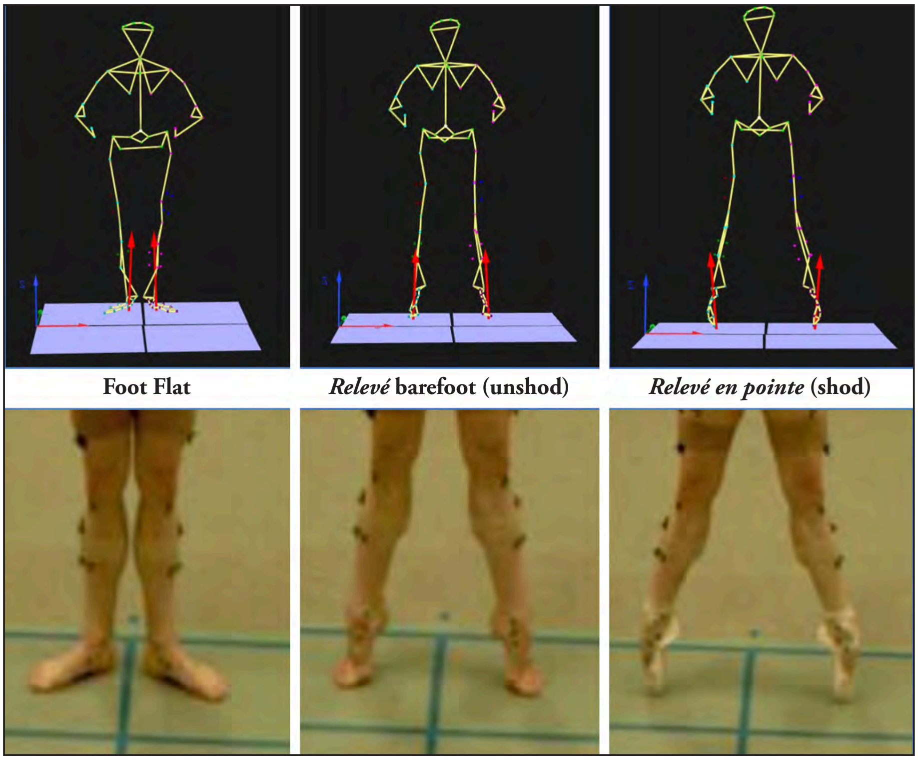
Kimberly P Veirs, MPT, PhD, ATC[1];
Jonathan D Baldwin, MS, CNMT[1]; Josiah Rippetoe, BS[1];
Andrew Fagg, PhD[2]; Amgad Haleem, MD, PhD[1];
Lynn Jeffries, PT, DPT, PhD[1]; Ken Randall, PT, PhD[1];
Susan Sisson, PhD[1]; Carol P Dionne, PT, DPT, PhD, MS, OCSM[1]

[1]University of Oklahoma Health Sciences Center, Oklahoma, OK
[2]University of Oklahoma, Norman, OK

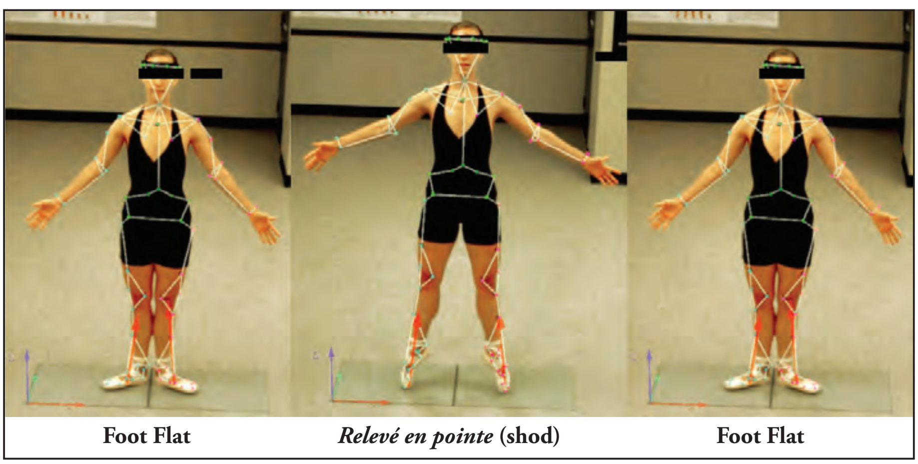
As many as 95% of dancers sustain at least one injury each year throughout their career.[1] Epidemiologists link dance-related injury rates to multiple factors, such as level of training, demographics (eg, age and gender), poor muscle strength and motor control, flexibility (insufficient or excessive), faulty alignment, and joint range of motion (ROM) (eg, hypermobility).[1,2] Although the definitive risk factors linked to the high prevalence of injury are largely unknown, there is extensive evidence that overuse, linked to repetitive movement, causes the preponderance of injuries among ballet dancers.[2] Fundamental ballet dance repertoire requires the performer to repetitively move through and balance in extreme ranges of motion of the foot and ankle complex, possibly contributing to the high rates of injuries among dancers.[3] Unique to ballet art form, dancers must balance and perform while in *relevé* barefoot (Picture 1; standing unshod on the balls of the feet [the metatarsal heads]; also called "demi-pointe") and *en pointe* (Picture 1; standing on the toes in pointe shoes [shod] with maximum plantar flexion (PF) of the ankle joint in pointe shoes). One way to assume *relevé* is to rise onto demi-pointe or *en pointe* by plantar flexing the foot (lifting the heel then the midfoot) with the knees and hips extended and the trunk held upright. This movement is commonly called *elevé* (Picture 2).[4]

Dancing barefoot and *en pointe* places different stresses and strains on the dancers' body and requires distinctive technical demands in part because the pointe shoe functions to provide stiffness for support and stability.[3,5,6] Pointe shoes are fabricated of a toe box (layers of burlap, cardboard, and/or paper glued together to form the standing platform and the vamp), shank (the cardboard and/or leather insole of the shoe), and satin covering.[6] When *en pointe*, the dancer stands on the toe box platform and must have support from the shank for safety.[6] The dancers' fully plantar flexed or "pointed" foot is proposed to come from the combined movement of the ankle (talocrural) joint and the 4 segments of the foot-complex: the hindfoot, midfoot, forefoot, and first meta-

PERFORMING ARTS / FOOT & ANKLE



Picture 1. First position images from Qualisys™ (Red arrows are ground reaction force arrows from AMTI force plates).



Picture 2. *Elevé* event (foot flat to foot flat events).

tarsal phalangeal (MTP) joint or hallux.[3] This combined movement allows for tri-planar ROM (supination and pronation) with 3 degrees of freedom: PF/dorsiflexion (DF), adduction/abduction, and inversion/eversion.[3] Radiographic studies measuring dancers at end-range of DF and PF found that, on average, the talocrural joint provides 70% of the ROM while the combined movement of the foot-complex joints account for the remaining 30%.[7] Precisely which joints and to what degree each of the foot-complex segments move to attain the remaining 30% of these movements have not been described.[4] Only recently have technological advances provided the tools necessary to evaluate the foot-complex *in vivo* during movement.

Three-dimensional (3D) motion capture systems are valid and reliable tools that have the capacity to record *in vivo* kinematics of the ankle and foot in all three planes of movement (sagittal, frontal, and transverse) during gait and other dynamic movements using reflective tracking markers.[8,9] Much like sports medicine, dance medicine researchers are using whole-body 3D motion capture technology as an initial assessment tool to describe biomechanics unique to the dance population and ascertain risk for injury.[4] Yet, there is a dearth of literature describing the *in vivo* kinetics and kinematics of the foot-complex during fundamental dance-specific movements, limiting the clinician's ability to adequately evaluate dancers' technique.

The foot and ankle are assessed during whole-body motion capture to varying degrees of specificity based on the number and placement of reflective tracking markers.[9] The number and placement of tracking markers on anatomical landmarks create a biomechanical model used for analyzing *in vivo* kinematics.[10] The 3D single-segment foot models combine the foot-ankle complex into one rigid body whereas 3D multi-segment foot models (3DMFM) allow for evaluation of the foot segments separate from the ankle joint.[9,10] Thus, a comprehensive evaluation of the dancers' foot-complex separate from the ankle joint requires evaluation of dance-specific movement using a 3DMFM.[8]

Carter et al[11-13] were the first to analyze dance-specific movement using a 3DMFM by modifying 6 components of the Rizzoli foot model (RFM) on barefoot dancers. Carter et al[11] specifically tested reliability of their proposed 3DMFM specific for dance movement using intraclass correlation coefficients (ICC). Investigators reported high intra- and inter-assessor reliability for first MTP sagittal plane joint movement (ICC ≥ 0.75) and poor to excellent inter-assessor reliability (0.5 > ICC ≥ 0.75) for 3 of the 5 inter-segmental angles during the point-flex-point trials, including the midfoot segments. These results provide evidence that using a multi-segment foot model has the potential to be a valuable tool to evaluate total, segmental, and inter-segmental ROM of the foot and ankle during dance-specific movement.[11] A thorough literature review through 2018 garnered no evidence of a study that applied a 3DMFM to dancers in pointe shoes or a study that directly compared *in vivo* biomechanics of dancers performing movement barefoot (BF) and *en pointe*,[4] whereby necessitating a pilot study to explore the capability of a biomechanical foot model to describe foot movement in these two conditions.

The primary purposes of this manuscript are to advance the physical therapists' understanding of the unique demands placed on the foot-complex when balancing in *relevé* and describe the biomechanical differences between the barefoot and *en pointe* conditions. Evidence presented is based on results from a larger cross-sectional pilot study and aim to augment the dance-specific functional evaluation of the ankle and foot-complex. The pilot study was conducted to describe and compare the kinematics at 18 joint angles (Table 1) for healthy, elite ballet dancer's foot and ankle in two conditions, BF and *en pointe*, during *relevé* in first position using a modified RFM.[14,15] Investigators chose the RFM over other multi-segment foot models described in the literature because it has been validated for use with several different patient populations[9,16-19] and is one of the few 3DMFM's consistently described as highly reliable[11,18,20] and repeatable[16,21] on the BF. Additionally, the RFM demonstrated repeatability thresholds that are consistent with BF findings when applied to a shoe during gait.[22] Because dance-specific movement requires extreme ROM to perform correctly[3,7,11,23] (eg, ankle PF and hallux extension in BF *relevé*), the RFM required modifications to design the BF and shod dance-specific models. These modifications also aimed to increase the accuracy of marker placement on the shoe.[24] The pilot study model included 5 segments, the ankle, hindfoot/calcaneus, midfoot, forefoot/metatarsals, and the hallux, which enabled analysis of the total, segmental, and intersegmental kinematics of the foot-ankle complex during dance-specific movement (see Table 1).

MATERIALS AND METHODS

Instrumentation and Biomechanical Model

A 12-camera Qualisys™ Motion Analysis System housed in the Center for Human Performance (CHPM) laboratory at the University of Oklahoma Health Sciences Center (OUHSC), College of Allied Health recorded 3D kinematic and kinetic data on 11 elite ballet dancers. The cameras, mounted in a fixed configuration, tracked reflective surface markers that were attached to anatomical landmarks using double-sided tape. A digitized procedure captured the 3D coordinates of each marker subsequently used as the basis for calculating segmental joint angles[25] during dance-specific movement. The AMTI Force plates (AMTI, Watertown, MA) simultaneously recorded ground reaction forces and center of pressure location data at 2,400 Hz.

Seventy-six reflective skin-mounted anatomical markers and two sets of cluster tracking markers affixed in the same stepwise fashion using double-sided tape enabled whole-body recording of *in vivo* motion-related data.[4] Forty of the reflexive markers were secured to the trunk and pelvis (sternum, R/L acromions, C7, R/L infrascapular angles, L3, R/L posterior superior iliac spines, R/L iliac crests, R/L anterior superior iliac spines [ASIS], and the apex of the sacrum), the upper extremities (R/L humeri, R/L medial and lateral epicondyles, R/L olecranons, R/L radii, and R/L ulnas), and the lower extremities (R/L greater trochanters, R/L thigh at

Table 1. Range of Motion Angle Differences (BF-Shod) at the Peak *Relevé* Event of the *Elevé*

Angle	HL Estimates	95% CIs	p-values	Greater angle	Med BF	Med Shod	Med Diff
Ankle DF-PF	-5.9839	-12.7280, 2.5090	0.123	Shod	161.3	167.8	-6.5
Hallux Ext	-14.311	-25.4691, -3.6271	**0.0147***	Shod	120.7	134.6	-13.9
S2F	-6.0194	-11.3217, 2.3147	0.123	Shod	11.3	18.0	-6.8
S2V	6.9953	3.1586, 13.0299	**0.0005***	BF	19.6	13.1	6.6
MLA	8.9625	1.1523, 15.9241	**0.0115***	BF	99.9	90.9	9.1
Sha-Cal	-4.0922	-12.3305, 2.9732	0.2475	Shod	30.8	34.4	-3.6
Cal-Met X	-5.199	-22.6924, 10.8574	0.393	Shod	-5.7	2.2	-7.9
Cal-Met Y	-4.1718	-14.9302, 6.6361	0.4813	Shod	-6.9	-4.2	-2.6
Cal-Met Z	50.1423	36.8909, 62.0782	**<0.0001***	BF	-51.3	-93.7	42.3
Cal-Mid X	-4.0232	-13.2716, 6.0938	0.6305	Shod	-7.8	-5.1	-2.7
Cal-Mid Y	-0.3038	-5.9829, 5.4265	0.9705	Shod	-4.5	-4.8	0.33
Cal-Mid Z	21.4409	2.3898, 35.9351	**0.0355***	BF	7.5	-17.5	24.9
Met-Hal X	7.5787	-2.2257, 19.1839	0.123	BF	3.6	-2.9	6.5
Met-Hal Y	7.6086	-5.5495, 19.3123	0.315	BF	9.0	6.1	2.9
Met-Hal Z	-0.0927	-17.2969, 18.7823	0.9999	Shod	63.9	70.1	-6.1
Mid-Met X	2.5646	-12.0872, 22.5716	0.6842	BF	-5.2	-11.5	6.3
Mid-Met Y	5.4723	-10.4833, 24.9344	0.4813	BF	-7.9	-9.5	1.6
Mid-Met Z	25.181	8.9921, 52.0841	**0.0002***	BF	-52.7	-71.2	18.5

Negative (-) values = Shod greater than BF
Positive (+) values = BF greater than Shod

* $p < 0.05$

Hodges-Lehmann (HL) Estimates (degrees), exact Wilcoxon signed-rank p-values; Median joint angle (BF, shod, and angle difference)

the midpoint between the ASIS and superior apex of the patella, R/L lateral and medial condyles, R/L tibial tubercles, R/L fibular heads, and R/L shank at the midpoint between the tibial tubercle and ankle joint). Eight markers equally spaced on a headband, spanning from just proximal to the right mastoid process to the left mastoid process, defined the head segment. Two sets of cluster tracking markers with 4 reflective markers on each were placed on the midpoint of each thigh and shank.

The first author used a stepwise fashion to secure 14 reflective markers to each foot and ankle for all participants. The anatomical tracking markers, labeled with acronyms as per the modified RFM (Figures 1A and 1B), include the medial and lateral malleoli (MM, LM), proximal calcaneal ridge (FCP), distal calcaneus over the attachment of the Achilles tendon (FCD), sustentaculum tali (ST) of the calcaneus, apex of the peroneal tubercle, medial apex of the navicular tuberosity (TN), tuberosity of the 5th metatarsal (MT) (VMB), lateral aspect of the head of the 5th MT (VMH), medial aspect of the base and head of the 1st MT (FMB, FMH), base and head of the 2nd MT (SMB, SMH) and the distal hallux on the center of the toenail (HD). A second trained investigator confirmed all marker placements for accuracy.

Experimental Procedure

Data collection took an average of two hours per participant (n = 11; median age: 21 y, median height: 1.68 m, median weight: 55.11 kg). The OUHSC Institutional Review Board provided approval for this study before recruitment and protocol commencement and all participants were formally consented for human subject protection. All participants met the study's inclusion criteria (female ballet dancer, currently dances *en pointe* at the elite level (18 - 40 y), no current injuries preventing them from assuming the *en pointe* position, no chronic injury or past surgical history to the forefoot resulting in fusion of the first MTP joint, able to raise *en pointe* without handheld assistance or the use of a secure platform, such as a ballet *barré*, and English speaking). An "elite ballet dancer" was operationally defined as either a preprofessional ballet dancer (dancers either at the university level or pre-professional dance school with the intention of becoming a professional ballet dancer) or a professional ballet dancer (dancers currently under contract or employed with a professional ballet company) who currently train *en pointe*.

Participants completed an intake sheet including demographics (sex, age, current employment/school, pointe shoe type, age started dancing, and number of years *en pointe*) and medical information (current health status, medications, and past medical history including dance-related and non-dance-related injuries, and surgeries). Baseline measurements included height (m), weight (kg), baseline heart rate (bpm), baseline blood pressure, generalized or specific pain level on the Wong-Baker FACES® Pain Rating Scale,[26] and a posture screen. The first author, a licensed physical therapist, conducted foot and ankle evaluations (goniometric ROM, joint mobility, and manual muscle testing) and inspected the pointe shoes to ensure the shank and box were "broken in" but not "broken" or unstable as described in a previous study investigating pointe shoe deterioration.[5] Documentation of the shoe included the brand, wear patterns, and stability of the shoes' vamp, box, platform, and shank.

Data collection

Participants wore a sleeveless leotard during data collection. Standardization of attire intended to limit clothing artifact to reduce tracking errors of the markers and improve the accuracy of measures.[8] A standardized protocol for data collection included performing the standard Qualisys™ motion capture system calibration and 10 minutes of ballet-specific warm-up. The BF trials preceded shod trials for all participants to allow investigators to locate anatomical landmarks on the BF to mirror the application of markers on the pointe shoe. Dancers performed 10 to 15 repetitions of *elevé* (see Picture 2) in an open first position (small separation between the heels; Picture 1)[11] at the dancers' self-selected pace and their natural degree of turnout (lower extremity external rotation). The open first position ensured that the two calcaneal markers did not touch during data collection.[11] The stepwise protocol was repeated for the shod trials.

Data processing

Before data processing, every digitized raw data point for each marker was labeled as per the dance-specific biomechanical model created for this pilot study using the Qualisys™ software. The "peak *relevé*" and "foot flat" events were marked for each trial (see Picture 1). The "peak *relevé*" event was defined as the point in time when the dancer was balanced or paused in the *relevé* position with maximum ankle PF and bodyweight most centered between the two legs. The ground reaction force arrows derived from the AMTI force plates (see Picture 1) and the sinusoidal *in vivo* waveform graphs were used to determine the point in time when the dancer was balanced and weight most symmetrically distributed between the lower extremities. The "foot-flat" angle event was the point in time when the dancer assumes the most symmetrical weight bearing between the two legs with knees extended, ankles dorsiflexed, and the feet flat on the floor in first position. The precise requisite for marking these *in vivo* events occurred when the force arrows demonstrated the most symmetry between the lower extremities before changing position during the "*elevé* event." The "*elevé* event" was defined as the movement between 2 foot-flat events (see Picture 2). Raw data marked with the events were transferred from Qualisys™ into Visual 3D (V3D) for filtering and processing.

Data were analyzed on 10 of the 11 participants. Researchers excluded Dancer 1 data after technological upgrades to the motion capture system in the CHPM rendered the technical reference frames of her data inconsistent with the other 10 participants' data. As *relevé* in first position is a symmetrical movement[27] and a previous study reported high correlation (ICC = 0.99) in ankle movement patterns between the two extremities during *relevé en pointe*,[28] data analysis was performed on one foot-ankle complex per participant (n_{Right} = 5; n_{Left} = 5). The foot and ankle with "full fill" of marker tracking during 5 consecutive movement trials was chosen as the criteria for determining which LE to use for analyses. "Full fill" indicates that at least part of the tracking marker is visible during the entire movement trial 100% of the time[29] to ensure robust data collection. Data were processed in V3D using a low-pass Butterworth filter and a standard cutoff frequency of 6 Hz and normalized for each participant using body weight (kg) and height (m).[10] *Post hoc* analysis found no significant difference between the right and left extremities for all variables tested in the pilot study.[4]

Data analysis

The absolute mean difference angle of the 5 consecutive first position *elevé* events for each of the 10 participants determined the absolute value for the total amount of ROM for the group (|Total

ROM $_{individual}$|= |peak *relevé* angle $_{individual}$ – foot flat angle $_{individual}$|) for the 18 variables tested. Movement between segments included 4 tri-planar intersegmental articulations (calcaneus-metatarsal [cal-met], calcaneus-midfoot [cal-mid], metatarsal-hallux [met-hal], midfoot-metatarsal [mid-met]), as defined by the modified RFM (Figure 1C).[15] Note, that when interpreting the intersegmental movement, the reference or non-moving segment is listed first and the moving segment is listed second (eg, for the cal-mid interseg-ment, the midfoot segment is moving relative to the calcaneus segment).[14] The other 6 joint angles analyzed were measured in one plane each: 3 in the sagittal plane (medial longitudinal arch [MLA], ankle, and hallux), one in the frontal plane of the hindfoot (shank-calcaneus [sha-cal]), and two in the transverse plane of the forefoot (the angle between the second and first metatarsals [S2F] and second and fifth metatarsals [S2V]) (see Table 1). The MLA, shank-calcaneus, S2F, and S2V joint angles were derived as per the RFM with modifications as described by Veirs et al.[4] The ankle and hallux joint angles assessed in the pilot study 3DMFM aimed to replicate how ROM is typically measured by clinicians. The ankle angle was measured using the fibular head (FH), LM, and 5th metatarsal head (VMH) tracking markers. The hallux angle was measured using the head of the first MTP (proximal), the base of the first MTP (center), and the distal hallux (distal) tracking markers.[4]

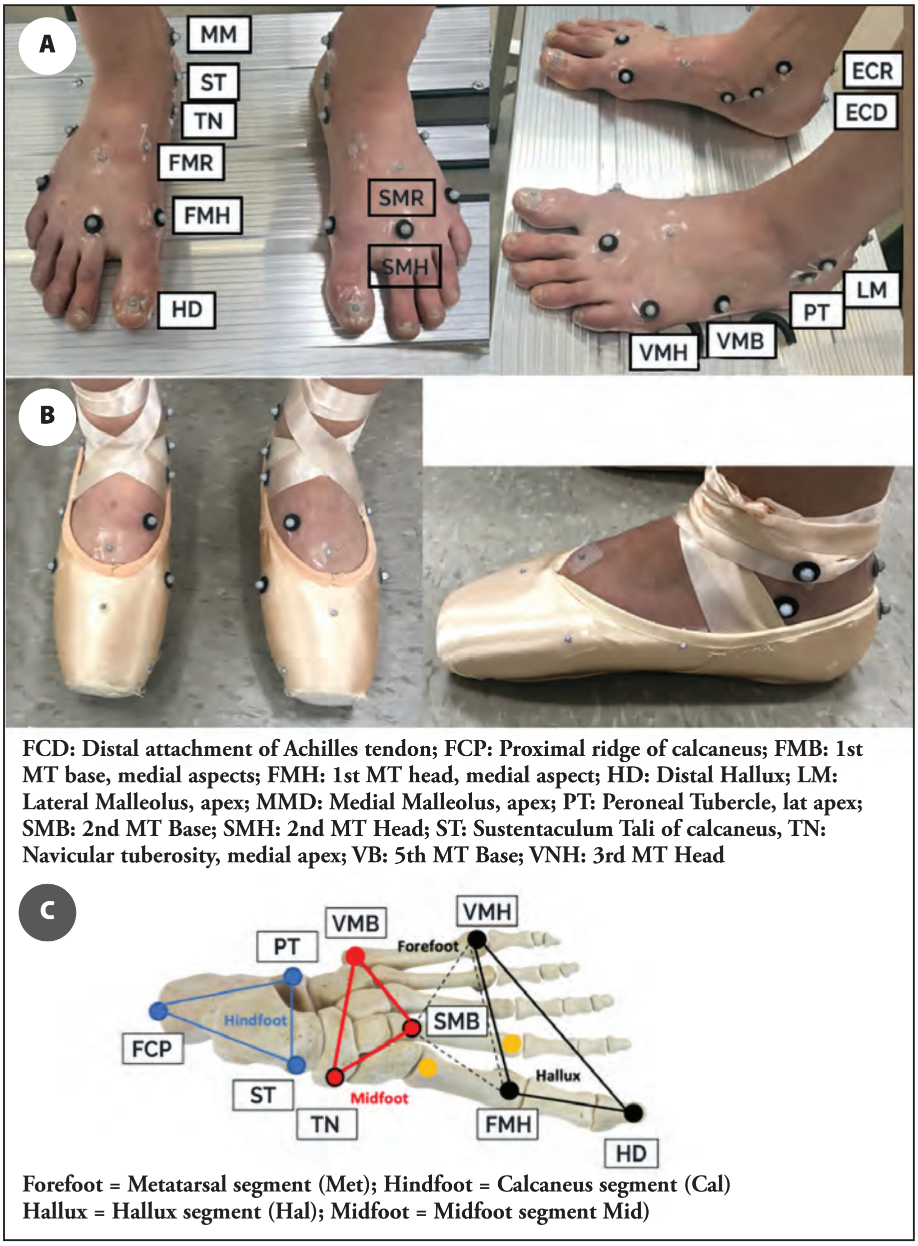


Figure 1. 3D Multi-Segment Foot Model (Modified Rizzoli Foot Model [RFM])[4] Placement of anatomical target markers.* A, barefoot. B, Pointe shoe. C, Foot model segments.

*** Fibular Head (FH) marker: Not pictured (used when calculating kinematics of the ankle joint segment).**

Statistical analysis

Data did not follow a normal distribution; therefore, non-parametric Wilcoxon signed-rank test and Hodges-Lehmann (HL) estimates with 95% confidence intervals (CIs) were used. Range of motion values and differences between measures of central tendencies (median) for the two conditions were reported for the peak angle (see Table 1). The null hypothesis for the peak ROM data were not different between condition (BF and shod) for each of the 18 variables tested at an alpha level of 0.05.

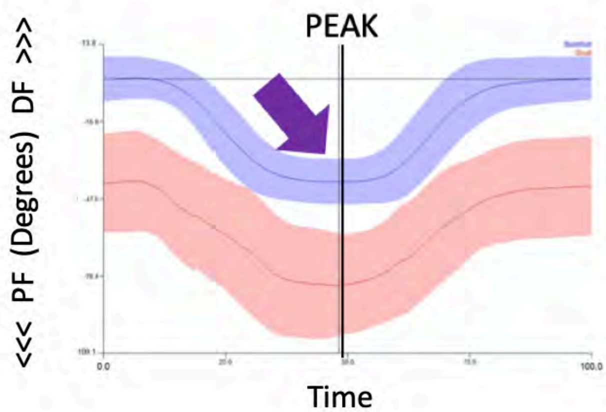
Results

No differences were found between 12 of the 18 variables tested for ROM at the peak angle of the *relevé* in first position and resulted in failure to reject the null hypothesis for those variables (Table 1). Results describe significantly greater ROM at 5 variables in the BF condition and 1 variable in the shod condition. In BF, greater movement resulted between 3 foot-complex segments in the sagittal plane: the calcaneus-metatarsal (Figure 2A; HL 50.14°, 95% CI: (36.89°, 62.08°), p<01), the calcaneus-midfoot (Figure 2B; HL 21.44°, 95% CI: (2.39°, 35.94°), p=0.03), and the midfoot-metatarsal (Figure 2C: HL 25.18°, 95% CI: (8.99°, 52.08°), p<0.01). When BF, more movement occurred in the arch of the foot as greater excursion was observed at the MLA (Figure 2D; HL 8.96°, 95% CI: (1.15°, 15.92°), p<0.01), and S2V (Figure 2E; HL 6.99°, 95% CI: (3.16°, 13.03°), p<0.01) angles. The sagittal plane peak angle of the hallux was the only segment with significantly greater ROM in the shod condition (Figure 2F; HL 14.31°, 95% CI: (3.63°, 25.47°), p = 0.01).

DISCUSSION

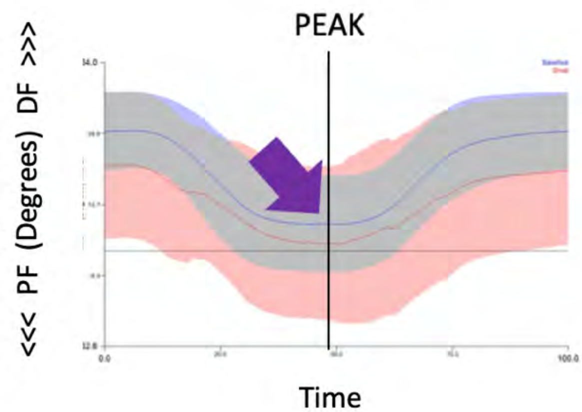
Results from the current study suggest there is greater sagittal movement between 3 segments of the foot-complex (the hindfoot [calcaneus], midfoot, and forefoot [metatarsals]) and the MLA (arch height[15]), and greater rotational movement in the foot (S2V: second MT relative to the fifth MT) when the dancer is balancing in *relevé* BF

A



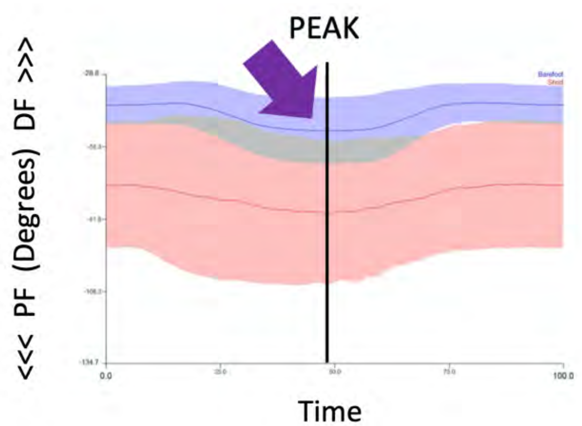
A, Calcaneus-Metatarsal (sagittal plane angle forefoot movement relative to the hindfoot) Greater ROM BF than shod (DF+/PF -)

B



B, Calcaneus-Midfoot (sagittal plane angle midfoot movement relative to the hindfoot) Greater ROM BF than shod (DF +/PF -)

C



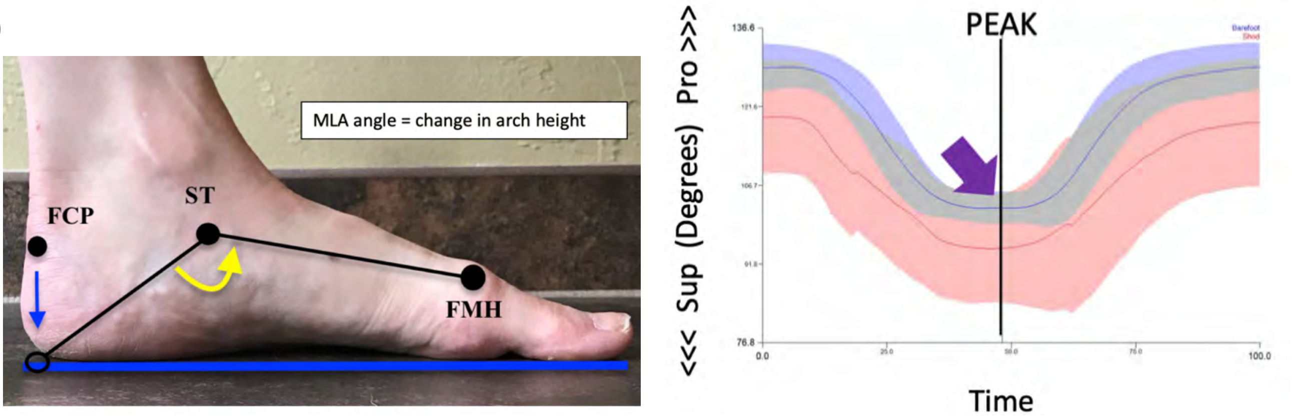
C, Midfoot-Metatarsal (sagittal plane angle forefoot movement relative to the midfoot) Greater ROM BF than shod (DF +/PF -)

Figure 2. ***In vivo*** **waveform graphs during first position** ***elevé*** **for the 6 variables with significant ROM differences at the peak** ***relevé*** **event.**

Kinematic waveform graphs of the 6 variables (A) calcaneus-metatarsal, (B) calcaneus-midfoot, (C) midfoot-metatarsal, (D) MLA, (E) S2V, and (F) the hallux angle of the right foot and ankle (n = 5) during first position ***elevé*** **from foot flat to foot flat: BF compared to shod conditions (group mean ± SD between foot flat and foot flat events). The black vertical line at approximately the 50% timeframe is the** ***relevé*** **event (mean ± SD). The darker colored red and blue lines are the means for each condition. The red shaded areas are the SD's for the shod condition. The blue shaded areas are the SD's for the BF condition. The gray areas are where the two conditions overlap. Positive HL estimates indicate BF angles were greater. Negative HL estimates indicate shod angles were greater. Note: 3D motion capture systems measure movement relative to the plantar surface/ the floor (eg, PF angle values are negative and DF values are positive) with the exception of the MLA.** ***Refer to Figure 1 for description of hindfoot, midfoot, and forefoot segments and marker placement.***

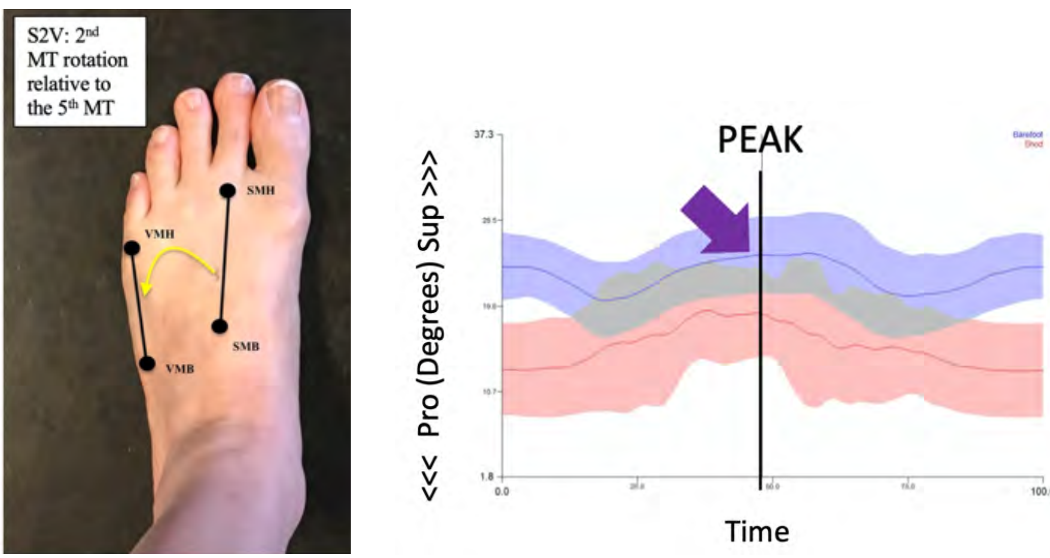
(Figure 2 continued on page 173)

D



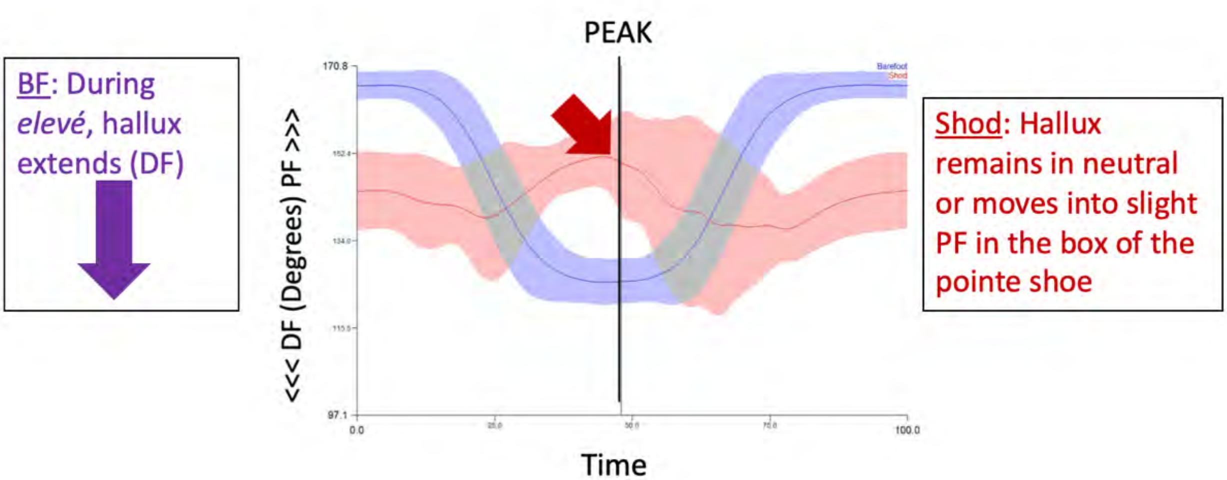
D, Medial Longitudinal Arch (MLA) angles Greater ROM BF than shod (Angle calculated relative to the arch of the foot; Pronation > Supination)

E



E, S2V rotational angle Greater ROM BF than shod (Angle calculated relative to the plantar surface of the foot; Supination > Pronation)

F



F, Hallux angle (Greater ROM angle shod than BF)
The V3D software calculates the hallux angle relative to the plantar surface.

than *en pointe*. These differences align with the evidence that the forefoot and midfoot are blocked by the pointe shoe[6] when shod but during barefoot movement, the foot is free to move in its full tri-planar ROM to its peak *relevé* position. A significant greater angle difference was found in the shod condition at the hallux segment. These results specifically demonstrate how the hallux segment must move a greater distance from its resting position on the floor in foot flat to get into *relevé en pointe* than BF.

The extrinsic stability to stand *en pointe* on the platform of the pointe shoe comes, in part, from the stiff toe box that bundles the toes together to absorb forces during axial loading[6] and the shank of the shoe. As the pointe shoe restricts the forefoot and toes[6] and the toes maintain a relatively neutral alignment,[3,7] the results of the current study support that the sagittal motion necessary to balance *en pointe* must come entirely from foot segments proximal to the forefoot. When shod, there was significantly less ROM of the S2V angle (rotational movement of the second MT relative to the fifth MT) and MLA as compared to BF. These results suggest that the shank of the pointe shoe limits rotational and sagittal movement of the midfoot and forefoot, respectively.

Previous authors indicate that the dancer's base of support is less stable when the lower extremities are turned-out than parallel because the longitudinal axis of the foot changes from the anterior-posterior plane to the medio-lateral plane.[30] However, classical ballet technique dictates the lower extremities to be maintained in a turned out position, ideally defined as a combination of 180° between the two legs.[13,31,32] The demand for the "ideal" or "perfect turnout"[33] among ballet dancers lends to "forced turnout" when dancers force their hips, knees, or feet and ankles beyond their physiological limits.[13,34] Resultant compensatory strategies include destabilization of the MLA into pronation, abduction of the forefoot, and external rotation at the knees[12,13,34] placing undue stress and strain on soft tissues, predisposing dancers to injury.[31] The authors of the current study suggest that clinicians should evaluate the dancer turned-out in the first position both barefooted and in pointe shoes. Measuring the change in arch height, pronation, and foot abduction could potentially determine if there are differences in compensatory strategies between the two conditions when balancing in *relevé*.

Dancers perform *elevé en pointe* either by springing up or rolling through demi-pointe to get onto the box of the pointe shoe. Either way, the dancer must press the hallux and forefoot into the ground against the hard shank of the pointe shoe to get from foot flat to *en pointe*. While balancing in barefoot *relevé*, the MTP joints, especially the first MTP joint, must have sufficient flexibility and mobility for balance. In addition to the differences in the hallux angle, the difference in body weight placement in BF and shod was observed at the peak of the *relevé* using the direction of the force arrows in Qualisys™ (Pictures 1 and 2). These observations align with imagery studies using magnetic resonance imaging[3] and radiography[7] of dancers *en pointe* that illustrate how the anterior surface of the talus becomes the primary weight-bearing site in the ankle. Clinicians could use this evidence when evaluating dancers as they balance in *relevé* barefoot and shod to visualize where they balance their weight and how they shift their weight to balance in *relevé*. This recommendation is analogous to using an imaginary plumb line when evaluating posture.

Although peak ankle PF ROM angles were not significantly different between conditions ($p=0.123$) in the pilot study, clinicians should be aware that ballet dancers' functional PF ROM needs measurably exceeded normative values of the general population (0-50°).[3,7] Results from this study (med_{BF} = 161.3°, med_{shod} = 176.8°) are consistent with other studies describing that the greatest amount of dancers' PF movement occurs at the talocrural joint when both weight-bearing *en pointe*[3] and plantar flexing or "pointing" the foot in non-weight bearing.[7] Based on observation of the position of the talocrural joint relative to the foot-complex weight-bearing point of this sample of elite dancers during the peak ROM event (see Pictures 1 and 2), the talocrural joint should generally align over the weight-bearing surface of the foot: the first MTP joint when BF and the distal hallux point (box of the pointe shoe) when *en pointe*. If the talocrural joint is not in these alignments, the clinician should conduct joint-specific mobility and ROM testing to determine how the dancer could achieve better alignment when in *relevé*. Based on the current study, a biomechanical dance-specific evaluation of the foot and ankle should include (1) static posture evaluations in the turned-out position in foot flat and *relevé* (barefoot and *en pointe*); (2) functional evaluation of dynamic dance-specific movement, including the *elevé* movement and static *relevé*, BF, and shod *en pointe*; and (3) functional ROM and mobility testing of the ankle and foot-complex.

CONCLUSION

The current study was the first to describe and compare *in vivo*, tri-planar movement of the foot-ankle complex with dancers BF and *en pointe* using a 3DMFM. Results support the contention that dancing BF involves different biomechanics than dancing *en pointe*. Ballet dancers must repeatedly balance in *relevé*, which places atypical stresses and strains on the joints and soft tissues of the foot and ankle.[3] The repetitive forces placed on the foot and ankle during dance-specific movement possibly contributes to injuries unique to the dance population, including stress fractures at the second and third metatarsals, flexor hallucis longus tendinopathies, and sprains/strains at the tarsometatarsal (Lisfranc) joint complex.[1,2]

The current study advances the physical therapists' understanding of the unique demands placed on the foot-complex when balancing in *relevé* and describe the biomechanical differences between the barefoot and *en pointe* conditions. Evidence presented are based on results from a larger cross-sectional pilot study and aim to augment the dance-specific functional evaluation of the ankle and foot-complex. The information provided is not intended to be an all-inclusive discussion of how to conduct a full and comprehensive dance-specific evaluation, considering other factors were not discussed or explored in the pilot study (eg, strength, proprioception, endurance). In short, investigators intend that the newfound knowledge from the pilot study will contribute to the clinicians' understanding of the biomechanics of the foot-complex during dance-specific movement that are unique and specific to the art form.

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PERFORMING ARTS SIG

(Continued from page 167)

ing hospitals, physical therapists have been redeployed to help with COVID-19 efforts, working on acute care units and in the intensive care units. Others have closed their clinics for in-person visits and are developing their telehealth practices. This has been a challenging landscape to navigate with policies restricting the number of visits and delivery of services across state lines. Technology can be a great resource, but it has its limits. Certain tests and measures cannot be administered virtually and manual therapy techniques are on hold, but the critical role of movement analysis is highlighted in these virtual environments. One of our PASIG members shared that the increased use of telehealth during the COVID-19 crisis has actually led to improved interprofessional communication. She shared that for two particular cases (a mid foot stress fracture and an anterior cruciate ligament reconstruction) she has been having telehealth interprofessional meetings with the physicians, dietitians, and psychologists with and without the patients to ensure that they are getting proper care. Thanks to telehealth, they are having more team meetings rather than multiple one-on one conversations. This encouraging anecdote leaves me hopeful that we could come out of this crisis stronger, with new creative and efficient ways to meet the health needs of our artists.

Many of you are likely feeling the financial impact of the pandemic. You have been providing pro-bono services and wellness programming to your artists, while at the same time struggling to stay afloat. Hopefully some of you were able to take advantage of the digital performances offered on the web by companies like New York City Ballet (https://www.nycballet.com), Alvin Ailey (https://www.alvinailey.org), Ballet Hispanico (https://www.ballethispanico.org/bunidos/watch-party), and The Metropolitan Opera (https://metoperafree.brightcove.services/?videoId=6152402347001). Our very own Academy of Orthopaedics is also offering the archived Independent Study Course (ISC) "Physical Therapy for the Performing Artist" at a reduced rate of $10. [A bargain not to be missed!]. This course is available at: https://www.orthopt.org/content/education/independent-study-courses/browse-archived-courses/physical-therapy-for-the-performing-artist. Now is a great time to explore affordable on-line professional development offerings and virtual classes.

Even with all of the changes associated with the pandemic, the business of the PASIG moves on. In our case, the show does go on. I want to welcome the newest member of the PASIG leadership team, Tiffani Marulli, the Performing Arts Fellowship Director at The Ohio State University. She will take on the role of PASIG Fellowship Advisory Board Chair. She will work with the directors at Harkness Center for Dance Injuries at NYU Langone, Johns Hopkins Medicine, and Columbia University Irving Medical Center / West Side Dance PT to support our new Performing Arts Fellowship Programs.

Under the leadership of our new Research Chair, Mark Romanick, we continue to send out citation blasts to our PASIG list serve. In March we had, "Respiratory Issues in Wind Instrumentalists" (Mark Romanick, PT, PhD, ATC), in April, "Returning to Dance After ACL Reconstruction" (Kynaston Schultz, SPT), in May, "Biomechanics, Motor Control, and Injury in Percussionists" (Stephen Cabebe, SPT), and in June, "Resistance Training for Female Ballet Dancers" (Danielle Farzanegan, PT, DPT, Sports PT Resident). The research team is also working on ways to make some of our archived blasts more accessible and to recruit new contributors for *OPTP.*

Rosie Canizares has been working with presenters and has secured two performing arts education session proposals for CSM 2021 (Emergency Medical Response for the Performer and Management of the Adolescent and Pre-professional Dancer) and two pre-conference courses focused on aerial artists and upper extremity ultrasound. We will be reinvigorating the ISC Taskforce, under Rosie's leadership, in order to develop new interactive learning modules focused on physical therapy for performing artists.

Our Membership Chair, Jessica Waters, is working on a member survey that will help to identify programming interests and research needs. We currently have a gap between our 699 members registered through AOPT and our 220 Facebook members. The link to our PASIG Facebook Page is: https://www.facebook.com/groups/PT4PERFORMERS/. It is a closed group and sometimes takes a while to cross-reference membership lists, but we encourage you to join. It is a great way to have quick access to the performing arts physical therapist community.

Lastly, I would like to spotlight one of our PASIG student members, Isabella Scangamore, a member of our PASIG Communications/PR Committee. As you will hear from Isabella, it is never too soon to get involved in APTA activities, and the PASIG is a very accessible first step.

As a student member, you should also know that you are eligible for the PASIG research scholarship if you have had an abstract accepted for CSM!

STUDENT SPOTLIGHT:

I am Isabella Scangamor, a third-year DPT student from Thomas Jefferson University in Philadelphia. I completed my undergraduate education at Muhlenberg College in Allentown, PA, where I was a dance major. I have consistently been passionate about working with dancers since it is very close to my heart, and such a fascinating population with unique demands on the body and mind, melding sport and artistry. I started looking for opportunities to get involved in performing arts physical therapy as soon as I started graduate school. I joined the PASIG the fall of my first year in physical therapy school after we had an in-class discussion about Sections and SIGs through the APTA, which spurred some self-research. I thought that this group would be a perfect way to get involved in performing arts physical therapy, see what it was all about, and start connecting with practicing clinicians and researchers already in the field.

It is so easy to get involved in the PASIG as a student! I am on the PR Committee, and other students have written citation blasts, case studies for *OPTP,* served on various committees, presented research, and created educational resources (like the figure skating glossary). It is a brilliant opportunity to start networking with like-minded people who are passionate about the same things as you, including dance, music, gymnastics, circus arts, theatre, and figure skating. The commitment to the PASIG is flexible, with opportunities to learn how to contribute to the field and build your resume. I found it exciting, especially at CSM since I had the privilege to attend this past February, to be in a room and "nerd-out" about all things performing arts-related, future research, new treatment methodology, and advancements in education. As the only person interested in performing arts physical therapy in my cohort, this was heaven. Every time I get a notification from our Facebook group, I get excited to see what is happening at the moment. If you are considering joining the PASIG, especially as a student, I highly recommend taking the leap.

FOOT & ANKLE SIG

(Continued from page 167)

partially, or fully, online. Our hope is this may allow an expanded opportunity to share that programming with the FASIG community. So, stay-tuned because at the time this edition of *OP* reaches you there will likely be more plans in place for this "virtual" conference. www.aofas.org/annual-meeting

- We previously reported on the progress of the foot and ankle fellowship initiative. As an update, our Declaration of Intent Letter was accepted by the American Board of Physical Therapy Residency and Fellowship Education (ABPTRFE) in February 2020. We have now submitted a *Practice Analysis Survey* that will form the backbone of the document to develop the specialty practice. Please stay tuned for updates on this initiative as the FASIG and the AOPT are eager to move this process ahead. Again, many thanks to our Practice Analysis Coordinators, Project consultant, and the entire taskforce working on this.
- The FASIG Practice Committee together with guidance from the AOPT Public Relations Committee is working on creating infographics to share information about common foot and ankle pathologies. These will be shared across the AOPT. Versions may also be developed to inform patients about common conditions and what to expect when seeking treatment. A special thanks to the FASIG Practice Chair, Megan Peach, DPT, OCS, CSCS, who is coordinating this effort.

We wish everyone in the FASIG, and the whole AOPT, health and well-being as the world adjusts in the wake of the COVID-19 pandemic. We are certainly all impacted as educators, health care providers, parents, community members, citizens, and partners in the process to get through this uncertain time. We will see how the summer and fall progress to allow us to return to many of our prior activities—but likely with a new wealth of online experiences.

The FASIG Leadership

https://www.orthopt.org/content/special-interest-groups/foot-ankle