

Academy of Orthopaedic Physical Therapy, APTA, Inc. Grant Program Final Report Form

Date: 24 September 2018

Name of Investigators: Kornelia Kulig (Co-PI), K. Michael Rowley (Co-PI), and Steffi (Hai-Jung) Shih (Co-Investigator)

Name of Grant: Investigating a novel intervention for flexor hallucis longus tendinopathy in dancers

Award Period: 19 April 2016 – 24 July 2018 (extension approved 7 Feb 2018)

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1. Briefly summarize major accomplishments of this project (2-4 pages)

With support from this APTA, Orthopaedic Section, Performing Arts Special Interest Group grant, we completed our investigation into the effects of a “toes-off” modified heel raise on lower leg muscle coordination in dancers with and without flexor hallucis longus (FHL) tendinopathy. In addition to the summary below highlighting findings based on our aims, the support from PASIG allowed us to involve multiple DPT students in the research, each asking unique questions and using data gathered in our comprehensive participant screening to answer these questions. Many of these projects are still on-going, but already have resulted in conference and meeting abstract presentations. Finally, connections made through these grant activities led to our Division hosting a 2018 Regional Meeting for the International Association for Dance Medicine and Science in conjunction with a continuing education course. This provided our 90+ dance researcher and practitioner attendees from throughout the Southwest US the opportunity to learn, present, and network with representatives from PASIG, IADMS, our Division, and other groups including the Dance/USA Task Force on Dancer Health. In addition to the interesting and impactful findings from our research work, support from this PASIG grant has allowed us to build and develop our dance research program and network.

Recruitment

At the Annual Report, we shared that a power analysis from our first five participants in each group led to a sample size estimate of 11 per group. We fell short of reaching that goal in one group since it was difficult to find dancers with solely FHL tendinopathy. While we recruited and screened 14 with posterior ankle pain, 5 of these were found to have had either no FHL involvement or the addition of Achilles involvement after PT screening. Therefore, we report findings from 9 dancers with FHL tendinopathy (Figure 1). In our manuscript we will recommend strategies for recruitment and for dealing with dancers with multiple sources of symptoms at the ankle.

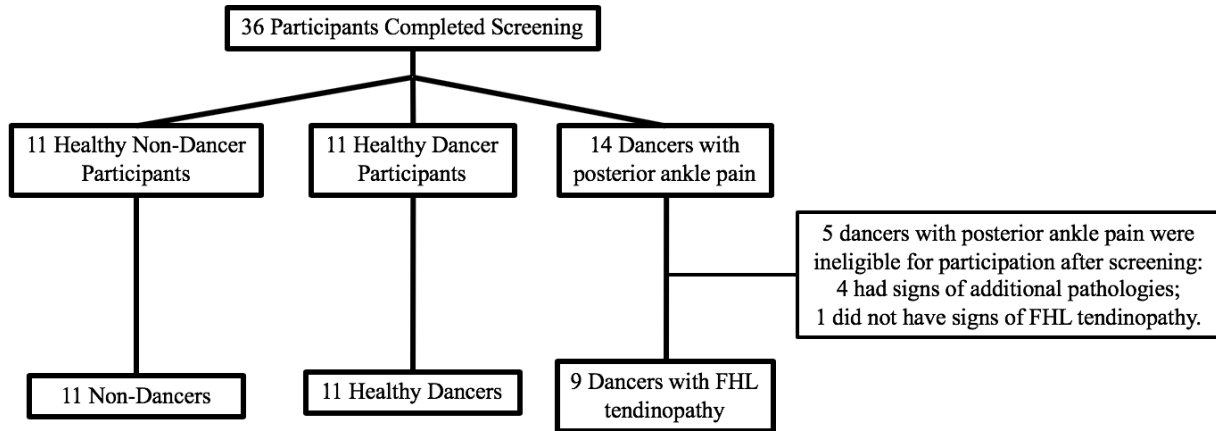


Figure 1. Recruitment consort diagram.

	Healthy Non-Dancers	Healthy Dancers	Dancers with FHL tendinopathy	ANOVA
Medial Longitudinal Arch Flexibility (%)	35.0 ± 12.3	37.0 ± 13.4	28.8 ± 13.8	F=1.0, p=0.379
Passive MTP Flexion ROM (deg)	52.8 ± 8.8	54.7 ± 10.2	55.7 ± 7.13	F=0.3, p=0.750
Passive MTP Extension ROM (deg)	36.7 ± 9.6	43.8 ± 14.1*	29.9 ± 9.3*	F=3.7, p=0.037
Functional MTP Extension ROM (deg)	52.7 ± 9.8	61.4 ± 8.2	57.8 ± 9.5	F=2.9, p=0.072
Single-Limb Balance Eyes-Open (s, 30s max)	29.1 ± 2.8	30.0 ± 0.0	30.0 ± 0.0	F=0.9, p=0.417
Single-Limb Balance Eyes-Closed (s, 30s max)	14.8 ± 12.4*	24.5 ± 9.7	27.4 ± 7.7*	F=4.3, p=0.024
Single-Limb Balance Relevé (s, 30s max)	5.4 ± 3.3	7.5 ± 3.7	18.0 ± 12.1*	F=8.7, p=0.001

*Groups significantly different a p<0.05 level.

Table 1. Data from participant characterization.

Comparing relevé performance between groups – healthy non-dancers, healthy dancers, and dancers with FHL tendinopathy

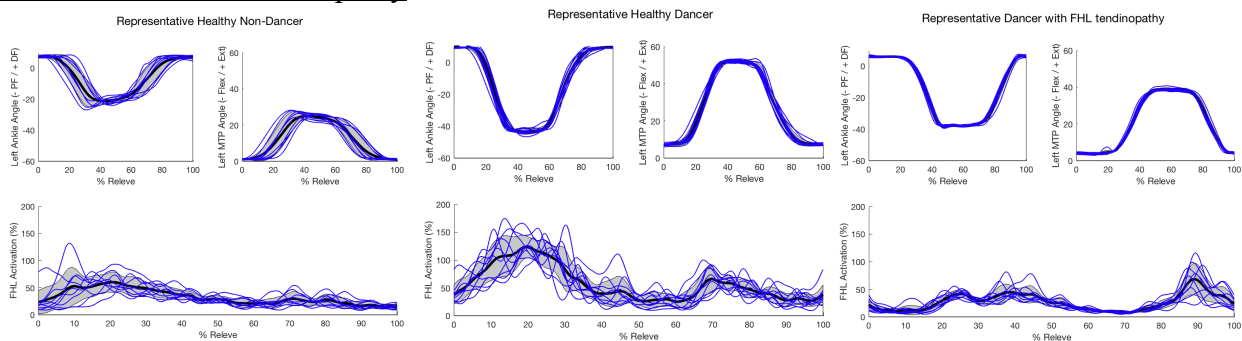


Figure 2. Traditional (“toes-on”) unilateral heel raises for a representative healthy non-dancer (left), healthy dancer (middle), and dancer with FHL tendinopathy (right). Within each figure, ankle angle (top left), MTP angle (top right), and FHL activation level as a percent of the traditional, bilateral condition (bottom). Each plot shows 8-10 heel raise repetitions in blue with a between-trials, within-subject mean and standard deviation in black and grey, respectively.

Kinematics

The group of healthy non-dancers completed these traditional relevés with statistically significantly less ankle plantarflexion excursion ($F=3.553$, $p=0.043$). There was no difference in ankle plantarflexion excursion between the healthy dancers and dancers with FHL tendinopathy, and there were no differences in MTP excursion between any group. Notably, the healthy non-dancers performed relevé repetition with much more inter-repetition variability as can be easily observed in the representative figures here (Figure 2), and as would be expected given the high volume of specific motor skill practice in the dancer groups.

Muscle Activation

A main effect of group was tested in one-way ANOVAs for each muscle instrumented using the muscle activation level during traditional (“toes-on”), unilateral heel raises. Data are summarized Figure 3. No muscles exhibited a significant effect of group. Only the soleus trended toward significance ($F=2.942$, $p=0.069$, effect size=0.147) where the healthy non-dancers utilized greater soleus activation.

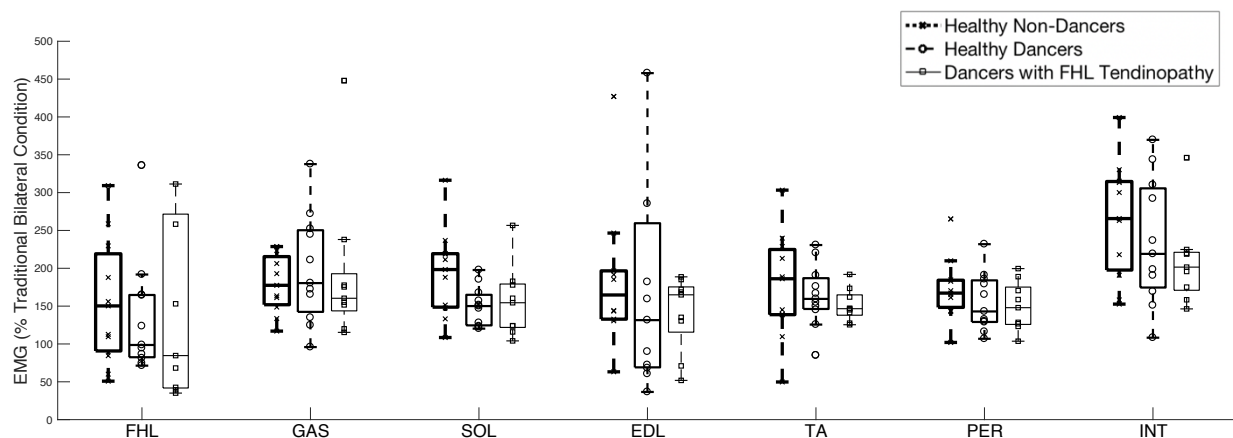


Figure 3. EMG activation level for flexor hallucis longus (FHL), gastrocnemius (GAS), soleus (SOL), extensor digitorum longus (EDL), tibialis anterior (TA), peroneus (PER), and intrinsic foot muscles (INT) during traditional (“toes-on”) unilateral heel raises. Activation level shown as a percent of the traditional, bilateral condition. (One outlier for FHL and one outlier for EDL not shown to preserve axis scale and visibility.)

Effect of modified “toes-off” heel raise on relevé performance

Kinematics

The significant difference in ankle plantarflexion excursion for the healthy non-dancer group was maintained in the modified (“toes-off”) heel raises ($F=3.484$, $p=0.045$). There were no differences in ankle excursion between the traditional and modified heel raises ($F=2.338$, $p=0.138$). As with the traditional heel raises, there were no differences between groups in MTP excursion ($F=1.057$, $p=0.361$). There were, however, significant differences in MTP excursion between conditions ($F=9.705$, $p=0.004$). The MTP joint was significantly more flexed in the “toes-off” condition, when the toes could “fall” off the edge of the support surface.

Muscle Coordination

Contrary to our hypothesis, there were no significant interaction effects or main effects of group or condition for the majority of muscles instrumented including the primary targets – FHL,

gastrocnemius, and soleus (Figure 4). Notably, there was wide between-subject variation in the response to the “toes-off” condition, especially in the dancers with FHL tendinopathy. This observation fits with findings from one of our analyses of the dance leaps where some of the dancers with FHL tendinopathy increased load on their MTP joint (“overuse”) and others decreased load on their MTP joint (“avoidance”). We plan to investigate the potential for subgroups during this task as well and will explore explanations and predictors for why some participants greatly increased FHL activation with the “toes-off” maneuver (some up to 5-6x) and others decreased FHL activation. This was in contrast to the majority of the healthy dancers who decreased FHL activation with the “toes-off” maneuver.

The only muscle that did show a significant main effect of condition was the surface electrode placed over the medial longitudinal arch capturing intrinsic foot muscle activation ($F=45.532$, $p<0.001$). This intrinsic foot muscle activation decreased in the “toes-off” heel raise in all groups, most drastically in the dancers with FHL tendinopathy (Figure 5).

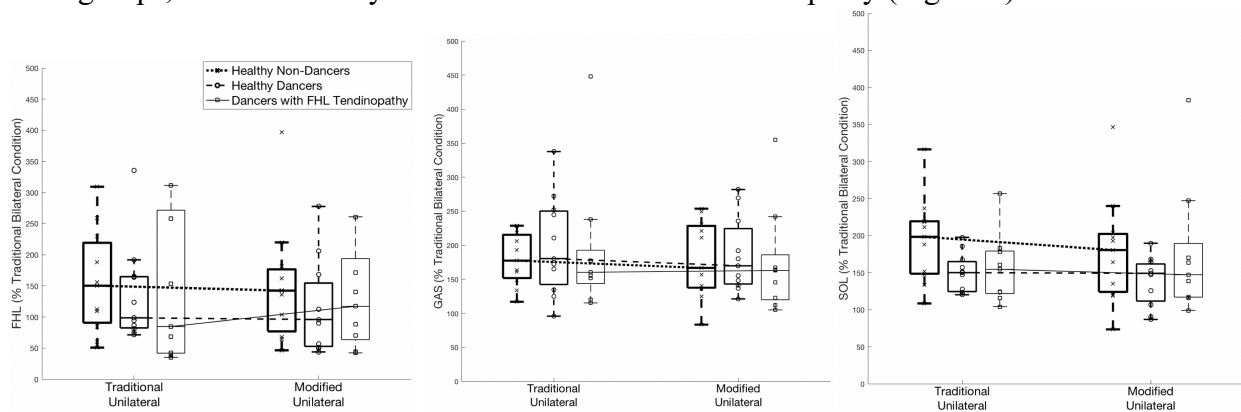


Figure 4. EMG activation level for flexor hallucis longus (FHL) (left), gastrocnemius (GAS) (middle), and soleus (SOL) (right) during traditional (“toes-on”) unilateral heel raises and modified (“toes-off”) unilateral heel raises. Activation level shown as a percent of the traditional, bilateral condition. (Three outliers from two different subjects for FHL not shown to preserve axis scale and visibility.)

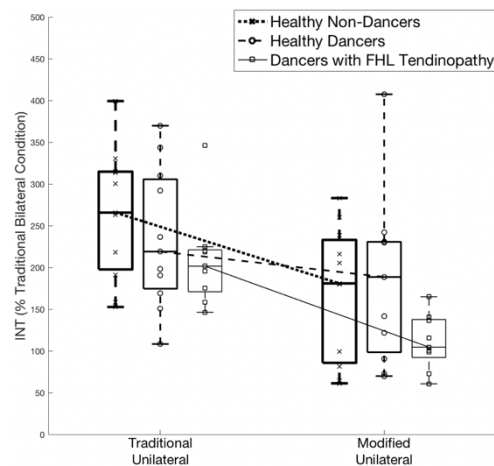


Figure 5. EMG activation level for intrinsic foot muscles (INT) during traditional (“toes-on”) unilateral heel raises and modified (“toes-off”) unilateral heel raises. Activation level shown as a percent of the traditional, bilateral condition.

In summary, notable differences about the performance of heel raises in the non-dancer group were observed. The modified heel raises exhibited the largest effects on MTP motion – allowing more flexed MTP joints during the heel raises – and on intrinsic foot musculature – decreasing activation. No differences between healthy dancers and dancers with FHL tendinopathy were observed except for the greater between-subject variability in the patient

group for most muscle activation measures. Strategies to investigate these patients in subgroups and as individuals will be pursued in further data analysis and manuscript preparation.

Additional on-going projects

- Effects of FHL tendinopathy on mechanics and muscle coordination of dance jumps (sautés)
- Effects of FHL tendinopathy on mechanics and muscle coordination of dance leaps (saut de chats)
- Effect of FHL tendinopathy on macro- and micro-morphology of FHL tendon and tendon sheath
 - Ultrasound imaging collected as part of this grant protocol
 - Magnetic resonance imaging with the support of an in-house Radiology pilot grant
- Characterizing longitudinal foot arch flexibility in dancers and non-dancers

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2. Provide a one-paragraph summary of results or abstract suitable for posting on the Academy website.

Healthy non-dancers, healthy dancers, and dancers with FHL tendinopathy performed repetitive relevés (heel raises) in two conditions – traditional and modified with toes off the edge of the support surface. During the traditional heel raises, notable differences in the non-dancer group were observed including greater between-repetition variability and less ankle plantarflexion - excursion. The largest effects of modifying the heel raises were on MTP excursion – allowing more flexed MTP joints during the modified heel raises – and on intrinsic foot musculature – decreasing muscle activation levels from traditional to modified heel raises. No differences between healthy dancers and dancers with FHL tendinopathy were observed except for greater between-subject variability in the patient group for most muscle activation measures. Strategies to investigate these patients in subgroups and as individuals will be pursued in future investigations and analyses.

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3. Attach a list of your publications published or accepted during the past year, or currently being written. Send reprints when available. List presentations made and abstracts accepted for presentation based on this work. Indicate with an asterisk (*) those publications supported by Academy of Orthopaedic Physical Therapy funding.

Manuscripts are in preparation:

*Rowley KM, Shih HJS, Trejo L, Yamaguchi A, Traina K, Winder B, Mikkelsen P, and Kulig K. Effects of a “toes-off” modified heel raise on lower leg muscle coordination in non-dancers, dancers, and dancers with flexor hallucis longus tendinopathy. *Journal of Orthopaedic and Sport Physical Therapy*. In preparation.

Abstract Presentations, upcoming:

*Andersen A, Rowley KM, Shih HJS, Kulig K. (2019) Flexor Hallucis Longus Tendon Morphology in Dancers with and without Tendinopathy. *American Physical Therapy Association Combined Sections Meeting*. Washington, D.C., USA. Platform Presentation.

*Yu B, Rowley KM, Andersen A, Shih HJS, Kulig, K. (2019) Comparing Imaging Methods in Flexor Hallucis Longus Tendinopathy. *American Physical Therapy Association Combined Sections Meeting*. Washington, D.C., USA. Poster.

*Shih HJS, Trejo L, Rowley KM, and Kulig K. (2018) Mechanism of metatarsophalangeal joint overload in dancers with flexor hallucis longus tendinopathy. *International Association for Dance Medicine and Science*, Helsinki, Finland. Podium.

Abstract Presentations, completed:

*Trejo L, Shih HJS, Rowley KM, Kulig K. (2018) Dancers with unilateral FHL tendinopathy show signs of overuse during the propulsive phase of sautés. *8th World Congress of Biomechanics*, Dublin, Ireland. Podium.

*Rowley KM, Shih HJS, Sutton-Traina K, and Kulig K (2017) Lower-limb muscle contributions to relevé in dancers with and without flexor hallucis longus tendinopathy and the effects of unloading the toes. *International Association for Dance Medicine and Science*, Houston, TX, USA. Podium.

*Shih HJS, Trejo L, Rowley KM, Jarvis DN, Kulig K. (2017) Investigating potential mechanisms of overuse during dance leaps in a dancer with flexor hallucis longus tendinopathy. *International Society of Biomechanics*. Brisbane, Australia. Poster.

*Shih HJS, Rowley KM, and Kulig K. (2017) Flexor Hallucis Longus Activation in a Dancer's Modified Heel Raise – Preliminary Results. *American Physical Therapy Association Combined Sections Meeting*, San Antonio, TX, USA. Poster.

*Backiev L, Rowley KM, Shih HJS, and Kulig K. (2017) An initial investigation into a clinically feasible measure of medial longitudinal arch flexibility. *American Physical Therapy Association Combined Sections Meeting*, San Antonio, TX, USA. Poster.



Budget:


4. Provide a budget, using the original approved budget. Indicate total funds spent to date per major categories. If there was > 25% deviation (greater or less spent) of use of funds for any of the budget category, please BRIEFLY indicate the rationale.

	Budgeted	Spent	Final
Supplies	3623.00	4397.43	-774.43
Personnel	4675.00	3070.53	+1604.47
Other	5700.00	6002.27	-602.27
	13998.00	13470.23	+527.77

- All deviations beyond 25% of budgeted amount were pre-approved by Daniel White and Tara Fredrickson.
- Approval was requested and received to keep the \$527.77 remaining funds for motion capture and EMG system maintenance.

5. Budget: please send out a final print-out from your institution indicating monies spent per major categories.

Print-out attached. Note that the account was set up for a \$15,000 total, but we were only awarded \$13,998 based on our projected budget. Therefore, the spent total is correct, but the remaining funds value will be off by \$1,002.

 Your Signature	<i>24 Sept. 2018</i> Date
Return to: Tara Fredrickson, Executive Associate Academy of Orthopaedic Physical Therapy, APTA, Inc. 2920 East Avenue South, Suite 200 LaCrosse, WI 54601-7202 tfred@orthopt.org	