Athletics meets aesthetics: injury mechanisms and treatment in dance and sport

University of Southern California
Jacquelin Perry Musculoskeletal Biomechanics Research Lab

Combined Sections Meeting 2018
New Orleans, LA, February 21 – 24

2

Athletics meets aesthetics: injury mechanisms and treatment in dance and sport

K. Michael Rowley
on the FHL tendinopathy

H-J Steffi Shih
on Anterior Knee Pain

Pamela Mikkelsen
on Hip Pain

Brooke Winder
on Pelvic Pain

3

COURSE OBJECTIVES

1. Discuss the biomechanical demands with performance of typical dance technique and how these differ from sports athletes
2. Discuss the pathomechanics that contribute to common pathologies seen in dancers in the ankle, knee, hip, and lumbopelvic region and compare these to injury mechanisms typically seen in sports athletes.
3. Discuss the clinical evaluation for these common pathologies and how assessment will differ between dancers and sports athletes
4. Discuss treatment approaches to address these biomechanical demands while addressing the intrinsic aesthetic demands in dance.

Athletics Meets Aesthetics: Foot and Ankle

K. Michael Rowley

Jacquelin Perry Musculoskeletal Biomechanics Research Lab
Division of Biokinesiology and Physical Therapy
University of Southern California, Los Angeles, CA, USA

5

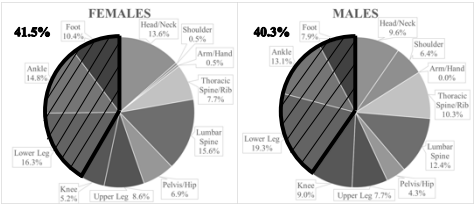
Disclosures

- This speaker has no disclosures to report

6

Introduction

- A 52-member elite ballet company was followed for one year[1]
  - 355 injuries were recorded at a rate of 4.4 injuries per 1000 hours and 6.8 injuries per dancer



(1) Allen et. al., *JOSPT*, 2012

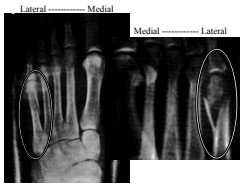
Dancer-Named Injuries

7

"Dancer's Tendinitis"

A tenosynovitis of the flexor hallucis longus (FHL)

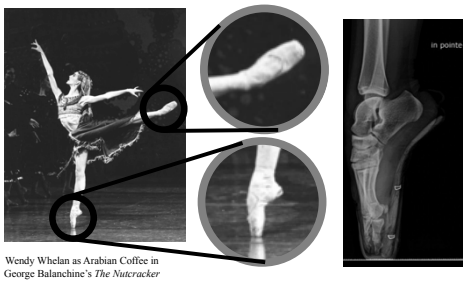
"Dancer's Fracture"



O'Malley et. al., *Am J Sports Medicine*, 1996 (right)

"The Line"

8



Wendy Whelan as Arabian Coffee in George Balanchine's *The Nutcracker*

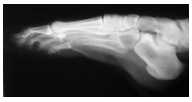
Musculoskeletal Key (right)

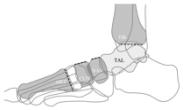
Biomechanics

9

Where does the *pointe* come from? In the sagittal plane…

In seven female ballet dancers…





Bone Pair	Degrees of Motion (mean ± SD)	% Total PF (mean)
Tibia – Talus	57.6° ± 5.2	72.3%
Talus – Navicular	8.6° ± 2.5	10.8%
Navicular - Cuneiform	8.2° ± 3.1	10.2%
Cuneiform - Metatarsal	5.4° ± 4.1	6.7%
Tibia – Metatarsal	79.7° ± 6.4	100%

Russell et. al., *Foot & Ankle Int*, 2011
Selina Shah, Dance & Sport Medicine (top left)

Biomechanics

10

Where does the *pointe* come from? In the frontal plane…

"Winging" Neutral "Sickling"

Dance Teacher Magazine

Footwear

11

Compare to shod sports, where midfoot is constrained…

Selina Shah, Dance & Sport Medicine
Nike, Inc. Weissman, Inc.

Metatarsophalangeal Joints

12

First MTP Joint Flexibility

Functional Extension

Functional Balance

Modified Heel Raises

In 25 dancers and 25 non-dancers…

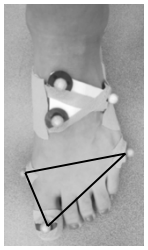
- Dancers had 10.8° more functional extension ($p<0.001$)
- Dancers could balance in *demi-pointe* 5.5 s longer ($p=0.013$)
- Dancers could do 6.6 fewer modified relevés ($p=0.001$)

Rowley, Jarvis, Kurihara, Chang, Fietzer, and Kulig, *Med Problems Performing Artists*, 2015

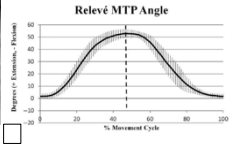
Metatarsophalangeal Joints

13

Multisegmental Foot



Greatest Range of Motion: Relevé

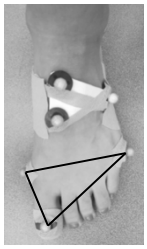


Jarvis and Kulig, *J Sports Sci*, 2016

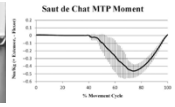
Metatarsophalangeal Joints

14

Multisegmental Foot



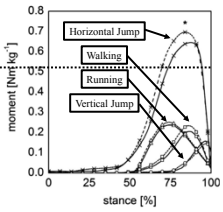
Greatest Net Joint Moment: Saut du chat



Jarvis and Kulig, *J Sports Sci*, 2016

Do the toe flexors contribute to athletic performance?

15



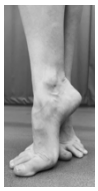
FHL Tendinopathy also seen in sprinters.

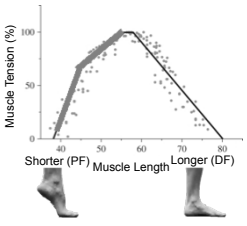
Authors highlight movements with a forward lean and forward propulsion.

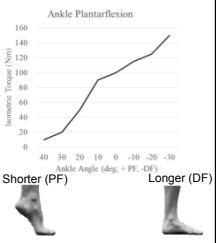
Goldmann et. al., *J Sports Sci*, 2013
Digital Track and Field

Muscle Length-Tension

16



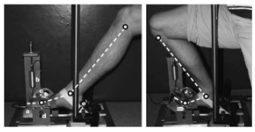


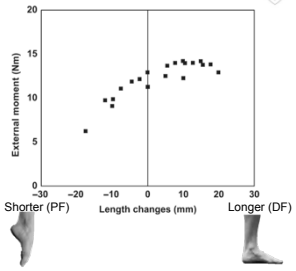


Lieber and Ward, *Philos Trans R Soc Lond B Biol Sci*, 2011 (center)
Anderson, et. al., *J Biomech*, 2007 (right)

Muscle Length-Tension

17

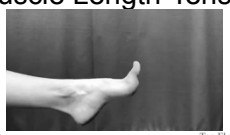


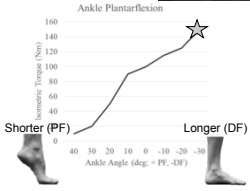


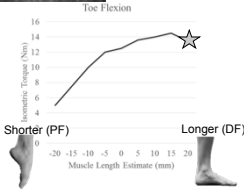
Goldmann and Brüggemann, *J Anat*, 2012

Muscle Length-Tension

18







Anderson et. al., *J Biomech*, 2007; Goldmann and Brüggemann, *J Anat*, 2012

Control in Weight-Bearing

19

FHL has been called the "dancer's Achilles"

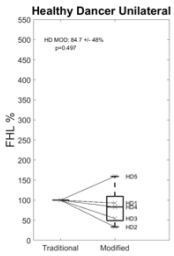
Using eight cadaveric lower legs in weight-bearing relevé…

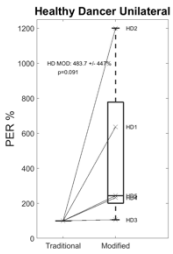
- **FHL tension** stabilized the arch, but inverted the foot
- **Peroneus + FHL tension** stabilized the foot and ankle

Femino et. al., *J Dance Medicine & Science*, 2000

Our Research

20





Rowley, Kulig, Shih, Traina, Winder, Mikkelesen, Unpublished Data

Evaluation

21

Contributors to posterior ankle pain

- Posterior ankle impingement
- Retrocalcaneal bursitis
- FHL tendinopathy, tendinitis, tenosynovitis
- Achilles tendinopathy, tendinitis, tendinosis
- Os trigonum (symptomatic or not)
- Avulsion fracture

Musculoskeletal Key (left)

Importance of Palpation and Strength Testing

22

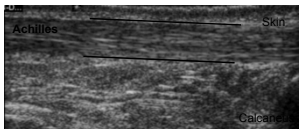
Achilles Palpation

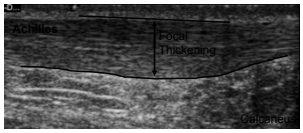
FHL Palpation

Break Test - Strength? Pain?

What can ultrasound show us?

23

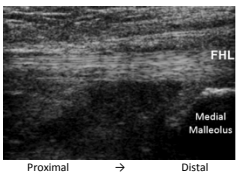




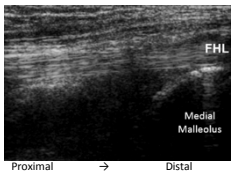
What can ultrasound show us?

24

Affected Side



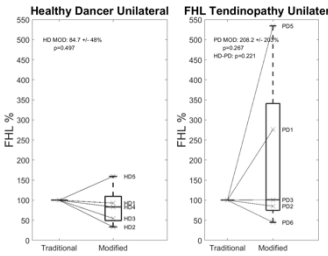
Unaffected Side



Rowley, Kulig, Shih, Traina, Winder, Mikkelesen, Unpublished Data

Our Research

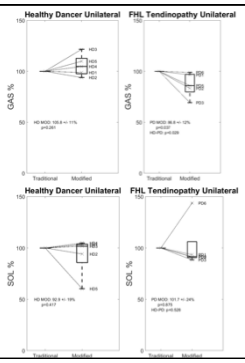
25



Subj	FHL
HD01	↓
HD02	↓
HD03	↓
HD04	↓
HD05	↑
PD01	↑
PD02	↓
PD03	~
PD05	↑
PD06	↓

Rowley, Kulig, Shih, Traina, Winder, Mikkelesen, Unpublished Data

26



Subj	FHL	GAS	SOL
HD01	↓	~	↑
HD02	↓	↓	↓
HD03	↓	↑	↑
HD04	↓	↑	↑
HD05	↑	↑	↓
PD01	↑	↓	↓
PD02	↓	↓	↓
PD03	~	↓	↓
PD05	↑	↓	↓
PD06	↓	↓	↑

Rowley, Kulig, Shih, Traina, Winder, Mikkelesen, Unpublished Data

Summary

27

Traditional Eval +

- Palpation of FHL @ sustentaculum tali
- Toe curl break test
- Assessment in relevant ranges of motion
- Midfoot and talocural mobility
- Ultrasound – thickening? sliding?
- Test "toes-off" – increase FHL? decrease gastrocsoleus?
- Test balance in relevant ranges of motion and challenging conditions
- Use "Human EMG"

Musculoskeletal Key (left)

Treatment

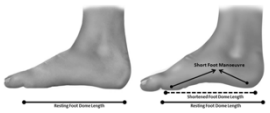
28

- Appropriate range of motion from each joint
  - Don't forget midfoot contributes ~23% of pointe
- Work in relevant ranges of motion
- Modified heel raises as potentially preventative
  - Limitations to their use as treatment for FHL tendinopathy
- Compare to other muscle coordination altering cues and exercises
- Challenge frontal and transverse plane stability as well
- "Optimization of motion"

"Add to your arsenal…"

29

Exercise for shifting control to deep muscles



Exercise for shifting control to intrinsic muscles

Exercise for shifting control to superficial muscles

Albisetti et. al., *Ankle Pain*, 2009 (top, left)
Rowley et. al., *Med Problems Performing Artists*, 2015 (right)
McKeon et. al., *Br J Sports Med*, 2014 (bottom, left)

REFERENCES

30

- Allen N, Nevill A, Brooks J, Koutedakis Y, Wyon M. Ballet Injuries: Injury Incidence and Severity Over 1 Year. J Orthop Sport Phys Ther. 2012;42(9):781-A1. doi:10.2519/jospt.2012.3893.
- O'Malley MJ, Hamilton WG, Munyak J. Fractures of the Distal Shaft of the Fifth Metatarsal. Am J Sports Med. 1996;24(2):240-243. doi:10.1177/036354659602400223.
- Russell JA, Shave RM, Kruse DW, Koutedakis Y, Wyon MA. Ankle and Foot Contributions to Extreme Plantar- and Dorsiflexion in Female Ballet Dancers. Foot Ankle Int. 2011;32(2):183-188. doi:10.3113/FAI.2011.0183.
- Rowley KM, Jarvis DN, Kurihara T, Chang Y, Fietzer AL, Kulig K. Toe Flexor Strength, Flexibility and Function and Flexor Hallucis Longus Tendon Morphology in Dancers and Non-Dancers. Med Probl Perform Art. 2015;30(3): 152-156.
- Jarvis DN, Kulig K. Kinematic and kinetic analyses of the toes in dance movements. J Sports Sci. 2016;34(17): 1612-1618. doi:10.1080/02640414.2015.1126672.
- Goldmann JP, Brüggemann GP. The potential of human toe flexor muscles to produce force. J Anat. 2012;221(2): 187-194. doi:10.1111/j.1469-7580.2012.01524.x.
- Anderson DE, Madigan ML, Nussbaum M a. Maximum voluntary joint torque as a function of joint angle and angular velocity: model development and application to the lower limb. J Biomech. 2007;40(14):3105-3113. doi: 10.1016/j.jbiomech.2007.03.022.

31

REFERENCES

- Lieber RL, Ward SR. Skeletal muscle design to meet functional demands. Philos Trans R Soc Lond B Biol Sci. 2011;366(1570):1466-1476. doi:10.1098/rstb.2010.0316.
- Goldmann JP, Sanno M, Willwacher S, Heinrich K, Brüggemann GP. The potential of toe flexor muscles to enhance performance. J Sports Sci. 2013;31(4):424-433. doi:10.1080/02640414.2012.736627.
- Femino JE, Trepman E, Chisholm K, Razzano L. The role of the Flexor Hallucis Longus and Peroneus Longus in the stabilization of the ballet foot. J Danc Med Sci. 2000;4(3):86-89.
- Albisetti W, Ometti M, Pascale V, De Bartolomeo O. Clinical evaluation and treatment of posterior impingement in dancers. Am J Phys Med Rehabil. 2009;88(5):349-354. doi:10.1097/PHM.0b013e31817fa31d.
- McKeon PO, Hertel J, Bramble D, Davis I. The foot core system: a new paradigm for understanding intrinsic foot muscle function. Br J Sports Med. 2015;49:290-299. doi:10.1136/bjsports-2013-092690.

32

Aesthetics meets athletics: Knee

Speaker: Hai-Jung (Steffi) Shih
APTA Combined Section Meeting
Feb 24th, 2018

33

Disclosures

- This speaker has no disclosures to report

34

Demands on the knees: athletes vs dancer

https://www.youtube.com/watch?v=FMtUqoxfR50

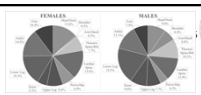
https://www.youtube.com/watch?v=JQCDSKsVQLg

35

Common knee injuries

- Overuse
  - Patellofemoral pain
  - Patellar tendinopathy
  - Iliotibial band syndrome
  - Infrapatella bursitis
  - Fat pad impingement
- Traumatic
  - ACL/PCL tears
  - MCL/LCL tears
  - Meniscal tears
  - Cartilage defects

Prevalence



- Knee injuries account for up to 6-36% of injuries in dancers[1]

	Dancers	Athletes
Patellofemoral pain	29%[2]	25%[3]
Patellar tendinopathy	42%[4]	14.2% general athletes (30-50% jumping athletes)[5]
ACL injury	0.2-0.4%[6]	1-8%[6]

1. Smith et al, *Orthop J Sports Med*, 2015
2. Winslow & Yoder, JOSPT , 1995
3. Cutbill et al, *Clin J Sport Med*, 1997
4. Kulig et al, *Med Probl Perform Arts*, 2014
5. Lian et al, *Am J Sports Med*, 2005
6. Liederbach, *Am J Sports Med*, 2008

37

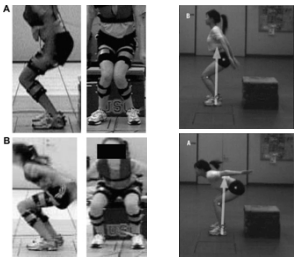
Pathomechanics – dynamic valgus

- Associated with traumatic and overuse knee injuries[1]
- Hip[1,2]
  - Adduction
  - Internal rotation
- Knee[1,3]
  - Abduction
- Foot[3]
  - Pronation

1. Powers, JOSPT, 2010
2. Nakagawa et al, Int J Sports Med, 2013
3. Joseph, Am J Sports Med, 2008

38

Pathomechanics – sagittal plane



1. Pollard, *Clin Biomech*, 2010
2. Powers, JOSPT, 2010
3. Blackburn and Padua, *J Athl Train*, 2009

39

Pathomechanics – pelvic drop / trunk lean

Pelvic drop & trunk lean away from stance leg
↑ knee varus moment

Desired

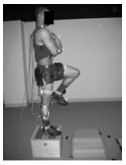
Pelvic drop & trunk lean towards stance leg
↑ knee valgus moment

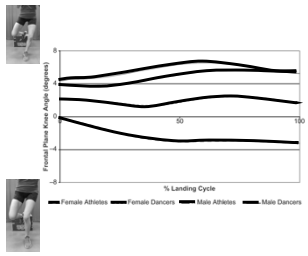
1. Powers, JOSPT, 2010

Here is some good news…

40

Dancers vs. athletes in landing knee angle



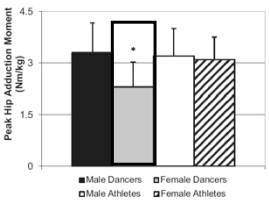


1. Orishimo, Am J Sports Med, 2014

Here is some good news…

41

Dancers vs. athletes in landing hip moment

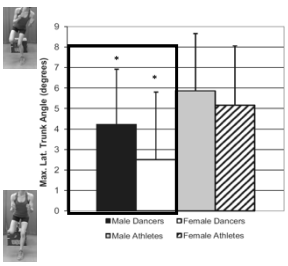


1. Orishimo, Am J Sports Med, 2014

Here is some good news…

42

Dancers vs. athletes in trunk lean



1. Orishimo, Am J Sports Med, 2014

Here is the bad news…

43

Aesthetic requirements in dance

- 5 jumps / min * 2 hours = 600 jumps/ performance

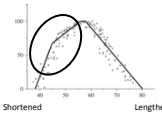
1. Wyon et al, Int J Sports Med, 2011

Here is the bad news…

44

Gluteus muscles: Mechanical disadvantage

- Gluteus maximus: prevents dynamic valgus
  - Extension
  - External rotation
  - Abduction (upper fibers)
- Mechanical disadvantage (length tension relationship)

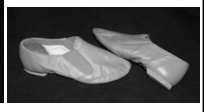


Here is the bad news…

45

Dance footwear lack arch support

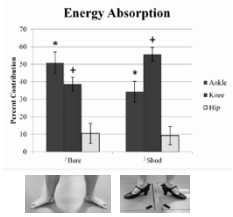
- Pronation of the foot is linked to knee dynamic valgus
- Barefoot dancing
- Ballet, jazz, modern, and character shoes usually emphasize flexibility over support

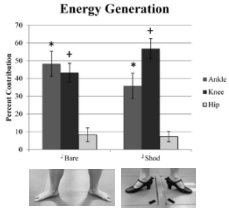


Here is the bad news…

46

Character shoes: Shifts demands to the knee





1. Mikkelsen et al, unpublished data

Evaluation – Identify knee valgus in turn out plane ("Hiption")

47

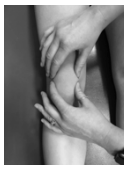
Front

Side

"Hiption plane"

Evaluation – The basics

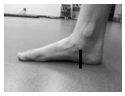
48



Patellar (hyper)mobility

Hip range of motion: tibial external rotation compensates for turn out

Flexibility

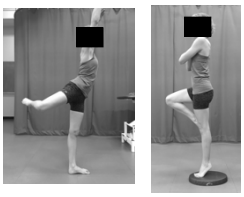


Arch height

1. Nowacki et al, J Dance Med Sci, 2013

Evaluation – Functional tasks

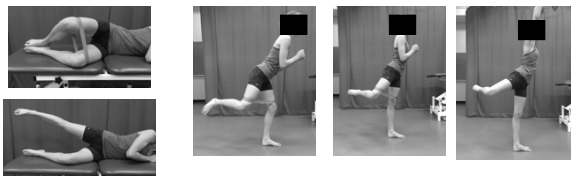
49



https://www.youtube.com/watch?v=ovc4D5pamco

Treatment – Gluteal muscles

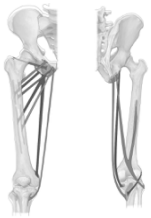
- Glute & deep hip external rotators activation
- Human EMG: making sure feeling it at the right place



Treatment – Adductors and hamstrings

51

- Adductors have mechanical advantage to act as extensors in turned out position
- Using adductors and hamstrings to share quadriceps load during plies…
  - Caviat: over-relying on hamstrings vs. gluteal
  - Dosen't work as well in single leg activities
- Imagery
  - Imagine squeezing your legs together like a jelly fish when coming up from a plie

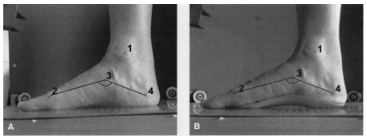


Anterior view Posterior view

Treatment - Foot orthosis

52

- Custom made orthosis worn during the day (not during dance)
  - Decreased pain by 1.9/10 (a variety of symptoms including PFPS)
  - Improvement in ability to dance without symptoms by 4.6/10
- Unloading the tissue throughout the day helps!



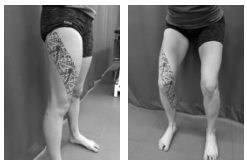
1. Nowacki et al, J Dance Med Sci, 2013

Treatment – Taping

53

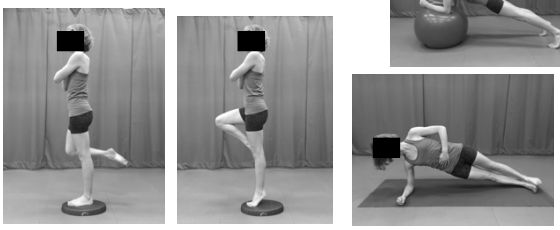
Knee/patellar taping

Arch support



Hip external rotation cue

Treatment – Proprioception and stability



On different surface / remove vision

Treatment – Return to dance

55

- Dance-specific exercise training
- Endurance[1]

1. Koutedakis et al, Sports Med, 2004

Treatment – Education for self-management

56

- Allow rest and load share during the day
- When to cold pack / hot pack
- Self-taping before classes

Take home message

57

- Anterior knee pain and other knee injuries have common pathomechanics
- In non-dance specific activities, dancers may be protected from these pathomechanical patterns
- However, when considering the aesthetic requirements of dance, there may be some disadvantages in lower extremity alignment that predispose dancers to overuse knee injuries
- We need to evaluate and treat dancers in dance-specific positions and activities

Questions & Discussions

58

REFERENCES

59

- Smith PJ, Gerrie BJ, Varner KE, McCulloch PC, Lintner DM, Harris JD. Incidence and Prevalence of Musculoskeletal Injury in Ballet: A Systematic Review. Orthop J Sport Med. 2015;3(7):31-34. doi:10.1177/2325967115592621.
- Winslow J, Yoder E. Patellofemoral Pain in Female Ballet Dancers: Correlation With Iliotibial Band Tightness and Tibial External Rotation. J Orthop Sport Phys Ther. 1995;22(1):18-21. doi:10.2519/jospt.1995.22.1.18.
- Cutbill JW, Ladly KO, Bray RC, Thorne P, Verhoef M. Anterior knee pain: a review. Clin J Sport Med. 1997;7(1):40-45.
- Kulig K, Oki KC, Chang Y-J, Bashford GR. Achilles and patellar tendon morphology in dancers with and without tendon pain. Med Probl Perform Art. 2014;29(4):221-228.
- Lian OB, Engebretsen L, Bahr R. Prevalence of jumper's knee among elite athletes from different sports: a cross-sectional study. Am J Sports Med. 2005;33(4):561-567. doi:10.1177/0363546504270454.
- Liederbach M, Dilgen FE, Rose DJ. Incidence of anterior cruciate ligament injuries among elite ballet and modern dancers: A 5-year prospective study. Am J Sports Med. 2008;36(9):1779-1788. doi:10.1177/0363546508323644.
- Powers CM. The Influence of Abnormal Hip Mechanics on Knee Injury: A Biomechanical Perspective. J Orthop Sport Phys Ther. 2010;40(2):42-51. doi:10.2519/jospt.2010.3337.
- Nakagawa TH, Serrão F V, Maciel CD, Powers CM. Hip and knee kinematics are associated with pain and self-reported functional status in males and females with patellofemoral pain. Int J Sports Med. 2013;34(11):997-1002. doi:10.1055/s-0033-1334966.

REFERENCES

60

- Joseph M, Tiberio D, Baird JL, et al. Knee valgus during drop jumps in National Collegiate Athletic Association Division I female athletes: The effect of a medial post. Am J Sports Med. 2008;36(2):285-289. doi: 10.1177/0363546507308362.
- Pollard CD, Sigward SM, Powers CM. Limited hip and knee flexion during landing is associated with increased frontal plane knee motion and moments. Clin Biomech. 2010;25(2):142-146. doi:10.1016/j.clinbiomech. 2009.10.005.
- Blackburn JT, Padua DA. Sagittal-plane trunk position, landing forces, and quadriceps electromyographic activity. J Athl Train. 2009;44(2):174-179. doi:10.4085/1062-6050-44.2.174.
- Orishimo KF, Liederbach M, Kremenic IJ, Hagins M, Pappas E. Comparison of landing biomechanics between male and female dancers and athletes, part 1: Influence of sex on risk of anterior cruciate ligament injury. Am J Sports Med. 2014;42(5):1082-1088. doi:10.1177/0363546514523928.
- Wyon MA, Twitchett E, Angioi M, Clarke F, Metsios G, Koutedakis Y. Time motion and video analysis of classical ballet and contemporary dance performance. Int J Sports Med. 2011;32(11):851-855. doi:10.1055/s-0031-1279718.
- Mikkelsen P, Jarvis, DN, Kulig K. Increased work at the knee in dancers wearing heeled character shoes compared to barefoot while jumping. Poster presented at: APTA combined section meeting, Feb 4-7, 2015; Indianapolis, IN.
- Nowacki RME, Air ME, Rietveld ABM. Use and effectiveness of orthotics in hyperpronated dancers. J Dance Med Sci. 2013;17(1):3-10. doi:10.12678/1O89-313X.17.1.3.

Athletics meets aesthetics:
Hip

Pamela Mikkelsen, PT, DPT, OCS
Jacquelin Perry Musculoskeletal Biomechanics Research Lab
Division of Biokinesiology and Physical Therapy

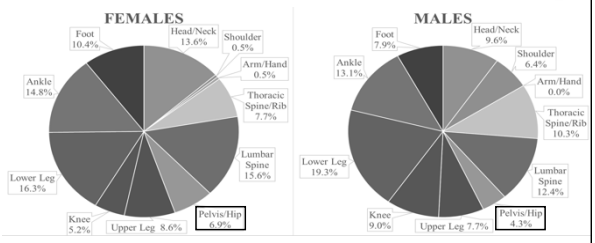
62

Disclosures

- This speaker has no disclosures to report

63

Dance vs sport



Allen et. al., JOSPT, 2012

64

Dance vs sport

- Hip injuries account for
  - 11-17% of dance injuries
  - 4-6% of sports injuries
- More Common with cutting, pivoting, speed changes

	Injuries per 1000 exposure hours	% attributed to overuse
Male hockey players	1.03	17.5
Female hockey players	0.78	18.4
Dancers	0.09	85

Trentacosta, Sports Health, 2017
Lynch, J Am Acad Orthop Surg, 2017
Dalton, Orthop J Sports Medi, 2016

65

Common Hip Injuries

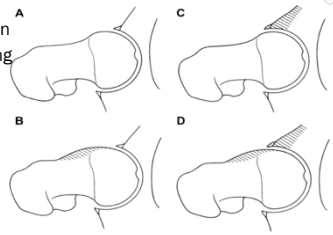
- Femoral acetabular impingement (FAI)
- Labral Tears
- Iliopsoas syndrome
- Snapping hip
- Greater trochanteric –pelvic impingement
- Microinstability
- Glute tendon tear
- Ligamentum teres sprains and tears
- Greater trochanteric bursitis

Sobrino, Orthop J Sports Med2015
Mayes, Clin Rheumatol 2016
Mayes, Skeletal Radiol, 2016

66

FAI

- CAM, Pincer, or combination
- Deformities vary in reporting from 10-71%
- 68% in hockey players

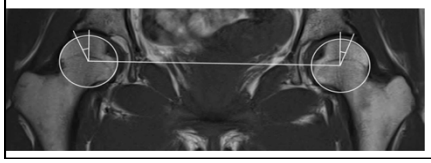


Harris, Am J Sports Med, 2016
Brunner, Am J Sports Med, 2015
Leunig, Osteoarthritis and Cartilage, 2013

FAI in Dancers

67

- Conflicting evidence
  - CAM deformity in Females: 12%; males: 57% of subjects
  - 74.6% of subjects had ≥2 of 6 signs of pincer deformity
  - No difference in LCE angle between ballet vs sporting population
  - One out of 59 female dancers with CAM deformity



Harris, Am J Sports Med 2016
Mayes, Skeletal Radiol, 2016
Kolo, Skeletal Radiol, 2013

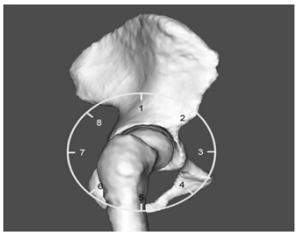
CAM Impingement

68

Labral Lesion Location

69

- Controls: anterosuperior (2) or anterior (3)
- Dance: anterosuperior (2), superior (1), or posterosuperior (8)



Kolo, Skeletal Radiol, 2013
Suarez-Ahedo, Am J Sports Med, 2017
Shibata, Knee Surg Sports Traumatol Arthrosc, 2017

Dance vs Sport

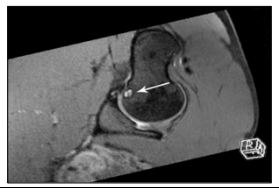
70

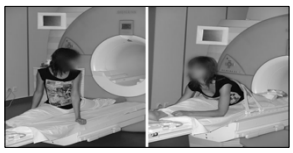
Weber, Sports Health, 2015

Extreme ROM

71

	Dancers	Non-dancers
Cartilage Lesions	55.9%	21.4%
Herniation Pits	52.5%	17.9%
Mean Subluxation distance	2.05 mm	Not Tested



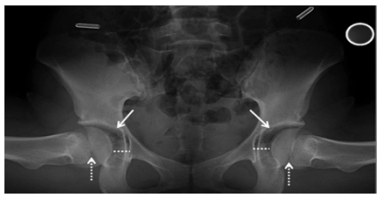


Kolo, Skeletal Radiol, 2013

Extreme ROM

72

- Radiograph of dancer in "center" splits
  - Vacuum sign (solid arrow) shows subluxation
  - Greater trochanteric-pelvic impingement at posterior rim (dotted arrows)



Harris, Am J Sports Med, 2016

Creating impingement?

73

- Not the typical FAI morphological deviations
- Perhaps a mechanical cause of "pincer-like" positioning of the hip = tissue stress
- Abnormalities may be problematic sooner
- Dancers without abnormalities can have injuries with repetitive movements

Kolo, Skeletal Radiol, 2013

Evaluation: DDx

74

- Lumbar referral
- AVN
- Stress fx
- Nerve entrapment
- Pelvic floor dysfunction

Weber, Sports Health, 2015

Evaluation

75

- Hx of DDH, LCP, SCFE
- Pain assessment
  - Where is the pain?
  - When is the pain?
- Hip special tests appropriate?
  - FADIR (anterior hip impingement test)
  - Impingement sign (flexion, IR)
  - FABER
- ROM
  - Beighton Score
  - Popliteal angle?

Figure 1. The 9-point Beighton hypermobility score.

	Right	Left
Ability to		
1. Passively dorsiflex the 5th metacarpophalangeal joint to ≥ 90°	1	1
2. Oppose the thumb to the volar aspect of the ipsilateral forearm	1	1
3. Hyperextend the elbow to ≥ 10°	1	1
4. Hyperextend the knees to ≥ 10°	1	1
5. Place the hands flat on the floor without bending the knees	1	
Maximum total	9	

One point is gained for each side for maneuvers 1 to 4.

Mayes, Clin Rheumatol, 2016
Sanches, Rheumatol Int, 2014
Russek, Clin Rheumatol, 2014

Triple hop for FAI

76

- Medial triple hop and lateral triple hop tests
  - 3 consecutive hops for distance

Kivlan, Int J Sports Phys Ther, 2016

Triple hop for FAI

77

- Medial triple hop and lateral triple hop test
  - Consider quality of the hops

Distance Traveled (cm)	Healthy Dancers	Painful Dancers
Medial hop	410 ± 50	354 ± 43
Lateral Hop	343 ± 54	294 ± 38

Kivlan, Int J Sports Phys Ther, 2016

Treatment considerations in Dance

78

- Extreme ranges of motion (ER, flexion, extension, IR)
- Hypermobility – Joint stability
- Rigid aesthetics

Aesthetics

79

Similarities in treatment

80

- Understand anatomy and mechanics
- Work within abilities of the athlete
- Work within the context of the movement
- Imagery and external focus
  - Internal focus: malleolus points to the ceiling, short foot and gluteal engagement
  - External focus: Stretching like a star, elevating like a balloon
  - Combination: Two legs spiraling out from each other, Jump over a puddle… with pelvic initiation at top of jump

Guss-West, J Dance Med Sci, 2016

Glutes

81

- Sport and dance
  - powerful movement generator
  - Eccentric control and dynamic shock absorber
  - Injury prevention with LE alignment
- Often weak with FAI symptoms
- Cannot maintain turnout in all dance motions
- When should they be working?

Deep Hip External Rotators

82

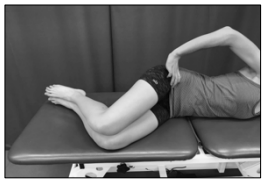
- Rotator cuff of the hip
  - Piriformis, gemelli, quadratus femoris, obturator internus, obturator externus
- Maintain a stable instantaneous center of rotation of the femoral head
- Injury prevention or rehab in sports?

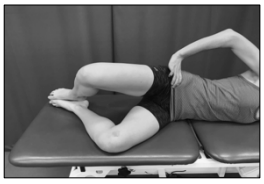
Narveson, J Orthop Sports Phys Ther, 2016

Task: Deep Hip Muscle Activation

83

- Externally rotate without the glutes
  - Sidelying Clam
  - Human EMG

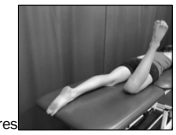




Task: Deep Hip Muscle Activation

84

- Prone hip ER/IR, watch glute and hamstring compensation

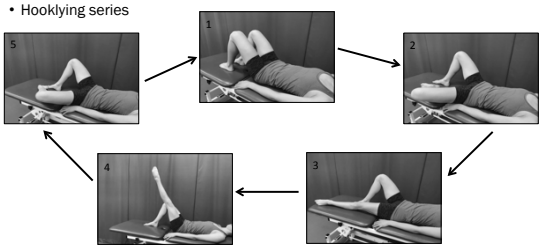


- Add res

Task: Deep Hip Muscle Control

85

- Externally rotate without the glutes
  - Hooklying series



Task: Deep Hip Muscle Strengthening

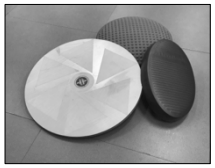
86

- Weightbearing
  - Standing body on leg ER

Task: Dance Specific Hip Control

87

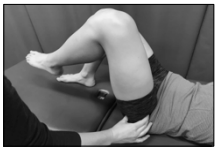
- Control the turnout
  - Plie imagery – feel the bone turn out more and more until you have no other option but to bend the legs
  - Tendu/degaje
  - Unstable surfaces for balance training
  - "Do less work"



Task: "Normalize" hip ROM

88

- Anterior translation of the femur with hip flexion
- Palpate for excessive superficial muscle activation?



Hip Flexion

89

- Smaller iliopsoas with hip pain
- Excessive use of superficial hip flexors (TFL, rectus femoris) anterior translation
- Deep hip flexors (iliopsoas) have a line of pull closer to the joint center

Emery et al, La Trobe University, IADMS Annual Conference 2017

Hip Flexion - Treatment

90

- Manual therapy
- If a dancer is hypermobile, and the muscles are pulling the femur anteriorly, are joint mobs appropriate?

Task: Activation of Deep Hip Flexors

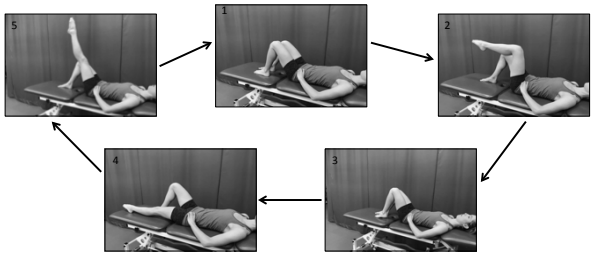
91

- Hooklying marching
  - Feedback with palpation of the anterior hip
  - Cues to feel the "abdominals" pull the leg up
    - Like a marionette but the strings are attached near the joint

Task: Control of hip flexors

92

- Supine developpe series



Final Thoughts

93

- Dancers move through large ranges of motion that can cause pathology despite no morphological issues
- Motor control and efficiency
- Everybody's working!

REFERENCES

94

- Allen, N., Nevill, A., Brooks, J., Koutedakis, Y., & Wyon, M. (2012). Ballet injuries: injury incidence and severity over 1 year. *Journal of Orthopaedic & Sports Physical Therapy*. 42(9), pp.781-A1.
- Trentacosta N, Sugimoto D, Micheli LJ. Hip and Groin Injuries in Dancers: A Systematic Review. *Sports Health: A Multidisciplinary Approach*. 2017;9(5):422-427. doi:10.1177/1941738117724159.
- Lynch TS, Bedi A, Larson CM. Athletic Hip Injuries. *Journal of the American Academy of Orthopaedic Surgeons*. 2017;25(4): 269-279. doi:10.5435/jaaos-d-16-00171.
- Dalton, S. L., Zupon, A. B., Gardner, E. C., Djoko, A., Dompier, T. P., & Kerr, Z. Y. (2016). The Epidemiology of Hip/Groin Injuries in National Collegiate Athletic Association Men's and Women's Ice Hockey: 2009-2010 Through 2014-2015 Academic Years. *Orthopaedic Journal of Sports Medicine*. 4(3).
- Sobrino, F. J., de la Cuadra, C., & Guillén, P. (2015). Overuse injuries in professional ballet: Injury-based differences among ballet disciplines. Orthopaedic Journal of Sports Medicine, 3(6), 2325967115590114.
- Mayes S, Ferris A-R, Smith P, Garnham A, Cook J. Professional ballet dancers have a similar prevalence of articular cartilage defects compared to age- and sex-matched non-dancing athletes. *Clinical Rheumatology*. 2016;35(12):3037-3043. doi:10.1007/s10067-016-3389-4.
- Mayes, S., Ferris, A. R., Smith, P., Garnham, A., & Cook, J. (2016). Atraumatic tears of the ligamentum teres are more frequent in professional ballet dancers than a sporting population. *Skeletal Radiology*, 45(7), 959-967.
- Harris JD, Gerrie BJ, Varner KE, Lintner DM, Mcculloch PC. Radiographic Prevalence of Dysplasia, Cam, and Pincer Deformities in Elite Ballet. *The American Journal of Sports Medicine*. 2015;44(1):20-27. doi:10.1177/0363546515601996.
- Brunner R, Maffiuletti NA, Casartelli NC, et al. Prevalence and Functional Consequences of Femoroacetabular Impingement in Young Male Ice Hockey Players. *The American Journal of Sports Medicine*. 2015;44(1):46-53. doi:10.1177/0363546515607000.
- Leunig M, Jüni P, Werlen S, et al. Prevalence of cam and pincer-type deformities on hip MRI in an asymptomatic young Swiss female population: a cross-sectional study. *Osteoarthritis and Cartilage*. 2013;21(4):544-550. doi:10.1016/j.joca.2013.01.003.

REFERENCES

95

- Kolo FC, Charbonnier C, Pfirrmann CWA, et al. Extreme hip motion in professional ballet dancers: dynamic and morphological evaluation based on magnetic resonance imaging. *Skeletal Radiology*. 2012;42(5):689-698. doi:10.1007/s00256-012-1544-9.
- Suarez-Ahedo C, Gui C, Rabe SM, Chandrasekaran S, Lodhia P, Domb BG. Acetabular Chondral Lesions in Hip Arthroscopy: Relationships Between Grade, Topography, and Demographics. *The American Journal of Sports Medicine*. 2017;45(11):2501-2506. doi:10.1177/0363546517708192.
- Shibata KR, Matsuda S, Safran MR. Is there a distinct pattern to the acetabular labrum and articular cartilage damage in the non-dysplastic hip with instability? Knee Surgery, *Sports Traumatology, Arthroscopy*. 2016;25(1):84-93. doi:10.1007/s00167-016-4342-4.
- Weber AE, Bedi A, Tibor LM, Zaltz I, Larson CM. The Hyperflexible Hip. *Sports Health: A Multidisciplinary Approach*. 2014;7(4): 346-358. doi:10.1177/1941738114532431.
- Sanches SB, Oliveira GM, Osório FL, Crippa JAS, Martín-Santos R. Hypermobility and joint hypermobility syndrome in Brazilian students and teachers of ballet dance. *Rheumatology International*. 2014;35(4):741-747. doi:10.1007/s00296-014-3127-7.
- Russek LN, Errico DM. Prevalence, injury rate and, symptom frequency in generalized joint laxity and joint hypermobility syndrome in a "healthy" college population. *Clinical Rheumatology*. 2015;35(4):1029-1039. doi:10.1007/s10067-015-2951-9.
- Kivlan, B. R., Carcia, C. R., Christoforetti, J. J., & Martin, R. L. (2016). Comparison of Range of Motion, Strength, and Hop Test Performance of dancers with and without a Clinical Diagnosis of Femoroacetabular Impingement. *International Journal of Sports Physical Therapy*. 11(4), 527.
- Guss-West C, Wulf G. Attentional Focus in Classical Ballet: A Survey Of Professional Dancers. *Journal of Dance Medicine & Science*. 2016;20(1):23-29. doi:10.12678/1089-313x.20.1.23.
- Narveson JR, Haberl MD, Grabowski PJ. Management of a Patient With Acute Acetabular Labral Tear and Femoral Acetabular Impingement With Intra-articular Steroid Injection and a Neuromotor Training Program. *Journal of Orthopaedic & Sports Physical Therapy*. 2016;46(11):965-975. doi:10.2519/jospt.2016.6573.

Athletics Meets Aesthetics: Pelvic Floor

Brooke Winder, PT, DPT, OCS
Jaquelin Perry Musculoskeletal Biomechanics Research Lab
University of Southern California
Division of Biokinesiology
and Physical Therapy

PELVIC FLOOR DYSFUNCTION: EXAMPLE DIAGNOSES

97

- Stress and urge urinary incontinence (UI)
- Fecal incontinence
- Urinary frequency or urgency
- Overactive bladder
- Pelvic organ prolapse

Abrams et al., *Neurology and Urodynamics*, 2010
Nygaard et al., *JAMA*, 2008

Disclosures

98

- This speaker has no disclosures to report

PELVIC PAIN

99

- Pain localized to the pelvis, perineum, anterior abdominal wall at/below the umbilicus, lumbosacral back and/or buttocks, vulva, vagina, or coccyx

Le P, and Fitzgerald CM; *Phys Med Rehabil Clin N Am*, 2017

PELVIC PAIN

100

- Coccydynia
- Vulvodynia
- Dysmenorrhea
- Dyspareunia
- Painful bladder syndrome
- Pelvic floor tension myalgia
- Pudendal neuralgia
- Myofascial pelvic pain syndrome
- Levator ani syndrome
- Chronic pelvic pain syndrome

Bonder et al., *Phys Med Rehabil Clin N Am*, 2017
Le and Fitzgerald, *Phys Med Rehabil Clin N Am*, 2017
Prather et al., *Phys Med Rehabil Clin N Am*, 2009
Prather et al., *Phys Med Rehabil Clin N Am*, 2007

PELVIC FLOOR DYSFUNCTION IN DANCERS

101

- Young, female athletes are at increased risk for
  - Incontinence
  - Pelvic pain
  - Sexual dysfunction
- Symptoms are highly underreported

Non-dance athletes:
- Trampolinists
- Gymnasts
- Volleyball players
- Runners
- Triathletes
- Basketball players
- Soccer players

Almeida et al., *Scand J Med Sci.*, 2016
Da Roza et al., *Current Womens Health Reviews*, 2013
Vitton et al., *J Womens Health*, 2011

PELVIC FLOOR DYSFUNCTION IN DANCERS

102

SPORT	% Urinary leakage during sport
Gymnastics	56%
Ballet	43%
Aerobics	40%
Badminton	31%
Volleyball	30%
Handball	21%
Basketball	17%

Cross-sectional study of stress urinary incontinence in female athletes, N= 291, Mean age = 22.8 y.o.

Thyssen et al., *Int Urogynecol J*, 2002

ASSOCIATED FACTORS WITH PFD COMMON TO THE DANCE POPULATION

103

- Low estrogen levels, amenorrhea, female athlete triad[1,2]
- Low Vitamin D status[3,4]
- Low back pain
- Hip joint pathology
- Impact activity: repetitive jumping and landing

1. Araujo et al., *Rev Assoc Med Bras*, 2008
2. Bo and Borgen, *Med Sci Sports Exerc*, 2001
3. Constantini et al., *Clin J Sports Med*, 2010
4. Badalian and Rosenbaum, *Obstetrics & Gynecology* , 2010

LOW BACK PAIN: ASSOCIATION WITH PELVIC FLOOR DYSFUNCTION

104

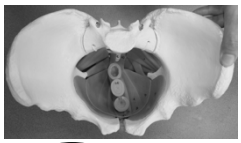
- Common in dancers; prevalence similar to other elite sports[1]
- Low back pain has high association with urinary incontinence[2,3]
- Low back pain associated with pelvic floor muscle dysfunction[4]

1. Swain et al., *Phys Ther in Sport*, 2017
2. Toprak C., *Turk J Med Sci*, 2017
3. Eliasson et al, *Man Ther*, 2008
4. Arab et al, *Man Ther*. 2010

HIP PATHOLOGY: ASSOCIATION WITH PELVIC FLOOR DYSFUNCTION

105

- Obturator internus (OI)
  - Primary hip rotator
  - Direct anatomic relationship to pelvic floor

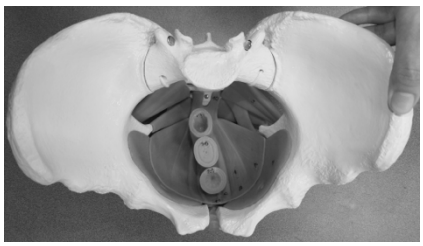


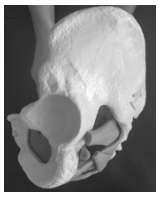
Hip pathology → Compensatory guarding in pelvic floor → Increased resting state of pelvic floor muscles

Weber et al, *Sports Health*, 2015
Prather et al, *Phys Med Rehabil Clin N Am*, 2009
Prather et al, *Phys Med Rehabil Clin N Am*, 2007
Hunt et al, *Phys Med Rehabil Clin N Am*, 2007

HIP PATHOLOGY: ASSOCIATION WITH PELVIC FLOOR DYSFUNCTION

106





RISK FACTORS IN DANCERS: REPETITIVE JUMPS AND LANDINGS

107

- Dance leaps involve high vertical ground reaction forces (3.5-4.4x body weight)[1]
- Repetitive, abrupt increases in intra-abdominal pressure alters demand on pelvic floor[2,3]
- Pelvic floor (levator ani) EMG activation levels correlate with increased IAP levels and the weight of the viscera[4]

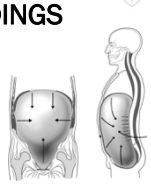


*Image credit: Frank et al, *Int J Sports Phys Ther*, 2013

1. Kulig K, Fietzer A, and Popovich JM. *Journal of Sports Sciences*, 2011
2. Cobb et al., *J Surg Res.*, 2005
3. Almeida et al., *Scand J Med Sci.*, 2016
4. Shafik et al., *World J Surg*, 2003

RISK FACTORS IN DANCERS: REPETITIVE JUMPS AND LANDINGS

108

Repetitive impact and abrupt increases in IAP

Positive training effect: improves strength and control of pelvic floor muscles

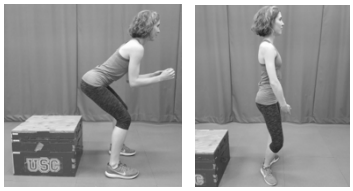
Persistent overload contributes to tissue damage, weakness

Almeida et al., *Scand J Med Sci.*, 2016
Vitton et al., *J Womens Health*, 2011
Sung and Hampton, *Obstet Gynecol Clin N Am*, 2009

PELVIC FLOOR IN IMPACT ATHLETES/ DANCERS

109

- Computational modeling study of female pelvic floor and surrounding fascial/visceral structures in jumping:
  - Valsalva caused descent of pelvic floor tissues posterior-inferiorly
  - Box jump/landing caused higher IAP and horizontal compression of bladder against pubic bone



Dias N., *Clin Biomech*, 2017

WHAT IF WE NOW ADD ANOTHER DEMAND? TURNOUT AND THE PELVIC FLOOR

Repetitive activation of obturator internus/ deep external rotators

- Altered pelvic floor muscle length-tension relationship
- Potential for pelvic floor shortening, increased muscle resting state, or repetitive use injury?
- Does this further increase the pelvic floor demand in jumps?

DANCER: BIOMECHANICAL CASE STUDY

111

- 37 y.o. professional dancer with chief complaint of chronic SI/low back pain
- Pain increased with positions of turnout
- Pain with increased hours dancing

- Concurrent symptoms
  - Painful intercourse
  - Urinary frequency
  - Difficulty initiating urine stream
  - Feeling of incomplete voiding
  - Chronic bladder irritation
  - Constipation/straining with bowel movements

DANCER: BIOMECHANICAL CASE STUDY

112

- Surface EMG:
- Gluteus maximus
- Intra-rectal EMG sensor for pelvic floor activation
- Observed pelvic floor activation during several basic dance tasks

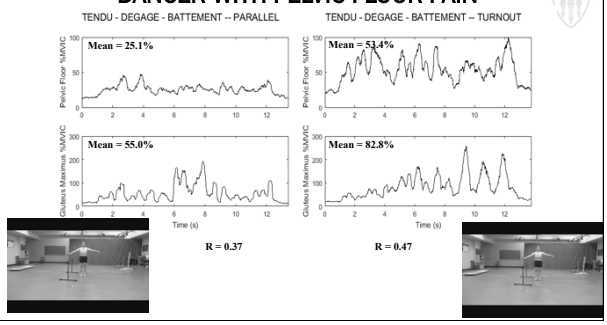
DANCER: BIOMECHANICAL CASE STUDY

113

- Basic dance motions assessed:
  - Plies, tendus, degages, battements in parallel and turnout
  - Sautes: Parallel and turnout

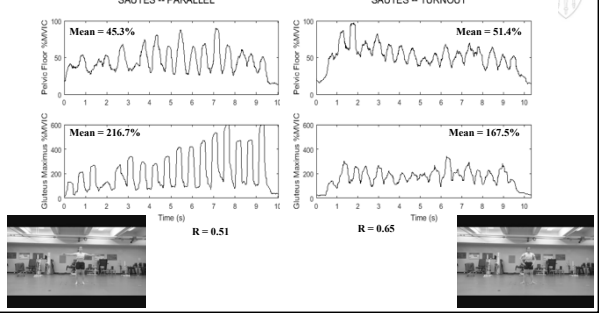
DANCER WITH PELVIC FLOOR PAIN

114



DANCER WITH PELVIC FLOOR PAIN

115



TURNOUT INCREASES PELVIC FLOOR ACTIVATION IN A DANCER WITH PELVIC PAIN

116

INTERVENTIONS:

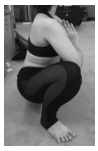
- Balance this dancer's turnout demand with interventions to increase internal rotation and pelvic floor relaxation
- Initial offload pelvic floor by limiting turnout and jumps when possible
- Refer to pelvic floor physical therapist for internal muscle examination!

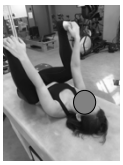
INTERVENTIONS

117

Pelvic floor relaxation

- Diaphragmatic breathing
- Child's pose
- Deep squat
- Modified happy baby





INTERVENTIONS

118

Focus on hip internal rotation and posterior hip mobility:

- Manual therapy to improve hip internal rotation ROM as needed
  - Joint mobilization with/without belt, soft tissue/fascial mobilization to gluteus maximus and deep outward rotators
- Patient performs:
  - AROM and strengthening into hip internal rotation
  - Self mobilization to posterior hip (ball, foam roller)
  - Posterior hip stretches

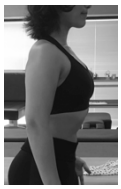
COMPOUNDING THE STRESS FROM ABOVE: ALTERATIONS IN DANCE TECHNIQUE

119

1. Excessive abdominal wall activation

Possible result:

- Creation of excessive intra-abdominal pressure
- Facilitates pelvic floor concentric lift without adequate lengthening phase
- Contribute to abdominal myofascial restrictions and referred pain to pelvic region[1]



1. Hartmann and Sarton, *Best Practice & Research Clinical Obstetrics and Gynaecology*, 2014

COMPOUNDING THE STRESS FROM ABOVE: ALTERATIONS IN DANCE TECHNIQUE

120

2. Breath-holding or non-optimal breathing mechanics

Results in…

- Limited diaphragm and pelvic floor descent
- Poor intra-abdominal pressure (IAP) regulation

121

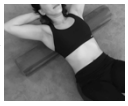
INTERVENTIONS: ABDOMINAL WALL MOBILITY

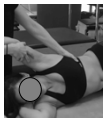
- Address myofascial restrictions along abdominal wall
  - Can decrease pain referral patterns to pelvis, groin and pelvic floor
  - Decreases fascial pull on pelvic floor region
  - Improve ability to properly recruit abdominal muscles in a balanced manner

122

INTERVENTIONS: BREATHING MECHANICS

- Re-educate proper breathing mechanics:
- Diaphragmatic breathing and lateral rib expansion
- May need to improve thoracic mobility to reduce inspiratory position of ribs
  - Manual therapy for rib mobility
  - Self mobilization techniques for ribs and thoracic spine





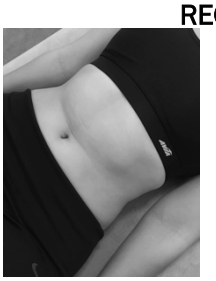
123

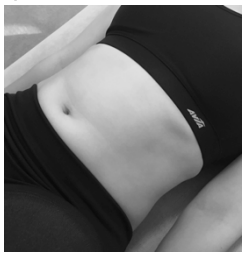
INTERVENTIONS: BREATHING MECHANICS

- Re-educate proper breathing mechanics:
- Proprioceptive feedback to improve lower lateral rib expansion
  - Theraband or towel roll at lower ribs

124

INTERVENTIONS: IMPROVE IAP REGULATION





125

SUGGESTIONS FOR ORTHOPEDIC PT's

- Include screening questions in intake forms and subjective history
- <u>EXAMPLES:</u>
  - Urinary leakage with coughing, sneezing, or activity/exercise?
  - Feeling of difficulty initiating a urine stream?
  - Feeling of incomplete emptying of the bladder?
  - Strong urge to urinate that occurs frequently?
  - Leakage or dribble after emptying your bladder?
  - Constipation/straining with bowel movements?
  - Pain with intercourse? Pain with menstruation?

126

QUESTIONNAIRES

- Pelvic Floor Distress Inventory
- Pelvic Floor Impact Questionnaire—short form 7
- Pelvic Pain and Urgency/Frequency Questionnaire

SIGNS OF PELVIC FLOOR AS A CONTRIBUTING FACTOR

127

- Yes to screening questions/questionnaires
- Cues for abdominal or pelvic floor recruitment increases back, hip, SI joint or pelvic pain
- Back pain/hip pain worsens cyclically during menstrual cycle
- Patient not responding to back or hip interventions as expected

DANCERS WITH PELVIC FLOOR DYSFUNCTION

128

- Include in your differential diagnosis with low back, sacroiliac and hip pain
- Consider the likely relationship between turnout and the demand on pelvic floor
- Understand the demands of jumping on your dancers' pelvic floors
- Kegels may not be appropriate in the case of pelvic pain and/or urinary incontinence that results from a hypertonic pelvic floor
- Address breathing and intra-abdominal pressure regulation
- Refer to pelvic floor physical therapist for internal muscle assessment

REFERENCES

129

- Abrams P, Andersson KE, Birder L, et al. Fourth international consultation on incontinence recommendations of the international scientific committee: Evaluation and treatment of urinary incontinence, pelvic organ prolapse, and fecal incontinence. *Neurourol Urodyn*. 2010;29(1):213-240. doi:10.1002/nau.20870.
- Arab AM, Behbahani RB, Lorestani L, Azari A. Assessment of pelvic floor muscle function in women with and without low back pain using transabdominal ultrasound. *Man Ther*. 2010;15(3):235-239. doi:10.1016/j.math.2009.12.005.
- de Araujo MP. The relationship between urinary incontinence and eating disorders in female long-distance runners. *Rev Assoc Med Bras*. 2008;54(2):146-149.
- Almeida MBA, Barra AA, Saltiel F, Silva-Filho AL, Fonseca AMRM, Figueiredo EM. Urinary incontinence and other pelvic floor dysfunctions in female athletes in Brazil: A cross-sectional study. *Scand J Med Sci Sport*. 2016;26(9):1109-1116. doi:10.1111/sms.12546.
- Badellian SS, Rosenbaum PF. Vitamin D and pelvic floor disorders in women: Results from the national health and nutrition examination survey. *Obstet Gynecol*. 2010;115(4):795-803. doi:10.1097/AOG.0b013e3181d34806.
- Bo K. Urinary incontinence, pelvic floor dysfunction, exercise and sport. *Sport Med*. 2004;34 (7):451-464. doi:http://dx.doi.org/10.2165/00007256-200434070-00004.
- Bø K, Borgen JS. Prevalence of stress and urge urinary incontinence in elite athletes and controls. *Med Sci Sports Exerc*. 2001;33(11):1797-1802. doi:10.1097/00005768-200111000-00001.

REFERENCES

130

- Bonder J et al. Myofascial Pelvic Pain and Related Disorders. *Phys Med Rehabil Clin N Am*. 2017;28(3):501-515.
- Cobb WS, Burns JM, Kercher KW, Matthews BD, James Norton H, Todd Henlford B. Normal intraabdominal pressure in healthy adults. *J Surg Res*. 2005;129(2):231-235. doi:10.1016/j.jss.2005.06.015.
- Constantini NW, Arieli R, Chodick G, Dubnov-Raz G. High prevalence of vitamin D insufficiency in athletes and dancers. *Clin J Sport Med*. 2010;20(5):368-371. doi:10.1097/JSM.0b013e3181f20ff2.
- Da Roza T, Natal Jorge R, Mascarenhas T, Alberto Duarte J. Urinary incontinence in sport women: from risk factors to treatment-a review. *Curr Womens Health Rev*. 2013;9(2):77-84.
- Dias N, Peng Y, Khavari R, et al. Pelvic floor dynamics during high-impact athletic activities: A computational modeling study. *Clin Biomech*. 2017;41:20-27. doi:10.1016/j.clinbiomech.2016.11.003.
- Eliasson K, Elfving B, Nordgren B, Mattsson E. Urinary incontinence in women with low back pain. *Man Ther*. 2008;13(3):206-212. doi:10.1016/j.math.2006.12.006.
- Hartmann D, Sarton J. Chronic pelvic floor dysfunction. *Best Pract Res Clin Obstet Gynaecol*. 2014;28:977-990. doi:10.1016/j.bpobgyn.2014.07.008.
- Hunt D, Ciohisy J, Prather H. Acetabular Labral Tears of the Hip in Women. *Phys Med Rehabil Clin N Am*. 2007;18(3):497-520. doi:10.1016/j.pmr.2007.05.007.
- Itza F, Zarza D, Serra L, Gómez-Sancha F, Salinas J, Allona-Almagro a. Myofascial pain syndrome in the pelvic floor: a common urological condition. *Actas Urol Esp*. 2010;34(4):318-326. doi:10.1016/S2173-5786(10)70077-9.

REFERENCES

131

- Kruger JA, Murphy BA, Heap SW. Alterations in levator ani morphology in elite nulliparous athletes: A pilot study. *Aust New Zeal J Obstet Gynaecol*. 2005;45(1):42-47. doi:10.1111/j.1479-828X.2005.00349.x.
- Kruger JA, Dietz HP, Murphy BA. Pelvic floor function in elite nulliparous athletes. *Ultrasound Obstet Gynecol*. 2007;30(1):81-85. doi:10.1002/uog.4027.
- Kulig K, Fietzer AL, Popovich JM. Ground reaction forces and knee mechanics in the weight acceptance phase of a dance leap take-off and landing. *J Sports Sci*. 2011;29(2):125-131. doi:10.1080/02640414.2010.534807.
- Le PU, Fitzgerald CM. Pelvic Pain: An Overview. *Phys Med Rehabil Clin N Am*. 2017;28(3):449-454. doi:10.1016/j.pmr.2017.03.002.
- Nygaard I, Barber MD, Burgio KL, et al. Prevalence of symptomatic pelvic floor disorders in US women. *JAMA - J Am Med Assoc*. 2008;300(11):1311-1316. doi:10.1001/jama.300.11.1311.
- Prather H, Dugan S, Fitzgerald C, Hunt D. Review of Anatomy, Evaluation, and Treatment of Musculoskeletal Pelvic Floor Pain in Women. *PM R*. 2009;1(4):346-358. doi:10.1016/j.pmrj.2009.01.003.
- Prather H, Spitznagle TM, Dugan SA. Recognizing and Treating Pelvic Pain and Pelvic Floor Dysfunction. *Phys Med Rehabil Clin N Am*. 2007;18(3):477-496. doi:10.1016/j.pmr.2007.06.004.
- Shafik A, Doss S, Asaad S. Etiology of the resting myoelectric activity of the levator ani muscle: Physioanatomic study with a new theory. *World J Surg*. 2003;27(3):309-314. doi:10.1007/s00268-002-6584-1.

REFERENCES

132

- Sung VW, Hampton BS. Epidemiology of Pelvic Floor Dysfunction. *Obstet Gynecol Clin North Am*. 2009;36(3):421-443. doi:10.1016/j.ogc.2009.08.002.
- Swain CT V, Bradshaw EJ, Whyte DG, Ekegren CL. Life history and point prevalence of low back pain in pre-professional and professional dancers. *Phys Ther Sport*. 2017;25:34-38. doi:10.1016/j.ptsp.2017.01.005.
- Thyssen HH, Clevin L, Olesen S, Lose G. Urinary incontinence in elite female athletes and dancers. *Int Urogynecol J Pelvic Floor Dysfunct*. 2002;13(1):15-17. doi:10.1007/s001920200003.
- Toprak Çelenay Ş, ÖZER Kaya D. Relationship of spinal curvature, mobility, and low back pain in women with and without urinary incontinence. *Turkish J Med Sci*. 2017;47(4):1257-1262. doi:10.3906/sag-1609-67.
- Vitton V, Baumstarck-Barrau K, Brardjanian S, Caballe I, Bouvier M, Grimaud J-C. Impact of High-Level Sport Practice on Anal Incontinence in a Healthy Young Female Population. *J Women's Heal*. 2011;20(5):757-763. doi:10.1089/jwh.2010.2454.
- Weber AE, Bedi A, Tibor LM, Zaltz I, Larson CM. The Hyperflexible Hip: Managing Hip Pain in the Dancer and Gymnast. *Sports Health*. 2015;7(4):346-358. doi:10.1177/1941738114532431.