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Return to Sport Following Anterior Cruciate Ligament Reconstruction In the Professional Female Ballet Dancer

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Anterior cruciate ligament (ACL) injuries in dance medicine present an interesting comparison to many other sports. When ACL injuries occur, the mechanics required for dance and more specifically ballet, place the knee in positions that put increased load on the graft, which creates challenges to safely return a dancer to a full workload of rehearsals and performances. Unlike most sports, dancers present with a lower rate of ACL injuries in females versus males. In addition to returning to jumping and landing with external rotation at the hip and lower leg, females must also return to dancing en pointe. This manuscript will aim to lay a framework for dance medicine providers to use in returning musculoskeletal mature female professional dancers to full participation. Additional considerations should be reviewed regarding pre-professional and adolescent dancers.

Anterior cruciate ligament (ACL) injuries in dance medicine present an interesting comparison to many other sports. Dancers are often landing from jumps in a turned-out position throughout the lower extremity which could create suboptimal alignment and increased valgus force at the knee. Since these landing mechanics can be a primary mechanism of ACL injury, it is interesting to discover that the rate of ACL injuries is actually lower in dance compared to other sports that involve jumping and landing[1–3]. In addition to the demand for landing in a potentially high-risk position, dancers also tend to have high levels of hypermobility, which has been shown to be a risk factor for ACL injuries[1,4–7].

There have been multiple studies exploring ACL injury incidence in dance, but all measure rates of injury differently. Studies by Liederbach at al., Meuffles and Verhaarand and Ramkumar et al. studied professional dance companies and showed injury rates of 0.009/1000 exposures, 0.032/1000 days and 4/520 years, respectively[1,2,8]. Ambegaonkar et al. studied university level dancers and showed an injury rate of 1.2/1000 years[3]. While each of these studies have varied in how they reported incidence, all show a much lower rate of injury than other sports involving a high amount of jumping[3].

There are several proposed reasons for this decreased incidence. Dancers have demonstrated proper landing technique and safer landing mechanics, including decreased joint stiffness, decreased knee valgus angle and greater gluteus maximus activation upon landing a drop jump[9–12]. Starting dance training at a younger age is correlated with improved landing mechanics[9]. In addition, dancers spend a significant amount of

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time in single limb stance, which may contribute to protective improvement in single limb stability[1].

A factor to consider in ACL injuries is the role of fatigue. Several studies have shown that fatigue can negatively affect landing mechanics. This may help explain a trend in ACL injuries in dancers that occurs with higher levels of fatigue, such as at the end of the day or the end of a performance[1,13]. Liederbach et al. demonstrated that while performing a single leg drop jump, both dancers' and team athletes' form decreased with fatigue, but dancers took significantly longer to fatigue than team athletes[13]. This delay in loss of form may serve as a protective mechanism, helping to lower the rate of ACL injuries in dancers. Determining this aspect further is a challenge in the dance medicine population since exposure hours and workload values are difficult to capture accurately. More research is needed in this area of study.

In dance medicine populations, ACL tears tend to occur more in males than females[1,2]. Males are often performing complex power jumps that involve rotation and beats. Females often jump with pointe shoes versus flat shoes and therefore experience a different ground reaction force. Both genders will often have different demands placed on their workload in terms of the types of steps performed in classical and neo classical repertoire. In recent literature, female dancers have demonstrated better landing mechanics than other female athletes[10,11,13–16].

While dance is not considered a high-risk sport for ACL injuries, when they do occur, they lead to significant time loss from dancing and at a significant cost to both the athlete and dance company[8]. Many case studies in the professional community have suggested that ACL injuries may present a significant challenge in returning to dance and could contribute to early retirement[17]. End stage rehab protocols that are dance specific are limited. There are several studies that have examined return to jumping and plyometrics, but the intent of these protocols was not specific to the unique aspects of ACL reconstruction alone.

BALLET-SPECIFIC REHABILITATION

There are many available articles and protocols for general ACL rehabilitation for return to team sports in the literature and these general principles apply in dance medicine as well. This article will focus on the specifics in return to ballet at the professional level in the adult population. Several important distinguishing factors to consider in return to ballet are the following: the need to perform exercises in a turned-out position, high demand for single leg stability, increased calf and foot strength demands, and aesthetic demands of the sport. Aesthetically it is vital to achieve full extension through the knee to create the desired visual lines artistically. Compared to cutting and pivoting sports, there is less demand for running and responding to unpredictable movements and contact. While exceptions exist, most movements are choreographed in a controlled environment. These factors need to be considered throughout all stages of rehab to achieve a successful return to dance.

The following protocol is ballet specific for the professional athlete. It is important to consider the level at which the dancer is participating, such as a new corps de ballet dancer versus a veteran soloist, and how that is likely to impact the progression through each phase due to varied technique and load demands. Phases are broken down by functional ballet tasks, the criteria needed to progress to each task and the considerations in that phase to progress to the next stage. Anticipated timelines are provided. These should be the earliest a dancer progresses, and all criteria must be met prior to progressing. If a dancer underwent reconstruction with an allograft, these stages may be delayed. The timing of any protocol should be discussed with the referring physician and all members of the rehabilitation team.

It is important to consider graft type throughout each stage of rehabilitation. It may take a dancer with a hamstring autograft longer to meet the criteria for phase 2 due to difficulty in regaining hamstring strength on the donor side. With a patella tendon autograft, there is higher risk of anterior knee pain from either patellofemoral joint dysfunction or patellar tendinopathy, both of which are common dance injuries. If a dancer is experiencing anterior knee pain, that is an indication that progression should be slowed to allow this to resolve. If a dancer has an allograft versus autograft, this will delay the anticipated timeline due to decreased initial strength of the allograft[18,19].

PHASE 1: INITIAL POST-OPERATIVE PHASE

During this stage, dancers will follow a general ACL protocol with a focus on regaining range of motion (ROM), improving patellofemoral joint

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mobility, decreasing swelling and regaining strength. Regaining full extension ROM will be critical. During this time, there should be added attention to calf strength, foot intrinsic strength, ankle joint mobility, single leg balance, pelvic stability, hip strength, core strength and gait. It remains important to ensure that proper criteria are met prior to progressing activities.

During the first three months of rehab, dancers may begin cross training activities with guided supervision such as modified Pilates, GYROTONIC® and floor barre to address conditioning needs while in this protective phase. These supplemental movement systems will continue to be helpful tools for neuromuscular retraining in the later stages of rehab. Cardio conditioning will also be important and may begin on a stationary bike. Once gait is normalized and the dancer can perform a single leg squat to 30 degrees with proper form, the elliptical can be incorporated. After the incision is healed, pool therapy can be introduced. Running is typically not an impact-based activity that would take priority in a dance specific protocol. Ballet dancers are jumping athletes and therefore, introducing impact with dance-specific plyometrics take priority over running-based activities based on the principle of specificity of training.

PHASE 2. 3 - 4 MONTHS POSTOPERATIVELY: BARRE/TURNOUT PREP IN FLAT SHOES

Criteria for phase:

- No swelling
- Full hip, knee and ankle ROM equal to contralateral side
- Normal patellofemoral joint mobility
- Glute and external rotator strength within 5% operated limb
- 80% quad and hamstring strength
- Full intrinsic foot strength as evidenced by ability to complete short foot doming without excessive anterior tib or extrinsic toe flexor activation in standing [20]

Goals for phase:

- Establish double limb stance in parallel and first position with equal weight bearing, neutral pelvic positioning and appropriate leg alignment with the emphasis on turnout from the hip and minimizing compensatory turnout strategies.
- Demonstrate the ability to maintain appropriate alignment with weight shifting and dynamic movement tasks such as a plié or tendu.
- Continue to build strength.

Maintaining safe postures and accessing the appropriate motor planning for turnout is key. One could begin this reintroduction with the use of turnout discs either on the Pilates reformer or in standing so that the dancer can maintain a full quad set and focus on the deep hip rotator recruitment in an active assisted manner. Turnout discs, if used properly, can help significantly reduce the dancer's ability to compensate with lower leg turnout only and access the appropriate proximal musculature. Turnout discs also provide an external focus of control which has been proven to assist in improving motor learning[21–24]. As the dancer gains strength and improved motor planning, weight shifts, dynamic movement and turn out without the use of the discs should be incorporated. Common compensations may include the following: excessive lower leg rotation, navicular drop, posterior or anterior pelvic tilt, and knee valgus. These issues should be corrected with verbal, tactile or visual feedback which can be faded as a goal.

PHASE 3. 4 – 6 MONTHS POSTOPERATIVELY: MODIFIED BARRE AND POINTE PREPARATION

Criteria for phase:

Above criteria from Phase 2 plus:

- Able to maintain single leg balance with eyes closed for 30 seconds with proper alignment and foot posture
- Able to complete 27 elevés and relevés with controlled lowering for females (30 for male)[25]
- Symmetric joint position sense with less than 5 degrees of error[26]
- Able to successfully perform airplane test with 4 out of 5 repetitions[27]
- Able to complete 5 single leg pliés off a bench to 90 degrees knee flexion with proper knee and hip alignment

Note: Extra caution should be taken with females with greater than 10 degrees of knee hyperextension and a positive Beighton score: ensure there is muscular control while moving into end range knee extension to avoid "snapping" into hyperextension, particularly as the dancer is beginning barre.

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Modified Barre
Goals for phase:
- Introduce ballet specific movements and motor control patterns
- Introduce turnout

Table 1. Phase 3 Rehabilitation Guidelines

4 Months	5 months	6+ months
· Modified turnout to available range where pelvic positioning and plié placement can be maintained with minimal torsion of lower leg · Working from first · NO: o Grande pliés o Fifth position o Fourth position o Fondu o Frappé o Ronde de jambe en l'air · Decrease speed to accommodate motor planning · Perform with flat shoes	· Increase tempo and combination difficulty, more single leg stance, add third position · Still NO: o Fifth or fourth o Grand pliés o Fondu o Ronde de jambe en l'air	· Modified fifth position can be added, which may be in a less turned-out position than the dancer's baseline · Fifth position checklist: o Full active and passive ROM at hip and full strength through available range o Negative Thomas test o Negative Ely test o Adequate core control o Consistently demonstrating appropriate lumbopelvic movement patterns and stability · Add tendues with turn prep only and adagio combination in center · Introduce pointe shoes as the dancer can demonstrate proper technique following the pointe progression below · Introduce fourth position with physical therapist supervision and guidance · Introduce turn prep starting with relevé from fifth and working up to fourth (see below)

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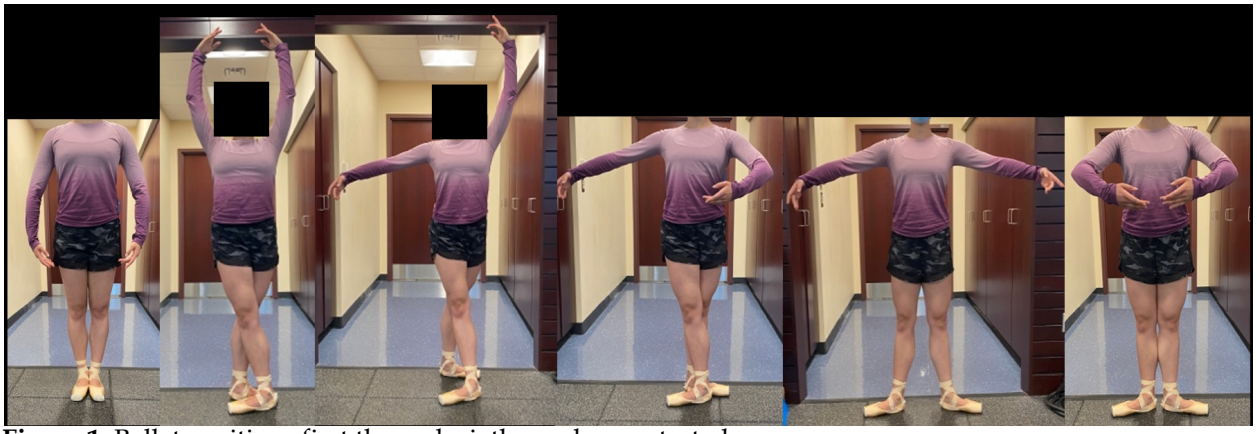

Figure 1. Ballet positions first through sixth are demonstrated.

Pointe progression

Goals for phase:

- Establish proper foot and ankle strength and mechanics en pointe
- Improve stability en pointe with both double and single limb stance

Returning to dancing en pointe will be critical for female ballet dancers. The need to weight bear in hyperextension and with a decreased base of support presents an increased challenge as a dancer returns from an ACL injury. The dancer can likely begin to put their pointe shoes on at 4 months with supervision. Initially without relevé, she may start wearing pointe shoes at barre to get accustomed to the base of support/balance differences of the shank as well as the added resistance with active plantarflexion. The Pilates reformer or shuttle press can be helpful tools to work on pointe tasks with reduced load, degrees of freedom and balance demands. Gradually increasing reps, challenging stance from parallel to turn out, and adding increased resistance to simulate standing weight bearing, will all be helpful prior to working over ground. Pointe exercises at the barre at this stage will entail working on two feet in parallel and progressively adding higher level tasks like turnout, weight transfer and single leg work as appropriate. This process could take up to two months before consideration of pointe work in the center is introduced.

Figure 2. Proper alignment en pointe in center is demonstrated.

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PHASE 4. 6 – 9 MONTHS POSTOPERATIVELY: CENTER, TURN PROGRESSION, JUMP PROGRESSION

Criteria for phase:

- Ability to maintain single limb stance in parallel with eyes closed for 60 seconds
- Hamstring and Quadriceps limb symmetry index between 90-110%
- Gluteus medius, gluteus maximus, and adductor limb symmetry index between 95-105 %
- Consistently performing pointe work at barre without any increase in symptoms
- Ability to complete airplane test with rotation 2 times on each side[27,28]
- Ability to complete single leg sauté test 8 out of 16 trials[27,28]
- Ability perform >/= 30 single leg elevés and relevés[25]
- Proper form in turnout en pointe in center as shown in image 2

Note: The dancer should concurrently be passing standard ACL Hop testing (SL hop, triple hop and crossover hop) as moving through this stage, and prior to progressing power jumps, such as medium allegro.

Goals for phase:

- Complete full barre
- Initiate center work
- Initiate turn progressions
- Initiate dance specific jumps

Center

Center work may begin around 6 months provided the above criteria has been met. Center work will be limited to where a dancer is in their jump and turn progression. Adding center work progresses the dancer's load with increased weightbearing, complex movement patterns and impact-based activity. Therefore, the dancer should be consistently demonstrating proper technique even if fatigued prior to progressing further in class.

Turn Progression

There are several components to turning that need to be addressed with physical therapist guidance and supervision. The starting position, spotting mechanics, force/propulsion, type of turn, gesture leg position and proprioception should all be examined[29,30]. The dancer can start working on these concepts initially by reducing the level of complexity such as working from parallel and getting to the desired passe position effectively. Another option is to allow the dancer to work on the concepts of timing and spotting with a protective straight leg position such as with a soutenu at the barre[31]. When she is ready to advance, chaînés in the center and later piqué turns will provide an opportunity to advance these skills onto a single leg stance. For pirouettes, once motor planning has improved, turnout can be introduced by gradually increasing the complexity of the starting position and addressing the prep to the balance without the turn. It is important to establish appropriate mechanics with one's port de bras and trunk stability prior to adding the task of a full turn. Additional exercises for obliques and shoulder girdle stability may be helpful to consider[32,33]. Programming should be advanced to include higher level relevé work with proprioception challenges as well as multi-directional lunges to the desired turning position. The topple test can be a helpful tool to indicate if full turns are appropriate[27]

As the dancer progresses through various turns, it will be important to be mindful of the forces created at the knee by different movements. For example, the take off for turns en dehors has the potential to create greater torsion at the knee. If there was medial meniscal involvement this is something to watch. Turns en dedans have the potential to create increased valgus force at the knee if there is a lack of appropriate hip muscle recruitment. It is important to ensure proper technique with each type of turn and direction.

Figure 3: Appropriate turn prep alignment from fourth position

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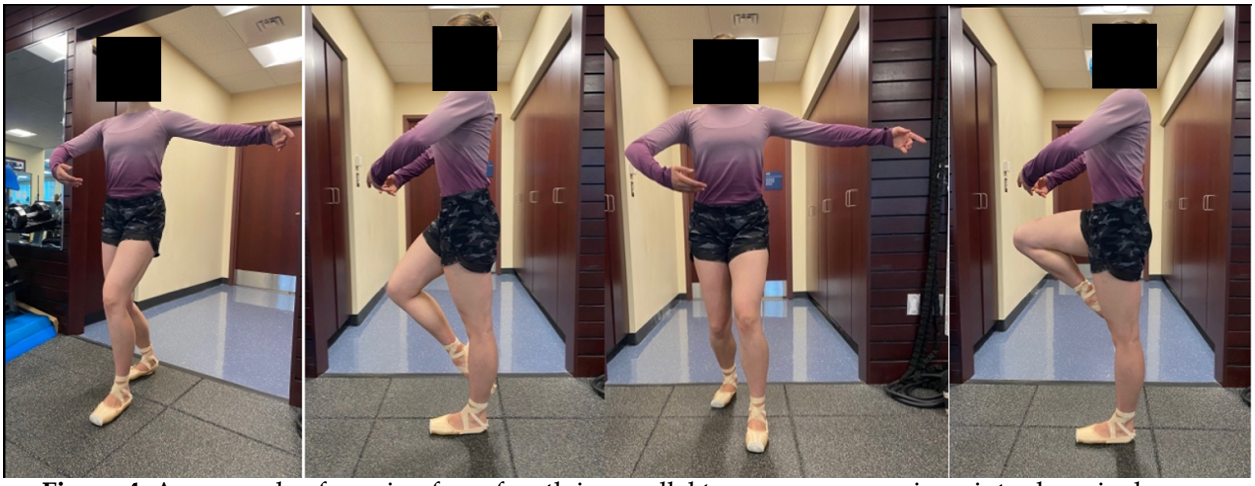

Figure 4. An example of moving from fourth in parallel to coupe or passe in pointe shoes is shown, focusing on proper alignment and weight shift.

Jump Progression

Plyometrics are added into a standard ACL rehab program at 3-4 months starting with double leg then single leg jumps in parallel or sixth position, and this is appropriate to continue to build fast twitch muscle fibers and to build force production and load attenuation. Depending on the dance company, a dancer may be seeing an off-site physical therapist as well as a dance specific PT. Therefore, it is essential to coordinate care between the various providers so that load and progressions are communicated clearly.

Dance specific jumps should be held until the 4th phase. Jumping should begin in the pool or on the reformer or shuttle press with light resistance on 2 feet. This may begin about a month prior to initiating jumps over ground if the dancer is able to maintain proper alignment and demonstrate good eccentric control through the landing. The dancer should be taking off and landing with their heels down. There are several factors that should be considered throughout this progression. These include but are not limited to: take-off and landing position, if the jump travels, complexity of the gesture leg, beats, rotation, the complexity of the combination of movements together, the amplitude/power of the jump and the tempo of the jump to allow for motor planning throughout the movement. Each of these factors should be considered as jumps are progressed, allowing the dancer to first master less complex jumps and gradually progress in each area. Prior to each progression, a dancer should be demonstrating proficient technique. It is important to consider the environment and floor surface the dancer is working on. When starting a jump progression especially grand allegro, it is helpful to begin in a closed environment, and open it up to a busier class environment gradually. It is also important to consider the psychological impact of returning to the jump or movement during which they sustained their injury.

The dancer should have full resolution of soreness over 24 hours and add ~10% load each week. Ultimately, one of the most important factors during this phase is being mindful of the dancer's overall load. While the dancer is progressing in class, they are likely continuing a strength-based program and plyometric protocol. With the goal of a dancer returning to a full workday which often requires full class (a typical ballet class often consisting of ~200+ jump count) and up to 6 hours of rehearsal, their overall jump count, including ongoing rehab exercises, needs to be considered and monitored closely.

Typical Class Order (with PT modifications/additional exercises bolded)

- Jumps in first
- Jumps in fifth
- Écheppé
- Glissade
- Glissade/assemble

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- Petite allegro – **first adding jete and small sissonne on two feet**
- **Chasse/traveling step – may perform this after jumps on two feet**
- Medium allégro – increasing power and complexity
- Grand allégro- power based jumps, traveling with higher amplitude

Example of a typical progression (each phase may take ~2-3 weeks depending on the dancer's response to loading)

Part 1

- Reformer/Shuttle Pool Jumps (initial pool jumps will begin in armpit deep water and gradually progress to waist deep)
- Plyometric program – pogo jumps in multi-direction, box jumps
- Class exercises: gradually add jumps in first, fifth, and échappé

Part 2

- Glissades
- Glissades/Assemblé
- Small Sissonne from two feet-two feet
- Chassé in multiple directions
- Countermovement jumps

Part 3

- Working on single leg hops
- Petite allegro – starting with Jeté

Part 4

- Two-feet to one-foot landings
- Increasing power-based work
- Challenging tempo and speed with extrinsic cuing like music or the metronome versus allowing the dancer to self- select their speed.
- Able to pass standard hop test battery prior to progressing

Part 5

- Medium allegro
- Increase dance specific plyometric training

Part 6

- Grand allegro

PHASE 5. ~ 9-12 MONTHS: RETURN TO FULL CLASS

It is anticipated that return to full class will occur at ~9 months in dancers who underwent reconstruction with autograft. However, this will be dependent on progress through the prior stages. It is important to ensure all criteria have been met and technique is correct without compensatory strategies at each stage prior to progressing.

PHASE 6. RETURN TO DANCE: ANTICIPATED TO BE APPROXIMATELY 1-YEAR POST-OPERATIVELY

Timelines for return to sports vary widely. Biologic healing timelines, psychological readiness to return and specific tests and measures should be combined when deciding the return to sport timeline[36]. There is evidence that as part of the neoligamentization process, maturation of the ACL graft occurs for up to two years after surgery[37-40]. The Delaware-Oslo ACL cohort study revealed a 51% reduction in reinjury rate for each month return to sport was delayed up to 9 months and that there is a 7x increased risk of new ACL injury for athletes that return to sports prior to 9 months post-op[41,42]. Re-injury rates have been studied, but much of this data is in relation to running, pivoting and cutting sports[43]. Graft type continues to be considered as there is some evidence that allografts heal slower than autografts[18,19]. In terms of psychological readiness to return there is a recently validated questionnaire that can act as a part of the readiness to return to sport cluster. The Anterior Cruciate Ligament Return to Sport After Injury (ACL-RSI) short-version suggests that athletes scoring greater than 60% at 6 months after surgery were highly likely to return to sport by 12 months. This measure has not been studied in the dance population, but may still be beneficial as psychological factors have been shown to be an indicator for successful return to dance[44,45]. For dance specific psychological readiness for return, the Dance Functional Outcome Survey (DFOS) is an effective measure, with a cut-off score for normal function at 77.5 or higher[46,47].

Criteria for full return to dance include meeting criteria of all prior stages, side-to-side strength values within 5% of each other, demonstrating proper technique with full ballet class activities, not demonstrating or reporting increased swelling or pain following these activities, and a score of at least 77.5 on the Dance Functional Outcome Survey (DFOS) [46].

Return timelines and progress will vary based on the dancer's gender, skill level and anticipated load. It will be important to consider a dancer's

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ability to modify their activity and roles as they return to full clearance. Just because a dancer can complete a full class effectively does not mean that they will not encounter setbacks with a full rehearsal and performance schedule. Rehearsal and performances will introduce new movement patterns or tasks that may not have been encountered in formal rehab such as partnering, floorwork and kneeling. There may be different psychological and physical pressures placed on them depending on their rank, the types and number of roles they are expected to perform, the timing of their re-entry into the planned repertoire of the season, auditions and their history within a company.

As return to full dance approaches, it is essential to have appropriate clear communication between the dancer, medical team and artistic staff as appropriate to ensure proper return without increasing load too rapidly or placing a dancer in a role or position that is likely to lead to reinjury. Often, additional care providers such as mental health and nutrition will be critical. There should be a primary clinician within the rehab team who can understand and track that dancer's load and adjust their program accordingly. Education regarding recovery and not overloading the tissues should be provided to the dancer. It is important to advocate for the dancer when needed, should they require specialized resources or support in communicating specific participation restrictions with either artistic or worker's compensation.

Return to dance is a complex process that requires attention at the various stages of rehabilitation to the demands of each movement sequence and should follow a criteria-based approach in addition to meeting minimal timelines.

This commentary is intended to guide physical therapists who work routinely with a dance medicine population and understand the unique demands of the sport. There is more research needed in this area, such as normative strength data in this population and appropriate functional tests that may be predictive of injury. There have been several studies researching return to sport criteria in field or ball sports, but the mechanics of these sports are very different from the demands of ballet. For this reason, the tests that are currently published in the literature have limited carryover to the dance world.

Conflict of Interest Statement
The authors report no conflict of interest with the contents of this manuscript.

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APPENDIX 1

Term	Definition
Soutenu	Sustained. Turning in a sus-sous, or fifth position en pointe, and ending up with the opposite foot in front.
Chaînés	Chains, links. A series of rapid turns on the points or demi-pointes done in a straight line or in a circle.
Port de bras	A movement or series of movements made by passing the arm or arms through various positions.
Piqué	Pricked, pricking. Executed by stepping directly on the point or demi-pointe of the working foot in any desired direction or position with the other foot raised in the air.
En dehors	Outward. In steps and exercises the term en dehors indicates that the leg, in a position à terre or en l'air, moves in a circular direction, clockwise. For pirouettes, the term indicates that a pirouette is made outward toward the working leg.
En dedans	Inward. In steps and exercises the term en dedans indicates that the leg, in a position à terre or en l'air, moves in a circular direction, counterclockwise from back to front. For pirouettes, the term indicates that a pirouette is made inward toward the supporting leg.
Échappé	An échappé is a level opening of both feet from a closed to an open position.
Glissade	Glide. A traveling step, executed by gliding the working foot from the fifth position in the required direction, the other foot closing to it.
Assemblé	Assembled or joined together. A step in which the working foot slides well along the ground before being swept into the air. As the foot goes into the air the dancer pushes off the floor with the supporting leg, extending the toes. Both legs come to the ground simultaneously in the fifth position.
Jeté	Throwing step. A jump from one foot to the other in which the working leg is brushed into the air and appears to have been thrown. There is a wide variety of jetés and they may be performed in all directions.
Chassé	Chased. A step in which one foot literally chases the other foot out of its position; done in a series.
Sissonne	A general term for a jump from both feet onto one foot. There are several versions of sissonne.
Petite allegro/grand allegro	A series of jumps done quickly in combination, such as sissonne and assemblés. Petite refers to several small jumps. Grand refers to large jumps covering more ground with higher amplitude requiring more power and eccentric control.
Relevé	Raised. A raising of the body en pointe or demi-pointes from a demi-plie position.
Élevé	A raising of the body en pointe or demi-point from a straight leg position.
Fondu	Sinking down. A term used to describe a lowering of the body made by bending the knee of the supporting leg.
Frappé	A quick striking motion of the floor, the working leg moves from the stance leg out quickly to the front, the side or the back.
Tendu	The working leg extends away from the body until only the toes are touching the floor.
Ronde de jambe en l'air	With the working leg in an abducted position. The working toes draws an oval from the stance knee all the way back out, while keeping the thigh stable and bending the working knee.
Grand plié	Bend the knees so that the thighs are parallel to the ground and the heels lift off the ground.
Sauté	Jump

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