Hip Instability in Ballet Dancers
A Narrative Review

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Abstract

Background: Dancers possess a large degree of hip range of motion that results from a combination of innate and acquired osseous morphology and permissive soft tissues. Generalized hypermobility in dancers may predispose them to a spectrum of hip instability. The objective of this narrative review is to discuss the anatomical characteristics, pathogenesis, risk factors, clinical signs and symptoms, management, and outcomes of hip instability treatments in dancers.

Methods: A retrospective search was performed beginning November 1, 2017, for English language articles regarding hip stability in the dancer. Key words used included but were not limited to: dance(r), ballet, hip, hypermobility, range of motion, instability, microinstability, and laxity. PubMed, Scopus, and MEDLINE databases were used.

Results: Forty-three studies were analyzed. Groin pain was found to be the most common presenting symptom of hip instability. A variety of impingement and instability signs may be elicited during physical examination. Hypermobility is frequently observed and is thought to be a necessity for participation in elite levels of ballet. Radiographs and advanced planar imaging (magnetic resonance imaging and computed tomography) should be scrutinized to evaluate for dysplasia, cam, pincer, subspine, and rotational morphologies. Dysplasia (low volume acetabulum), cam morphology, femoral retroversion, and coxa valga are common findings in the ballet dancers' hip. Labral injuries and ligamentum teres tears are common and may potentiate instability in the hip. Management options include education, oral non-opioid medications, activity modification, exercise prescription, and surgery. Reported outcomes of these treatments in ballet are limited.

Conclusion: Hip hypermobility is prevalent in the ballet population and is a clear advantage. However, it may increase the risk of instability. It is important to identify the multifactorial osseous and soft tissue etiology of hip or groin pain in dancers. Practitioners should have a high level of suspicion for hip instability in the dancer presenting with hip pain and treat accordingly. There is a significant need for increased quantity and quality of investigation into the outcomes of treatment for hip instability in the dancer.

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Ballet dancers possess a large degree of joint motion throughout the body, but particularly in the hips.[1-3] The increased motion they possess may be due to advantageous osseous morphology (femur, acetabulum, and spinopelvic) or permissive soft tissues (muscle, tendon, ligament, and nerve). Excessive motion may be due to congenital or acquired (i.e., training) etiologies. This combination of factors that portends hypermobility may be both a blessing and a curse: a blessing for their career in dance but a possible curse to the stability and health of their joints.

There is a spectrum of mobility at the hip that ranges from stiffness (less than normal motion in any plane), to normal range of motion (Table 1 and 2), laxity (asymptomatic hypermobility), and instability (symptomatic hypermobility). Hip hypermobility is defined as more than normal motion in any plane. The difference between laxity and instability is the absence or presence of symptoms, respectively. Hip instability may present across a diverse spectrum from microinstability to frank dislocation.[1,4-6] Thus, "microinstability," by definition, mandates the presence of symptoms.[4] Microinstability can be a cause or effect of several other pathological conditions in the hip. These include osseous, chondrolabral, capsulo-

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Table 1 Normal Range of Motion Values

Sagittal Plane	Flexion	120° (with contralateral hip at 0° flexion)
		140° (with contralateral hip forced maximal flexion)
		75° (with knee at 0° flexion due to hamstring tension)
	Extension	20°
Coronal Plane	Abduction	40°
	Adduction	25°
Axial Plane	Internal rotation	35°
	External rotation	45°
	Distraction	0 mm
	Compression	0 mm

ligamentous, musculotendinous, or kinetic chain neuromechanical causes.

The nebulous term "microinstability" may be better termed "the hypermobile hip syndrome."[13] Hypermobile hip syndrome may be defined as a triad of symptoms (unwanted or undesired subjective complaints), signs (physical examination abnormalities with excessive motion that provoke the inciting symptoms), and imaging findings (plain radiographs, magnetic resonance imaging [MRI], computed tomography [CT], or ultrasound) consistent with instability. Femoroacetabular impingement (FAI) syndrome is a motion- and position-specific triad of symptoms, clinical signs, and imaging findings, similar to that of hypermobile hip syndrome.[14,15]

The attractiveness of extreme hip motion leads dancers, coaches, trainers, agents, directors, family members, friends, and others, to encourage forced stretching and greater amounts of motion attainment. However, if motion range is forced beyond a variable threshold, it may lead to symptoms. It is well known that abnormal osseous morphology associated with FAI is common in the general population and to greater degrees in athletes.[16] It is the addition of excessive motion that may take a dancer from asymptomatic laxity to symptomatic instability with or without abnormal osseous patho-

Table 2 Summary of Studies Evaluating Hip Range of Motion in Various Populations

Study	Participants	Number of Hips	Flexion (degrees)	Internal Rotation (degrees)	External Rotation (degrees)
Roaas and Andersson[7] 1982	Healthy males, 30-40 years age, Sweden	210	120.4	32.6	33.7
AAOS[8] 1965	Not reported	NR	113	35	48
Boone and Azen[9] 1979	Healthy males, 20-50 years age	56	121.3	44.4	44.2
Roach and Miles[10] 1991	Healthy males, females, 25-74 years age, USA	1,313	123 M (25-39 yrs); 121 M (40-59 yrs); 118 M (60-74 yrs); 123 F (25-39 yrs); 121 F (40-59 yrs); 119 F (60-74 yrs)	34 M (25-39 yrs); 33 M (40-59 yrs); 31 M (60-74 yrs); 33 F (25-39 yrs); 30 F (40-59 yrs); 29 F (60-74 yrs)	33 M (25-39 yrs); 31 M (40-59 yrs); 27 M (60-74 yrs); 36 F (25-39 yrs); 34 F (40-59 yrs); 32 F (60-74 yrs)
Hallaceli, et al[11] 2014	Healthy males, females; 19-32 years age, Turkey	1,974	128.2	43.3	41.9
Kumar, et al[12] 2011	Healthy males, females; 1-75 years age, India	648	138.5 (15-25 yrs); 137.0 (25-75 yrs)	31.2 (15-25 yrs; sitting); 23.7 (15-25 yrs; supine); 38.3 (15-25 yrs; prone); 27.2 (25-75 yrs; sitting); 20.5 (25-75 yrs; supine); 32.2 (25-75 yrs; prone)	35.8 (15-25 yrs; sitting); 30.7 (15-25 yrs; supine); 44.7 (15-25 yrs; prone); 30.5 (25-75 yrs; sitting); 25.9 (25-75 yrs; supine); 38.1 (25-75 yrs; prone)

NR, not reported.

morphology. This narrative review will discuss the anatomic characteristics, pathogenesis, risk factors, clinical signs and symptoms, investigations, and management of hip instability as it pertains to the dancer.

The purpose of this narrative review is to provide a qualitative summary of the ballet dancer's hip through a discussion of the anatomical characteristics, pathogenesis, risk factors, clinical symptoms and signs, management, and outcomes of hip instability treatments in ballet dancers.

Methods

A retrospective search was performed beginning November 1, 2017, for English language articles regarding hip stability in the dancer. Key words used included but were not limited to: dance(r), ballet, hip, hypermobility, range of motion, instability, microinstability, and laxity. PubMed, Scopus, and MEDLINE databases were used. The search was supplemented by cross-referencing articles. Anatomic, clinical, technical, and basic science literature was included and examined as it related to hip instability in the dancer. All non-English language publications and those not concerning dancers specifically were excluded.

Results

No studies were found that discussed hip instability in the dancer specifically. Two studies were found that discussed the dancer's hip as it relates to pain and injury in general. Additionally, 41 studies were found that discussed either hypermobility in general, hip pain, hip anatomy, or turnout as they relate to the dancer. These studies along with many others that investigate hip movement patterns, anatomy, conditions, signs and symptoms, management, and outcomes in the general and hypermobile population were compiled to discuss some of the nuances found in understanding, evaluating, and treating hip instability in ballet dancers.

Movement Patterns

Ballet dancers' hip range of motion necessitates extremes of flexion, extension, external rotation, and abduction. Furthermore, dancers strive to achieve "perfect turnout," which is the ability to stand with the second metatarsophalangeal joint of each foot at 180° to each other with the knees extended, pelvis in a neutral rotation, and the lumbar spine in minimal lordosis.[17,18] This is a unique aspect of dance that warrants detailed discussion.

At an anatomic level, turnout is a result of femoral and acetabular version (McKibbin's Index),[19] tibial torsion, and ankle and foot alignment.[20] The bony limitation for turnout at the hip is impingement of the femoral neck ("traditionally" known as FAI) or greater or lesser trochanter upon the posterior acetabular wall or ischium (ischiofemoral impingement).[21] In dancers, posterosuperior trochanteric impingement upon the ischium is likely more of a rule rather than an exception. This type of impingement is found in up to 84% of general population male and female cadaveric specimens, with just 10° of extension, 10° of adduction, and 29° of external rotation.[21] Theoretically, to reduce this impingement, the hip morphology should include a relatively retroverted shallow acetabulum, long femoral neck, coxa valga, high femoral head-neck offset, and femoral retroversion. Greater external tibial torsion will lead to an increased amount of turnout as well.[18,22]

Soft tissue components that affect turnout and motion at the hip include the hip capsule (iliofemoral ligament resists hip extension and external rotation; pubofemoral and ischiofemoral ligaments resist abduction; ischiofemoral ligament resists hip flexion; and the zona orbicularis resists distraction), and the periarticular musculotendinous units for contractile dynamic hip stability.[23,24] The internal rotators and adductors should be flexible to allow for maximal turnout.[18] Based on general anatomic and biomechanical knowledge, strong short external rotators and posterior fibers of the gluteus maximus are important for maintenance of standing turnout. This strength is especially important for maintaining turnout in the standing leg while the opposite leg is performing movement. Turnout is used in all dance forms to a certain extent, but ballet demands turnout in both legs nearly 100% of the time whether airborne or grounded.

Anatomic Findings

There are some unique anatomic findings in the dancer's hip that may explain their ability to attain the extreme range of motion they require. This includes multiple aspects of acetabular and femoral orientations in addition to periarticular soft tissue attributes. Regarding the acetabulum, normal acetabular version is said to be 15° to 20° of anteversion, yet acetabular retroversion is associated with greater hip external rotation.[25] Unfortunately, acetabular retroversion may be prone to anterior FAI.[26] Thus, theoretically, the ideal ballet hip has relative acetabular retroversion without excessive anterior coverage to allow for the greatest amount of femoral external rotation while maximizing the hip flexion required to perform the développé or battement en avant movement (Table 3). Harris et al.[41] found that more than 70% of professional ballet dancers had at least one sign of acetabular retroversion based on radiographic parameters including ischial spine, posterior wall, and crossover sign. This was far more common among males, which may indicate that males require more acetabular retroversion to compensate for their relative lack of soft tissue laxity. Soft tissue laxity is more common among females[27,28] and they may not require the osseous leeway needed by their male counterparts. On the other hand, Duthon et al.[29] found no difference in acetabular version measured by MRI between a group of pre-professional and professional ballet dancers versus controls. However, their population only included females and incorporating pre-professional dancers in their cohort confounds their findings because this population has not completed the selection process for becoming a professional ballet dancer. Nonetheless, acetabular version is a factor that can alter a dancer's range of motion

Table 3 Common Ballet Positions with Descriptions of Each Position and Their Effect on the Hip Joint Anatomy; In all Positions the Knees are Straight and Lumbar Spine is Held with Minimal Lordosis While Limiting Posterior Pelvic Tilt

Position		Description	Effect on Hip Anatomy
First		Thighs together, legs externally rotated to ideally achieve 180° from right second toe to left second toe.	Iliofemoral ligament taut, high posterior labral strain.
Second		Heels abducted approximately two foot breadths. Legs externally rotated to ideally achieve 180° from right second toe to left second toe.	Iliofemoral ligament taut with increasing tension on pubofemoral and ischiofemoral ligaments, high posterior labral strain.
Fourth		One heel approximately one foot breadth in front of the other with legs externally rotated to ideally achieve 180° from right second toe to left second toe. Forward foot is crossed to the line of the posterior metatarsophalangeal joint or tip of great toe.	Iliofemoral ligament taut bilaterally with increased ischiofemoral ligament tightness on the forward leg, high posterior labral strain on posterior leg.
Fifth		One leg in front of the other with forward heel at the tip of the posterior great toe. Legs externally rotated to ideally achieve 180° from right second toe to left second toe.	Iliofemoral ligament taut, high posterior labral strain.

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Position		Description	Effect on Hip Anatomy
Développé en avant		Standing leg maximally turned out with extended leg maximally turned out and maximally forward flexed at the hip.	Gesture leg ischiofemoral ligament taut, lateral or superior labrum strain.
Développé écarté devant		Standing leg maximally turned out with extended leg maximally turned out and maximally abducted at the hip.	Gesture leg iliofemoral, pubofemoral and ischiofemoral ligaments taut, high superior labral strain.
First arabesque		Standing leg turned out maximally with extended leg maximally turned out and maximally abducted at the hip.	Gesture leg iliofemoral ligament taut, high posterior labral strain.

Gesture leg = leg off the ground.

(ROM) at the hip, but the shape of the proximal femur is also a significant osseous factor to consider.

Normal femoral version is approximately 10° to 25° of anteversion.[30,31] Femoral retroversion has been shown to be associated with greater hip external rotation.[32] Thus, decreased femoral version may be advantageous to the ballet dancer for obtaining optimal turnout. Bauman et al.[33] found femoral version in professional ballet dancers was not decreased on average when compared to a pooled average found in general population studies. The authors noted, however, that no dancer possessed excessive anteversion (average: 11.4°; range: 4° to 24°). Conversely, a more recent study by Sutton-Traina et al.[34] found that professional and university level dancers had significantly lower femoral version than non-dancers. Interestingly, Hamilton et al.[35] found that pre-professional dancers who trained for more than 6 hours per week during the ages of 11 to 14 years had significantly less femoral version than those who trained fewer hours during those ages. In combination with a prospective study by Svenningsen et al.[36] that found femoral version decreases from childhood until proximal femoral physeal closure, this suggests that molding or adaptation to stress at an early age may result in favorable femoral alignment. If the dancer does not possess an advantageous amount (degree of which is yet to be determined) of femoral version, posterior impingement of the femoral neck on the acetabulum may result in a degree of anterior subluxation when attempting to obtain the desired amount of hip ROM.[1,4,29,37,38] In addition to axial plane angular differences of hip morphology, coronal plane variations also affect ROM at the hip and can contribute to impingement.

The normal femoral neck-shaft angle is approximately 130°,[30] and decreased neck-shaft angles, or varus morphology of the femoral neck, has been associated with protrusio and pincer-type FAI which can reduce hip ROM and increase repetitive impingement.[39] Even without concurrent acetabular pathomorphology, a coxa vara hip may demonstrate ischiofemoral impingement, particularly with abduction.[40] This has been seen with greater trochanteric impingement in the side splits position, which may result in subluxation of the femoral head.[1,29,37,41] Considering this, it is not surprising that professional ballet dancers have been found to have higher neck-shaft angles, or coxa valga, compared to age-matched team sport athletes.[42] This morphology allows for greater ROM by decreasing the likelihood of greater trochanteric impingement on the pelvis. Unfortunately, valgus neck-shaft angles have been associated with lesser trochanteric-ischial (ischiofemoral) impingement particularly with hip extension and adduction,[43-45] which may impede the dancer from obtaining the desired extent of the arabesque position (Table 3). Thus, the ideal neck-shaft angle is yet to be elucidated.

There is a complex interplay of the osseous morphology of the acetabulum and femur. Taking all these factors into consideration, in general, the ideal morphology for allowing the greatest amount of hip ROM while avoiding impingement is relatively low acetabular and femoral version angles and relatively high femoral neck-shaft angles. While variations in the osseous structure of the hip may allow for increased ROM, the periarticular soft tissues are a confounding factor in the permissiveness of the joint as well.

The hip capsule is one important soft tissue stabilizer of the hip joint. It is composed of the iliofemoral ligament (medial and lateral limbs) anteriorly, the pubofemoral ligament anteroinferiorly, the ischiofemoral ligament posteriorly, and the zona orbicularis circumferentially.[23] Individually they have been found to limit movement in a few distinct ways.[46] Martin et al.[46] and others[47-50] have found that the lateral limb of the iliofemoral ligament predominantly limits external rotation. The medial iliofemoral ligament limits extension and, while in extension, significantly limits external rotation. The pubofemoral ligament limits abduction and, while in abduction, limits external rotation.[46-50] Ischiofemoral strain is highest when the hip is in maximal internal rotation and abduction.[48] Based on these findings, it is easy to see the anterior structures of the hip capsule are constantly stretched by the dancer who continuously works to obtain increased turnout in extension, abduction, and flexion at the hip. There are no reports of the specific characteristics of the dancer's hip capsule, but the hip capsule has been shown to be thinner in subjects with hypermobility, which is common among dancers.[51]

Another important soft tissue stabilizer in the hip is the acetabular labrum, which is a cartilaginous structure that deepens the hip socket providing additional support to the stability provided by the bony acetabulum.[52] The labrum increases acetabular surface area by 22% and volume by 33%, on average.[52] Additionally, the intact labrum creates a suction seal with negative fluid pressurization in the joint that increases femoroacetabular stability.[53] Thus, when the labrum is torn, the dancer may suffer from instability. In the dancer, the superior or posteriosuperior labrum experiences the most strain in developpé or battement a la second or écarté (external rotation and abduction), standing turnout (external rotation in neutral flexion), and arabesque (extension, external rotation, and adduction) positions (Table 3).[54,55] The lateral or superior labrum experiences the most strain in developpé or battement en avant (flexion and external rotation, Table 3).[55] These are the common extreme motions performed by the dancer and demonstrate that the dancer places the most strain on the lateral and posterior aspects of the acetabular labrum on a daily basis. While there are unique anatomic variations seen in dancers, it is not known whether these variations are genetically inherent to the individual or are an adaptive response occurring as the dancer grows and progresses through training. It is likely a combination of both factors.[56] Similarly, certain conditions are common in dancers likely because of the inherent demands they place on their bodies and the advantage of increased hip ROM that certain conditions provide.

Common Conditions

Ligamentum Teres Rupture

The ligamentum teres (LT) was thought to be a vestigial structure, but of late a LT tear has come into focus as a possible source of hip pain and instability.[57,58] Many authors have suggested LT tears are either a result of hip instability or exacerbate hip instability.[59-62] While LT tears have been found to be more prevalent in professional ballet dancers, LT tears have not been found to be associated with increased hip ROM nor generalized joint hypermobility in this population.[58] The LT is known to become taut during hip external rotation[60,63,64] and acts as a secondary restraint in high flexion, adduction, and external rotation.[47] Martin et al.[65] found that the LT restricted external and internal rotation in cadaveric specimens particularly with the hip in neutral extension. The constant strain on the LT from years of practicing turnout may be one reason dancers have a higher prevalence of LT tears than other athletes. It is important to note that while LT tears may be more prevalent in dancers, this pathology is not necessarily associated with pain.[58] Unfortunately for the dancer, LT tears, whether or not they are symptomatic, are associated with damage to the acetabular labrum and cartilage.[66-68]

Labral Tears

Labral tears have been identified as a source of hip pain[69-72] and are common in the dancer population. Duthon et al.[29] found that 90% of one cohort of dancers had acetabular labral or chondral lesions on MRI. Yin et al.[73] found acetabular labral injuries accounted for 5.9% of all injuries in the pediatric dance population. In fact, Cianci et al.[74] found the highest number of labral tears (18.4%) were sustained by dancers versus other athletes over a 3-year prospective chart review of patients 8 to 20 years of age. While imaging studies by Kolo et al.[37] found the number of labral lesions in female pre-professional and professional ballet dancers was not significantly different than controls, the dancers had more severe lesions, particularly in the superior and posterosuperior regions. When compared to other athletes matched for age and sex, Mayes et al.[75] found that professional and retired professional dancers had a similar prevalence of labral tears. However, it was noted that the presence of labral tears was significantly associated with age.[75] Labral lesions in dancers are similar in morphology to patients with FAI but different in location.[75] Lesion are found in the superior and posterosuperior region versus the anterior and anterosuperior location where they are most commonly found in the general and sporting population.[29,76] This suggests that the dancer experiences a range of motion induced FAI and unique activity related risk for various portions of the labrum. While dancers may have a high prevalence of labral pathology, they may or may not be symptomatic. Duthon et al.[29] found no significant difference in radiographic, ROM, and MRI findings between symptomatic dancers with labral tears and asymptomatic dancers with labral tears. While the source of pain remains unclear, the symptomatic dancer may experience pain due to a combination of dynamic and static mechanical stressors around the hip leading to periarticular muscle disfunction.[77] Relevant to any discussion of labral injuries in dancers is a discussion of the high prevalence of labral tears in asymptomatic team sport athletes.[78] Thus, when clinically evaluating a dancer, the astute clinician must be cognizant of the latter and ensure to "treat the patient, not the MRI."[15]

Femoroacetabular Impingement

Femoroacetabular impingement (FAI) syndrome[15] is another cause of hip pain and instability in the dancer. Instability in this setting is due to the levering action of the femur on the acetabulum when a dancer attempts ROM beyond the point of impingement. There are two main morphologies observed in FAI syndrome: cam and pincer. Cam morphology is a complex three-dimensional asphericity at the femoral head-neck junction. It is measured radiographically by increased alpha angle, decreased head-neck offset, and decreased head-neck offset ratio. Pincer morphology is more complex and refers to morphologic over-coverage, with either a focal loss of cranial acetabular anteversion (relative retroversion at 12 to 3 o'clock; crossover sign [but must ensure not a prominent anterior inferior iliac spine, especially in dancers]), global retroversion (posterior wall sign, ischial spine sign), or global over-coverage (lateral center edge angle > 40°) with or without a deep acetabulum (coxa profunda) and deep femoral head (protrusio acetabulae). Prominent subspine morphology (anterior inferior iliac spine) is a very common cause of subspine impingement in dancers[79] as contact occurs distal anteromedially on the femoral neck with excessive straight sagittal plane flexion.[80]

There is evidence that FAI is more prevalent in athletes in general due to "stress on the developing physis"[81] resulting in physeal overgrowth and subsequent cam formation.[82] The maximal period of osseous cam growth likely occurs around 11 to 12 years of age.[82] However, FAI would appear to be detrimental to the dancer's hip ROM by limiting motion beyond the degree to which impingement occurs. Accordingly, there is a lower prevalence of cam morphology in dancers,[42] but they are not immune to it. Mayes et al.[83] found the superior alpha angle lower in ballet dancers (38.9° ± 6.9°) compared to other athletes (46.7° ± 10.6°). Harris et al.[41] reported a 25.5% prevalence of cam morphology in professional ballet dancers, with a significantly greater prevalence in male dancers than females (48% hips and 57% subjects vs 8% hips and 12% subjects, respectively). Values for female dancers are less than that reported for the general population (37%), and values for males are less than that for the sporting population (54.8%).[16] Thus, overall, dancers likely have a lower prevalence of cam morphology compared to other athletes due to its detrimental effect on hip ROM and subsequent selection bias.

Similarly, dancers may have radiographic signs of pincer impingement.[41] However, more commonly they are found to have impingement because of the extreme ROM they obtain at the hip.[4] Thus, they develop unique patterns of FAI.[16] Whereas signs of FAI, such as cartilage or labral findings, are commonly seen in the anterior and anterosuperior acetabulum, FAI in dancers is overwhelming found at the superior or posterosuperior acetabular rim and is often associated with a levering action producing hip subluxation.[1,29,37,84] It is this subluxation that contributes to hip instability in the dancer. Results from Kolo et al.[37] indicate that this constant impingement may lead to damage to the acetabular cartilage with subchondral cyst formation or pitting in the femoral neck. Additionally, dancers experience greater trochanteric-pelvic impingement that occurs particularly in the grand écarte facial position.[1] Charbonnier et al.[54] found dancers without radiographic signs of pincer or cam morphology experienced femoroacetabular impingement and subluxation events during four common ballet movements (développé à la seconde, grand écart facial, grand écart latéral, and grand plié). Thus, there are likely a myriad of dancers without radiographic definitions of FAI that experience femoroacetabular impingement while dancing due to their increased ROM.

Hypermobility

Hypermobility is associated with instability in many joints, including the hip.[85-88] Generalized joint hypermobility (GJH) and joint hypermobility syndrome (JHS) have been shown in several publications to be more prevalent among dancers.[89-93] Per the 2017 International Criteria for Ehlers-Danlos syndrome, terminology referring to JHS is now called "hypermobility spectrum disorder" (HSD); similarly, previous terminology referring to Ehlers-Danlos-hypermobility type (EDS-HT / EDS III) is now called "hypermobile Ehlers-Danlos syndrome" (hEDS).[85] The latter still lacks any known genetic marker, but there is a high prevalence of hypermobility-associated connective tissue variants in professional ballet.[56] Hypermobility is often measured via the Beighton score, but may also be evaluated by the Brighton criteria, Hakim and Graham, Carter and Wilkinson, Rotés criteria, and other measures.[94-96] However, they are all very similar in the measurements used and have been found to be equally effective.[97] Devitt et al.[51] found hypermobile individuals (Beighton ≥ 4) had significantly less hip capsular thickness (< 10 mm) than individuals without hypermobility. They also reported a higher incidence of LT tears in patients with capsular thickness of ≤ 7.5 mm.[51] Stein et al.[88] described the case of a hypermobile ballet dancer who sustained a non-traumatic anterosuperior hip dislocation during a ballet class. The authors noted that the femoral head was buttonholed through the rectus muscle forcing them to perform an open reduction. They found the patient had a Beighton score of 9 and hip dysplasia. While hypermobility may be advantageous by increasing the dancers hip ROM, the hypermobile dancer may be at increased risk of hip instability secondary to the molecular and gross changes seen in the soft tissue stabilizers of the hip.

Hip Dysplasia

There is a high prevalence of dysplasia and borderline dysplasia in the ballet population.[41,42] Harris et al.[41] found 37% of professional ballet dancers had dysplasia with 89% having dysplasia or borderline dysplasia in at least one hip. It is not clear whether this is a trait self-selected through the training process or is due to the training process itself. Dysplasia is often diagnosed on an anterioposterior pelvis radiograph via the lateral center edge angle (LCEA). However, this is an overly simplistic two-dimensional representation of a complex three-dimensional entity. On radiographs, the Tönnis angle, anterior center edge angle, femoral head extrusion index, Sharp's angle, Shenton's line, and medial clear space must also be evaluated.[41] Radiographic measurements of dysplasia do not necessarily indicate stability of the hip and Wyatt et al.[98] described the femoro-epiphyseal acetabular roof (FEAR) index as a radiographic indication of hip stability in the borderline dysplastic hip. Three dimensionally, MRI and CT may better define true coverage characteristics. Anatomically, the dysplastic acetabulum may exhibit under-coverage in any direction (anterior, superolateral, posterior) where it is shallower or more vertical than the normal acetabulum.[99] This global under-coverage results in increased motion in the hip, particularly in flexion, rotation, abduction, and adduction, but has not been shown to significantly affect extension.[100] Steppacher et al.[100] found a higher prevalence of impingement at the anterior inferior iliac spine in the dysplastic hip compared to controls. The dysplastic hip has been shown to have a much higher incidence of labral tear,[101] larger labrum,[102,103] hypertrophied iliocapsularis muscle,[104] and hypertrophied LT.[105] These findings indicate that the dysplastic hip is unstable and illustrate the increased strain on the surrounding soft tissues that are attempting to adapt to the bony instability caused by dysplasia and create other static and dynamic stabilizers. Furthermore, there is a higher prevalence of hypermobility among individuals with hip dysplasia.[106-109] Thus, the dysplastic hip is unstable due to its lack of bony coverage but is often also associated with inherent or acquired soft tissue laxity and carries a high risk of hip instability.

Clinical Signs and Symptoms

The practitioner must maintain a high index of suspicion of instability in the dancer presenting with hip pain, as it significantly confounds treatment decisions. Hip instability usually presents as a deep anterior groin pain.[6,13,110] The patient may also complain of pain in the lateral hip, thigh, or buttock and exhibit a "C-sign" or "between the fingers" sign.[6] Often, the patient will complain of activity related pain especially associated with extremes of motion including battement, développé, grand plié, grand saut de chat, and any other movements that involve extreme flexion, abduction, and external rotation (see Table 3).[5,29] They may complain of giving way, fear, apprehension, or instability,[111] but more often the dancer will paradoxically complain of hip stiffness. Any personal or family history of connective tissue disorders (i.e., Marfan syndrome, Ehlers-Danlos syndrome, osteogenesis imperfecta, and so forth) should be obtained from the dancer.

The physical exam will often identify limited hip internal rotation with increased external rotation with normal total rotation (femoral version influence) in conjunction with excessive flexion, abduction, and extension.[2,83,112] Gait or standing examination may identify abductor muscle weakness via Trendelenburg gait or stance.[6,13,79,110] The posterior impingement test (hip extension with external rotation) may cause pain or apprehension, and it is important to distinguish these two subjective complaints.[13,110] The anterior impingement sign (flexion, adduction, internal rotation [FADIR]) is sensitive, but poorly specific, for labral tears in dancers and will often elicit discomfort.[75] The dial, log roll, or external rotation recoil test will show a lack of end point or failure to return to a comparatively symmetric rotation when passively externally rotated.[60] The external rotation recoil test has been shown to correlate well with capsular laxity.[113] The flexion abduction external rotation (FABER) test may reveal asymmetry (distance from knee to examination table) between the affected and nonaffected side indicating impingement.[114] Apprehension with axial distraction and subsequent resolution of this with axial loading may be indicative of instability. Finally, a Beighton score should also be measured, calculated, and recorded for these patients. A Beighton score ≥ 5 indicates GJH.[115]

As described by Harris et al.,[41] the exam should also include the following radiographs: standing anteroposterior (AP) pelvis, standing false profile of the affected hip, and supine Dunn 45°. These images should be evaluated for signs of impingement and dysplasia. Measurements on the AP radiograph should include: Tönnis grade and mean joint space (medial, middle, lateral sourcil) to evaluate for arthritis; alpha angle to evaluate cam morphology; neck-shaft angle and tip of greater trochanter relation to center of femoral head for coxa valga or vara deformity; and Tönnis angle, lateral center edge angle, ischial spine sign, posterior wall sign, crossover sign, coxa profunda, protrusio acetabulae, and femoral head extrusion index to identify under- or over-coverage of the acetabulum.[116] On the false profile, anterior center edge angle should be measured to evaluate for acetabular coverage, anterior inferior iliac spine type should be evaluated for possible subspine impingement, and alpha angle for cam morphology.[117,118] On the Dunn 45° radiograph, alpha angle, head neck offset, and head neck offset ratio should be measured to evaluate for cam morphology.[41]

Management

Non-Operative

The initial management of hip instability in the dancer should include education, limited or relative rest, activity modification, guided physical therapy exercises, and medical management as needed (topical, oral, intra-articular injection). Education for the dancer and the company training and artistic staff is one of the most critical components of a successful non-surgical rehabilitation program. Dancers should be evaluated for alignment and ballet technique errors with a focus on decreasing stress on the capsulolabral, musculotendinous, and kinetic chain spinopelvic mechanoneural painful hip structures.[119] With the high prevalence of hip dysplasia and hypermobility, therapy should include exercises to increase stability to the joint with peri-articular muscle strengthening. Exercises should focus specifically on the hip flexors, hip abductors, short external rotators, abdominal core, and low back muscle groups.[6] Specific exercises have been outlined in a prior publication and have shown a decrease in injuries in dancers that perform these exercise for as little as 4 weeks.[120] Sensory motor training may also be beneficial in this population due to the decreased proprioception associated with hypermobility syndromes.[121] Corticosteroid injections in conjunction with local anesthetic into the hip joint can demonstrate significant utility for both diagnostic and therapeutic purposes.[70,122] Even short-term relief from an intraarticular injection confirms an intraarticular pain generator. It can allow a dancer to get through a particular repertoire or season until a more convenient time to pursue more invasive measures. Injections can even provide long-term relief for patients in some situations and may be cost effective.[62,123] Intraarticular platelet rich plasma (PRP) injections have been studied for pain relief in the setting of osteoarthritis with limited short-term success.[124,125] While there is no literature on its use in hip instability, it is another minimally invasive option for the dancer with hip pain. It does have the advantage of no artificial synthetic ingredients. It has the disadvantage of post-injection downtime due to the lack of intra-articular local anesthetic (as this degranulates alpha granules and prevents PRP efficacy). Further, this precludes any immediate diagnostic confirmation of the intra-articular location of pain and other symptoms. Surgical intervention is indicated in the presence of failure of all non-surgical treatments and the dancer being dissatisfied with their hip condition due to the inability to dance.

Operative

Operative procedures for dancers with intra-articular pathology may be either open, arthroscopic, or both and are non-arthroplasty in nature. Arthroscopic hip preservation surgery is effective in treating pain arising from FAI and labral tears.[126,127] Its success is predicated on the absence of significant dysplasia (nothing more than borderline) and osteoarthritis (more than Tonnis 1). Labral tears should be treated arthroscopically with labral preservation.[128] Pincer and cam morphologies may be addressed with acetabular and femoral osteoplasty, respectively.[80,81] Hip instability due to capsular insufficiency may also be treated with capsular plication or inferior capsular shift.[86] Subspine evaluation and decompression is likely highly common and necessary in dancers in combination with ensuring distal anteromedial cam evaluation and correction as needed.[79] Ligamentum teres tears may be effectively managed with arthroscopic reconstruction in the setting of instability after LT debridement or complete LT tear.[57] Different graft options have been reported, including polyethylene terephthalate,[129] tibialis anterior allograft,[57,87] and semitendinosus tendon autograft.[59] Dysplasia may be effectively treated with a variety of periacetabular osteotomy (PAO) techniques (the Ganz Bernese PAO is most common) with or without staged or simultaneous hip arthroscopy for cam, pincer, labrum, articular cartilage, capsule, and ligamentum teres pathology.[130] Femoral version abnormalities may be treated with derotational osteotomy for excessive anteversion or rotational osteotomy for excessive retroversion.[131,132] Dancers commonly present with more than one pathology and each one must be address accordingly. Most importantly, the underlying pathoanatomy must be considered and addressed prior to correction of more peripheral pathologies.

Outcomes

Outcomes of treatments for hip instability in the dancer are limited. However, a few case reports have been published. Nonoperative treatment has been shown to be successful in treating FAI in the general and athletic population.[62,133,134] There are no reports of the effects of non-operative management for hip instability in general. However, it is widely accepted that a trial of non-operative treatment is recommended prior to surgical intervention.[62,74,80,135-139] Specifically in the dancer, Khoo-Summers et al.[119] showed that functional alignment assessment and correction with formal and home therapy exercises relieved hip pain from a suspected labral tear with return to pain free dancing in one professional ballet dancer.

Simpson et al.[129] described a LT reconstruction in a professional dancer with a complete LT tear and concomitant acetabular osteochondral lesion. The dancer had failed non-operative and prior operative management with microfracture and capsular plication. At 8 months postoperatively, the patient had not returned to dance but had improvement of symptoms and was progressing into a return-to-dance physical therapy program. Other reports of runners[59] and patients with Ehlers-Danlos syndrome (EDS)[87] have shown positive outcomes with return to pain free activity after LT reconstruction as well.

Kocher et al.[140] reported on a series of 30 patients with "a significant history of dance" who underwent labral debridement for refractory hip pain limiting their ability to dance. All but two patients had a decrease in symptoms postoperatively. Twenty-two (78%) subjects returned to dance and 19 (86.4%) of these subjects were satisfied with their level of activity. In the general population, labral repair and debridement have shown improved postoperative outcomes.[141-143] Repair was shown to be superior in two studies.[141,142] One study showed no significant difference in outcomes between the two procedures, but this may be because the debridement group was older and likely placed less demand on their hip than the repair group.[143] Furthermore, the labrum's contribution to hip stability[144,145] warrants its repair in the dance population with their tendency toward hip hypermobility.

Dancers treated arthroscopically for FAI have been shown to have a high rate of return to dance.[146] Ukwuani et al.[146] found that 97% of dancers returned to dance at an average of 6.9 months after hip arthroscopy for FAI. Procedures included labral repair, acetabular and femoral osteoplasty, subspine decompression, and microfracture based on patient needs. All patients underwent capsular closure at the end of the procedure. All patients had improved patient reported outcome scores postoperatively that met minimal clinically important difference criteria. No difference was found in outcomes between patients with or without generalized hypermobility based on their Beighton score. Most dancers were able to return to a higher level of dance participation after surgery.

In the setting of capsular redundancy, treatment with arthroscopic capsulorrhaphy was reported by Philippon[147] in one professional dancer; the procedure was successful in treating symptoms of hip instability and the patient returned to pre-injury activity. Hip arthroscopy with capsular plication may be a better option for the dancer. It has been shown to have good outcomes for hip instability in the EDS population.[86] While this population does not necessarily place the same physical demands on their body, the extreme laxity they are known to have is beyond that of the dancer such that their outcomes may be comparable. Furthermore, Larson et al.[148] and Domb et al.[149] have shown improved patient reported outcome scores in the general population with mild dysplasia who underwent hip arthroscopy with labral repair and capsular plication for hip instability.

Novais et al.[150] described a series of dancers with moderate to severe hip dysplasia treated with PAO. They found patient reported outcome scores improved significantly postoperatively, and 63% (19/30) returned to dance by 1 year. Those that did not return to dance had no difference in demographic, physical, or radiographic features. However, they noted that postoperative flexion and abduction were significantly reduced in all subjects.[150] It is unclear if the reduced motion will negatively impact subjects' dancing career. Also, it is uncertain whether the subjects that did not return to dance did so by choice or due to physical limitations. Other studies report similar return to play rates in the general athletic population after PAO.[151-153]

Limitations

The objective of this narrative review was to discuss the anatomical characteristics, pathogenesis, risk factors, clinical symptoms and signs, management, and outcomes of hip instability treatments in dancers. Thus, it is not meant to be an exhaustive review of all aspects of hip instability in the ballet dancer as this would take chapters. Due to the expansive and complex nature of hip instability in the ballet dancer, and the limited literature addressing this topic directly, a systematic review was not undertaken for this review. Thus, not all data present in the literature may have been presented in this article.

Conclusion

Hip hypermobility is prevalent in the ballet population and is a clear advantage. However, it may increase the risk of instability. It is important to identify the multifactorial osseous and soft tissue etiology of hip and groin pain in dancers. Practitioners should have a high level of suspicion for hip instability in the dancer presenting with hip pain and treat accordingly. There is a significant need for increased quantity and quality of investigation into the outcomes of treatment for hip instability in the dancer.

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