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## Functional movement impairment in dancers: An assessment and treatment approach utilizing the Biomechanical Asymmetry Corrector (BAC) to restore normal mechanics of the spine and pelvis

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### Abstract

Musculoskeletal injuries to the spine and pelvis are common in dancers. These injuries are associated with mechanical dysfunctions that impair spinal adaptation to the movement demands of the art form. This article introduces the biomechanical asymmetry corrector (BAC), a dynamic assessment and treatment tool, designed to restore normal spinal mechanics and functional movement patterns in dancers. A discussion of lumbo-pelvic mechanics and dance injury provides a theoretical context for describing exercises on the BAC.

**Keywords:** Dance injury; Remedial exercise; Lumbo-pelvic mechanics; Scoliosis; Biomechanical asymmetry corrector

### 1. Introduction

The spine and pelvis are common sites of musculoskeletal injury in professional dancers [1,2]. These injuries are associated with mechanical dysfunctions [3] that impair the dancers' ability to execute the full range of movement required of

the dance discipline. A thorough biomechanical assessment to identify the mechanical dysfunctions associated with functional impairment is essential for determining treatment [4]. The treatment must address the neuromusculoskeletal demands of the art form if the professional dancer is to return to the requisite high level of function [5]. In view of these objectives, the authors developed the biomechanical asymmetry corrector (BAC), a dynamic tool for the assessment and treatment of dance-related injuries to the spine

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and pelvis. The BAC is designed to restore normal spinal mechanics and functional movement patterns in dancers.

This article reviews the biomechanics of spine and pelvic function in relation to dance technique and the genesis of back injuries in dancers. It introduces the BAC and describes its applications to assessment and treatment strategies. To provide a theoretical context, the salient features of spinal mechanics including spinal adaptive responses, functional alignment and coupling mechanics are presented.

## 2. Injury patterns in dancers

Dance injuries are typically categorized as either acute, resulting from a sudden impact or deforming force, or overuse, resulting from repetitive microtrauma [6]. Uniting the two ends of this injury spectrum is the idea that the cumulative effects of constant, occupational stresses of moderate force can give rise to the same kind of musculoskeletal injuries as a sudden trauma [7,8]. Whether the precipitating mechanism is sudden or chronic, asymmetrical loading of articular and soft tissue structures is a common denominator in dance injuries. This results in mechanical dysfunction and movement impairment if there is an underlying weakness.

Mechanical dysfunction in the spine (defined as an increase or decrease in spinal motion and joint play from the normal range) [9,10] alters the normal adaptive spinal response to many dance movements. Dance movements routinely involve, for example, both leveling and unleveling of the pelvis. The normal adaptive response to unleveling of the pelvis is lumbar sidebending to the high side of the pelvis [11]. The thoracic spine, meanwhile, compensates for the displaced center of gravity by contralateral sidebending [12]. Complex or 'off-axis' [13] dance movements increase the radius of the center of gravity displacement, further challenging the thoraco-lumbar adaptive response. Adaptive mechanics have to match both the subtle and extreme ranges of dance movement so that the dancer's center of gravity can effectively shift across the movement radius. This normal adaptive response requires mobility of

spinal segments and adequate joint play in the hips (e.g. medial and lateral glides) [12]. The adaptive response serves to distribute loading throughout the spinal curves thereby minimizing the concentration of injurious force at any one particular vertebral level [3].

Injury, however, occurs when the movement demands of dance training and choreography exceed the dancer's capacity for dynamic spinal adaptation. The presence of mechanical dysfunction in the spine and hips impairs the mobility necessary for normal adaptation [3,10,14]. Impaired function is in turn compensated for by neighboring or even distant motor segments. The increased demands on compensating structures may result in further injury [15]. It is important to note that disturbances in mechanical function alone do not cause injury [11]. When changes in mechanics are amplified by the repetitive motions of dance training, extreme ranges of motion or sudden impact, injury can occur.

Clearly, in addition to faulty spinal adaptation, there are many other patterns of dance injury. Rotational movements of the spine, pelvis and hip, performed at end-ranges of joint capacity can precipitate injury of ligamentous and musculoskeletal structures [14,15]. The risk of injury increases as combined rotation, extension and flexion movements of the spine progress toward the extreme. Muscle imbalances also contribute to faulty mechanics and asymmetrical loading of the spine and pelvis [3,4,6,16]. If a force is then imparted through the lower extremities, as in jumps, or from the trunk above, as in lifts, the potential for injury from the compressive, tensile and shear overload to the various structures is increased [6,12,15].

## 3. Clinical assessment of dance injuries

The dancer's history of asymmetrical movement limitation helps guide the clinician's line of inquiry in the biomechanical assessment of underlying mechanical dysfunctions. In the clinical setting, dancers typically describe their physical complaints in functional terms. They describe asymmetrical limitation of movement when performing dance steps such as *arabesque*, *developpé*, and

turn-out on one side versus the other. Loss of symmetry with active movements, such as backward bending and sidebending, is characteristic of patients with spine dysfunction [4].

Clinical biomechanical assessment of lower quarter dysfunction has been eloquently described by several osteopathic and physical therapy experts, most notably Fred Mitchell [17], Philip Greenman [18], Mark Bookhout [4], Robert Donatelli [13] and Diane Lee [19]. Of the tests they describe, those that are of particular relevance to dance injury assessment include: observation of posture, analysis of physiological spinal motion, ROM and strength testing of the hips, extensibility tests for the trunk and pelvic girdle musculature, sacroiliac and lumbo-sacral mobility tests (e.g. hip drop test), weight-bearing proprioceptive tests and biomechanical assessment of foot and ankle mechanics in both open and closed chain function and gait.

In addition, evaluation of the dancer should include assessment of alignment and technique [5] in basic dance positions and transitional dance movements (e.g. *plié*, *relevé*, *tendu*). In dancers with a history of back problems, it is important to assess technique in lifts and jumps.

The BAC, in the authors' experience, can be used as a dynamic tool to enhance current evaluation methods for the injured dancer (see BAC exercises one through six). In the BAC evaluation, emphasis is placed on assessment of spinal mobility, muscle function and adaptive responses to pelvic and lower extremity movement.

The BAC is particularly useful in assessing faulty mechanics in the thoraco-lumbar and pelvic complex, including faulty adaptive spinal response to pelvic obliquity (unleveling of the pelvis). The authors acknowledge Karel Lewit's [11] criteria for a normal response to movements involving pelvic obliquity (see below). They have included these criteria in their assessment on the BAC:

- (1) the apex of the induced lumbar curve is to the lower side;
- (2) there is contralateral coupling of rotation;
- (3) the pelvis shifts to the higher side;
- (4) the thoraco-lumbar junction remains aligned with the sacrum;

The responses described above, may be altered in the case of chronic pelvic obliquity. This obliquity, associated with fixation of the spinal adaptive curves, is often produced by a structural or longstanding functional leg length discrepancy [3,20]. Radiographic (X-ray) analysis helps confirm the presence of a leg length discrepancy and changes in static function [11]. In chronic pelvic obliquity, the posterolateral trunk muscles and lumbodorsal fascia are tighter on the high side of the pelvis, while the abductors and tensor fascia lata are tighter on the low side. On the high side, the femur assumes an adducted position in relation to the pelvis, while on the low side the femur is relatively abducted [3,15,21]. Assessment of spinal and pelvic mobility on the BAC helps identify these musculoskeletal asymmetries and the component joint and soft tissue restrictions that impair accommodation to leg length discrepancy.

#### 4. Description of the BAC and functional treatment goals

The BAC apparatus consists of a framework that supports two rotary discs on tracks. The discs function as fulcrums for spinal mobilization. Additionally, a foot bar and lever permit leveling and unleveling of the pelvis in both supine and standing positions. In supine, the lateral trunk muscles create the unleveling, while in standing the pelvi-femoral muscles unlevel the pelvis. The unleveling exercises are used to assess and treat adaptive spinal responses to pelvic motion.

There are many ways to set-up the discs for active mobilization of specific joint restrictions. The discs can be used dynamically along the track or locked in place. Axial rotation, localized to a specific spinal segment, is concurrent with translation of the superior and inferior aspects of the segment through an arc of motion. Use of the discs in a horizontal slide along the track imparts localized translation to the specific segment. Patient positioning relative to the discs determines the site of movement localization. For example, 'locking up' a segment of the lumbar spine via axial rotation on the lower disc, provides the counterforce for localized thoracic movement on the adjacent upper disc. By attaching light

springs to the discs, they can also be used to produce longitudinal traction on the spine.

With the discs removed, two underlying platforms serve as surfaces for standing exercises. Pivoting foot plates, with the fulcrum located in the mechanical axis of the legs [7], can be added to the platforms to provide dynamic surfaces for turn-out. Spring resistances of variable tension can be applied to the platforms, foot plates and foot lever to create muscular challenges.

In accordance with the SAID principle (specific adaptation to imposed demand) of functional rehabilitation, retraining exercises on the BAC are directed toward the specific demands of dancing [15,22]. Advanced exercises on the BAC, performed in parallel and turned-out positions, replicate functional dance positions and movements. The exercises challenge weight distribution, alignment, muscle synergies, proprioception and adaptive spinal responses. Corresponding to the human developmental sequence [23], exercises on the BAC progress from quadruped to contralateral motion and then to weight-bearing stance.

The inspiration for the design of the BAC and development of the exercise progression derives from Rudolph Klapp and Yves Cotrel's early contributions to treatment of scoliosis. In 1904, Klapp [24,25] introduced an approach to corrective exercises for rotoscoliosis based on principles of movement localization and coupling mechanics for derotation. Klapp identified six variations of the quadruped position to localize the 'straightening effect' of the exercises to specific apexes of the scoliotic curves. For example, in the quadruped position with the trunk parallel to the ground, movement is localized to the eighth thoracic segment, while in quadruped with the body lowered onto the elbows, the T3 segment is localized.

In the 1970s, Dr. Yves Cotrel elaborated on this approach to scoliosis curve correction with a combination of exercises and traction based on the principles of elongation, derotation and lateral flexion known as EDF [26]. Directed breathing techniques are utilized in conjunction with the exercises. In one exercise, for example, the patient assumes a heel-sitting, prayer position to stabilize the lumbar spine, and then, on inhalation, the

patient 'walks' the arms laterally to the side of the thoracic convexity. This corrective movement is intended to elicit 'paradoxical' derotation and mid-line translation of the vertebrae.

The Klapp/Cotrel treatment concepts of movement localization, directed breathing and corrective coupling mechanics are incorporated in the BAC program. Indeed, the BAC was initially conceived of in 1992 for selective use with the scoliotic dance patient population [27]. Scoliosis, which occurs with higher than normal frequency among ballet dancers [28], can complicate the treatment of back injuries. More recently, the clinicians have extended use of the BAC to treatment of back-injured dancers in general.

## 5. Treatment goals

The objective of treatment is to return the patient to functional dance activities. Toward this objective, remedial exercises on the BAC serve to normalize spinal adaptive mechanics and correct faulty movement patterns. This requires restoration of functional alignment, segmental motion and synergistic muscle function. Specifically, treatment goals on the BAC are as follows:

- (1) Restore sagittal spinal curves (thoracic kyphosis, lumbar lordosis);
- (2) promote normal mobility of the pelvis, lumbar and thoracic spine;
- (3) enhance postural adaptive responses to pelvic unleveling;
- (4) improve muscle balance and functional motor patterns for dance.

## 6. Background: dance terminology and technique in relation to lumbo-pelvic mechanics

Correct dance technique requires an interplay of stability and segmental mobility for integration of pelvis, thorax and lower extremity function [23]. In treatment of back injuries, it is important to understand the lumbo-pelvic mechanics inherent in dance movement. With the center of gravity over the standing leg, function at the pelvis is primarily closed chain stabilization. The working

leg performs dynamic, open chain movements: *à terre* (on the ground) and *en l'air* (in the air). *A terre* movements require maintenance of a level pelvis. *En l'air* movements engender an unleveling of the pelvis as the leg passes the degree of functional allowance of the hip [29,30]. As the leg is raised, for example, *en l'air à la seconde*, beyond 45 degrees of hip abduction, the lumbar-pelvic rhythm increases the available range of motion by the addition of movement at the pelvi-femoral junction and lumbar spine. The lumbar spine laterally flexes and the pelvis laterally tilts upward toward the working leg (see Fig. 1). In the normally adaptive lumbar spine the sacrum faces the concavity of the lumbar spinal curve [14].

In addition to these mechanics, the authors note a pelvi-femoral rhythm in which rotation of the innominate re-positions the acetabulum for maximal external rotation and elevation of the femur. With the added factor of flexibility, these mechanisms permit what is known as 'high extension' in dance jargon. 'High extension' therefore, requires not only motion of the leg and hip, but also compensatory motion of the pelvis and spine.

Since dance is a locomotor and weight bearing activity, normal mechanics of the gait cycle serve

as a reference point for assessing mechanical dysfunction in dancers. With each step in the gait cycle, the pelvis shifts laterally and inclines in the frontal plane around the supporting hip joint. This pelvic obliquity induces lateral flexion of the lumbar spine with the convexity to the side of the low pelvis. As the ilium goes into posterior rotation it pulls the L5 segment, via the iliolumbar ligament, into convex-side rotation. The sacrum undergoes a forward sacral torsion relative to the ilium about an oblique axis [12,17]. A subtle increase, decrease, or both, in the pelvic determinants of gait can lead to lumbo-pelvic dysfunction [12,31].

The lumbo-pelvic musculature is primarily responsible for returning the pelvis to a level or neutral position. Specifically, the hip abductors on one side and lateral trunk muscles on the other, assisted by the adductors, work synergistically to return the pelvis to neutral in the frontal plane [7,30]. In dance jargon, restoration or maintenance of a level pelvis is termed 'squaring the hips'. The neuro-musculo-skeletal ability to 'square the hips' is fundamental to correct technique in many dance positions. Muscle imbalance of the abductor/adductor complex, a characteris-

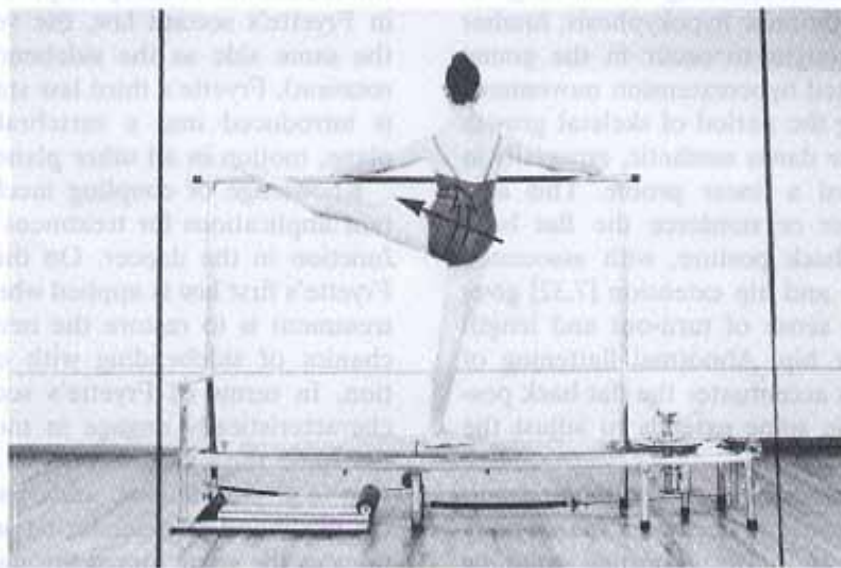


Fig. 1. Développé à la seconde. Pelvic unleveling in this position is concurrent with lumbar sidebending to the high pelvic side. (Note the slight pelvic and thoracic lateral displacements compensatory for thoracic and lumbo-sacral sidebending restrictions.)

tic finding in the professional dancer [28], interferes with this ability. Unilateral shortening of lumbo-pelvic ligaments and muscles, including the iliopsoas [16] and the quadratus lumborum [7], are also implicated in asymmetrical function.

Faulty dance technique, described as non-facilitative alignment and/or biomechanically inefficient movement patterns [5,16,22], contributes to asymmetries in function. Faulty technique associated with impaired lumbo-pelvic mechanics includes excess hip adduction on the standing leg, referred to as 'sinking into the hip', and contralateral displacement of the thorax relative to the pelvis. Thoracic displacement prevents the hip musculature from contributing to pelvic stability. Without under-valuing the influence of lower extremity joint mechanics on functional alignment, it is important to recognize that the pelvis directly influences movement of the super-incumbent spinal column [12]. Mechanical inefficiencies are reinforced when the dancer goes to effect movements that require unleveling of the pelvis with opposite side lumbar response.

## 7. Spinal configuration and coupling mechanics

The 'flat spine' [7] is a common postural characteristic in dancers. Flattening of the sagittal spinal curves (e.g. thoracic hypokyphosis, lumbar hypolordosis) is thought to occur in the young dancer from repeated hyperextension movements of the spine during the period of skeletal growth [7]. Additionally, the dance aesthetic, especially in ballet, tends toward a linear profile. This aesthetic may promote or reinforce the flat back posture. The flat back posture, with associated posterior pelvic tilt and hip extension [7,32] gives the dancer a false sense of turn-out and length across the anterior hip. Abnormal flattening of the lumbar lordosis accentuates the flat back posture as the thoracic spine extends to adjust the center of gravity.

Flattening of the spinal curves is biomechanically significant because it decreases the stability of the spine [33] and affects normal coupling mechanics. Coupled motion refers to the concu-

rent pattern of lateral flexion and rotation produced as a consequence of spinal movement [34]. In the thoracic (T4–12 only) and lumbar spine, lateral flexion couples with rotation of the vertebral bodies into the convexity of the induced curve. This normal convex-side rotation occurs only if adequate [11] lumbar lordosis and thoracic kyphosis are present [34,35]. In the flat thoracic spine, the facets are engaged in extension and rotation is reversed [35]. Similarly, in the flat lumbar spine, the flexed facets dictate motion and rotation is toward the concavity of the sidebend [36]. Scoliosis also adversely affects the direction of coupled rotation. In this regard, there is controversy in the literature, with some authors claiming concave-side rotation [35,37], and others claiming exaggeration of convex-side rotation [33,38].

Robert Lovett was the first researcher to record observations of coupling mechanics in relation to scoliosis [35]. Harrison Fryette elaborated on Lovett's observations, establishing the laws of coupled spinal motion [7,36]. Fryette's first law states that when the vertebral segments are in the neutral position, rotation and sidebending occur in opposite directions. The direction of coupling changes when the spine is in the fully flexed or extended positions. In these positions, non-neutral mechanics of the spine predominate. As stated in Fryette's second law, the vertebrae rotate to the same side as the sidebending (concave-side rotation). Fryette's third law states that if motion is introduced into a vertebral segment in any plane, motion in all other planes is reduced.

Knowledge of coupling mechanics has important implications for treatment of segmental dysfunction in the dancer. On the BAC apparatus, Fryette's first law is applied when the intention of treatment is to restore the neutral adaptive mechanics of sidebending with contralateral rotation. In terms of Fryette's second law, dancers characteristically engage in movements that arc the spine through extremes of flexion and extension (e.g. *port de bras*, *arabesque*). This increases the likelihood of engendering acute joint dysfunctions as the spine moves through cross-over areas from flexion to extension, in which coupling me-

chanics reverse [18,38]. Fryette's third law is applied in three-dimensional positioning for movement localization on the BAC.

## 8. BAC exercises

The BAC exercises are sequenced so that first normal sagittal plane alignment is restored and then spinal restrictions mobilized (exercises one and two). As discussed, this sequence is important because spinal configuration affects stability and coupling mechanics. Following spinal mobilization, spinal adaptive responses to pelvic unleveling are addressed (exercises three and four). Correct alignment strategies and motor patterns are then applied to specific dance positions and steps (exercises five and six). Palpation and manual therapy techniques are applied by the clinician in conjunction with the exercises. In general terms, exercises on the BAC apparatus are functional adaptations of muscle energy technique [18], in keeping with Brian Mulligan's mobilization with movement concept [39]. The six exercises described below are representative of the treatment strategies applied in numerous other BAC exercises.

### 8.1. Exercise one

#### 8.1.1. Assessment / treatment of thoraco-lumbar configuration and mobility — in quadruped

*Exercise description.*

- (A) The patient is in quadruped, with the hands and knees supported on both discs. In the starting position, the pelvis is in neutral alignment and the arms are extended forward to create thoracic extension. The patient is cued to approximate the discs by raising the xyphoid in both a dorsal and caudal direction. In accordance with Lewit's precept that inhalation is the most effective method of mobilizing flexion in the thoracic spine [11], cues for inhalation are given to facilitate thoracic flexion (see Figs. 2a & 2b).

#### *Purpose.*

- (1) To assess thoraco-lumbar sagittal configuration and functional alignment.
- (2) To assess motion restrictions and determine positional diagnoses (type I and II) through

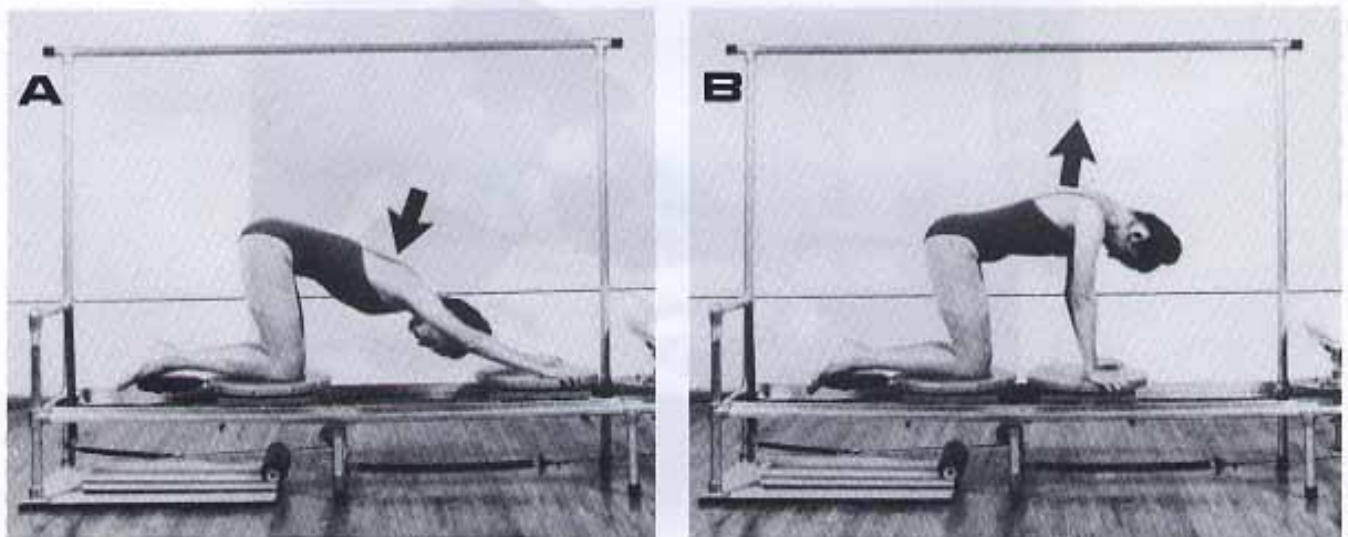


Fig. 2. Mid-thoracic active mobilization to re-educate kinesthetic support for thoracic kyphosis. (2a) Starting position in thoracic extension. (2b) Ending position in thoracic flexion with maintenance of lumbar lordosis.

the flexion-extension arc of thoracic spinal movement [18].

- (3) To restore thoracic flexion at the T6–8 segment (i.e. normal apex) and re-educate kinesthetic support for the thoracic kyphosis.

*Comments.* Mobility in the mid-thoracic region is essential for normal thoraco-lumbar opposition in locomotor movement [13].

- (B) In the second part of this exercise, the patient is instructed to rotate the upper disc to create a sidebending action in the thoracic spine while maintaining lumbar lordosis. The patient is cued to direct inhalation and rib expansion to the postero-lateral convex side of the curve. The lumbar spine can be pre-set in opposite sidebending on the lower disc to further localize motion to the thoracic region (see Fig. 3).

#### *Purpose.*

- (1) To assess and mobilize thoracic sidebending restrictions.
- (2) To restore normal thoracic coupling mechanics.

*Comments.* This exercise is a dynamic adaptation of the Klapp and Cotrel's flexion/derotation concept. In treatment on the BAC, spinal derotation is defined as the direction that decreases asymmetry or increases leveling of the transverse processes.

In regard to coupling mechanics, it is important to recognize that the direction of coupling is influenced by the sequence of induced movements. For example, in the mid-thoracic spine, if rotation as opposed to sideflexion, is introduced first, then ipsilateral and not contralateral sidebending is believed to occur [40].

#### 8.2. Exercise two

##### 8.2.1. Assessment / treatment of thoracic sidebending restrictions and lumbo-pelvic functional stabilization — in supine hooklying

*Exercise description.* The patient is positioned supine and perpendicular to the track of the BAC apparatus. The thoracic and lumbar spine are supported on separate rotary discs. Upper or lower segments of the thoracic spine are centered on the disc in accordance with the intended localization of the thoracic fulcrum of motion. The patient positions his or her arms in 90 degrees forward

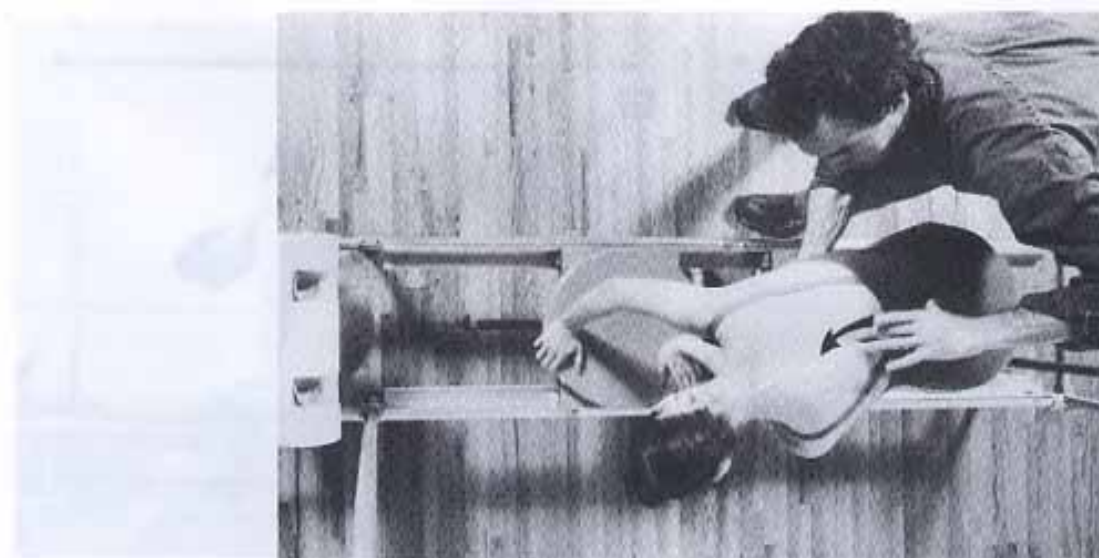


Fig. 3. Disc rotation in quadruped to produce localized thoracic sidebending. The lumbar spine can be pre-set in opposite sidebending to further localize motion to the thoracic region. The clinician palpates for movement localization and coupled mechanics.



flexion, termed 'low fifth' in dance vocabulary. This position of the arms is used to promote correct placement of the scapulae on the thorax while decreasing activation of shoulder girdle muscles that act as accessory thoracic sidebenders.

- (A) In the first part of this exercise, the patient is instructed to rotate the disc in the desired direction (i.e. towards or away from the motion restriction) by sidebending the trunk while maintaining a neutral pelvis (see Fig. 4). Isolation of thoracic sidebending (i.e. without lumbar participation) is promoted by cueing the contralateral stabilizing action of the quadratus lumborum on the lower rib cage. Bucket handle motion of the upper



Fig. 4. Axial rotation in supine to produce localized thoracic sidebending with maintenance of neutral pelvic position.

ribs is promoted by manual facilitation of the serratus anterior.

*Purpose.*

- (1) To assess and mobilize thoracic sidebending restrictions.
- (2) To identify lumbar compensations for restricted thoracic mobility.
- (3) To access intrinsic spinal musculature.
- (4) To integrate pelvic stability with thoracic mobility.
- (5) To strengthen synergistic trunk muscles in functional patterns.

*Comments.* Thoracic sidebending mobility is essential for normal spinal adaptive behavior in functional movement [3,14].

- (B) In the second part of the exercise, the patient is instructed to laterally translate the disc along the track without sidebending the trunk (see Fig. 5). Spring resistance can be added to promote right to left muscle balance.

*Purpose.*

- (1) To assess and restore accessory joint play (i.e. lateral translation) as a component of physiological sidebending.
- (2) To promote thoracic muscle balance.

*Comments.* Osteokinematically, lateral translation is a joint play component of sidebending [34].

### 8.3. Exercise three

#### 8.3.1. Assessment / treatment of lumbar sidebending restrictions and spinal response to pelvic unleveling — in supine

*Exercise description.* The patient is positioned supine on the discs, with the base of the spine centered on the lower disc and the mid-thoracics centered on the upper disc. The discs are positioned to create mild longitudinal traction on the spine. The heels of the feet are placed hip width apart on the foot bar. The patient is cued to

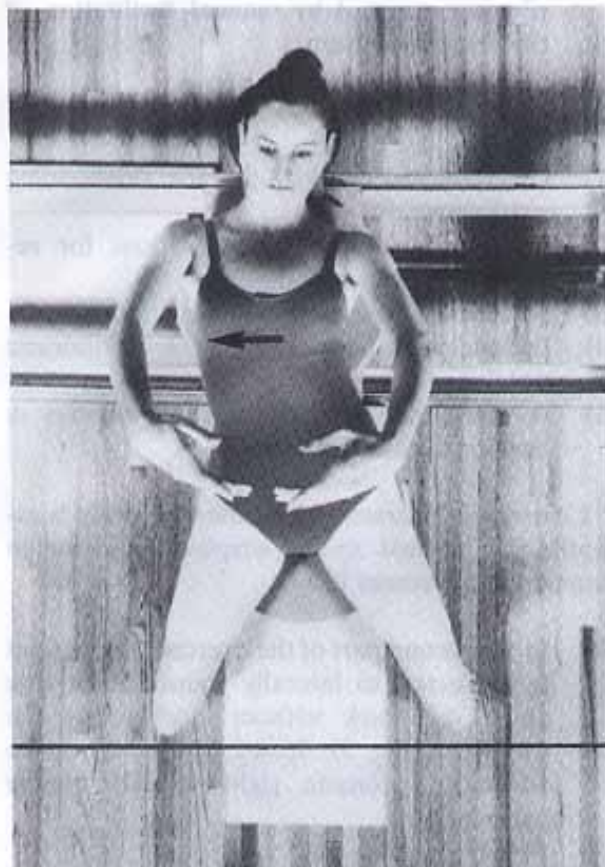


Fig. 5. Lateral (right) thoracic translation along the BAC track to mobilize the translatory component of left thoracic sidebending.

alternately press the right and left heel into the bar. This leg reach action unlevels the pelvis imparting contralateral sidebending in the lumbar spine (see Fig. 6).

#### *Purpose.*

- (1) To assess the relative lumbar sidebending excursion to one side versus the other. This is achieved by both observing the relative unleveling capacity of the pelvis and palpating the translatory motion at the L3 segment.
- (2) To assess thoraco-lumbar junction response to unleveling of the pelvis. In normal locomotor mechanics, the thoraco-lumbar junction should remain vertically aligned over

the sacrum, regardless of lumbo-pelvic unleveling [11].

- (3) To mobilize lumbar sidebending restrictions. Localization is achieved by pre-setting the thoracic spine in a sidebent position via rotation of the upper disc. This position locks the thoracic spine from above such that movement is localized to the appropriate lumbar segments below.

For example, in mobilizing a right lumbar sidebending restriction, the thoracic spine is pre-set in left sidebending such that a reach with the left leg produces localized right lumbar sidebending.

- (4) To increase symmetry of the sidebending response to pelvic unleveling.

*Comments.* A small tractional force, sufficient to equal the natural apposition of the joints, serves to decompress soft tissues and enhance segmental mobility [32].

The thoraco-lumbar junction is one of the 'key regions' of the spine and the transitional zone between the thoracic kyphosis and lumbar lordosis [11,13]. Disturbance in function at key regions impairs functioning of the spinal column as a whole [11].

#### *8.4. Exercise four*

##### *8.4.1. Assessment / treatment of hip muscle function and spinal response to pelvic unleveling — in weight bearing stance*

*Exercise description.* With a disc removed and the underlying platform locked, the patient stands facing the ballet barre with the supporting leg on the platform. The position of the locked platform can be varied to accommodate the patient's stance width, or to impose a wider stance to access higher segments in the spine. The foot of the working leg is placed on a lever bar to which spring resistance is attached. From the starting position, in which both feet are level on a horizontal plane, the patient is asked to 'press the lever down towards the floor' and then to 'release the lever with control, allowing the pelvis to hike up' (see Figs. 7a, 7b & 7c).

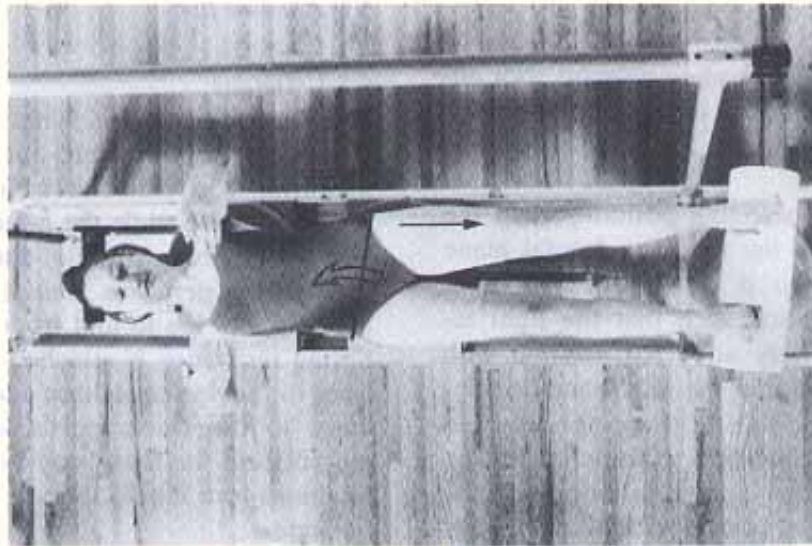


Fig. 6. Pelvic unleveling in supine. The left heel press produces right lumbar sidebending and elongation of the convex-side tissues. Palpation of the lumbar spine, suspended between the discs, enables the clinician to assess the relative range of side-to-side translatory motion.

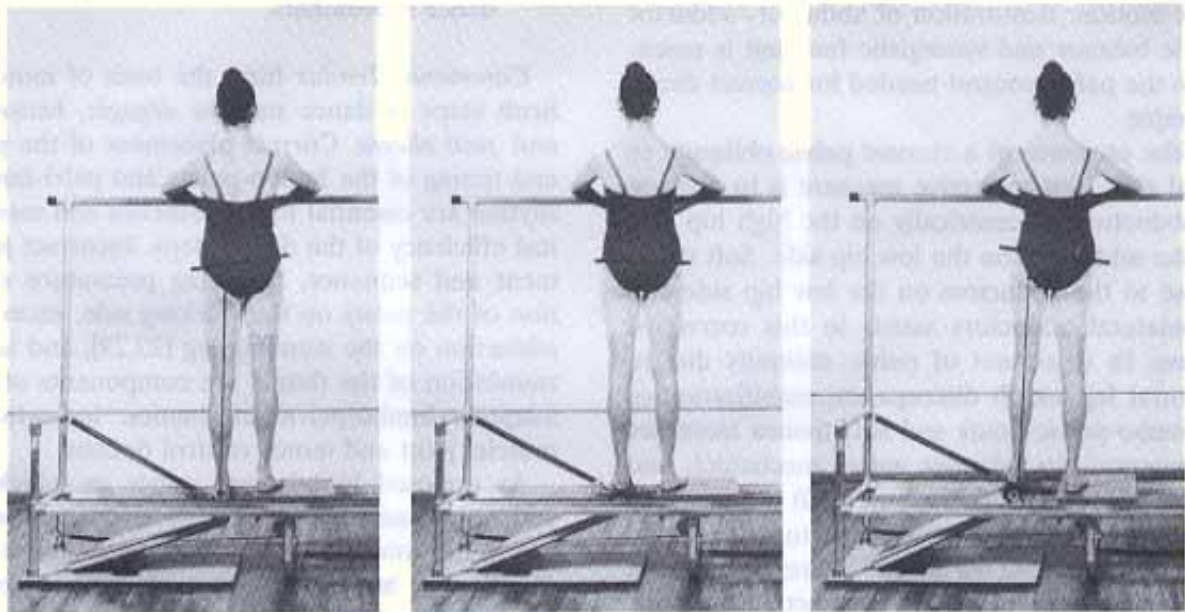


Fig. 7. Pelvic unleveling in weight bearing stance to mobilize lumbar sidebending restrictions and promote synergistic lumbo-pelvic muscle function. (7a) Depression of the foot lever engenders pelvic obliquity and right femoral adduction, (7b) Controlled return of the lever to the horizontal plane requires a deceleratory contraction of the standing leg adductors, (7c) Release of the lever above the horizontal plane reverses the pelvic obliquity.

### Purpose.

- (1) Same as supine unleveling exercise with addition of pelvic muscle dynamics and proprioceptive challenge.

*Comments.* In the standing position, when the lever is depressed by the left foot, frontal plane obliquity of the pelvis is concurrent with right femoral head translation such that the right femur adopts a relatively adducted position with respect to the pelvis, and the left femur is relatively abducted [30]. With light springs attached to the lever bar, a concentric contraction of the standing leg abductors assists in returning the lever to the horizontal plane. With heavy springs attached, an eccentric, deceleratory contraction of the standing leg adductors is required to control return of the lever. The significance of the muscle dynamics created with this exercise is the utilization of the adductor/abductor synergy in the context of closed chain, functional control of pelvic motion. Restoration of abductor/adductor muscle balance and synergistic function is essential to the pelvic control needed for correct dance technique.

In the presence of a chronic pelvic obliquity or lateral shift, the corrective measure is to activate the abductors concentrically on the high hip side and the adductors on the low hip side. Soft tissue release to the abductors on the low hip side and contralateral adductors assists in this corrective process. In treatment of pelvic obliquity due to structural leg length discrepancy, mobilization of the lumbo-pelvic joints and soft tissues increases the potential for adaptive spinal mechanics, and contributes to the success of heel-lift therapy [21]. Mobilization of lumbo-pelvic structures can help correct a functional leg length discrepancy that is due to superincumbent joint dysfunctions and soft tissue imbalances.

Assessment of the response to pelvic unleveling, standing on the BAC is similar in intent to the 'hip drop' test for lumbosacral mobility [4,17], the heel lift leg length discrepancy test [15,17] and the lateral pelvic shift test for the adaptive response of the femurs and lumbar spine [19].

### 8.5. Exercise five

#### 8.5.1. Tendus

*Exercise description.* With the discs removed, the patient stands in turn-out with a foot on each platform. The platform of the standing leg is locked in place while the platform of the working leg is left free to slide along the track. The working leg performs *tendus*; a sliding action of the foot and leg to and from a pointed position. Spring resistance is attached to the mobile platform to provide concentric and/or eccentric challenge to the trunk, pelvis and lower extremity musculature in their stabilizing and movement functions (see Fig. 8).

#### Purpose.

- (1) To maintain a level pelvis and integrity of the thorax-to-pelvis relationship during performance of open chain movements in unilateral stance.
- (2) To restore functional motor patterns of dance movements.

*Comments.* *Tendus* form the basis of more difficult steps in dance such as *dégagés*, *battements* and *petit allegro*. Correct placement of the pelvis and timing of the lumbo-pelvic and pelvi-femoral rhythm are essential to the esthetics and mechanical efficiency of the dance steps. Incorrect placement and sequence, including premature elevation of the pelvis on the working side, excess hip adduction on the standing leg [22,29], and lateral translation of the thorax are components of maladaptive lumbo-pelvic mechanics, indicative of muscle, joint and motor control deficits.

As opposed to bilateral stance in which the adductors assist the abductors in control of the pelvis, hip joint stability in unilateral stance (e.g. standing leg in *tendus*) is the sole function of the hip abductors [30].

### 8.6. Exercise six

#### 8.6.1. Turn-out

*Exercise description and purpose.* The patient stands on two pivoting foot plates with the me-

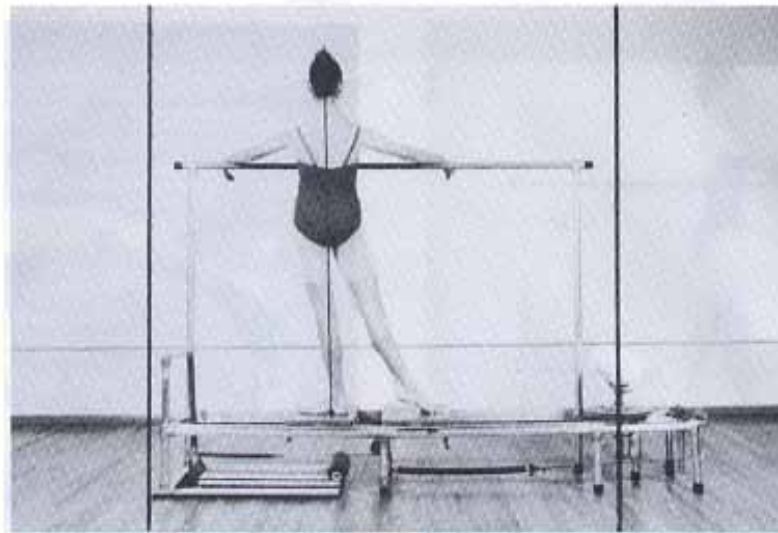


Fig. 8. *Tendus à la seconde*. Spring resistance can be added to the mobile platform.

chanical axes of the legs aligned with the fulcrum of the plates [7]. Turn-out exercises are performed in first, fourth and other dance positions (see Figs. 9 & 10).

The exercises are used to assess strength, flex-

ibility and joint limitations, as well as maladaptive compensations. Cues for movement initiation, weight distribution and lateral translation of the thorax promote more efficient alignment strategies and motor patterns. The turn-out exercises

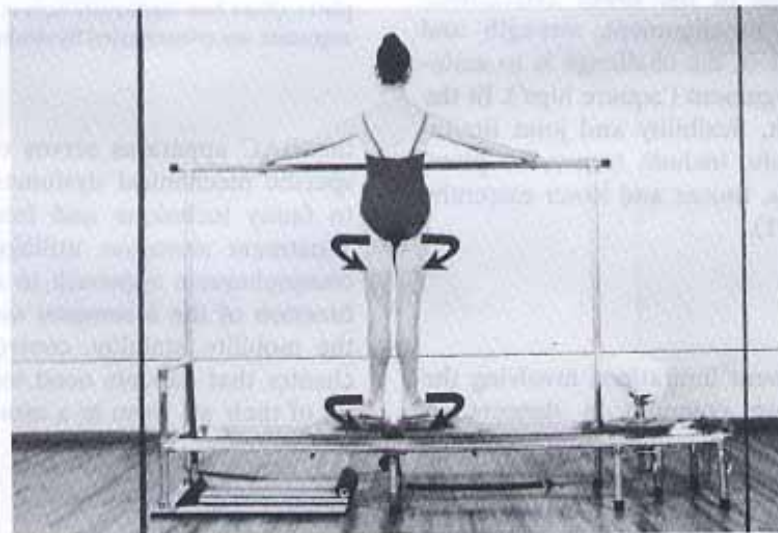


Fig. 9. Turn-out in first position on pivoting foot plates. Asymmetries in pelvic function and hip mobility are significant in their adverse kinetic chain influence on the spinal and lower extremity mechanics of dance technique.

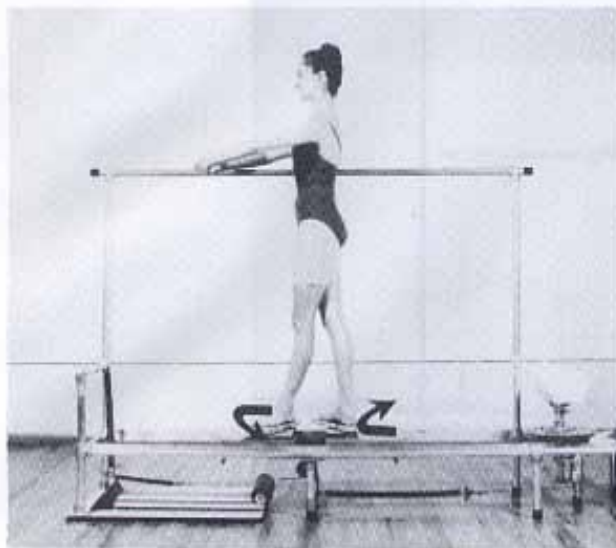


Fig. 10. Turning-out to fourth position.

are progressed in difficulty with the addition of resistance and transitional movements such as *plié*, *relevé* and *chassé*.

*Comments.* Turned-out positions are a fundamental requirement in classical ballet and most other dance styles. Turn-out, defined in its ideal as the position of 180 degrees of combined maximal external rotation of the lower extremities, presents challenges to alignment, strength and flexibility. At the pelvis, the challenge is to maintain frontal plane alignment ('square hips'). In the presence of strength, flexibility and joint limitations, technique faults include transverse plane torsions of the pelvis, thorax and lower extremity segments (see Fig. 11).

## 9. Summary

Injury and movement limitations involving the spine and pelvis are common in dancers. A thorough biomechanical evaluation is essential for appropriate clinical intervention. Treatment of dance injuries that is limited to localized intervention and application of physical agents will fail to address the dynamic interplay of structure and function that is the hallmark of mechanical disorders of the lumbo-pelvic complex. The clinician,



Fig. 11. Aerial view of fourth position on the pivoting foot plates. (Note how inadequate turn-out and frontal plane pelvic alignment are compensated by clockwise torsion of the thorax.

the BAC apparatus serves to identify and treat specific mechanical dysfunctions that contribute to faulty technique and functional disturbance. Treatment strategies utilizing the BAC offer a comprehensive approach to addressing disturbed function of the locomotor system while restoring the mobility, stability, control and adaptive mechanics that dancers need to pursue the aesthetics of their art form in a non-injurious manner.

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We wish to thank Peter Peirce for the photography, and Anna Schmitz and Janice Horowitz for the editing assistance.

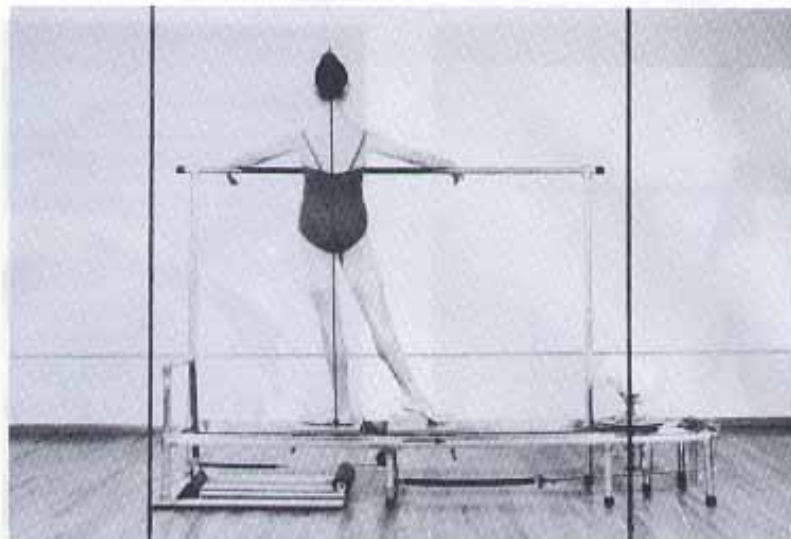


Fig. 8. *Tendus à la seconde*. Spring resistance can be added to the mobile platform.

chanical axes of the legs aligned with the fulcrum of the plates [7]. Turn-out exercises are performed in first, fourth and other dance positions (see Figs. 9 & 10).

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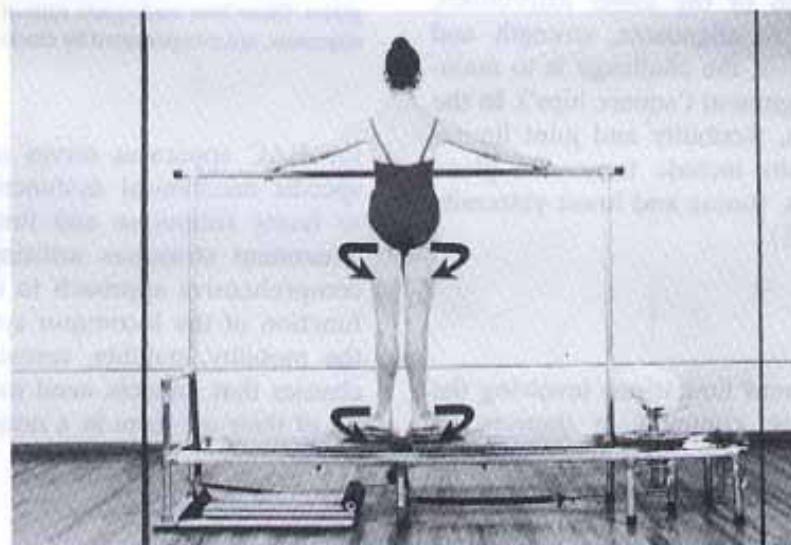


Fig. 9. Turn-out in first position on pivoting foot plates. Asymmetries in pelvic function and hip mobility are significant in their adverse kinetic chain influence on the spinal and lower extremity mechanics of dance technique.

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