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Analysis of components of the "turnout" in beginning and advanced female ballet dancers

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ANALYSIS OF COMPONENTS OF THE "TURNOUT" IN BEGINNING AND ADVANCED FEMALE BALLET DANCERS

by

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ABSTRACT

Lateral rotation of the left and right hip, knee, ankle and intertarsal joints during three trials of turnout from the straight leg and demi-plie positions was quantified with the use of a specially designed friction-free weightbearing goniometer, projecting fin-like body markers, and overhead photography. The female subjects were dancers (10 beginners, 11 advanced) recruited from University of Arizona ballet classes. MANOVAS revealed that turnout as measured from the feet was: (1) significantly greater in the advanced group in both positions, (2) significantly greater in the demi-plie position than in the straight leg, (3) a cumulative joint rotation effect with the hip contributing the greatest absolute and relative amounts. Positive significant correlations occurred between: (1) pedal turnout and lateral hip rotation for the advanced group in both positions and for the beginning group in demi-plie, and (2) pedal turnout and lateral ankle rotation for the advanced dancers in the straight leg position. Alignment of the lower extremity segments during turnout from both positions did not exist for either group.

CHAPTER I

INTRODUCTION

A lateral rotation of the legs is probably the most distinguishing characteristic of the classical ballet dancer. Turnout, a noun derived from the classroom command to "turn the leg outward" (Wilson, in press) is part of the ballet tradition which has been maintained for over 300 years (Hammond, 1974). Turnout of each leg from the hip joint at an angle of ninety degrees to the body is the prime convention of ballet (Lawson, 1960). The consensus throughout ballet literature is that turnout should take place primarily at the hip joints although no known studies have examined this assumption.

Clippinger-Robertson (1987), Ryman (1979) and Wilson (in press) explain that the normal range of motion for the hip joint varies according to the individual's innate musculature, ligamentous and skeletal structure, and also according to her degree of dance training which can alter strength, flexibility and coordination of the leg muscles. Many writers (Noverre, 1966; Paskevska, 1981; Ryman, 1978; Sparger, 1949) on ballet technique believe that in the early stages of a dancer's training the relationship of the hip, knee, ankle and foot in turnout remains the same as when the feet are parallel, and the whole lower extremity rotates as one. As training progresses however, the ligaments around these joints, particularly at the ankle, are stretched in order to attain additional range to produce the ideal turned out position as seen from the feet (Gelabert, 1980; Paskevska, 1981; Sparger 1949).

The adoption of turnout was not based on empirical research but on aesthetics. Injuries to the lower extremities and back may result when the natural limitations of the body are overlooked or denied in an attempt to idealize the form of classical ballet technique. Lateral hip rotation is imperative for turnout. However, the extent to which other joints in the leg and foot also contribute to the dancer's turnout has not been investigated. There have apparently been no scientific studies that provide objective data regarding the contribution of lower extremity joints to turnout for beginning and advanced level dancers.

Purpose of the Study

The purpose of this thesis was to analyze lateral rotation of the lower extremity joints during turnout from the straight leg and demi-plie positions in beginning and advanced female ballet dancers. An investigation of related research revealed that no previous study has been conducted which is identical this one. The following questions were posed to guide the researcher in an analysis of the rotational components involved in a dancer's turnout of the legs.

1. **Are there significant trial-to-trial and right vs. left side differences in the maximum turnout position for beginning and advanced dancers?** To answer this question, the absolute joint degree and relative joint percentage trial-to-trial and side-to-side differences will be examined. Trial means will be averaged over two groups, two positions, four joints and two sides. A finding of no significant difference in maximum turnout position over the three test trials would indicate that the mean of all three trials would best represent each subject's performance. A finding that shows a significant difference over trials in which one trial is more disparate that the others would indicate that the most representative score for each subject may be the average of those trials that exclude the disparate one. Right vs. left side differences will be analyzed by comparing these two means, averaged over two groups, two positions, four joints, and three trials. Based on the findings obtained, a decision will be made as

to the best way of dealing with the variable of "side" in subsequent analyses.

2. **Is there a significant difference between the two positions of turnout (straight and demi-plie) and between the two groups of dancers (beginning and advanced) for each of the two positions of turnout as measured by a weightbearing friction-free goniometer pedal?** Turnout in demi-plie is hypothesized to be greater than in the straight leg position because of the potential lateral rotation at the flexed knee joints. Advanced level dancers are hypothesized to have greater turnout either because of a process of selection wherein they have an anatomical advantage or because increased training has resulted in a greater range. Since dancers take turnout from a weightbearing position, measurements from this position rather than from a supine or prone position are essential. A friction-free weightbearing goniometer has been devised as a test instrument so that lateral rotation of the legs can be maintained by muscular control rather than by friction between the turned out feet and the floor. A review of literature reveals that no such weightbearing friction-free measurements of turnout exist for dancers.

3. **What are the absolute (degrees) and the relative (percent) contributions of lower extremity joints to pedal turnout in both groups in both positions of**

turnout? Do these absolute and relative joint contributions to turnout differ significantly between the two groups of dancers, and between the two positions of turnout? When the dancer takes a position of maximum turnout on the weightbearing friction-free goniometer, the pedal turnout measurement will equal the sum of the lateral rotation in joints of the lower extremity (assuming that turnout is a cumulative joint effect). The use of leg segment markers and overhead photography will permit quantification of the absolute range (degrees) of lateral rotation in the hips, knees and ankles of beginning and advanced dancers in two friction-free weightbearing positions of turnout (straight legs and demi-plie). Also, the relative (percentage) contribution of these joints to the overall turnout value measured at the foot can be determined. It is hypothesized that the hip joint is primarily responsible for total turnout in both groups of dancers and in both the straight leg and demi-plie positions, although no data exists in the literature to support this view. A review of ballet literature strongly suggests that no knee rotation is possible in a straight leg position. However, dancers train for maximum turnout at all lower extremity joints, and results of this study should reveal if knee rotation occurs during weightbearing turnout on straight legs.

4. What is the relationship between the degree of turnout at each joint and total pedal turnout? Correlation coefficients will reflect the relationship between the pedal position at maximum turnout and the maximum range of each of the four lower extremity joints which contribute to turnout. Analyses of these correlation coefficients for each group within each of the two positions (straight and demi-plie) should indicate if lateral rotation in one or more of these joints is highly associated with a greater pedal turnout. Ballet scholars seem to be unanimous in their belief that greater turnout is associated primarily with lateral hip rotation.

5. If total turnout for a group of dancers is greater in demi-plie than in the straight leg position, which joint(s) in the lower extremity contribute to this increased range? It is possible that some or all joints may increase their range of motion to produce greater turnout of the feet. However, an increase in one or more joints may be accompanied by no change or a decrease at other joints.

6. When beginning and advanced ballet dancers take turnout from a straight leg position or from demi-plie, do they tend to keep their lower leg and thigh in line with their feet? It is advised by some authors that, no matter what degree or position of turnout is attempted, the alignment of the hip, knee and foot must be maintained (Benjamin, 1981; Lawson, 1960; Paskevska, 1981). Better lower extremity segment alignment in both weightbearing positions of turnout is hypothesized for the advanced level ballet dancers because of their training.

Scope of the Study

For this investigation, 21 female volunteers were recruited from beginning and advanced level ballet classes at the University of Arizona in Tucson. The population of local professional ballet dancers was not available for testing, thereby limiting the study in its comparative design.

Lateral rotation in the subjects' lower extremities was measured in two friction-free weightbearing positions (straight legs and demi-plie) of turnout. Turnout in these subjects was not measured under conditions typically used by dancers; that is, turnout taken in ballet slippers and/or pointe (toe) shoes using friction between the shoe and the floor sometimes aided by rosin, a sticky powder. A special goniometer was designed to permit angular measurements of turnout position of the feet from the two weightbearing positions. Although this goniometer greatly reduced friction between the dancer's feet and the floor in a weightbearing situation, it did not totally eliminate friction.

Turnout from parallel to first position of the feet was examined because it was the easiest turnout position for a dancer to take and the simplest one for the researcher to measure. The first position of the feet also eliminates any unnecessary twist of the hips (Lawson, 1960). In addition to testing the dancer's turnout on straight legs, turnout in demi-plie was studied because this position is considered to be an integral part of all ballet movement and because the knee joint is flexed and able to rotate slightly. This study was not concerned with judging the aesthetics of turnout, nor was the dancer's total body alignment measured. However, the investigator gave the subjects verbal instruction for good ballet posture while they were standing on the goniometer during their practice time.

This study focused on four joints of the lower extremity as potential sites for transverse plane motion that might contribute to foot turnout. These joints were the hip, knee, ankle and intertarsal joints. Segment markers (projecting fins) were used to deduce the rotational contribution of each lower extremity joint to total turnout. It is recognized by the investigator that this indirect method of measuring joint rotation may not be perfectly valid, particularly at the knee, ankle and intertarsal joints. However, techniques that might be used to validate these measurements (i.e., cineradiography, fluoroscopy, magnetic resonance imaging, etc.) were not feasible or readily available for this study. Also, it is recognized that certain variations in anatomical structure (i.e., tibial or femoral torsion, tibial or femoral varus or valgus, deviations in foot alignment, etc.) may exist among subjects in this study, but quantification of these structural variations was not attempted.

Significance of the Study

Turnout is a traditional practice that has been accepted without scientific scrutiny; factual information concerning it should be established. Ballet students and their parents, dance teachers, professional dancers and dance therapists can profit from knowing what amount of lateral rotation occurs in the dancer's hips, knees and ankles when turnout is taken. Some of the eventual benefits from an investigation of turnout may include: (1) determining a realistic amount of lateral rotation for goal achievement, (2) establishing a minimal angular turnout range to be used for initial screening of individuals for ballet training, (3) fostering an awareness of the complexity of segmental alignment in the lower extremities, and (4) a questioning and modification of current practices and teaching methods of ballet technique to avoid injury to soft tissues and joints of the lower extremities and spine.

Definition of Terms

The following English and French terms are defined in reference to their use in this study:

1. alignment - A universal definition for alignment of the lower extremity segments during turnout has not been agreed upon in the literature. Alignment of the lower extremity segments during maximum turnout is operationally defined by the investigator for purposes of this study as a condition in which the leg segment markers (thigh, calf, foot) are in vertical alignment with the pedal pointer. These markers are aligned, one above the other, in the same vertical plane as the pedal pointer in the subject's starting position. If alignment of these segments and the pedal is maintained during turnout, the segment markers will point in the same direction and rotate to the same degree.

2. barre - This is the French word for bar. It is generally a cylindrical piece of wood which is fastened horizontally to the wall or is free-standing at a height of about three feet six inches from the floor. It provides support and balance to the dancer as she develops her body alignment. Exercises done at the bar are the foundation of classical ballet.

3. demi-plie - This movement is a half bend of the knees rather than a full bend of the knees (grand plie). To execute a demi-plie, the knees flex as much as possible

but only to the extent that the heels are not lifted from the floor (i.e., until the depth of the demi-plie is reached); then the legs return to their original straight position. The depth of the demi-plie is determined by the length of the Achilles tendon (or the tension in the soleus muscle), as well as the joint structure of the ankle (or the abutment of the anterior edge of the tibia on the neck of the talus) (Bachrach, 1986b). Because a series of demi-plies increase the circulation of blood in the legs, they often are used to warm-up the joints, ligaments, tendons and muscles, and allow for greater flexibility and range of motion. The purpose of this movement is to stretch the soleus component of the triceps surae in preparation for a jump (Bachrach, 1986b). Almost every step in ballet involves a demi-plie, as a force-producing preparation or a shock-absorbing finish. Plies are done at the barre and in the center of the room in all five positions of the feet. In all plies the legs must be well turned out from the hips, the knees open and aligned over the toes, and the weight of the body evenly distributed on both feet with the entire foot on the floor.

4. <u>first position</u> - In this basic ballet pose, the feet attain an ideal position; that is, a position where the legs are turned out from the hips, the heels and knees are touching, and the feet form a straight line (a 180° turnout).

CHAPTER II

REVIEW OF LITERATURE

This study's primary purpose was to measure the amount of lateral rotation in the lower extremities of ballet dancers when they take turnout, and to determine the contribution of the lower extremity joints to the total turnout measured at the feet. A secondary purpose was to determine lower extremity segment alignment during turnout in both the straight leg and demi-plie positions. The review of literature contains anatomical and clinical descriptions of lateral rotation in the hip, knee, ankle and intertarsal joints, a history of turnout, currently accepted turnout theory, training for greater turnout, limitations and faults in performing turnout, body and foot alignment during turnout, and measurement of turnout in dancers. This chapter is divided into three main sections: anatomical and clinical descriptions of turnout, turnout in ballet, and measurement of turnout in ballet dancers.

Anatomical and Clinical Descriptions of Turnout

Turnout is movement in which the anterior surface of the lower extremity is laterally rotated, or moves away from the midsagittal plane (Kendall & Mc Creary, 1983).

CHAPTER II

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Anatomical and Clinical Descriptions of Turnout

Turnout is movement in which the anterior surface of the lower extremity is laterally rotated, or moves away from the midsagittal plane (Kendall & Mc Creary, 1983).

This movement occurs about a longitudinal axis in a transverse plane, and is freest in ball and socket joints such as the hip.

Hip Turnout

In anatomical terms, turnout at the hip is the lateral rotation of the femur in the acetabular socket of the pelvis. Rotation of the hip joint does not occur about the anatomical axis of the femur, but about the vertical, mechanical axis passing from the center of the hip joint or femoral head to the center of the knee joint and on through the talus and calcaneus of the foot (Kendall & Mc Creary, 1983; Wilson, in press). Hip rotation causes the kneecaps to face outward and the feet to point sideways (Ryman, 1978). The muscles or major portion of muscles that insert on the part of the femur posterior to the mechanical axis act as lateral or external rotators (Kendall & Mc Creary, 1983). There are six external rotators located on the posterior side of the hip (Kreighbaum & Barthels, 1985).

Many dance injuries of the lower extremities and of the low back are thought to be related to restriction of lateral rotation or turnout at the hip joint. Though Bachrach (1986c), Clippinger-Robertson (1987), Hoppenfeld (1976), and Wilson (in press) reported a number of genetic factors that influence a person's potential for hip rotation, the degree of version or turning of the femoral neck in relation to the shaft is considered to be foremost. Normally the neck of the femur is angled 15° anterior to the long axis of the shaft of the femur and the femoral condyles (Hoppenfeld, 1976). Any increase in this anterior angulation (anteversion) results in a greater internal rotation. A decreased anterior angulation (retroversion) results in a greater degree of external hip rotation (Hoppenfeld, 1976).

Other factors restricting turnout include: (1) the length of the femoral neck which affects the mechanical advantage of the lever system, (2) tightness of the anterior hip capsule, particularly of the iliofemoral, or Y ligament of Bigelow, (3) tightness of the muscles responsible for medial or internal rotation, and (4) the strength (or weakness) of the prime and supplementary hip rotator muscles.

An estimate of the average range of external hip rotation when measured in extension is 45° to 48° (Heck, Hendryson, Rowe, 1965; Hoppenfeld, 1976; Moore, 1978). To accurately evaluate hip motion it is the consensus of many (Bachrach, 1986c; Heck et al., 1965; Hoppenfeld, 1976) that compensatory motion in the pelvis and lumbar spine must be prevented. In the non-weightbearing method recommended by the American Academy of Orthopaedic Surgeons (Heck et al., 1965) and used by Bachrach (1986c), the degree of external rotation at the hip is most effectively determined with the patient lying prone (face down) with the thighs adducted and one knee flexed to 90°. Describing this method, Bachrach (1986c) wrote:

> External rotary force at the hip is then exerted by directing the leg medially. The other hand is on the buttock to monitor pelvis motion. The angle between the leg and the perpendicular at the end range of motion indicates the degree of external rotation. (p. 8)

Knee Turnout

The knee joint is formed by the articulation of the condyles of the femur, with the condyles of the tibia, and by the patella articulating with the patellar surface of the femur. The knee is a modified hinge joint capable of spiral movement. There is a screw-like action or rotation of the tibia on the femur in flexion and extension. The medial miniscus (attached to the head of the tibia) allows for the slight rotary and locking mechanism of the knee joint (Wright, 1985). The normal movement of the knee joint when bearing weight and under control of thigh muscles is a combination of extension with lateral rotation of the tibia on the femur by the quadriceps and of flexion with medial rotation of the tibia on the femur by the hamstrings (Helfet, 1982; Kendall & Mc Creary, 1983). The muscles of the knee joint are predominately two-joint muscles acting also at the hip. The location of the biceps femoris muscle on the lateral side of the fibula and the semimembranosus and semitendinosus on the medial side of the tibia allow them to produce lateral and medial rotation of the leg at the knee when the knee is flexed (Kreighbaum & Barthels, 1985).

The tibia can be rotated quite freely on the femur when the muscles crossing the knee joint are relaxed and the knee is flexed. Independent rotation of the tibia on the femur is not possible with straight leg weightbearing (Helfet, 1982). When the knee is extended it is essentially locked and the joint is stabilized as the internal and collateral ligaments are held tight. When the knee is flexed the internal cruciate and lateral collateral ligaments loosen to allow a change of direction while moving (Kreighbaum & Barthels, 1985; Wright, 1985).

The range of motion in rotation is dependent upon the position of the knee, i.e. the degree of flexion or extension (Helfet, 1982; Norkin & Levangie, 1983). According to Kreighbaum and Barthels (1985), maximum knee rotation is possible at approximately 90° of knee flexion. Norkin and Levangie (1983) wrote, "The amount of rotation (medial and lateral) that is available at the knee increases from zero at full extension to 70 or 80 degrees at 90 degrees of flexion and decreases as flexion continues." (p. 316) They reported a range for active or passive lateral rotation at the knee of 0° to 40°. Zarins, Rowe, Harris and Watkins (1983) conducted a study to determine how much passive axial rotation occurs in the knee at various degrees of flexion. Thirty-six subjects (17 with normal knees and 19 with anterior cruciate ligament tears) were tested from a side lying position. In the measurement technique described by Zarins et al. (1983):

> The upper leg was crossed over to get it out of the way and to help stabilize the pelvis. Pelvis and thigh were stabilized by manual pressure. Leg, ankle, and foot were secured in a short leg orthosis to prevent ankle, subtalar, and foot motion. (p. 153)

The subjects with normal knees (eight males and nine females) were found to have bilateral symmetric rotational knee motion at each angle of flexion tested. For these patients, results indicated no significant change in the arc of rotational motion when measured at 30, 60 or 90° of knee flexion. Between 30 and 90° of knee flexion there was approximately 45° external rotation. When the knee was in a position of 15° flexion, it had 47° external rotation. Rotation decreased with further extension and, at 5° of flexion, the knee had 23° external rotation. Rotation at the knee was not tested at 0° flexion (that is, full extension of the knee) because the researchers were unable to stabilize the thigh and prevent hip rotation.

Ankle and Foot Turnout

Movements of the foot and ankle almost always involve more than a single joint. In fact, Norkin and Levangie (1983) pointed out that there are 28 bones that form 25 component joints in each normal foot and ankle. The ankle (tibiotalar) and subtalar joints are discussed below as their movements allow for rotation in the ankle and foot.

Ankle Joint. The ankle joint is made up of three bones: the tibia and fibula, which together form a groove into which the talus fits. The ankle is a uniaxial hinge joint, capable of flexion (dorsi flexion) and extension (plantar flexion in which the toes are pointed downward) at the tibiotalar joint. The axis about which triplanar ankle motion takes place extends at an angle from the postero-lateral aspect of the fibular malleolus to the anteromedial aspect of the tibial malleolus (Kreighbaum & Barthels, 1985). According to Norkin and Levangie (1983):

> The angulation of the ankle joint axis in the transverse plane produces a toe-out in stance and is referred to as the normal tibial torsion. The oblique axis deflects motion somewhat so that dorsiflexion results in movement of the foot up and slightly laterally (increased toe-out). Plantar flexion results in movement of the foot down and medially (decreased toe-out). (p. 340)

Sideways and rotational movements do not normally occur in the ankle joint, although the entire foot can be directed inward or outward by action at the hip and the flexed knee joint.

Subtalar Joint. The subtalar joint is located between the talus and calcaneus. It is a uniaxial joint with a single complex triplanar motion of inversion and eversion (Hoppenfeld, 1976; Norkin & Levangie, 1983; Sparger, 1949). Inversion is a combination of foot supination (longitudinal axis), forefoot adduction (vertical axis) and foot plantarflexion (coronal or frontal axis). Eversion is a combination of foot pronation (longitudinal axis), forefoot abduction (vertical axis) and foot dorsiflexion (coronal or frontal axis). As Norkin and Levangie (1983, p. 343) stated, "Because of the nature of the joint surfaces, these component motions always occur together at the subtalar joint and cannot be combined differently." They noted that the axis for subtalar inversion-eversion is inclined forward and upward approximately 42° and inclined inward approximately 16°.

In weightbearing, inversion causes a raising of the inner borders of the feet so that bilateral weightbearing would occur on the outer edges of the feet. Lateral rotation of the tibia is a consequence of inversion of the weightbearing subtalar joint. Eversion results in a lifting of the lateral foot arches (outer borders of the feet) off the floor, along with dorsi flexion which causes a rolling of the ankle inward so that weight is forced onto the metatarsals (Kendall & Mc Creary, 1983; Kreighbaum & Barthels, 1985). A medial rotation of the tibia occurs with eversion of the weightbearing subtalar joint. Subtalar motion and tibial rotation are interdependent in the weightbearing foot. Inversion-eversion at the subtalar joint will cause rotation of the weightbearing tibia, and rotation of the tibia caused by joint rotation above it will impose inversion or eversion on the fixed foot (Norkin & Levangie, 1983).

Because of the angled orientation of the ankle and subtalar axes, the foot displays movement in an oblique plane during inversion and eversion. Since these two axes may be situated in many different combinations that vary from one individual's foot to another's, Kreighbaum and Barthels (1985) believe an average measure can not be used confidently in analyzing leg and foot postures and planes of foot motion.

There are conflicting ideas among orthopaedists concerning average ranges of motion at the foot and ankle; and few if any use the term lateral rotation. Rotation in the transverse (horizontal) plane occurs around a vertical axis. Abduction is the movement in which the toes and forefoot move outward or laterally in the transverse plane. Abduction occurs with foot pronation and dorsiflexion in eversion. Hoppenfeld (1976) reported the range of forefoot abduction as 10°. In a review of joint ranges in the ankle and foot, Kendall and Mc Creary (1983) stated that Whitman found 15° for abduction of each foot in the fully dorsi-flexed position. Norkin and Levangie (1983) wrote:

> Tibial rotation during the weight-bearing portion of gait has been measured as about 10 degrees. This would also represent the range of abduction-adduction of the talus and is the same as the total range of pronation-supination used during gait. (p. 345)

In the standard posture, the position of the feet is such that the heels are separated about three inches, and the front part of each foot is abducted about 8° to 10° from the midline (Kendall & Mc Creary, 1983). Kotwick (1982) reported a normal out-toeing of 6°.

Summary

Turnout in the ballet dancer is a lateral rotation of the lower extremities causing the thighs, lower leg and feet to turn away from the center of the body. Turnout occurs at the hip, knee, ankle and intertarsal joints. It is freest at the hip because of the ball and socket formation. Restriction of lateral rotation at the hip joint due primarily to the hereditary bony architecture is the culprit in numerous misalignment problems and resultant injuries of the spine and lower extremities.

The knee is a modified hinge joint allowing rotation during flexion. It is believed that no rotation occurs in the weightbearing straight leg position. The ankle and intertarsal joints move interdependently. Forefoot abduction (movement away from the midline) occurs with pronation and dorsiflexion in eversion and approximates lateral rotation in the ankle/foot complex.

Considering the average ranges for lateral rotation in the hip, knee, ankle and foot (only abduction) from a straight leg position reported in literature, a hypothetical mean cumulative turnout is proposed. This hypothetical total would be 54° which consists of 45° at the hip, 0° at the knee and 9° at the foot and ankle. From this hypothetical sum it is not likely that a dancer could exhibit the ideal 90° turnout from each lower extremity.

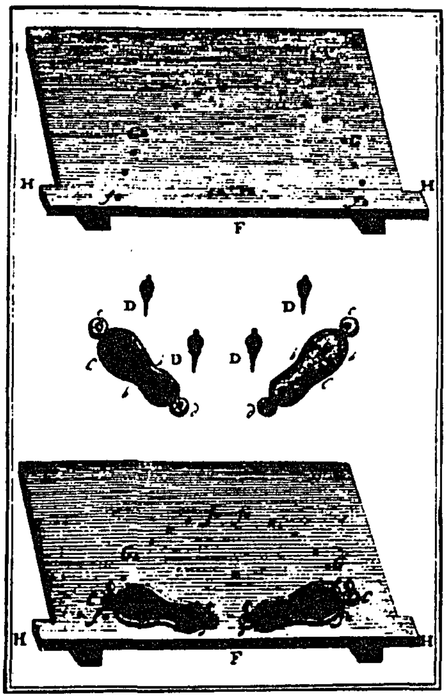
Turnout in Ballet

Turnout of the lower extremities is ballet's unique requirement. It is an absolute necessity if the dancer aims at the perfection of purely classical line (Lawson, 1960).

Historical Background

Turnout of each thigh and leg at a 90° angle has been recognized as fundamental for stage-dancing since the first and fifth positions in ballet were established (about 1700). The 180° turnout (the summed maximum of lateral rotation of both legs) is presupposed when describing the first position in ballet; Hammond (1974) depicted the first position as one in which the legs are turned out from the hip joints, the heels and knees are touching and the feet form a straight line. The ideal turnout is considered infinitely advantageous to ballet dancers, maximizing the visibility of their legs from the audience's point of view, as well as allowing for ease and breadth of movement sideways (Hammond, 1974; Lawson, 1960). The noted 19th century ballet pedagogue, Enrico Cecchetti, believed that the turning outward of the legs from the hips provided stability in the frontal plane while attempting to do a number of difficult movements otherwise impossible (Beaumont, 1977). Turnout received academic canonization somewhere between 1760 and 1780 (Kirstein, 1939).

Since turnout was considered so important, a machine called the tourne-hanche (hip-turner) was invented to accomplish it all the quicker (Kirstein, 1939). This device was in use from about 1750 to 1850. From pictures, the tourne-hanche appears to have been a wooden platform that had peg holes at various points along the perimeter of a 180° semi-circle which had been drawn on its surface. Two wooden feet were situated on top of the platform so that the heels were in line with the diameter of the 180° arc. These feet had small round attachments or extensions that were centered over and outside of the toes and heel of



THE TOURNE HANCHE, OR HIP TURNER
From Mereau's "Reflexions sur le Maintien et sur les Moyens d'en Corriger tous les Défauts." 1760

Figure 1. The Tourne-Hanche

from Noverre, J. G. Letters on Dancing and Ballets, 1966, p. 120a the dancer's feet. Peg-holes were made in these attachments so that pegs could hold the wooden feet at certain positions along the 180° arc (see Fig. 1). A dancer would place her feet on top of these wooden feet which would be laterally rotated to a predetermined amount of turnout. The dancer's turnout was maintained with the external force provided by pegs dropped into the peg-holes on the wooden feet. The lateral rotation of the wooden feet would be increased gradually to reach the desired 180° turnout.

In his Letters on Dancing and Ballets, first published in 1760, Noverre (1966) warned that this device was detrimental because it forced the feet outward without regard for the individual's structural capabilities at the thighs and knees. Noverre (1966) wrote:

> Again it is impossible to turn the foot outward without the help of the knee, which, in fact, has two movements only, that of flexion and that of extension ... Again, the knees cannot be carried outward by themselves, all depends essentially on the thigh, since it is that which controls the parts which it dominates and which are below it, consequently it turns them by a rotary movement by which it is endowed, and, in whatever direction it moves, the knee, leg and foot are compelled to follow it (pp. 118 & 119).

Theory, Limitations and Training

At least 200 years later, Noverre's beliefs about turnout (in part and in whole) were being reaffirmed and passed on to the next generation of dancers. Numerous individuals involved in the dance field have stated that the initiating force for the turnout of the legs must come from the hip and not from the floor (Hamilton, 1982; Karsavina, 1962; Lawson, 1960; Paskevska, 1981; Ryman, 1978). Before placing one's feet on the floor in turnout, each leg should be turned out in a non-weightbearing position, with the knee fully stretched, but not hyperextended (Hamilton, 1982; Ryman, 1978). How much the hip turns out is determined primarily by the bony architecture of the hip joint itself. Since the bones and ligaments of an individual's hip joint are largely determined by heredity, training for turnout must focus on stretching and strengthening the surrounding joint muscles and restrictive ligaments (Bachrach, 1986b, 1986c; Clippinger-Robertson, 1987; Hamilton, 1982; Kirstein, 1971; Noverre, 1966; Ryman, 1978; Sammarco, 1983; Wilson, in press). According to Sammarco (1983):

> Children who begin classical ballet training during their juvenile years, ages six to twelve, have the benefit of developing turnout while at the same time developing the femoral neck angle (retro, ante-version). It has been shown that after the age of 11

> the shape of the femoral neck can no longer be altered through the molding process of continual pressure, such as lying on the floor with the hips abducted and externally rotated.
>
> After the age of 11, turnout is achieved by stretching the hip capsule (iliofemoral ligament). Since the chemical structure of collagen permits relatively little elasticity, microscopic ruptures of the collagen fibers with subsequent scarring allow the increase in external rotation during the adolescent and young adult dancing years. (pp. 485 & 487)

Two hundred years ago Noverre (1966) said of turnout:

> It is impossible to bring about this change, of such vital importance in our art, without taking it in hand in the days of childhood; that is the only time when success is possible because then all the limbs are supple and may easily be made to take the desired position. (p. 117)

Wilson (in press) stated that increases of from 5° to 10° degrees of lateral hip rotation are not unusual as a result of careful training. Clippinger-Robertson (1987) reported from clinical experience that dancers can improve their use of turnout by 15 to 30°. She said, "Successful optimization of turnout is a multifaceted challenge demanding an understanding of correct mechanics, specific flexibility exercises, specific strengthening exercises (of the deep outward rotators) and appropriate use of the needed muscles."

Faults in Performing Turnout

When dancers are unable to get as much turnout as desired from the hip joints alone, they inevitably add potentially damaging adjustments in the spine, knees, ankles and feet. If the hips are unable to fully turnout, the compensatory lumbar spinal curvature increases, abdomen protrudes, pelvic tilt increases (decreasing the tension on the iliofemoral ligaments), knees hyperextend, and feet evert and pronate (Bachrach, 1986b; Dowd, 1984; Long, 1986; Marr, 1983; Micheli, 1983; Teitz, 1983). Hamilton (1982) recommended that someone with a turnout of less than 30° at the hip joint should hesitate to take on a serious pursuit of ballet. Bachrach (1986c) stated that:

> Care must be taken in developing turnout at the hip to avoid forcing the dancer beyond anatomical limits. Although a dancer ideally will exhibit 90° of turnout on each side (65° to 70° at the hip, 10° to 15° at the knee, and 5° to 10° at the ankle), it is a rare occurrence. Few dancers will exhibit external rotation or turnout at each hip joint greater than 45° to 65°. (pp. 8 & 10)

Through misalignment in the lower extremity and at the cost of injury, a dancer may appear to possess the ideal turnout as judged from the angle made by the feet. Because the knee is able to rotate when it is flexed, it is possible to press the heels forward to form a 180° angle as one takes demi-plie. The heels then hold the floor with an exaggerated position which cannot be maintained as the knees extend (Ryman, 1980). As the knees straighten into slight hyper-extension (mild hyper-extension is a reflection of laxity in the ligaments which allows the knee to rotate), the normal knee extension locking is inadequate. Then, lateral rotation in the lower leg diminishes until the tibia, and to a lesser extent, the femur, actually rotate inward with the foot everted and pronated (Bachrach, 1986c; Marr 1983). The inward femoral rotation accompanying the last phase of knee extension in a weightbearing leg is often called the "screw-home" mechanism. By setting one's turnout at the foot, it is the knee and ankle which are stressed and not the hip joint. The effect is similar to that of the archaic tourne-hanche of Noverre's day. Ryman (1978) stated:

> The overuse of rosin simulates the same effect. By increasing friction, rosin allows turnout to be taken from the feet, with the hip joint only passively involved. This gives the student a false impression of good turnout and may actually prevent her from working on true hip rotation. (p. 11)

Dance teachers and physicians cite "forcing the turnout" (i.e., the feet are turned out farther than the knees) as a major technical fault and cause of a host of leg deviations (e.g., relative internal femoral torsion, in-facing patella, relative tibial torsion) and injuries, yet students persist in the practice to achieve the look of an ideal turnout. Forced turnout only increases pronation and places extraordinary torsional forces on the ankle, the big toe, and the inner side of the knee (Bachrach, 1986a, 1986c; Benjamin, 1981; Karsavina, 1962; Teitz, 1983). Pronation can produce posterior tibial tendinitis, strains at the first metatarsophalangeal joint, and bunions (Teitz, 1982). Forcing turnout in this manner is considered to be a contributing factor in the genesis of chondromalacia patella (patellofemoral pain and/or damage) (Bachrach, 1986a; Clippinger-Robertson, Hutton, Miller and Nichols, 1985; Teitz, 1983).

Body and Foot Alignment During Turnout

In trying to meet the aesthetic demands which classical ballet places upon the body, individuals try to adapt themselves to the technique and force their body beyond its natural alignment. Axial alignment of the leg is both an aesthetic and practical factor for dancers (Hamilton, 1982). Correct alignment means that the center of gravity passes through the mechanical axis of the indi-

individual joints, enabling movements to become more effortless and economical as well as less prone to injuries.

Ideal alignment of the feet can be determined by observing how the feet align themselves with the midsagittal body plane. In the ideal alignment, the longitudinal axis of the foot segment is parallel with the midsagittal body plane. In the turned out position, the longitudinal axes of the feet are oblique to the midsagittal plane. According to Kreighbaum and Barthels (1985), "The toe-out position may be a result of lateral rotation at the hip, tibial torsion (lateral rotation of the tibia), or forefoot abduction." (p. 251) The toe-out position causes the line of force of the body's weight to move to the medial side of the foot as a person transfers his or her weight forward. This results in collapse of the medial side of the foot (pronation) and puts undue stress on the muscles that support the arch of the foot (Kreighbaum & Barthels, 1985).

Summary

Although accepted theory says a dancer's turnout originates from the hips, it obviously is not confined to the hip. In Wilson's (in press) definition of turnout, "the knee, ankle, and as many as six joints of the foot might contribute to the apparent lateral rotation of the hip. "Turnout, as it is taught and practiced, often results in injury when dancers disregard their anatomical limits.

Measurement of Turnout in Dancers

Orthopaedists and dance scholars have not verified, by scientific research, their diverse opinions on correct hip-knee-foot alignment during turnout. Opinions vary as to whether the knee should align with the foot (Paskevska, 1981; Vaganova, 1953), over the center of the foot (Kirstein, 1971; Teitz, 1983), or between the second and third toes (Kotwick, 1982; Lawson, 1975).

No studies were located which investigated the correlation between hip-knee-foot alignment measurements and injury to the knee, ankle and foot. It is possible that chronic injuries to the dancer's hip, knee, ankle and foot may be prevented by identifying incorrect lower extremity joint alignment during turnout. In 1985, Garrick and his colleagues conducted a study on a large sample of elite ballet students at the San Francisco School of Ballet (1985, unpublished research study). They took a non-weightbearing measurement of lateral hip rotation, hypothesizing that such a measure would be a prediction of a dancer's potential success in ballet based on her ability to maintain turnout with fewer injuries to the lower extremities. Normative data from this research were not available at the time of the present study. Garrick used the non-weightbearing method to measure lateral hip rotation in dancers, as Staheli, Corbett, Wyss and King (1985) used on non-dancers. This method varies slightly with that recommended by the American Academy of Orthopaedic Surgeons (Heck et. al, 1965) in that both knees are flexed to 90° and the lower legs cross over each other. Staheli's investigation examined 1,000 lower extremities in children and adults (500 subjects: 279 females and 221 males) to establish normal values for hip rotation. Results from this research showed a mean value for lateral hip rotation of 45° for each leg, and a normal range from 25° to 65°.

Summary

Many orthopaedists and researchers (Heck et al., 1965; Hoppenfeld, 1976; Kreighbaum & Barthels, 1985; Moore, 1978; Staheli et al., 1985; Zarins et al., 1983) have suggested normal values for lateral rotation of lower extremity joints for the general population. Since the manner of defining norms differs because of variations in instruments and examiners, it is difficult to achieve a logical and universally acceptable set of appraisals (Moore, 1978; Zarins et al., 1983). No published research has been found regarding joint range assessment in ballet dancers in which mean values of lateral rotation in lower extremity joints have been established. Since turnout is an integral part of ballet technique, such information is needed.

Summary

All ballet movements of the lower extremities are executed from a turned out position. Ability to assume turnout depends in part on the amount of lateral rotation available at the hip joint. Ballet turnout as practiced is a result of lateral rotation at the hip, knee, ankle and intertarsal joints. Many dance authorities have presented theories on the practice of turnout based on performing and teaching experience. Little scientific inquiry has been conducted to quantify lateral joint rotation in the lower extremity when dancers take turnout. If such factual information were available, it might be useful for injury prevention. This thesis intends to increase the data base concerning turnout in ballet dancers.

CHAPTER III

METHODOLOGY

The procedures used to obtain and analyze the data will be discussed in this chapter. The chapter is divided into three main sections: instrumentation, data collection, and data analysis.

Instrumentation

The primary instruments for subject measurement in this research study included: (1) a friction-free weightbearing goniometer to permit angular measurements of the subjects' turnouts and (2) a camera to photograph the subjects during turnout. The friction-free weightbearing goniometer and the camera used in this study are described in detail in the following sections.

The Friction-Free Weightbearing Goniometer

Objective. For this study a special goniometric instrument was designed to measure turnout of the legs in two friction-free weightbearing positions (straight leg and demi-plie). Since dancers take turnout from a weightbearing position, measurement of lateral rotation of leg segments in a weightbearing situation was essential. A friction-free situation was selected so that lateral rotation of the legs could be maintained by muscular control rather than by friction between the turned out feet and the floor.

Description. The goniometer consisted of a wooden platform measuring 40" long, 24" wide and 2.5" deep. It was constructed from 1" plywood and painted white. Two rectangular pieces of wood or pedals, also painted white, were situated side by side on top of the platform. Each pedal measured 18" x 6" and had a rotation axis that was centered 5" away from the other pedal's rotation axis. Each pedal's pivot axis bearing was a 4" diameter lazy susan bearing with an approximate capacity of 300 pounds. The bearing was used to make the axis "frictionless". Each lazy susan bearing was attached with screws to the top of the platform and was centered underneath the axis of rotation for each pedal. The pivot (axis) end of each pedal was parallel to and 6" away from one lengthwise end of the platform. A central vertical line was traced down each pedal and a horizontal line was traced across the pivot end of each pedal. Equidistant (1/4") color-coded hatch marks were drawn to the left, right and bottom of the pedal's axis of rotation, with the first hatch marks drawn 1" away from the pivot point. These marks were used to guide the subject so she could place her feet in the same starting position for every turnout trial. A nail was embedded into the far end of the pedal in alignment with the central vertical line. This nail was used as the angular pointer. At the opposite end of each pedal was a hard black rubber ball (bearing) with a 2" diameter. This ball was set into a circular hole that had been cut out of the pedal. The ball was attached to each pedal by a steel axel shaft. The purpose of this ball was to support the weight from the front part of each foot. Each pedal rotated laterally on the platform from an initial anterior position at 0°, outwards to 110°. Angular measurements were read from the platform, numbering from 0° to 90° with one degree increments for each pedal. See Figures 2 and 3 for photos of the goniometer.

Calibration Procedures. The amount of frictional torque that would be exerted on the goniometer from a subject who weighed an average of 120 pounds was measured by the investigator and an assistant from the Department of Physics at the University of Arizona. A gram/ounce spring scale was hooked onto a shallow screw set in a nail hole situated at the front end of the goniometer's foot pedal. Sixty pounds of weight (two 25 lb. discs and one 10 lb. disc) was centered on one foot pedal (Figure 3).

An average of 400 grams of force was recorded as the foot pedal was slowly pulled from 0° to 90°. An initial force of approximately 600 grams was due to acceleration. The scale fluctuated between 300 and 600 grams,

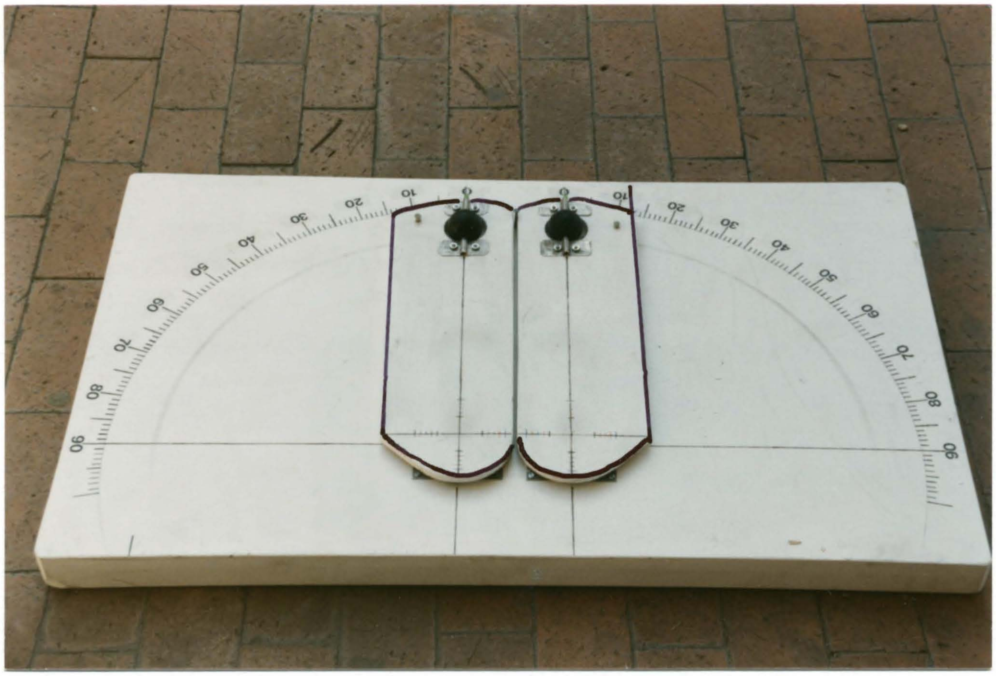


Figure 2. The Friction-Free Weightbearing Goniometer

Figure 3. Calibration Of The Friction-Free Weightbearing Goniometer

but remained relatively constant at 400 grams. This goniometer has 1.045 foot pounds of frictional torque based on 60 pounds of body weight on each pedal.

Camera

A Canon AE-1 with a Tamron 35-210 Zoom Lens, was used to photograph the subjects from an overhead balcony. This camera was centered directly over the center line (parallel to the body's vertical axis) that had been drawn between the goniometer's two foot pedals. The camera rested on a wooden rod to which a plumb bob was attached and dropped to the goniometer's center line.

Data Collection

Topics to be discussed in this section include subjects, filming procedures, measurements from photographs, and calculation of joint rotation.

Subjects

Two different groups of female dancers were asked to take part in this research study. The subjects were randomly assigned numbers for testing and came to the test site as scheduled. They were given forms to read and fill out before being fitted with body markers. Each subject followed a set warm-up and was allowed practice time on the goniometer before testing began.

Selection. The investigator recruited volunteers to participate in this study. A sample of 21 females, aged 18 years and older, was used. The volunteers were students in the beginning and advanced level ballet classes at the University of Arizona in Tucson.

An identification number was randomly assigned to each subject to protect her identity. To counterbalance a possible learning effect during testing, one-half of the subjects from each group (beginning and advanced) were randomly assigned to be tested first in turnout from straight legs while the other half were tested first from turnout in the demi-plie position.

Preparation And Markings. The subjects were asked to wear a dark colored leotard without tights or ballet slippers. Subjects also were asked to keep their hair off their foreheads so as not to obstruct the view from the overhead camera. If a subject had long hair, she was asked to fix it so that it was off her neck.

Subjects arrived at the test site at a pre-agreed time. They were asked to sign a consent form and questionnaire upon arrival (see copies in Appendices A and B). Each subject was given the same warm-up directions to read and follow two minutes before testing (see copy in Appendix C). The investigator then attached body markers to the subjects' lower extremities.

The body markers were designed to assess segment (thigh, shank, foot) rotation in the subjects' lower extremities. The body markers were fin-like pointers which projected at a right angle from a two-inch wide black velcro band. These fins were edged with colored tape for better visual identification. To clearly differentiate segment rotation in the photographs, the 8" long thigh fin was edged with green tape, the 11" long shank fin was edged with orange tape and the 10" long foot fin had hot pink tape attached to the tip as well as one-quarter and one-halfway down the fin. With fins pointing forward, the velcro bands were wrapped around the appropriate segment. The thigh fin was positioned just above the knee and the shank fin was placed on the widest part of the calf. The foot fin was attached to a pliable metal base plate that was taped to the top of both feet and was aligned with the space between the second and third toe of each foot. This foot marker was designated as the landmark for the longitudinal axis of each foot and was used to check for foot inversion and eversion.

Subject Descriptive Data. The subject's height and weight were recorded after the filming session. Weight was measured by a Detecto-Medic scale located in the women's locker room. Height was measured in a lab room nearby as each subject stood with her back against a metal tape measure which had been taped to the wall. Individual data sheets were used to record each subject's post-filming measurements.

Information regarding age, number of consecutive years of ballet training, and the number of hours per day spent in ballet class was requested in the subject questionnaire which was completed prior to testing on the goniometer. The descriptive data taken on each subject was listed according to group and appears in Tables 1 and 2.

Filming Of Subjects

The subjects were tested and photographed in the outdoor courtyard of the Ina Gittings Building on the University of Arizona campus during the spring of 1986. The study was conducted during the day in four test sessions on two consecutive weekends. Each subject arrived at the test site individually. Subjects were filmed every half hour with a 15 minute break after one hour.

Preparation Of The Filming Area. The friction-free weightbearing goniometer was placed at the southern end of the recessed courtyard. The goniometer was situated so that the subject faced east when standing on it during testing. A practice barre was placed to the right of the goniometer. Three index cards were taped to the ground in front of the goniometer to indicate subject identification number, turnout position, and trial number. (See Figure 4 for a diagram of the test site.)

TABLE 1. SUBJECT CHARACTERISTICS

FOR BEGINNING DANCERS (N = 1Ø)

Subj.#	Age	Ht(cm)	Wt(kg)	# Yrs. Trng.	# Class Hrs/Day	# Class Days/Wk.
1	18	168.1	58.1	1.Ø	2.Ø	2
3	18	168.8	73.4	2.Ø	2.Ø	2
6	18	163.1	54.5	Ø.5	1.Ø	2
7	21	163.8	51.8	Ø.5	1.Ø	2
1Ø	25	167.5	5Ø.4	5.Ø	2.Ø	2
11	19	163.8	59.4	3.Ø	1.Ø	2
17	37	166.9	62.1	1.8	1.5	2
18	23	165.Ø	54.5	3.Ø	1.Ø	2
2Ø	19	163.8	61.7	Ø.8	1.Ø	2
21	21	166.3	64.4	1.3	2.5	3

Group Wt. $\bar{X}$ = 165.7 $\pm$ 2.1

Group Ht. $\bar{X}$ = 59.Ø $\pm$ 6.8

TABLE 2. SUBJECT CHARACTERISTICS

FOR ADVANCED DANCERS (N = 11)

Subj.#	Age	Ht(cm)	Wt(kg)	# Yrs. Trng.	# Class Hrs/Day	# Class Days/Wk.
2	19	156.3	45.0	11.0	2.5	5
4	18	163.8	56.3	14.0	5.5	5
5	24	163.8	57.2	13.0	4.0	5
8	30	163.8	50.0	15.0	1.5	3
9	30	159.4	57.2	25.0	2.5	3
12	23	158.8	50.4	8.5	2.0	2
13	25	160.0	52.0	15.0	4.0	5
14	21	163.1	55.1	12.0	3.0	5
15	26	157.5	49.5	10.0	3.0	5
22	20	145.0	41.4	10.0	1.5	5
23	37	141.9	54.5	*	2.0	3

* subject did not answer in questionnaire

Group Ht. $\overline{X}$ = 157.6 cm $\pm$ 7.5

Group Wt. $\overline{X}$ = 51.7 cm $\pm$ 5.1

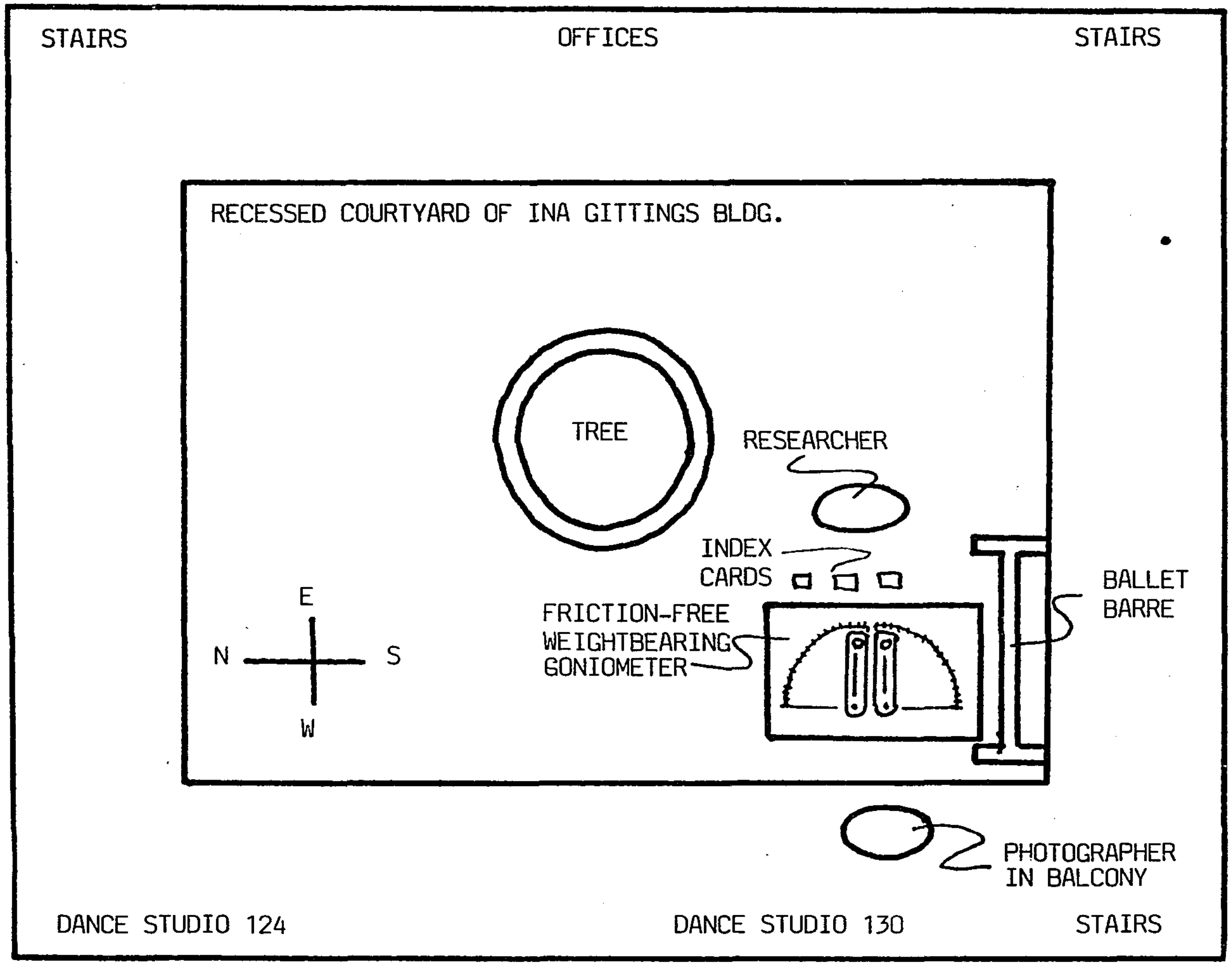


Figure 4. Diagram of the Test Site

Testing Procedures. After completing a consent form, a questionnaire and a warm-up, the subject was fitted with body markers. The dancer was allowed a few minutes of free practice on the friction-free weightbearing goniometer to familiarize herself with the device. Each subject was allowed at least three practice trials with feedback of turnout from both positions before three photographed test trials from each position were taken.

At the start of every trial, the three body segment markers were lined up with the goniometer's foot pedal pointers which were set at zero and held in place with nails. The investigator instructed the subject to place her feet on the goniometer's pedals so that the space between the second and third toes of each foot was in line with the pedal's pointers and her heels were centered over the pivot point of each foot pedal within comparable color-coded hatch marks. The starting position for each turnout trial was when the pedal pointers were aimed at zero and the subject's feet were correctly positioned on the foot pedals. At the start of each turnout trial the nails used to restrain pedal movement during subject positioning were removed.

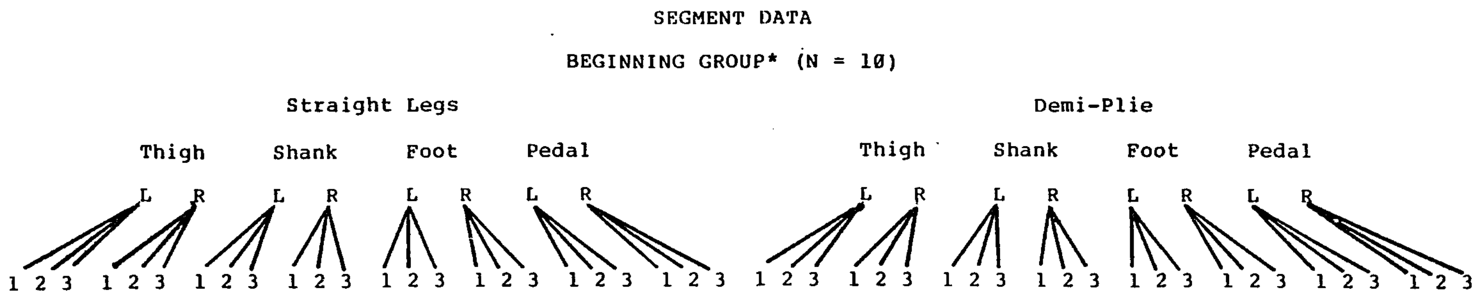
For the turnout on straight legs, the subject was asked to turn out from her hips as much as she could while looking straight ahead, maintaining a balletic posture (without hyperextending her lower back). For the turnout in the demi-plie position, the subject was asked to first laterally rotate her hips, then to bend her knees at the maximum turnout position without lifting her heels off the foot pedals. She was allowed to steady herself by lightly resting her hand on the barre which was situated to her right. In whichever turnout position had been randomly selected for initial testing, she took three trials. She was instructed to hold the maximum turnout position in each trial for five seconds with her arms in a low fifth position (arms held close to and in front of the body with elbows slightly bent and fingers almost touching). After each trial the investigator told the subject the degrees of right and left turnout as indicated by the pedal pointer. These right and left foot turnout measurements also were recorded on the subject's data sheet (Appendix D). Trials 1, 2 and 3 were photographed by the overhead camera in the maximum turnout positions. Following the three trials in one turnout position (straight legs or demi-plie), the subject took three trials in the remaining turnout position. Photographs and measurements were repeated as for the first turnout position.

Measurements From Photographs

Test data recorded from the photographs for each subject consisted of the angular position of turnout for two positions (straight leg and demi-plie), four segments (thigh, shank, foot and pedal), two sides (left and right) and three trials. There were 48 measurements per subject for each of the 21 subjects (10 beginners and 11 advanced) tested. The total number of measures recorded for analysis was 1,008. See Figure 5 for a diagram of these measurements.

Lower Extremity Segment Positions. The cumulative turnout position for the body segments of each lower extremity was represented by the recorded angular displacements read from the foot pedal pointers on the goniometer. These scores consisted of three trials in each turnout position which were read on-site as well as from the overhead photographs (sometimes with the help of a magnifying glass). See Figures 6 and 7 for photos of leg segment and pedal pointer rotation by one subject in two weightbearing conditions of turnout. The point at which the top edge of each body segment fin crossed the arc on the goniometer was defined as the measure of angular rotation in the overhead photograph.

The investigator chose to use the photographic data instead of the hand-recorded on-site data for the subsequent analysis of body segment displacement and total turnout (pedal position) in this study. The reasons for this decision were because the angular displacements of the thigh and shank could not be recorded from direct visual



* Advanced Group (N = 11) data include the same positions, segments, sides and trials

Figure 5. Schematic Representation Of Measurements From Photographs

Figure 6. Weightbearing Turnout On Straight Legs

a = thigh fin, b = shank fin, c = foot fin, d = foot pedal pointer

Figure 7. Weightbearing Turnout In Demi-Plie

a = thigh fin, b = shank fin, c = foot fin
d = foot pedal pointer

assessment and the photographs permitted more objective measurements than hand recordings from visual readings. The resulting measures from the photographs for each subject included turnout from straight and demi-plie positions at the thigh, shank, foot and pedal, on right and left sides over three trials.

Calculation of Joint Rotation (Absolute And Relative)

From the angular measurements of body segment positions, angular displacements at the hip, knee, ankle and intertarsal joints in each lower extremity during maximum turnout were calculated. The joint rotation measures were expressed both as absolute scores (degrees) and as relative scores (percentages of the total turnout expressed by the pedal) for each joint in the straight leg and demi-plie positions. The thigh markers were used to indicate hip rotation. The angular difference between the shank and thigh markers indicated knee rotation. The angular difference between the dorsal foot pointers and the shank markers was judged to be an indicator of ankle rotation. And the angular difference between the goniometer's foot pedal pointers and the dorsal foot pointers indicated inversion or eversion. As an example of joint degree and joint percentage calculations, the angular segment displacements of Subject #15 (seen in Figures 6 and 7 on pp. 5Ø & 51) during turnout are shown in Table 3. Joint degree data for all subjects are included in Appendix E.

Data Analysis

Procedures used to analyze the data will be discussed in this section which covers the following topics: reliability analysis on thigh and pedal data, descriptive data, ANOVA for pedal, MANOVAS for joints (degrees and percentages), post hoc tests and correlation analysis.

Reliability Analysis of Thigh and Pedal Data

Any error from independent muscle movement in relation to the underlying bones of the lower extremity (which would cause the body fins to move) was defined in this study as systematic error. If any systematic error occurred and the subjects were highly reliable (repeatable over trials), the results would still be meaningful as the error would occur similarly in both groups. Random error was reduced by using the same investigator to take all the measurements and using the same measurement procedures for all subjects.

The thigh had the potential for most independent muscle movement and therefore body fin movement. Thigh measurements might have contained systematic and random error. The goniometer foot pedal should not have contained any systematic error but possibly some random error. The reliability of thigh and pedal measurements was analyzed

TABLE 3. CALCULATIONS OF JOINT ROTATION

(ABSOLUTE AND RELATIVE) FOR ONE SUBJECT

(Subject #15 as seen in Figs. 6 & 7, pp. 5Ø & 51)

Turnout On Straight Legs

Body Site	Ang. Displ. Of Segment		Joint Degrees			Joint %	
	Lft	Rt	Jt	Lft	Rt	Lft	Rt
Thigh	32.5	39.Ø	Hip	32.5	39.Ø	44.8	53.4
Shank	57.Ø	57.5	Knee	24.5	18.5	33.7	25.3
Foot	7Ø.Ø	69.Ø	Ankle	13.Ø	11.5	17.9	15.8
Pedal	72.5	73.Ø	Inter.	2.5	4.Ø	3.4	5.5

Turnout In Demi-Plie

Body Site	Ang. Displ. Of Segment		Joint Degrees			Joint %	
	Lft	Rt	Jt	Lft	Rt	Lft	Rt
Thigh	58.Ø	61.5	Hip	58.Ø	61.5	65.9	67.6
Shank	81.Ø	8Ø.Ø	Knee	23.Ø	18.5	26.1	2Ø.3
Foot	87.Ø	88.Ø	Ankle	6.Ø	8.Ø	6.8	8.8
Pedal	88.Ø	91.Ø	Inter.	1.Ø	3.Ø	1.1	3.3

for all subjects through intra-class correlation coefficients from an ANOVA run on a University of Arizona RVAX using SPSSX (Statistical Package for Social Sciences, Version #10).

The two-way ANOVA summary tables provided mean-square error estimates associated with the main effects of Subjects And Trials and with the interaction of Subjects by Trials (S x T). The between-trial variance was considered as error and, therefore, was pooled with the variance due to the S x T interaction to obtain an estimate of "within-subject" variance. Reliability of the mean of all three trials (averaged over two sides) was calculated by the formula:

$$\frac{\text{Mean Square}_{\text{between subjects}} - \text{Mean square}_{\text{within subjects}}}{\text{Mean Square}_{\text{between subjects}}}$$

The resulting intraclass correlation coefficient estimates the ratio of true variance/obtained (total) variance and reflects the reliability or repeatability of subjects over trials (Safrit, Atwater, Baumgartner & West, 1976).

Results showed that the intra-class correlation coefficients for both the thigh and pedal data ranged from .94 to .97. This means that individuals within each group were highly repeatable over trials in their turnout. See

Table 4 for intra-class correlation coefficients for pedal and thigh in turnout on straight legs and in demi-plie.

TABLE 4. RELIABILITY OVER TRIALS ESTIMATED BY INTRA-CLASS CORRELATION COEFFICIENTS FOR PEDAL AND THIGH

	Pedal		Thigh	
	Plie	Straight	Plie	Straight
Grp. 1	Ø.94	Ø.95	Ø.94	Ø.94
Grp. 2	Ø.94	Ø.96	Ø.94	Ø.97

Descriptive Data

A computer program, SPSS, was used to obtain descriptive statistics for each group of subjects for joints in degrees and for joints as pedal percentages in two positions (straight leg and demi-plie) on two sides (right and left) for three trials.

ANOVA for Pedal Data

An ANOVA for the pedal data was run on the University of Arizona RVAX computer using SPSSX. The two factors analyzed were Group (beginning and advanced) and Position (straight leg and demi-plie). There was one interaction and that was Group by Position. See Figure 8 for a schematic representation of the ANOVA design.

MANOVAS For Joint Data (Degrees And Percentages)

The joint degree and joint percentage data were examined through multivariate analyses of variance (MANOVAS). For this study a descriptive multifactorial, 4x2x2x3x2 design was used for the analysis (see Figure 9 for a schematic representation of the design).

MANOVAS were input on the Dec-10 and run on the Cyber 175 to determine whether the mean values between sets of data differed statistically from one another by group (beginners vs. advanced). In each MANOVA, the between-subjects factor was group. The within-subject factors were body site (hip, knee, ankle and intertarsal), position (straight or demi-plie), side (right or left), and trial (1, 2, 3). Main effects and all possible interactions, alone and by group, were tested for statistical significance. An alpha level of $p < 0.05$ was chosen as the level of significance.

Post Hoc Tests

The Tukey post hoc test (Bruning & Kintz, 1977) was used to determine the source of mean differences for those main effects and interactions that proved statistically significant and that were meaningful to this study.

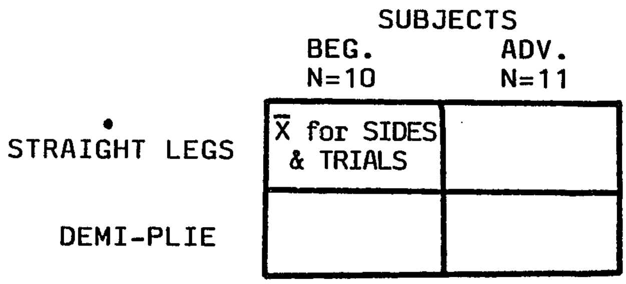


Figure 8. Schematic Representation of the Pedal ANOVA Design

FACTORS:	2 x 2
GROUPS (2):	Beginners (N = 10), Advanced (N= 11)
POSITIONS (2):	Straight Leg, Demi-Plie
SIDES (2):	Right, Left
TRIALS (3)	

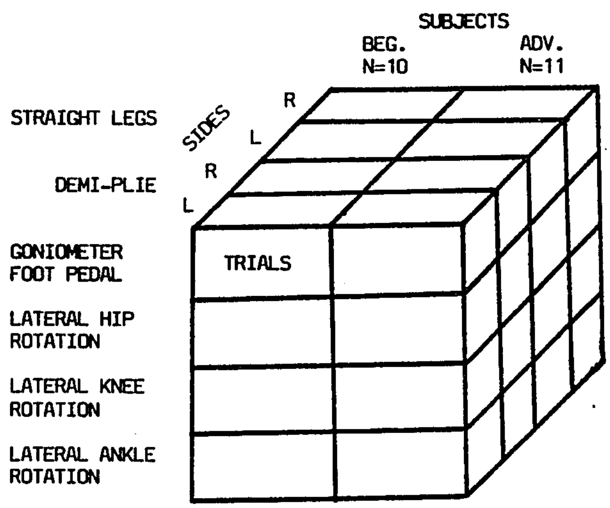


Figure 9. Schematic Representation Of The MANOVA Design

FACTORS:	4 X 2 X 2 X 3 X 2
GROUPS (2):	Beginners (N = 10), Advanced (N = 11)
POSITIONS(2):	Straight Legs, Demi-Plie
SIDES (2):	Right, Left
BODY SITES (4):	Thigh (Hip), Shank (Knee), Foot (Ankle), Foot Pedal (Intertarsal)
TRIALS (3)	

Correlation Analysis

Two-tailed Pearson Product Moment correlation coefficients were computed for the pedal vs. hip, knee, ankle and intertarsal joints for both groups in the straight leg and demi-plie positions. The level of significance of $p < 0.01$ was chosen because several correlation coefficients were being tested for each group.

Summary

Two groups of female dance students at the University of Arizona volunteered for participation in this study. The turnout positions of these subjects were measured with a friction-free weightbearing goniometer which was designed specially for this study. Overhead photos were taken of each subject as she performed turnout on the goniometer. Segment fins were attached to the subjects' right and left thighs, shanks and feet to assess lateral rotation in two conditions of weightbearing turnout (straight legs and demi-plie). The goniometer's pedal pointers (right and left) indicated cumulative turnout. Every subject took three trials in both positions of weightbearing turnout. Visual readings of the pedal scores on all trials were recorded on-site. Angular displacements of body segments and pedal pointers were recorded from overhead photos of trials 1, 2 & 3 during maximum turnout. Absolute and relative joint rotation in each lower extremity on straight legs and in demi-plie were calculated for both groups. Descriptive and inferential statistics were used to analyze the data.

CHAPTER IV

RESULTS AND INTERPRETATION

The purpose of this study was to analyze lateral rotation of the lower extremity joints during turnout from the straight leg and demi-plie positions in beginning and advanced female ballet dancers. The results are discussed below in relation to the questions raised in Chapter I. The initial questions are restated, the results from data collection and analysis are presented, and the findings are illustrated through the use of tables and graphs. A discussion of the results and their implications as they relate to the literature on turnout and to the available data on lateral rotation in the lower extremities will be included in Chapter V.

Trial-To-Trial and Side vs. Side Differences

Question 1

Are there significant trial-to-trial and right vs. left side differences in the maximum turnout position for beginning and advanced dancers?

The main effect of trial in the MANOVA For Joints In Degrees was significant (Table 5). The interaction of group by trial (G x T) was not significant. The absolute

TABLE 5

MANOVA FOR JOINTS IN DEGREES

SOURCE OF VARIATION	SS	DF	MS	F	SIG. OF F	
Total	278531.02					
Between Ss	6226.22	20				
Group (G)	3148.38	1	3148.38	19.44	0.00	*
Error	3077.84	19	161.99			
Within Ss	272304.80					
Joint Degree (JD)	226731.62	3	75577.21	463.02	0.00	*
Position (P)	2437.56	1	2437.56	68.84	0.97-007	*
Side (SI)	62.75	1	62.75	5.17	0.03	*
Trial (T)	92.23	2	46.12	25.19	1.08-007	*
JD x P	18758.92	3	6252.97	79.04	0.00	*
JD x SI	57.48	3	19.16	0.47	0.70	
JD x T	118.06	6	19.68	6.14	0.00	*
P x SI	4.52	1	4.52	0.88	0.36	
P x T	1.53	2	0.76	0.23	0.80	
SI x T	18.38	2	9.19	3.15	0.05	
JD x P x SI	56.43	3	18.80	1.13	0.35	
JD x P x T	67.28	6	11.21	2.38	0.03	*
JD x SI x T	33.49	6	5.58	1.36	0.24	
P x SI x T	7.72	2	3.86	0.86	0.43	
JD x P x SI x T	43.67	6	7.28	1.61	0.15	

* $p < 0.05$

TABLE 5 Continued

SOURCE OF VARIATION	SS	DF	MS	F	SIG. OF F	
Within Ss						
G x JD	2096.36	3	698.79	4.28	0.00	*
G x P	1.21	1	1.21	0.03	0.86	
G x SI	17.20	1	17.20	1.42	0.25	
G x T	3.87	2	1.94	1.06	0.36	
G x JD x P	693.32	3	231.12	2.92	0.04	*
G x JD x SI	224.29	3	74.76	1.84	0.15	
G x JD x T	16.64	6	2.77	0.87	0.52	
G x P x SI	20.54	1	20.54	4.00	0.06	
G x P x T	4.00	2	2.00	0.59	0.56	
G x SI x T	8.20	2	4.10	1.40	0.26	
G x JD x P x SI	152.05	3	50.68	3.04	0.04	*
G x JD x P x T	44.13	6	7.36	1.79	0.11	
G x JD x SI x T	51.16	6	8.53	1.81	0.10	
G x P x SI x T	1.45	2	0.72	0.16	0.85	
G x JD x P x SI x T	29.34	6	4.89	1.08	0.38	
Error 1	9303.91	57	163.23			
Error 2	672.74	19	35.41			
Error 3	230.51	19	12.13			
Error 4	69.57	38	1.83			
Error 5	4509.20	57	79.11			
Error 6	2317.62	57	40.66			
Error 7	365.08	114	3.20			
Error 8	97.45	19	5.13			
Error 9	128.91	38	3.39			
Error 10	110.97	38	2.92			
Error 11	950.79	57	16.68			
Error 12	468.79	114	4.11			
Error 13	537.49	114	4.71			
Error 14	171.16	38	4.50			
Error 15	515.21	114	4.52			

* $p < 0.05$

joint degree trial-to-trial differences were examined for the combined groups. The trial means and standard deviations in Table 6 represent the average across two groups, two positions, four joints and two sides. The total number of measurements used in these calculations was 336. A Tukey post hoc test showed all three trials for the combined groups to be significantly different from one another at the 0.05 level (Table 6). Specifically, this average score (over two groups, two positions, four joints and two sides) increased significantly from trial 1 to 2 and 2 to 3. This might indicate a learning or practice effect even though all subjects were given a few minutes of free practice (without feedback) followed by three practice trials with feedback prior to performing the three test trials. The significant trial-to-trial increase in performance might represent systematic within-subject variability. However, since the average scores for the three separate trials differed by less than 1° (Table 6) and standard deviations were similar, the decision was made to use the mean of each subject's three trial scores for a given position and joint to best represent that subject's performance. The main effect of trial and the interaction of group by trial (G x T) in Table 7, MANOVA For Joints As Percent Of Pedal, were not significant at the 0.05 level.

The absolute joint degree differences between right vs. left side were examined because the main effect

TABLE 6. COMPARISON OF TURNOUT TRIAL MEANS[a]

TRIALS	1	2	3
1	16.58[b] (2.43)	*	*
2		16.97 (2.51)	*
3			17.26 (2.61)

a = Each trial mean represents the joint measurement (in degrees) for turnout averaged across two groups, two positions, four joints and two sides. N = 336 separate measurements averaged for each trial.

b = Mean; Standard deviation in parentheses

* = $p < 0.05$; results of mean comparisons are presented only in the upper right triangle of this matrix

TABLE 7

MANOVA FOR JOINTS AS PERCENT OF PEDAL

SOURCE OF VARIATION	SS	DF	MS	F	SIG. OF F	
Total	563940.47					
Between Ss	208.73	20				
Group (G)	0.06	1	0.06	0.00	0.94	
Error	208.67	19	10.98			
Within Ss	563731.74					
Joint % (JP)	498567.24	3	166189.08	595.63	0.00	*
Position (P)	44.50	1	44.50	10.88	0.00	*
Side (SI)	8.69	1	8.69	2.16	0.16	
Trial (T)	0.46	2	0.23	0.12	0.89	
JP x P	22726.57	3	7575.52	45.50	0.00	*
JP x SI	150.30	3	50.10	0.50	0.68	
JP x T	130.57	6	21.76	2.46	0.03	*
P x SI	0.38	1	0.38	0.07	0.79	
P x T	1.30	2	0.65	0.17	0.85	
SI x T	8.43	2	4.22	1.10	0.34	
JP x P x SI	148.05	3	49.35	1.36	0.27	
JP x P x T	145.83	6	24.31	2.34	0.04	*
JP x SI x T	37.00	6	6.17	0.86	0.53	
P x SI x T	10.30	2	5.15	2.92	0.07	
JP x P x SI x T	56.16	6	9.36	0.91	0.49	

* $p < 0.05$

TABLE 7 Continued

SOURCE OF VARIATION	SS	DF	MS	F	SIG. OF F	
Within Ss						
G x JP	1523.31	3	507.77	1.82	0.15	
G x P	0.00	1	0.00	0.00	0.98	
G x SI	0.28	1	0.28	0.07	0.80	
G x T	1.68	2	0.84	0.44	0.65	
G x JP x P	977.60	3	325.87	1.96	0.13	
G x JP x SI	489.59	3	163.20	1.64	0.19	
G x JP x T	56.56	6	9.43	1.06	0.39	
G x P x SI	0.65	1	0.65	0.12	0.73	
G x P x T	8.62	2	4.31	1.12	0.34	
G x SI x T	4.88	2	2.44	0.64	0.53	
G x JP x P x SI	284.14	3	94.71	2.60	0.06	
G x JP x P x T	191.86	6	31.98	3.08	0.01	*
G x JP x SI x T	76.84	6	12.81	1.78	0.11	
G x P x SI x T	1.53	2	0.77	0.43	0.65	
G x JP x P x SI x T	62.71	6	10.45	1.02	0.42	
Error 1	15903.72	57	279.01			
Error 2	77.72	19	4.09			
Error 3	76.49	19	4.02			
Error 4	72.41	38	1.91			
Error 5	9490.74	57	166.50			
Error 6	5678.50	57	99.62			
Error 7	1009.77	114	8.86			
Error 8	103.85	19	5.47			
Error 9	146.66	38	3.86			
Error 10	145.12	38	3.82			
Error 11	2074.18	57	36.39			
Error 12	819.87	114	7.19			
Error 13	1183.26	114	10.38			
Error 14	·66.99	38	1.76			
Error 15	1166.43	114	10.23			

* $p < 0.05$

of side was significant when groups were combined but it was not significant by group (Table 5, pp. 62 & 63). A Tukey post hoc test showed that, for the combined groups, the two sides were significantly different from one another at the 0.05 level (Table 8). However, since these average scores (over two groups, two positions, four joints and three trials) differed by less than 1° and because the interaction of group by side (G x SI) was not significant, the decision was made to take the average of right and left sides for further analyses of each joint in both positions of turnout.

Turnout in dancers is not usually considered in terms of one leg at a time or as the average of right and left sides. Instead, it is viewed as a cumulative effect of rotation by both legs. Figures 10 and 11 illustrate the group average for straight leg and plie turnout produced by rotation of both the right anhd left legs in much the same way as one subject took turnout (Figures 6 & 7, pp. 50 and 51). These figures show that turnout for the right vs. left sides does not tend to differ appreciably by group, as was found in the MANOVA For Joint Degrees (Table 5, pg. 62). For simplicity of analysis in subsequent sections of this study a typical leg (averaging right and left sides) will be used for further calculations of the position of each joint in both positions of turnout.

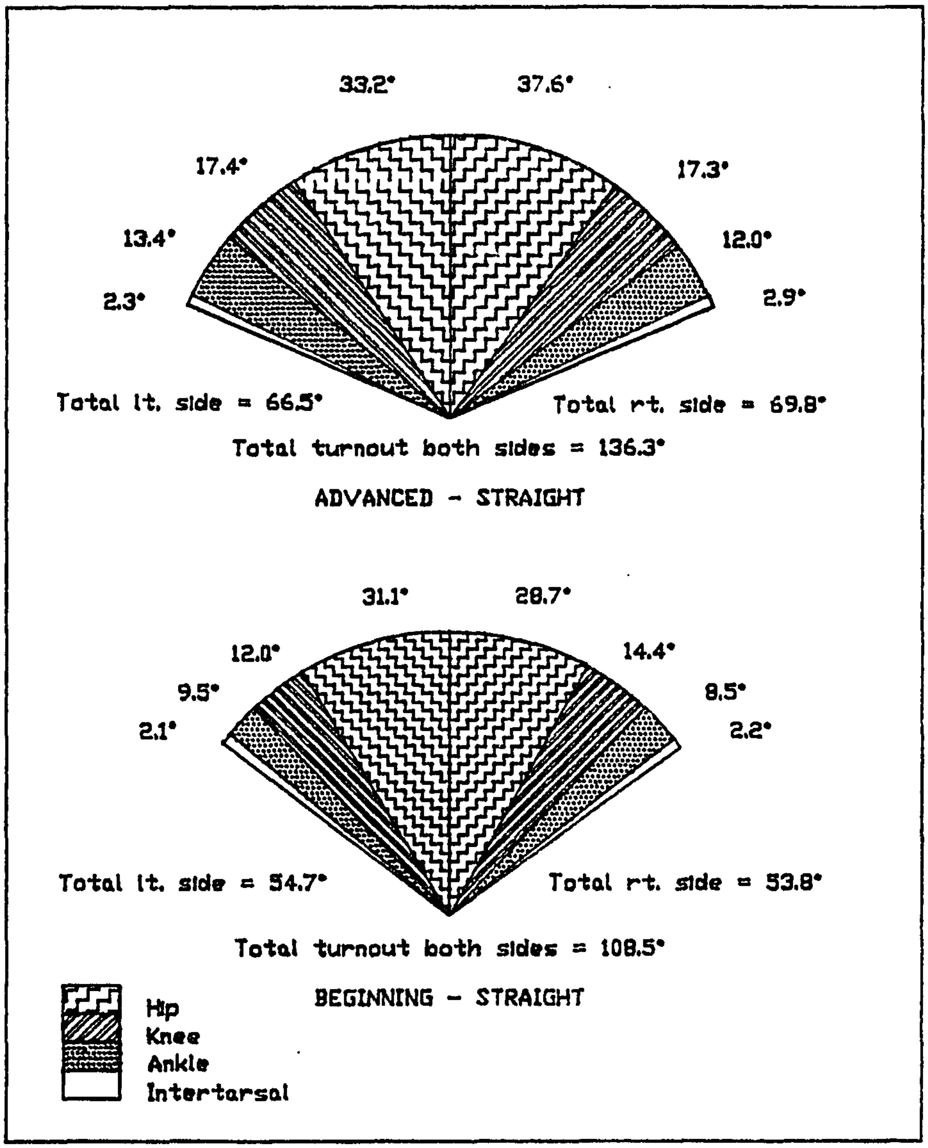


Figure 10. Lower Extremity Joint Contributions (Degrees) to Turnout on Right and Left Sides in the Straight Leg Position for the Beginning and Advanced Groups (mean of three trials).

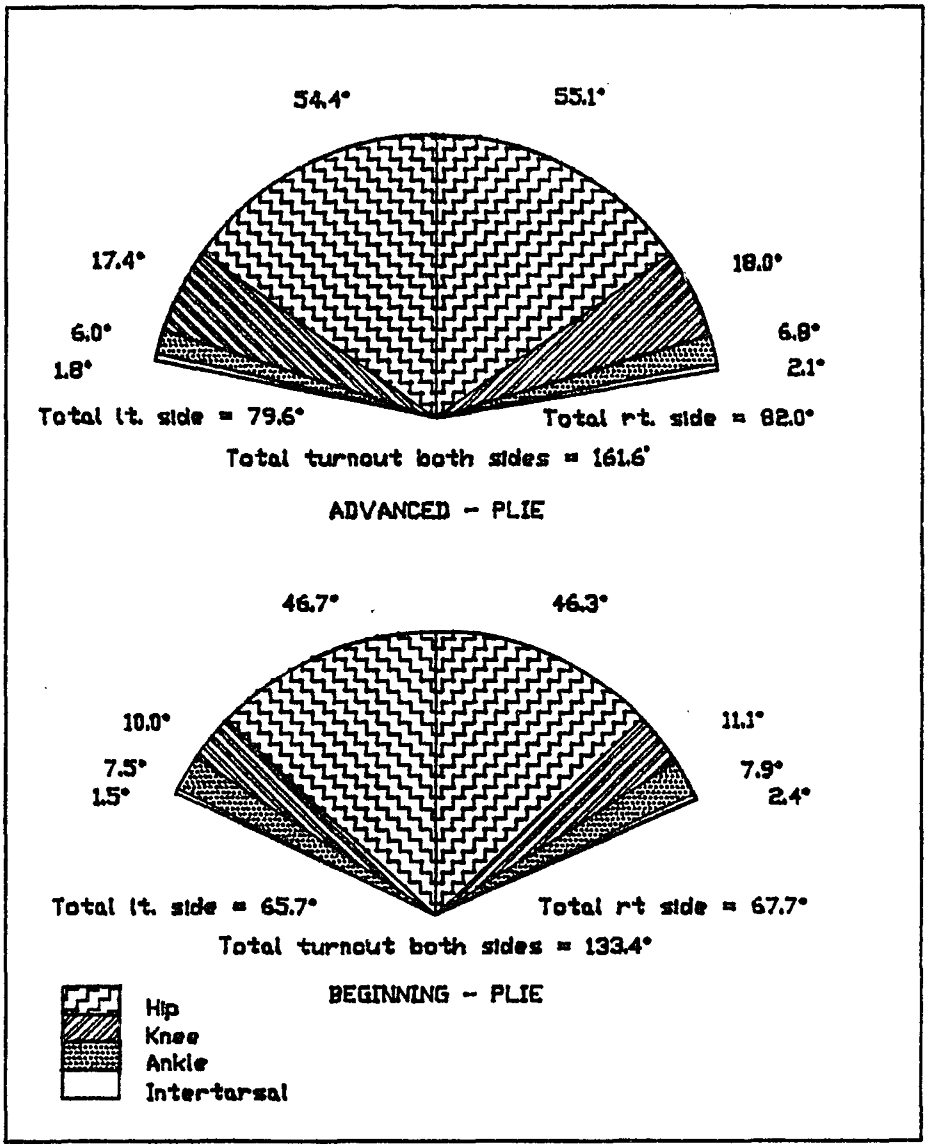


Figure 11. Lower Extremity Joint Contributions (Degrees) to Turnout on Right and Left Sides in the Demi-Plie Position for the Beginning and Advanced Groups (mean of three trials).

In conclusion, there are no significant trial-to-trial and right vs. left side differences in the maximum turnout position between the beginning and advanced groups of dancers. Therefore, trials and sides will be averaged for each subject and further analyses will deal only with two groups, four joints and two positions.

Differences Between Turnout Positions and Groups

Question 2

Is there a significant difference between the two positions of turnout (straight and demi-plie) and between the two groups of dancers (beginning and advanced) for each of the two positions of turnout as measured by a weight-bearing friction-free goniometer pedal?

The pedal measurements representing total turnout of the feet were analyzed using a two-way ANOVA. The two main factors analyzed were Group (beginning and advanced) and Position (straight leg and demi-plie). There was only one interaction and that was Group by Position (G x P). Results of the ANOVA (Table 9) showed that there was a significant difference between the two groups at the 0.05 level. There also was a significant difference between the two positions at the 0.05 level. The interaction of Group by Position (G x P) was not significant. See Figure 12 for a graph of the group means and standard deviations for the

TABLE 9. ANOVA RESULTS FOR PEDAL MEASUREMENTS COMPARING TURNOUT POSITIONS AND GROUPS

Source of Variation	SS	DF	MS	F	Sig. of F
Total	24703.36				
Between	17382.35				
Group (G)	8060.28	1	8060.28	16.43	.001 *
Error	9322.07	19	490.64		
Within	7321.01				
Position (P)	5451.01	1	5451.01	55.39	.000 *
G x P	.22	1	0.22	0.00	.963
Error	1869.78	19	98.41		

* = $p < 0.05$

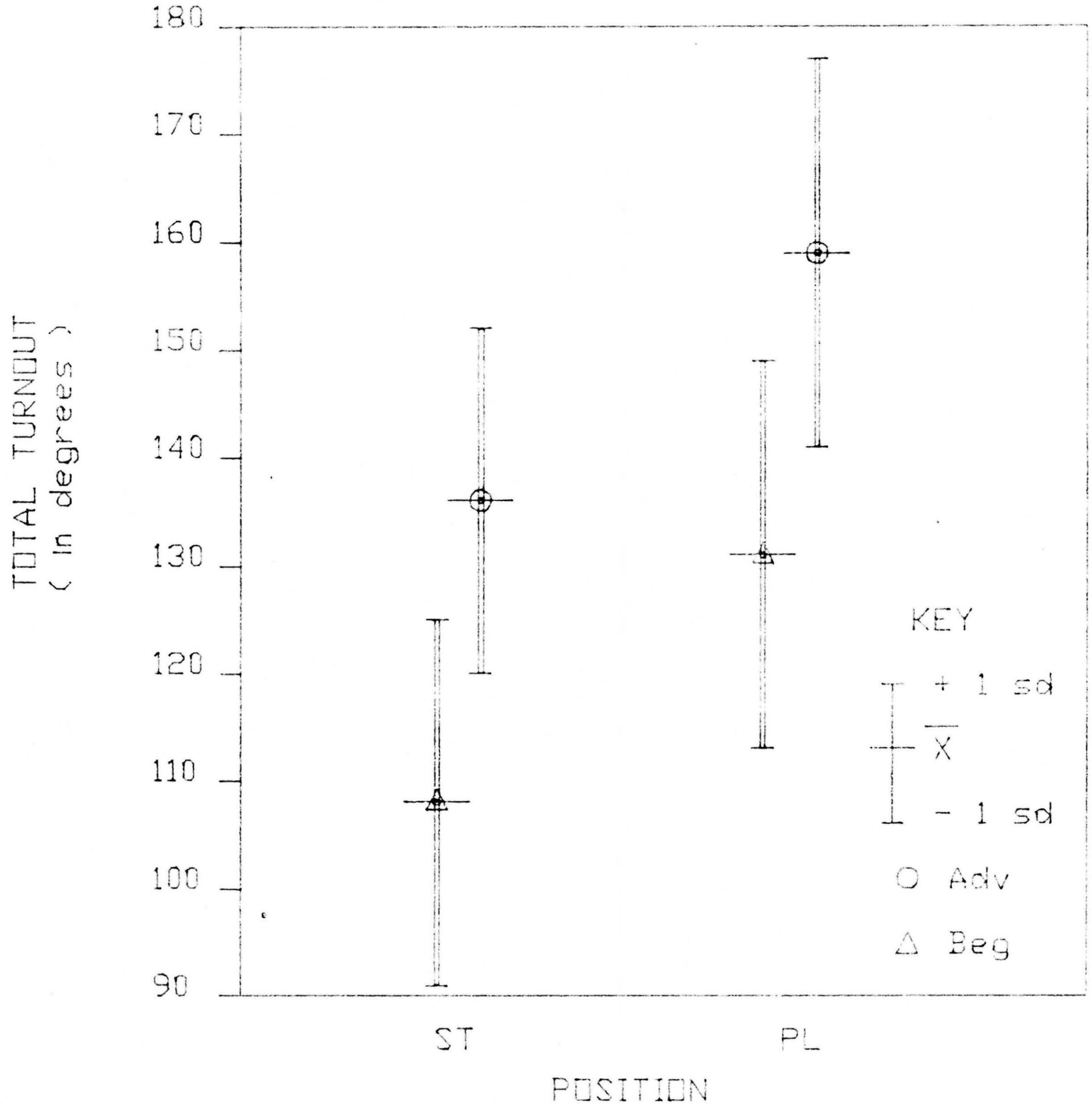


Figure 12. Group Means For Pedal Measurements Representing Total Turnout In Straight Leg and Demi-Plie Positions

pedal measurements representing total turnout in the straight leg (ST) and demi-plie (PL) positions.

Tukey post hoc tests were used to determine which group means and which position means were significantly different from one another. The following comparisons were tested: 1) within group and between positions, 2) within positions and between groups, and (3) between groups and between positions.

Both groups had significantly greater turnout in demi-plie than in straight legs. The advanced group had significantly greater turnout than the beginning group on straight legs and in demi-plie. There was no significant difference between the advanced group in the straight leg turnout and the beginning group in demi-plie turnout. See Table 10 for the Tukey post hoc test results for the pedal measurements (sum of the mean of four joints, two sides and three trials).

Absolute and Relative Contributions of Joints to Pedal Turnout in Both Postions

Question 3

What are the absolute (degrees) and the relative (percent) contributions of lower extremity joints to pedal turnout in both groups in both positions of turnout? Do these absolute and relative joint contributions to turnout

TABLE 10. TUKEY POST HOC TEST RESULTS COMPARING PEDAL MEANS REPRESENTING TOTAL TURNOUT FOR GROUPS AND POSITIONS[a]

	Beginning Straight	Beginning Demi-Plie	Advanced Straight	Advanced Demi-Plie
Beg.				
Str.	108.13[b] (17.07)	*	*	*
Plie		130.80 (17.69)		*
Adv.				
Str.			135.73 (15.85)	*
Plie				158.68 (18.00)

a = Each pedal mean represents the average across four joints, two sides and three trials.

b = Mean; Standard deviation in parentheses

* = $p < 0.05$; results of mean comparisons are presented only in the upper right triangle of this matrix

differ significantly between the two groups of dancers, and between the two positions of turnout?

Assuming that turnout is a cumulative joint effect, the pedal turnout measurement from the weightbearing friction-free goniometer will equal the sum of the lateral rotation in the joints of the lower extremity. Figure 13 shows the cumulative lower extremity joint contribution (degrees) to turnout averaged over right and left sides in straight leg and demi-plie positions for the beginning and advanced group of dancers. The amount of turnout at each joint site varied by group and by position. For both groups, the hip was responsible for the greatest amount of lateral rotation, with the knee, ankle and intertarsal joints contributing progressively smaller amounts.

Inferential statistics were used to analyze the significance of the interaction of the variables of group, position and joint. In the MANOVA for Joint Degrees (see Table 5, pp. 62 & 63), there were three interactions by group that were significant to the Ø.Ø5 level. The two-way interaction of group by joint degree (G x JD) was not examined because the three-way interaction of group by joint degree by position (G x JD x P) included the same variables, as well as including the effect of position. The four-way interaction of group by joint degree by position by side (G x JD x P x SI) was not examined further for two reasons: (1) the variable of side was not

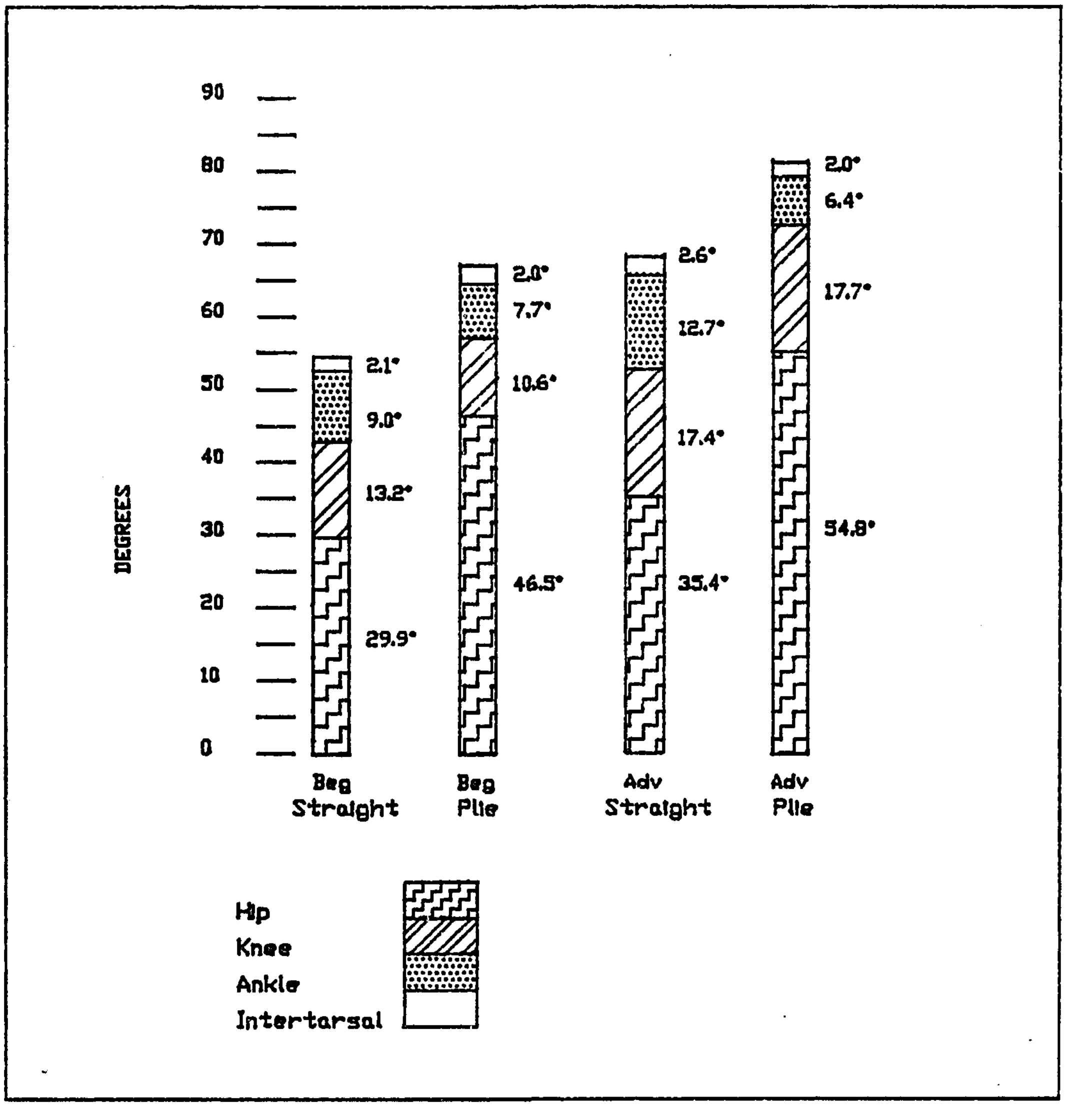


Figure 13. Cumulative Lower Extremity Joint Contributions (degrees) to Turnout Averaged Over Right and Left Sides in Straight Leg and Plie Positions for the Beginning and Advanced Groups

determined to be particularly meaningful to the purposes of this study and (2) the interaction of group by side (G x SI) was not significant. The three-way interaction was further examined by using Tukey post hoc tests (Table 11) to identify: (1) between group differences, within a position and within a joint, (2) between position differences, within a group and within each joint, and (3) between joint differences, within each group and within each position.

The Tukey post hoc tests revealed no significant differences between the beginning and advanced groups of dancers within a position and within a joint. Both groups had significantly greater turnout in demi-plie than in straight legs at the hip joint, but not at the knee, ankle or intertarsal joints. The hip joint contributed significantly greater turnout than the knee, ankle and intertarsal joints for both groups in both positions (straight and plie). No significant differences were found between the knee and ankle, knee and intertarsal or between the ankle and intertarsal. Figure 13 (pg. 78) illustrates these results.

Figure 14 shows the cumulative lower extremity joint contributions (percent) to turnout averaged over right and left sides in straight leg and plie positions for the beginning and advanced group of dancers. For both groups in both positions of turnout, joint contributions to

TABLE 11. TUKEY POST HOC TEST RESULTS FOR GROUP BY JOINT DEGREES BY POSITION[a]

			Beginning (Beg)								Advanced (Adv)							
			Straight (S)				Plie (P)				Straight (S)				Plie (P)			
			H	K	A	I	H	K	A	I	H	K	A	I	H	K	A	I
Beg.	S	H	29.85[b] (5.37)	* Jt.dif	* Jt.dif	* Jt.dif	* Pos.dif											
		K		13.23 (3.48)														
		A			8.97 (5.03)													
		I				2.13 (1.15)												
	P	H					46.48 (6.86)	* Jt.dif	* Jt.dif	* Jt.dif								
		K						10.54 (3.24)										
		A							7.70 (4.27)									
		I								1.94 (1.13)								
Adv.	S	H									35.41 (5.65)	* Jt.dif	* Jt.dif	* Jt.dif	* Pos.dif			
		K										17.36 (2.93)						
		A											12.70 (4.53)					
		I												2.58 (1.27)				
	P	H													54.73 (7.38)	* Jt.dif	* Jt.dif	* Jt.dif
		K														17.72 (4.54)		
		A															6.38 (3.92)	
		I																1.94 (0.89)

a = Each group mean represents the average across two sides and three trials.

b = Mean; Standard deviations in parentheses

* = $p < 0.05$

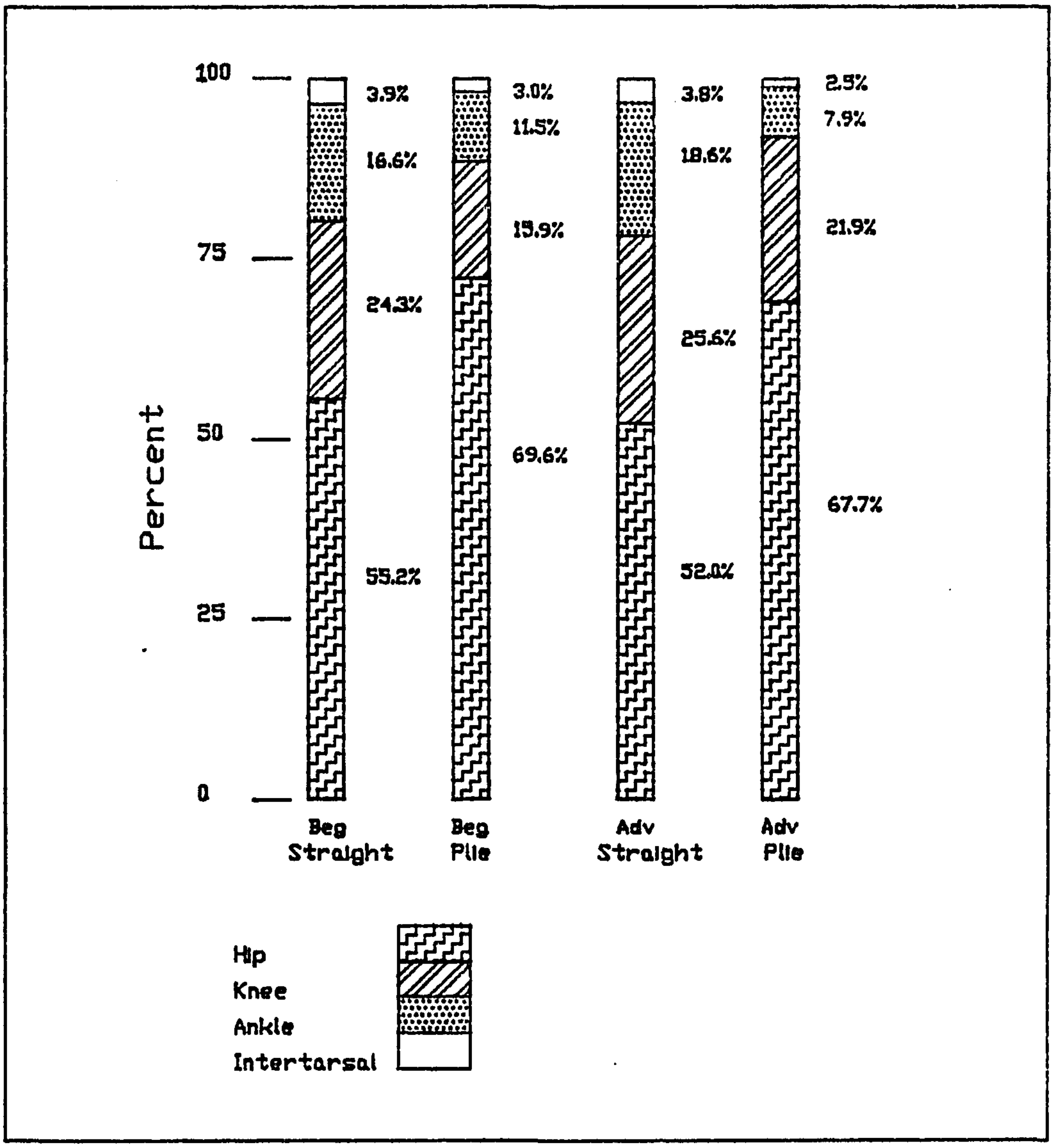


Figure 14. Cumulative Lower Extremity Joint Contribution (percent) to Turnout Averaged Over Right and Left Sides in Straight Leg and Plie Positions for the Beginning and Advanced Groups.

overall turnout occurred in a descending magnitude from hip to intertarsal. For both groups the hip joint tended to contribute relatively more to pedal turnout in the plie position than in the straight leg position, and the knee tended to contribute relatively less in plie than in straight legs. The MANOVA for Joints As a Percent of Pedal (Table 7, pp. 66 & 67) showed significance ($p < 0.05$) in the main effects of joints and positions and in the interaction of joint by position (JP x P) when groups were combined. However, there were no significant interactions by group that were significant at the 0.05 level, except for Group by Joint Percent by Position by Trial (G x JP X P X T). Since the decision had been made to use the average of all three trials, this interaction was not investigated further.

Relationship Between the Degree of Joint Turnout and Pedal Turnout

Question 4

What is the relationship between the degree of turnout at each joint and total pedal turnout?

Correlation coefficients between the pedal measurements and each of the four lower extremity joints are presented for straight leg turnout (Table 12) and for turnout in the demi-plie position (Table 13). In the straight leg position a positive significant correlation

TABLE 12. PEDAL/JOINT CORRELATIONS FOR TURNOUT IN THE STRAIGHT LEG POSITION

		Beg. (N=10)	Adv. (N=11)
Pedal vs.			
Hip	r	0.616	0.741*
Knee	r	0.353	-0.295
Ankle	r	0.637	0.758*
Intertarsal	r	0.622	0.601

* = $p < 0.01$, two-tailed test

r required for significance: Beg. = 0.765, Adv. = 0.735

TABLE 13. PEDAL/JOINT CORRELATIONS FOR TURNOUT IN DEMI-PLIE POSITION

		Beg. (N=10)	Adv. (N=11)
Pedal vs.			
Hip	r	0.841*	0.770*
Knee	r	0.349	0.089
Ankle	r	0.287	0.310
Intertarsal	r	-0.124	0.408

* = $p < 0.01$, two-tailed test

r required for significance: Beg. = 0.765, Adv. = 0.735

between the pedal and hip and between the pedal and ankle occurred for the advanced group of dancers. This indicates that greater turnout at the hip and ankle joints is a fairly good predictor of greater pedal turnout in advanced dancers. For the beginning group in the straight leg position, those subjects with greater pedal turnout did not have significantly greater range at the hip, knee, ankle or intertarsal joints than other subjects with less pedal turnout from the same group. In the demi-plie position a positive significant correlation occurred between the hip joint and the pedal for both groups. This indicates that the larger the hip joint turnout, the larger the overall turnout as measured from the pedal. However, the dancers who had greater pedal turnout within each group did not demonstrate significantly greater range at the knee, ankle and intertarsal joints than did those dancers who had less pedal turnout in demi-plie.

Correlation coefficients and two-tailed significance tests were not calculated for pedal and joint percent because the pedal measurement already represented 100% of turnout in all subjects.

Joint Changes from Straight to Demi-Plie Turnout

Question 5

If total turnout for a group of dancers is greater in demi-plie than in the straight leg position, which

joints(s) in the lower extremity contributed to this increased range?

It was determined previously (pg. 80) that both groups of dancers had significantly greater total turnout in the demi-plie position than in the straight leg position. Of concern in this section is the contribution made by each of the joints in the lower extremity to the increased turnout observed in the demi-plie position.

The amount of change in turnout between the straight leg and demi-plie positions was calculated at each joint for both groups using joint degree and joint percentage data, averaged over three trials and two sides; see Tables 14 and 15. In reference to the joint degree data (Table 14), the beginning group showed an increase in turnout from straight to demi-plie at the hip joint and a decrease in turnout at the other three joints. The increase in pedal turnout (the sum of the four joints) from straight leg to demi-plie positions was 12.6° for this group. The hip joint actually turned out farther (16.6°) than this total joint difference. Therefore, the knee, ankle and intertarsal joints decreased their range of motion during demi-plie to compensate for the increase in hip rotation.

A similar situation occurred in the advanced group (Table 14) in that the increase in the pedal turnout from

TABLE 14. JOINT DEGREE TURNOUT DIFFERENCES BETWEEN STRAIGHT LEG AND DEMI-PLIE POSITIONS

Beginning Group

Joint	Plie	Straight	Diff.
Hip	46.5	29.9	16.6
Knee	10.6	13.2	-2.6
Ankle	7.7	9.0	-1.3
Inter.	2.0	2.1	-0.1
Total	66.8	54.2	12.6

Advanced Group

Joint	Plie	Straight	Diff.
Hip	54.8	35.4	19.4
Knee	17.7	17.4	0.3
Ankle	6.4	12.7	-6.3
Inter.	2.0	2.6	-0.6
Total	80.9	68.1	12.8

TABLE 15. JOINT PERCENT TURNOUT DIFFERENCES BETWEEN STRAIGHT LEG AND DEMI-PLIE POSITIONS

Beginning Group

Joint	Plie	Straight	Diff.
Hip	69.6	55.2	14.4
Knee	15.9	24.3	-8.4
Ankle	11.5	16.6	-5.1
Inter.	3.0	3.9	-0.9
Total	100.0	100.0	0.0

Advanced Group

Joint	Plie	Straight	Diff.
Hip	67.7	52.0	15.7
Knee	21.9	25.6	-3.7
Ankle	7.9	18.6	-10.7
Inter.	2.5	3.8	-1.3
Total	100.0	100.0	0.0

straight to demi-plie (12.8°) was less than the hip joint increase (19.4°). The knee showed a negligible increase (Ø.3°) while the other two joints showed a decrease in turnout from straight to demi-plie with the largest differrence (-6.3°) at the ankle.

Using joint percentage data (Table 15) for each group (averaged over three trials and two sides) differences in turnout from straight to plie were examined at each lower extremity joint. For both the beginners and the advanced dancers there was a percentage increase (14 to 16%) in turnout at the hip joint with simultaneous percentage decreases (-1 to -11%) in the other joints as total turnout increased from the straight leg to the demi-plie positions. The beginning group showed the greatest percentage decrease in turnout at the knee joints from demi-plie to the straight leg position, while the advanced group showed the largest percentage decrease at the ankle.

In summary, there was an increase in total lower extremity turnout from straight leg to demi-plie positions but this increase was not derived from an increased rotation at each joint. Instead, the hip joint was primarily responsible for the increased turnout range while the other joints (with the minor exception of the absolute turnout at the knee in the advanced group) actually decreased in their contribution to turnout. Regarding the largest decrease in absolute and relative turnout from the straight leg to the demi-plie position, the advanced group of dancers showed it at the ankle joint and the beginning group exhibited it at the knee joint.

Lower Leg and Thigh Alignment in Both Groups

Question 6

When beginning and advanced ballet dancers take turnout from a straight leg position or from demi-plie, do they tend to keep their lower leg and thigh in line with their feet?

From an analysis of the overhead photographs of the lower extremity segment markers and pedal pointers it is obvious that neither group of dancers was able to maintain perfect alignment between their thigh, lower leg and the pedal. Group mean turnouts (averaged over three trials and two sides) for each segment and for the pedal were graphed (Figure 15) for both positions (straight and demi-plie). In both groups turnout of the thigh was less than that of the shank which was less than the turnout of the foot. The smallest difference in alignment between thigh and shank was in the demi-plie turnout of the beginning group (thigh $\bar{X} = 46.5^{\circ}$, shank $\bar{X} = 57.0^{\circ}$, difference = 10.5°) while the largest difference between these two segments was in the demi-plie turnout of the advanced group (thigh $\bar{X} = 54.7^{\circ}$, shank $\bar{X} = 72.4^{\circ}$, difference = 17.7°). The greatest misalignment between the shank and foot occurred in the

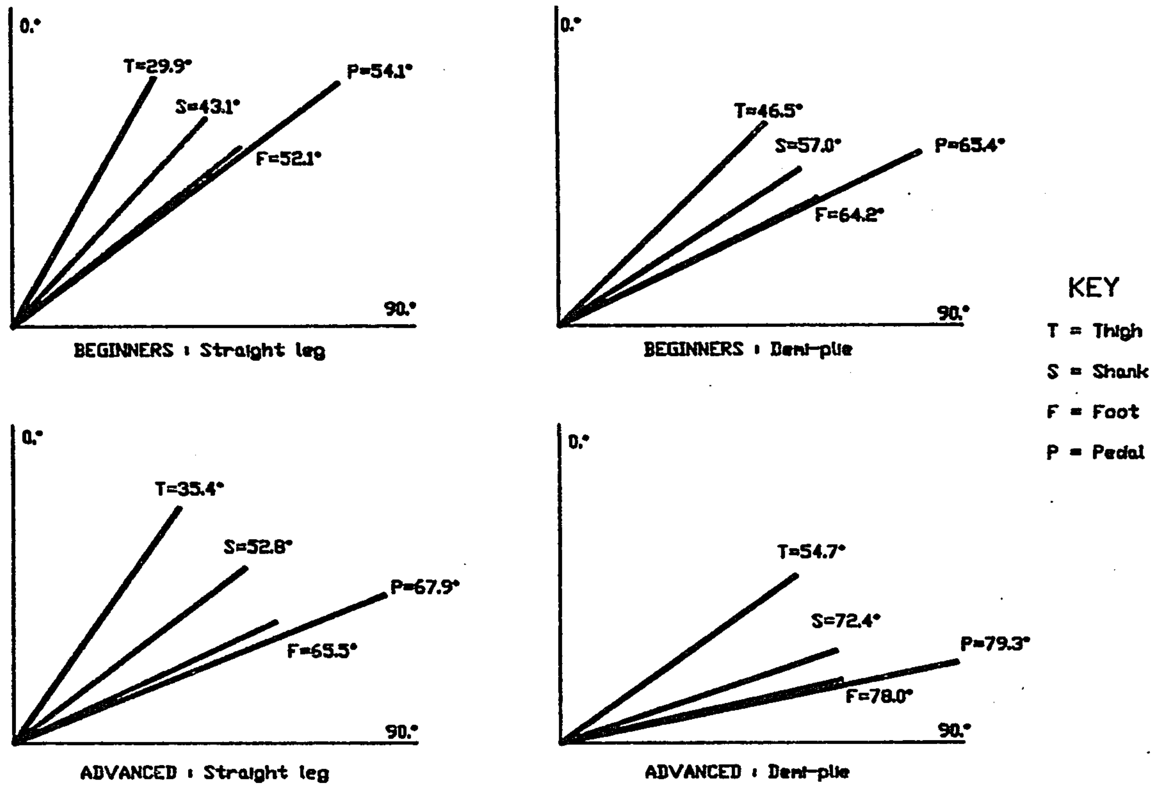


Figure 15. Segment and Pedal Angular Displacements by Group and Position

advanced group during the straight leg position of turnout (shank $\bar{X}$ = 52.8°, foot $\bar{X}$ = 65.5°, difference = 12.7°). The least misalignment between these two segments occurred in the advanced group during demi-plie (shank $\bar{X}$ = 72.4°, foot $\bar{X}$ = 78.0°, difference = 5.6°). The classroom dictum of "keep your knees over your feet" during turnout was not achieved by these dancers and, in fact may not be possible for any ballet dancers.

Summary

A quantification and analysis of lateral rotation in the hips, knees, ankles and intertarsals during two positions of turnout for two levels of ballet dancers revealed the following:

1. There were significant trial-to-trial increases and right vs. left side differences in turnout for all subjects. Since average mean score differences were less than 1°, the average of each subject's three trial scores and right and left scores for a given position and joint were used to best represent that subject's performance.

2. An ANOVA of pedal data (average of three trials and two sides), revealed a significant increase in turnout existed in the demi-plie position for both groups compared to the straight leg position. The advanced group had significantly greater turnout in both positions than the beginning group. No significant difference in turnout

existed between the advanced group in demi-plie and the beginning group in straight legs.

3. A MANOVA of joint degree data revealed that the interaction of group by joint degree by position (G x JD x P) was statistically significant at the 0.05 level. A Tukey post hoc test showed that both groups had significantly greater turnout at the hip joint in demi-plie than in straight legs. Also, the hip joint contributed significantly greater range in lateral rotation than did the other joints for both groups in both positions of turnout. A MANOVA of joint percent data indicated no meaningful significant interactions between groups of dancers.

4. A positive significant correlation existed between the pedal and hip and between the pedal and ankle for the advanced dancers in the straight leg position. In this position the beginning group exhibited no positive correlations between the pedal and lower extremity joints. In the demi-plie position, a positive correlation occurred only between the hip and pedal for both groups.

5. In both the beginning and advanced groups the hip joint alone (except for a negligible 0.3° knee increase) contributed to the increased pedal turnout from straight legs to demi-plie. Turnout at the knee, ankle and intertarsal decreased in demi-plie compared to the range achieved in the straight leg position. The greatest

decrease occurred at the ankle in the advanced group of dancers (a -6.3^{o} decrease in demi-plie from straight leg turnout). Another noticeable decrease (-2.6^{o}) was seen at the knee in the beginning group.

6. In turnout from either straight legs or demi-plie the whole lower extremity did not rotate as one unit. Segment alignment did not occur in beginners or advanced dancers. The lack of alignment between the thigh and shank and between the shank and foot may have potential implications for knee and ankle injury.

CHAPTER V

DISCUSSION AND IMPLICATIONS

The results of this study will be related to the literature on turnout and to the normative data on lateral rotation in the lower extremities. The implications of these findings to ballet dancers, teachers and researchers will be presented below. This research challenges conventional wisdom about turnout.

Since there was a significant increase in degrees of turnout over trials (averaged over two groups, two sides and two positions), it can be assumed that a dancer's total turnout (measured from the feet) is slightly greater at the end of practice (a ballet class or rehearsal) than at the start due to a warm-up effect. Most dancers, therefore, regardless of level, should be able to increase their turnout with a warm-up. The question that arises is whether more time (in number of classes and rehearsals each week) and/or more training (specific stretching and strengthening exercises) will enable a dancer to learn to use all the lateral hip rotation available based on anatomical structure. It is still unproven whether or not the ideal turnout (a 180° total) ensures better technique, even if the aesthetics of the movement are improved. It is also not known whether certain ballet steps and movements require a greater degree of turnout than others.

Although a Tukey post hoc test showed that the right side was significantly different than the left for all dancers, the difference in joint degree means was less than 0.5° and the standard deviations were small and quite similar. The slight right side turnout advantage might be the result of the traditional practice for dancers to always train from the right leg first. However, this difference was not viewed to be meaningful in the overall analysis of lower extremity joint contributions to turnout.

Significant differences between both groups of dancers did not occur for trial-to-trial or for right vs. left side measurements. The improved performance over trials of turnout was small and similar for both groups. The result of no significant difference for group by side (G x SI) was not unexpected because all dancers train both legs for maximum adaptability.

The finding of a significant difference between groups for pedal (cumulative) turnout was expected. The group mean turnout of the advanced dancers was larger than that of the beginners. This was due to either an anatomical advantage or a learning effect (i.e., improved facilitation of available lateral rotation in the lower extremities). However, it cannot be proved from this study whether training over time (from a beginning to an advanced level) increases a dancer's utilization of total turnout.

The turnout position of demi-plie was significantly greater in total range than the turnout from straight legs for both groups. As previously reported (pg. 84) this increase was due primarily to greater hip joint turnout, rather than the result of potential lateral knee rotation at the flexed knee joints, as hypothesized. Results (Table 14, pg. 87) indicated that in fact, for the beginning group, the knee rotation was greater in the straight leg position and approximately (0.3° smaller in straight legs) the same for the advanced group.

The interaction of group by position (G x P) was not statistically significant. A Tukey test revealed that turnout in the advanced group on straight legs was not significantly different from the turnout by the beginning group in demi-plie. Even with the availability of increased lateral hip and knee rotation in demi-plie, the beginning dancers did not achieve a significantly greater total turnout than the advanced dancers on straight legs. Again, either an increased ability to utilize the maximum turnout available or an anatomical advantage and selection process can be offered as the cause for the advanced group having greater turnout on straight legs than the beginning group had in demi-plie.

Regardless of skill level, the groups turned out similarly at each joint when tested from the same position. Both groups had greater turnout at the hip joint in demi-plie than in straight legs. This finding agrees with the anatomical literature (e.g., Bachrach, 1986b) which explains that, when the knees flex, the hip flexes and releases the normal restrictions of the Y ligament of Bigelow on the hip joint thereby allowing the dancer to increase her turnout. For both groups turnout at the knee, ankle and intertarsal was not significantly greater in demi-plie than on straight legs. Since turnout occurred at the knee in the straight leg position (which is contrary to the clinical literature on range of motion of the knee joint during extension) knee flexion in demi-plie may not have increased the turnout. In fact, Helfet (1982) and Kendall and Mc Creary (1983) state that the tibia rotates medially during knee flexion. To counterbalance this medial rotation a dancer may invert her foot (at the subtalar joint) which causes the tibia to rotate laterally. In so doing, the forefoot adducts somewhat thereby lessening the appearance of a turned out position. And in fact, the advanced group had much less turnout at the ankle during plie than in straight legs. Perhaps the dancers achieved the maximum degree of knee (as well as ankle and intertarsal) turnout from straight legs that could be attained due to specific training technique and methods which caused laxity in the ligaments (e.g., sur le cou de pied, rond de jambes en l'air, pirouettes, use of rosin). This maximum amount then was not significantly alterable during demi-plie.

Tukey post hoc tests showed that the hip joint contributed significantly greater turnout (in degrees) than the knee, ankle and intertarsal joints in both positions and for both groups. This finding is contrary to the general consensus of ballet literature that implies the entire lower extremity rotates outward as a unit. However, it confirms the impressions stated by some authors (i.e., Bachrach, 1986c; Hamilton, 1982; Wilson, in press) that the hip is the primary source of turnout although other lower extremity joints contribute to the final position achieved. Bachrach (1986c) acknowledged that a dancer might exhibit a 90° turnout from one side composed of $65-70^{\circ}$ at the hip, $10-15^{\circ}$ at the knee and $5-10^{\circ}$ at the ankle. The advanced group in this study, which averaged a 68° turnout in the straight leg position, had contributions to this range in the following amounts: 35° at the hip, 17° at the knee, 13° at the ankle and 3° at the intertarsals. For the advanced group executing an average turnout of 81° in the demi-plie position, the joints contributed as follows: 55° at the hip, 18° at the knee, 6° at the ankle and 2° at the intertarsals. While these joint contributions to turnout are not identical to those described by Bachrach (1986c), they occur with the greatest rotation taking place at the hip joint, particurlarly in demi-plie.

This study has shown that the advanced group had significantly greater total turnout (in both the straight leg and demi-plie positions) than the beginning group. How did the advanced group achieve greater total turnout? In the straight leg position, the advanced group averaged a greater (although not significantly greater) range of motion at each of the four joints measured than did the beginning group. In the demi-plie position the advanced dancers averaged a greater (although not significantly greater) range of rotation at the hip and knee than did the beginning dancers.

For the beginning group in the straight leg turnout, a greater range of lateral rotation in the hip, knee, ankle and intertarsal joints did not predict greater pedal turnout. For the advanced group in the straight leg position, an increase in lateral rotation at the hip and ankle was associated with an overall increase in turnout. For both groups of dancers in demi-plie, greater lateral hip rotation was significantly related to greater pedal turnout.

Most ballet literature implies that the turnout as seen from the feet should be the product of lateral hip rotation only. The significant correlation coefficient between pedal and hip joint rotation in the demi-plie position for both groups of dancers supports this thinking. However, the correlation analysis of the straight leg position for both groups provides contradictory evidence. In this position, the ankle joints assisted in increasing total turnout in the advanced group, whereas in the beginning group no significant correlations were found between total turnout and rotation at any lower extremity joints.

There was an increase in absolute and relative pedal turnout from straight to demi-plie for both groups (averaging over three trials and two sides). This total increase in turnout was not the result of an increase at each joint. It was due primarily to an increased hip turnout and a compensatory decreased turnout at the other lower extremity joints. This increase in turnout in demi-plie was intimated but not quantified by many dance authorities. The noticeable decreases in turnout range at the knee in beginners and at the ankle in the advanced dancers, as total turnout increased from the straight leg to the demi-plie positions, meant that during the straight leg position the dancers were getting more turnout at these particular joint sites. There may be some connection between this observation and research findings showing the knee, ankle and foot as the most common sites for injuries in ballet dancers (Micheli, 1983; Washington, 1978).

Results from this study show that the leg segment markers and pedal pointer were not in vertical alignment (pointing in the same direction and rotating to the same degree) during turnout in either the straight leg or demi-plie positions. As previously shown in Figure 15 (pg. 91) the advanced group in demi-plie had the greatest misalignment between thigh and shank, while the beginners in demi-plie had the least degree difference. The advanced dancers also had the worst alignment between shank and foot during the straight leg position of turnout. This is contrary to accepted thought concerning an advanced dancer's ability to maintain better segmental alignment because of increased training. It was not possible for these dancers to maintain the same thigh, leg and foot relationship in turnout as when their feet were parallel, as some dance authorities have implied is the case. However, it was not within the scope of this study to measure deviations in lower extremity anatomical alignment for these subjects, so it is possible that a structural factor such as tibial torsion may have contributed to the observed misalignment of the thigh and shank and between the shank and foot.

Beginning ballet students may be encouraged to work towards greater turnout because they appear to have good hip, knee and foot alignment in a less turned out position; however, the potential for injury may increase as they strive to increase turnout range. The exercises that are designed to increase a dancer's turnout at the knee and foot in order to achieve the ideal 180° turnout as seen from the feet tend to bring the lower leg into misalignment and predispose the dancer to knee and ankle injuries. These exercises are part of the ballet tradition and cannot be ignored; however, in this writer's opinion they should be underplayed as new exercises that encourage utilization of all available lateral rotation at the hips are introduced and practiced in the classroom.

A lower extremity alignment in which the segments are lined up one over the other does not appear to exist in the turnout of advanced dancers. Turnout as seen from the feet is not an accurate indication of the turnout that is taking place at the hip joints. The visual feedback a dancer uses in order to keep her knees over her feet during turnout is only a gross measure of alignment. What criteria can the dance teacher use to encourage alignment and minimize or prevent injury? A different and more realistic definition of alignment in the turned out position is needed. Perhaps the dancer should be trained to concentrate on maximizing lateral hip rotation and to lessen the emphasis on the angular measurement of the foot position during turnout.

Summary

Ballet technique capitalizes on the lateral rotation available in the hip, knee, ankle and foot. A dancer's ability to turnout is primarily determined by genetics; i.e., by the anatomical structure of the joints used in lateral rotation, and secondarily by the muscles, tendons and ligaments which move, strengthen and support these joints. Most dancers can increase their turnout at these joints with warm-up. The turnout achieved by the beginning group may not have been greater because of a lack of the necessary muscular control. This control may be an integral part of the learned skill of a dancer's turnout. A loosening of the ligamentous structure at the knee and ankle probably occurs to augment the lateral hip rotation in a straight leg position. However, sports medicine literature suggests that many lower back problems and lower extremity injuries are a result of cheating to get more turnout at the knee and ankle.

CHAPTER VI

SUMMARY, FINDINGS AND CONCLUSIONS, AND RECOMMENDATIONS FOR FUTURE RESEARCH

Turnout in the ballet dancer is an essential aesthetic requirement. The concept of ideal turnout is one in which the feet and knees face directly sideways (180° total). Many dancers strive to get as close to ideal turnout as their bodies will allow oftentimes stretching the ligaments surrounding the hip, knee and ankle joints. Because of the injuries and pain that dancers suffer due to improper turnout and the resultant excessive stresses at the back, hip, knee and foot, ballet technique has been questioned and examined by dance therapists, physicians and researchers.

Lateral hip rotation which is imperative for turnout is influenced by bony, ligamentous and musculotendinous factors. The hip is a ball and socket joint allowing flexion, extension and rotation. An estimate of average lateral hip rotation in the general population is 45° in each leg (Heck et al., 1965; Hoppenfeld, 1976; Moore, 1978; Staheli, et al., 1985). The knee is a modified hinge joint permitting screw-like movement with flexion and no rotation at full extension unless the restrictive ligaments have been over-stretched to allow some rotation. Lateral hip rotation and a flexed knee (permitting tibial rotation) can produce sideways and rotational movements in the foot. The subtalar joint of the foot allows inversion and eversion. Motion of the foot outward (abduction) in the amount of approximately 9° occurs in eversion and can be considered as a combination of lateral foot and ankle rotation.

It has been the consensus of numerous dance authorities that the lower extremity rotation for turnout should occur at the hip so that the lower leg and foot rotate out to the same degree as the hip. No known studies have tested this premise. The purpose of this thesis was to analyze lateral rotation of the lower extremity joints during turnout from the straight leg and demi-plie positions in beginning and advanced female ballet dancers.

Twenty-one University of Arizona dance students volunteered to participate in this research project. Subjects were recruited for a beginning group (N = 10) and an advanced group (N = 11) according to their level of training and ability in ballet. Since dancers take turnout from a weightbearing position, a friction-free weight-bearing goniometer was designed for this study to permit angular measurements of the subjects' turnouts. A friction-free condition was examined so that lateral rotation of the legs could be maintained by muscular control instead of by friction between the feet and floor. A camera was used to obtain overhead photos of the subjects during turnout.

Testing and filming took place outdoors at the Ina Gittings Building on the University of Arizona campus during the spring of 1986. The two groups of dancers were given numbers for testing. One-half of the subjects from each group were randomly assigned to be tested first in turnout from straight legs while the other half were tested first from turnout in the demi-plie position. This was done to reduce the influence of a possible learning effect during testing. A ballet barre was placed next to the friction-free goniometer and index cards were taped to the ground to identify subject number, trial number and turnout position. Each subject filled out a consent form and questionnaire and were required to do a specified warm-up before testing. Body markers of different lengths and colors were then fitted to the subject's thighs, calves and feet. Free practice time on the goniometer was allowed. Each subject was permitted to take three practice trials with feedback of her turnout on the goniometer.

Three trials of maximum turnout from the straight leg and demi-plie positions were photographed by an overhead camera for each subject. At the start of every trial the three body segment markers were aligned to the goniometer's foot pedal pointers which were held in place at zero with nails. The subject was advised as to the correct position for her feet on these pedals. After each trial the investigator told the subject the degrees of right and left turnout from the pedal and also hand-recorded the pedal data. Forty-eight measurements of turnout were made from the photographs for each subject (2 positions, 4 sites: 3 body segments and 1 pedal, 2 sides and 3 trials). The total number of measures recorded for analysis for 21 subjects was 1,008.

The cumulative turnout position for all body segments of each lower extremity was represented by the recorded angular displacements read from the foot pedal pointers on the goniometer. From these measurements, angular displacements were calculated at the hip, knee, ankle and intertarsal joints on the right and left side during maximum turnout. Absolute (degrees) and relative (percentages of the total turnout expressed by the pedal) scores for each joint in both turnout positions were calculated for each subject within the two groups. Inferential statistics were used to analyze the data.

The reliabilty of thigh and pedal measurements was analyzed for all subjects through intra-class correlation coefficients derived from an ANOVA of thigh and pedal data. The individuals within each group were highly repeatable over trials (r = 0.94 to 0.97) in their turnout from both the straight leg and demi-plie positions.

Joint degree and joint percentage data for each group of subjects in two positions on two sides and three trials were examined through MANOVAS. An F-ratio yielding a probability of less than 0.05 was chosen as the level of significance to determine whether the mean values between sets of data differed statistically from one another by group. A correlation analysis of pedal data vs. data of hip, knee, ankle and intertarsal joint rotations was calculated for each group in both positions of turnout.

Major Findings

Results from this study indicated the following:

1. There was a significant improvement in turnout over three trials for all subjects (both groups combined) but not when the subjects were categorized by skill level (beginning vs. advanced).
2. There was a significantly greater turnout by the right leg compared to the left leg for all subjects (both groups combined) but not when the subjects were categorized by skill level (beginning vs. advanced).
3. The turnout position in demi-plie (using pedal scores) was significantly greater than the turnout in the straight leg position.

4. The advanced group of dancers had significantly greater turnout than the beginning group of dancers in both positions of turnout (straight and demi-plie).
5. No significant difference in pedal (total) turnout occurred between the advanced group in the straight leg position and the beginning group in demi-plie.
6. Regardless of skill level, the groups turned out similarly at each joint when tested from the same position (either straight legs or demi-plie).
7. Both groups had significantly greater lateral hip rotation during turnout in the demi-plie position than in the straight leg position. The range of rotation (turnout) at the knee, ankle and intertarsal joints was not significantly different between the two positions of turnout for either of the groups.
8. The hip joint contributed significantly greater lateral rotation during turnout than the knee, ankle or intertarsal joints in both positions for both groups of dancers.
9. There were no meaningful significant interactions between the two groups for joint contributions expressed as a percent of pedal turnout.
10. A positive significant correlation occurred between the pedal turnout and lateral hip rotation for the advanced group in both positions of turnout, and for the beginning group only in the demi-plie turnout. In

the straight leg position there was also a significant positive correlation between the pedal turnout and lateral ankle rotation for the advanced group of dancers.

11. For both groups the hip joint contributed the most lateral rotation to the increased pedal turnout from straight legs to demi-plie.

12. A lower extremity alignment in which the segments are lined up one over the other did not exist in either turnout position (straight legs or demi-plie) for beginners or advanced dancers.

Recommendations for Future Research

Empirical study is needed in the following areas:

1. Research similar to this study should be conducted using dancers in a professional dance company as subjects because they are expected to have maximized lateral rotation in their lower extremity joints as well as increased the ligamentous laxity surrounding these joints.

2. Comparisons of the joint contributions to maximal turnout should be made between male and female dancers.

3. Weightbearing measurements of lateral rotation in the lower extremities of ballet dancers also should be taken in the normal condition in which they take

turnout, that is, standing on the floor in ballet slippers (with friction between the feet and the floor).

4. Weightbearing and non-weightbearing measurements of lateral joint rotation in the lower extremities should be compared.
5. Weightbearing measurements of lateral rotation in the lower extremities of ballet dancers should be taken on demi-pointe (a position in which the dancer's heels are raised off the floor with the body weight balanced over the metatarsals) and on full pointe (in toes shoes) for females.
6. X-rays of the knee and ankle joints during weight-bearing turnout should be taken to examine and validate the rotation that this study has found to occur at these joints in dancers in the straight leg position.
7. Dancers with chronic injuries to the back and lower extremity joints should have their turnout measured to reveal possible misalignment.
8. A learning experiment should be conducted on two groups of students (children under the age of 12). One group would receive ballet training, the other would not. Lateral hip, knee and ankle rotation should be measured at the beginning and at the end of the experiment to see whether or not training

increased the absolute turnout in the group of children that received ballet lessons.

9. A working definition of alignment in turnout should be agreed upon to assist teachers and dancers in order to prevent possible injuries.

Conclusions

The advanced level dancers had a significantly greater total turnout in the friction-free weightbearing situation than did the beginners. Turnout was significantly greater in the demi-plie position than in the straight leg position. Lateral rotation at the hip joint was responsible for contributing most of the dancer's total turnout especially during the demi-plie position; however, it was not the only joint to make a contribution to turnout. Turnout at the ankle joint for advanced level dancers also helped to increase total turnout, especially in the straight leg position. Alignment of the thigh, lower leg and foot, as operationally defined in Chapter I, did not occur in turnout on straight legs or in demi-plie for either group of dancers.

A 180° turnout (the summed maximum of lateral rotation of both legs) is the ideal in ballet. As this study has shown, a full 180° of turnout is rarely possible for the advanced student, much less the beginner. Dancers learn by training to increase the available lateral rotation at the hip, knee, ankle and intertarsals by stretching the surrounding ligaments. Quite often the natural limitations of the body are overlooked and even denied in the attempt to meet the accepted aesthetic ideal of classical ballet technique. It is recommended that a more realistic definition of lower extremity alignment in an ideal turnout position be considered by the ballet community so that dancers can prevent certain types of injuries to the lower spine, knee, ankle and foot.

APPENDIX A

SUBJECT'S CONSENT FORM

ASSESSMENT OF LATERAL HIP ROTATION AND LOWER EXTREMITY ALIGNMENT DURING "TURNOUT" IN BALLET

I have been invited to participate in the above-titled research study which is designed to determine the degree of lateral hip rotation I am capable of taking in two weightbearing positions of turnout. This project will also assess the alignment of my hips, knees and ankles of both legs during turnout from first position on straight legs and in demi-plie. There will be 21 female subjects involved in this study. The subjects will be volunteers who are beginning and advanced level ballet students at the University of Arizona during the spring of 1986.

If I agree to participate I will be asked to come to the filming site (the courtyard of the Ina Gittings Building), 10 minutes prior to the selected time and date for which I signed up. I understand that I am required to wear a dark colored leotard, no tights or ballet slippers during testing. In addition to this form I will be required to read and fill out a Subject Questionnaire, as well as select another time to have my height and weight taken and recorded. I will receive written warm-up directions before being tested in the weightbearing positions of turnout.

After warming-up, I will be fitted with a thigh and shank marker (a fin-like pointer attached to a velcro band) for both legs and a foot pointer will be taped to the top of both feet. I will be given a few minutes of free practice on the weightbearing goniometer to familiarize myself with the device (a wooden platform that has two friction-free foot pedals, each rotating through an arc of 90 degrees from the parallel position of zero). I will be given at least three practice trials with feedback in the two turnout positions on this goniomter. I will be tested in three trials of each position beginning with whichever position has been randomly assigned to me. All trials will be photographed from the overhead balcony. All pedal measurements will be recorded on data sheets by the reseacher. A practice barre will be available for support while I am on the friction-free weightbearing goniometer.

I understand that there is no monetary cost or remuneration to me as a participant in this study. There are no apparent risks involved in this study as described above. The benefits of my participation are that I will learn the angular amount of turnout I am capable of taking from straight legs and in demi-plie, and I will learn whether I can keep the thigh, lower leg and foot of both extremities in alignment during turnout in the two positions under the friction-free weightbearing condition.

I have read the above "Subject's Consent". The nature, demands, risks, and benefits of the project have been explained to me. I understand that I may ask questions and that I am free to withdraw from the project at any time without incurring ill will. I also understand that this consent form will be filed in an area designated by the Human Subjects Committee with access restricted to the principal investigator or authorized representatives of the particular department. A copy of this consent form will be given to me.

______________________________ __________________
Subject's Signature Date

I have carefully explained to the subject the nature of the above project. I hereby certify that to the best of my knowledge the subject signing this consent form understands clearly the nature, demands, benefits, and risks involved in participating in this study. A medical problem or language or educational barrier has not precluded a clear understanding of his/her involvement in this project.

______________________________ __________________
Investigator's Signature Date

APPENDIX B

SUBJECT QUESTIONNAIRE

The following questionnaire is in addition to the Human Subject Consent form which I have received at the same time, prior to testing. I understand the contents of this questionnaire will be kept confidential and that my identity will be protected by an assigned number.

Name: ______________________________ Age: ______ Phone: ______

Number of consecutive years of ballet training: __________

What ballet classes are you presently taking at the U of A and/or private dance studio?

On the average, how many hours a day do you spend in ballet class?

____

DO NOT WRITE BELOW THIS LINE

Your Subject ID Number will be: _____ You will be tested first in the following position:

____

APPENDIX C

SUBJECT WARM-UP DIRECTIONS

Please read the following exercises and begin to do them two minutes before your scheduled testing time.

Stand in parallel position. Begin with either leg. Brush one leg to the front and rotate it outward from the hip socket, then with the leg turned out, place it on the ground in first position. Repeat using the other leg. Demi-plie in first position four times. In first position, take four tendus to the front, to the side, and to the back. Repeat using the other leg. In first position, rond de jambe a terre en de hors eight (8) times, repeat rond de jambe a terre en de dans eight (8) times. Repeat rond de jambes using the other leg.

APPENDIX D

SUBJECT DATA SHEET

Subject # _____

Date & Time _______________

Height: _____ Weight: _____

Weightbearing Turnout - measured from foot pedals (Ø-9Ø°)

STRAIGHT LEGS

Testing Order: 1 or 2 (circle one)

	Left Leg	Right Leg
Trial 1.	________	________
2.	________	________
3.	________	________

DEMI-PLIE

Testing Order: 1 or 2 (circle one)

	Left Leg	Right Leg
Trial 1.	________	________
2.	________	________
3.	________	________

APPENDIX E

SUBJECT JOINT DEGREE DATA[a]

BEGINNING GROUP 1 (N = 10)

Straight Leg

Subject #	Hip	Knee	Ankle	Inter.
1	29.4	11.5	8.9	1.9
3	37.1	10.6	7.0	2.4
6	22.2	20.5	7.0	1.3
7	29.1	12.6	21.5	4.8
10	27.6	13.8	6.7	3.1
11	38.8	16.1	7.3	2.3
17	23.1	7.2	6.6	1.2
18	29.1	12.9	4.0	7.5
20	28.5	13.5	13.6	1.1
21	33.8	13.9	7.2	1.6

Demi-Plie

Subject #	Hip	Knee	Ankle	Inter.
1	45.7	8.8	1.0	1.2
3	40.7	14.4	9.5	3.4
6	47.8	15.4	0.3	1.6
7	49.7	7.8	13.0	1.8
11	60.8	9.8	10.2	0.4
17	34.9	4.3	14.9	-0.9
18	48.7	11.0	7.5	1.3
20	45.0	10.8	2.1	0.5
21	42.0	10.4	4.9	1.1

a = averaged over three trials and two sides

SUBJECT JOINT DEGREE DATA[a]

ADVANCED GROUP 2 (N = 11)

Straight Leg

Subject #	Hip	Knee	Ankle	Inter.
2	42.5	16.9	13.0	2.4
4	37.5	17.9	20.2	2.6
5	43.0	12.5	13.8	1.7
8	28.7	19.4	5.9	-1.0
9	32.3	17.5	15.3	4.7
12	39.9	18.1	5.0	1.8
13	28.4	18.2	11.6	2.3
14	40.9	13.6	18.3	5.3
15	35.7	22.4	11.6	2.8
22	27.9	20.3	11.4	2.3
23	33.3	14.5	13.8	1.5

Demi-Plie

Subject #	Hip	Knee	Ankle	Inter.
2	66.6	13.5	5.2	0.3
4	56.5	14.0	5.9	-0.3
5	57.1	20.4	2.9	-1.3
8	46.6	18.8	-3.4	2.6
9	66.7	20.5	3.6	3.1
12	51.9	15.9	6.8	0.7
13	49.4	15.4	8.6	1.2
14	54.0	17.3	16.4	3.5
15	58.8	19.9	7.3	1.8
22	44.0	28.0	-0.2	1.9
23	50.6	11.6	7.6	1.6

a = averaged over three trials and two sides

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