Comparison of Hip Rotation in Female Classical Ballet Dancers Versus Female Nondancers

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Abstract—The purpose of this pilot study and its follow-up research was to identify differences in hip internal rotation, external rotation, and total rotation between young female ballet dancers and female nondancers. Hip rotation in sitting and in prone positions was originally measured in dancers aged 5 to 18 years. A negative correlation between internal rotation and years of dance experience was found in this group. In a follow-up study, hip rotation measurements taken in sitting and prone were compared for dancers (n = 30) and nondancers (n = 30) aged 14 to 18 years. Data were analyzed using a three-way analysis of variance. Results indicated increased hip external rotation and decreased internal rotation in dancers, whereas nondancers had less external rotation than internal rotation. Nondancers showed greater differences in hip rotation measured in sitting versus prone than did dancers. Total available hip rotation between dancers and nondancers was comparable. *Med Probl Perform Art* 4:154–158, 1989.

The classical ballet dancer undergoes an intensive flexibility program to achieve the fundamental positions of classical dance, which allow her to be aesthetically pleasing to the audience.[1–3] Classical ballet is extremely demanding on all the joints and soft tissues of the body. These demands can result in injury and overuse syndromes.[1,4–10] The position referred to as "turnout" is especially demanding. Ideal turnout is defined by Teitz[11] as the position in which ". . .weight should fall from the body to the thigh and directly through the center of the knee and ankle." Ideal turnout is defined by Quirk as the position where the feet form an angle of 180 degrees, with the heels together and the knees straight (Fig. 1).[2] External rotation of the lower extremities must occur purely at the hip in order to achieve this distribution of weight.[2,6,9,11] External rotation

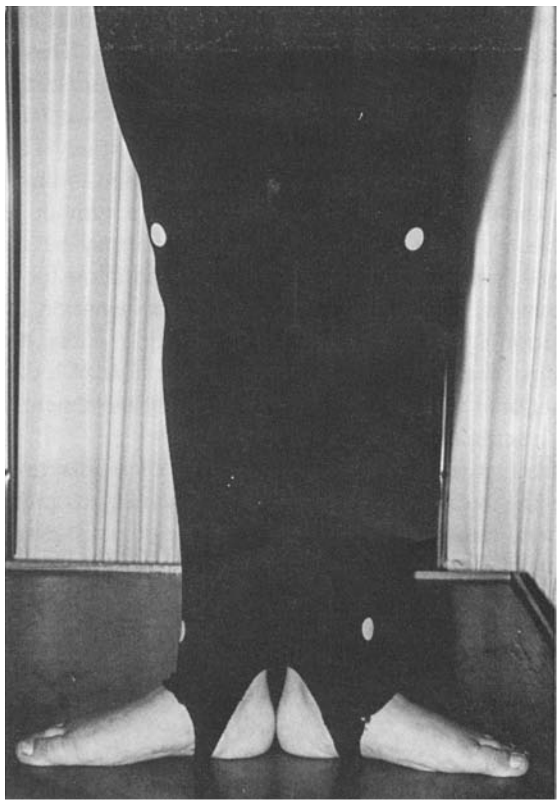

FIGURE 1. Turnout.

of the hip is influenced by the amount of relative femoral neck anteversion/retroversion (the angle of the femoral neck to the femoral condyles in a transverse plane) as well as by the soft tissue structures surrounding the joint.[1,5,9]

When ideal turnout is not anatomically possible in dancers, either due to bony block or soft tissue tightness, it may be forced by hyperextending the lumbar spine, "screwing" the knee during extension, or pronating the feet (Fig. 2). Such compensations are responsible for a significant number of dance injuries, making forced turnout both an

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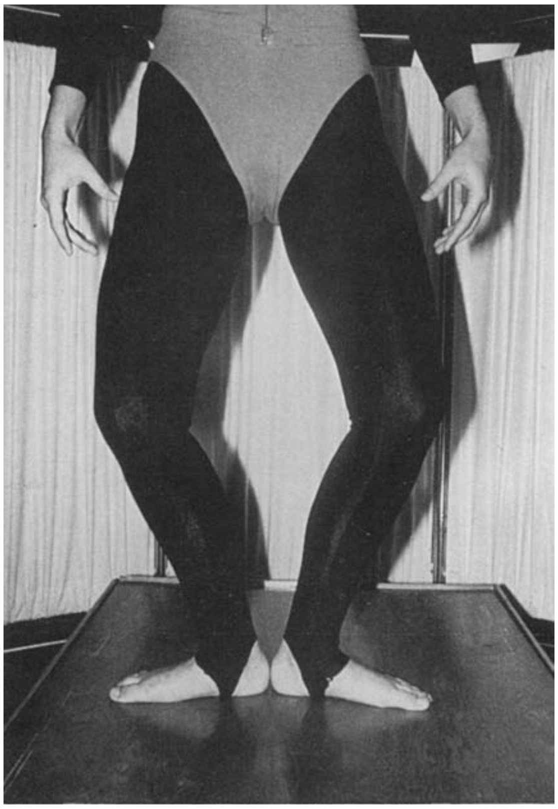

FIGURE 2. Forced turnout. Note pronation of right foot.

immediate hazard and a detriment to the dancer's career over the long term.[5,6,8,11,12]

Changes due to hip plasticity in a classical ballet dancer are greatly dependent upon the age at which dance training commences. Studies have shown that children who begin dancing before age 11 stand a better chance of achieving ideal turnout due to the amount of plasticity still available in the femoral neck. Conversely, femoral neck angles cannot be significantly altered in children who begin dancing after age 11. These older children must rely on stretching the soft tissue structures surrounding the hip joint to facilitate turnout.[1,2,4,5,9]

The resting length of soft tissue structures of the anterior hip joint, i.e., the anterior joint capsule and iliofemoral, ischiofemoral, and pubofemoral ligaments, can be influenced by position. Since one of the main functions of these structures is to prevent hip hyperextension, they become taut in the prone position, which extends the hip, and are put on slack in the sitting position, which flexes the hip.[13,14] Therefore, in the individual who has anterior tightness one could expect to find a greater degree of rotation in the sitting position over the prone position. Less difference in goniometric values between the two positions would be noted in the individual who has maximally stretched the soft tissues of the anterior hip joint.

To date, there has been little research done comparing internal to external hip rotation in dancers or comparing hip mobility in dancers to nondancers. One such study was performed by Miller et al.[4] that suggested a correlation between the age at which a person begins to dance and her ability to achieve ideal turnout. This study also documented greater external rotation in dancers than in the normal population by radiographic examination of their hips. No demonstrable changes in femoral neck angles were found, suggesting that these increases in external rotation were due to soft tissue stretching rather than bony remodelling.

PILOT STUDY

Thirty-seven classical ballet students, 14 from Princeton School of Ballet and 23 from Joffrey Ballet School, volunteered for the initial study. All were females aged 5 to 18 who started ballet instruction prior to age 12. Students had 3 months to 15 years of dance experience.

Measurements of hip internal and external rotation of the dominant leg were taken in two positions using a bubble goniometer* (Fig. 3). The extended hip position (prone)

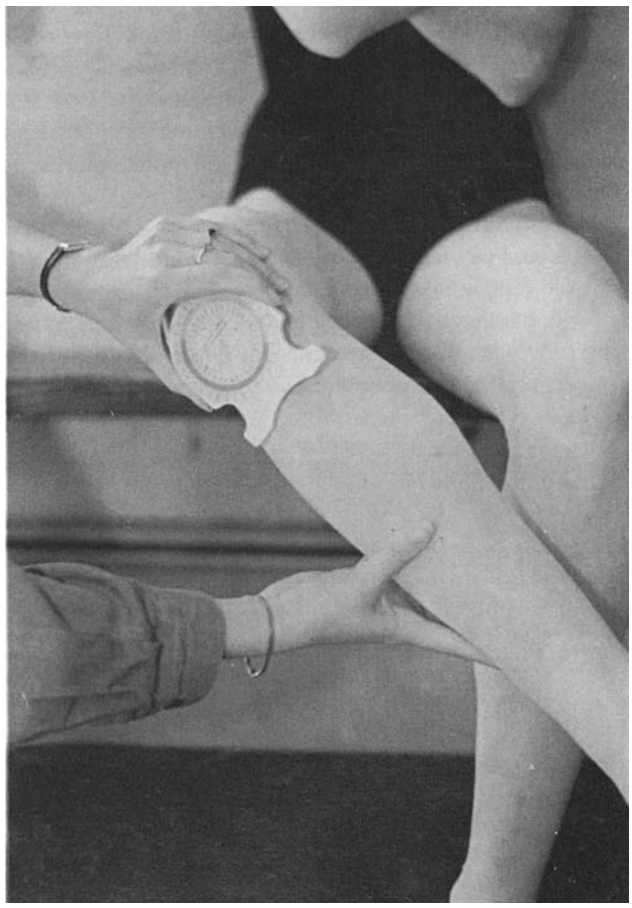

FIGURE 3. External rotation measured in sitting with bubble goniometer.

*Chattanooga Corporation, 101 Memorial Drive, P.O. Box 4287, Chattanooga, TN 37405.

placed the anterior structures on stretch, and the flexed position (sitting) placed these same structures on slack (Figs. 4 and 5). Measurements followed the protocol described by Root et al.[15] and by Erhard.[16] Actual goniometric values and the differences in values from sitting to prone were noted. Interrater reliability was documented ($r = 0.99$).

Correlation analyses were performed using NCSS* on the following: (1) difference in sitting and prone external rotation versus years of dance experience; (2) difference in sitting and prone internal rotation versus years of dance experience; and (3) internal rotation in prone versus years of dance experience (Table 1). Significance was assessed at $p = 0.05$ using a t-test. Significant negative correlations were found both between the difference in sitting and prone internal rotation, and the internal rotation values versus years of dance experience. These negative correlations suggested that dancers lose hip internal rotation range and that their internal rotation becomes less dependent on position as their dance experience increases.

HYPOTHESES

Based on the above findings, further research was indicated. A study was designed to analyze the differences in hip rotation between dancers and nondancers in both extended and flexed hip positions. It was hoped that this information could confirm the findings of the pilot study and rule out age alone as the source of the rotational changes. The *a priori* hypotheses were:

1. A significant difference in hip rotation exists between 14–18 year old female classical ballet dancers and 14–18 year old female nondancers.
2. A significant difference exists between prone and sitting hip rotation measurements for female classical ballet dancers and female nondancers.

FIGURE 4. Subject positioned in prone with knee flexed to 90°.

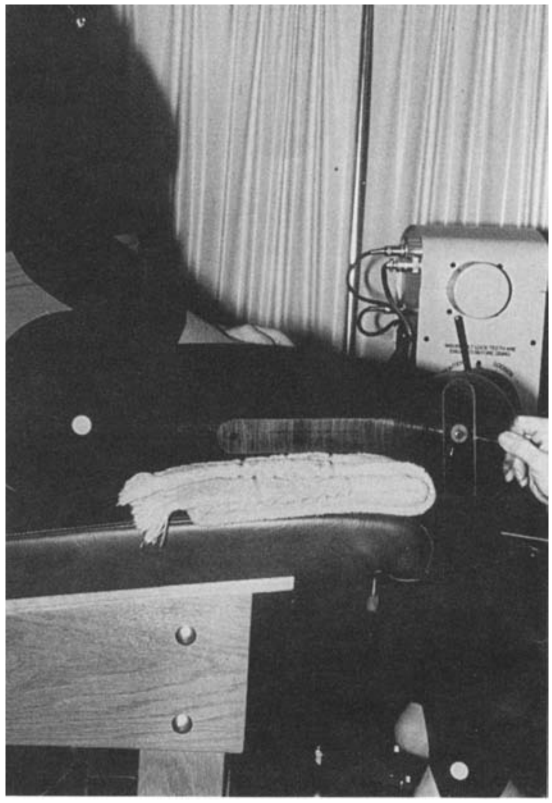

FIGURE 5. Subject positioned in sitting with knee flexed to 90°.

METHOD

For purposes of this study, a classical ballet dancer was defined as a female aged 14 to 18 years who began dancing before age 11, had at least 5 years of classical ballet instruction, and was currently dancing at least three times per week. A sample of convenience of dancers ($n = 30$) was taken from Pennsylvania Academy of Ballet, Pennsylvania

TABLE 1. Significant Data for Correlations Made Between Rotational Values and Number of Years Experience

Variables	*r*	r^2	*p*	*mean (x)*	*mean (y)*
Difference in external rotation vs. total no. yrs. experience	−0.30	0.09	0.06	6.81	7.56
Difference in internal rotation vs. total no. yrs. experience	−0.41	0.17	0.01	6.81	7.40
Total degrees internal rotation in prone vs. total no. yrs. experience	−0.69	0.47	0.01	6.81	44.67

*Number Cruncher Statistical System; Dr. Jerry L. Hintze, 865 East 400 North, Kayesville, UT 84037.

Center for Ballet, and Dance Center of West Chester. All dance schools used the techniques developed by Agrippina Vaganova. A sample of convenience of 14–18 year old nondancers was taken from Cardinal O'Hara High School, Central High School, Saint Maria Goretti High School, and Philadelphia College of Pharmacy and Science, all in Philadelphia, Pennsylvania. Neither sample included students of gymnastics or figure skating, as these could be considered confounding variables.[17]

A standard goniometer was used to measure dominant hip internal and external rotation in both sitting and prone. Intrarater reliability was documented ($r > 0.99$) and all stabilizations during measurements were performed by a second investigator. The Norkin and White protocol was used for all measurements.[18]

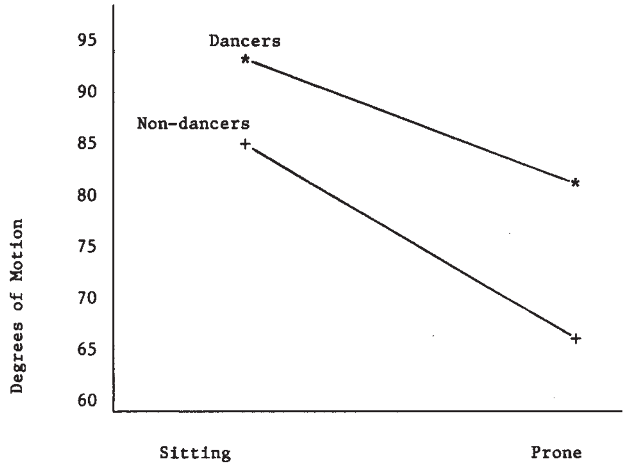

FIGURE 6. Paradigm—interaction A × B.

DATA ANALYSIS

A three-way analysis of variance was used to identify significant variations among the following factors:
Factor A—position (sitting versus prone)
Factor B—population (dancers versus nondancers)
Factor C—direction (internal versus external rotation).
Interactions among factors were also analyzed (Table 2).

RESULTS

Significant differences were found between groups ($p = 0.05$). Factor analysis indicated significant variance between sitting and prone measurements and between dancers and nondancers. Significant interaction between position and population was identified (Fig. 6), as well as a greater degree of hip range of motion in dancers. Significant interaction between population and direction was found (Fig. 7), indicating a greater amount of external rotation than internal rotation for dancers. The reverse relationship was found for nondancers. This reversal of internal/external rotation ratios for dancers and nondancers may account for the lack of significance noted for Factor C, direction of rotation across groups. A significant interaction between position and direction demonstrates greater directional difference in sitting than in prone for both dancers and nondancers (Fig. 8).

DISCUSSION

The differences in rotation values between dancers and nondancers might be explained functionally. Because dancers concentrate on achieving turnout, they could be expected to show lengthening of the internal rotator muscles and anterior structures of the hip with shortening of the external rotators and posterior structures.[1,19] It could be argued, based on Wolf's law of bone growth along lines of stress,[20,21] that remodelling of the femoral neck due to the mechanical stresses placed on it by a dancer during turnout contributes to the rotational differences noted.[20,21] All dancers in this study began dancing before age 11 and had been dancing for a minimum of 5 years prior to our study. Therefore, if it is indeed a change in other than soft tissue, most of the subjects in this study have taken advantage of selective molding of all of the structures surrounding the femoral neck to achieve greater rotation.[1,4,9] However, this would require radiographic evidence of bony changes, which

TABLE 2. Three-way ANOVA Results

Source	*S.S.*	*d.f.*	*M.S.*	*F*	*Signif.*
Within groups	14,638.93	232	63.10	—	—
Between groups	7,146.47	7	1,020.92	16.18	*
Factor A: Position	3,330.14	1	3,330.14	52.78	*
Factor B: population	2,196.15	1	2,196.15	34.80	*
Factor C: direction	72.60	1	72.60	1.15	ns
Interactions					
A × B	1,620.18	1	1,620.18	25.68	*
B × C	4,877.72	1	4,877.72	77.30	*
A × C	3,743.73	1	3,743.73	59.33	*
A × B × C	1,547.58	1	1,547.58	24.53	*
Total	21,785.40	239			

*$p < 0.05$. S.S. = sum of squares, d.f. = degrees of freedom, M.S. = mean square, F = F statistic for hypothesis testing.

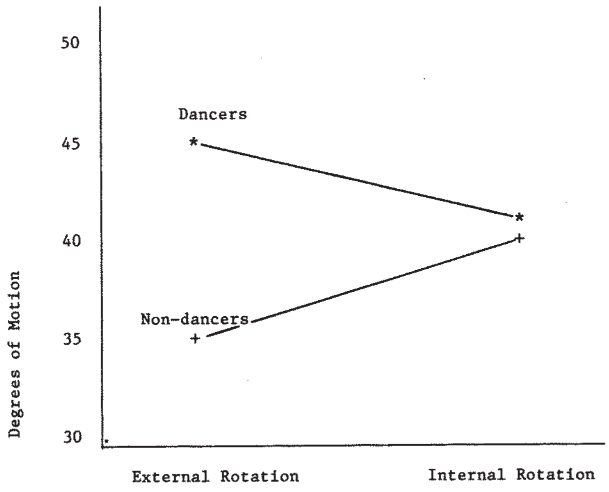

FIGURE 7. Paradigm—interaction B × C.

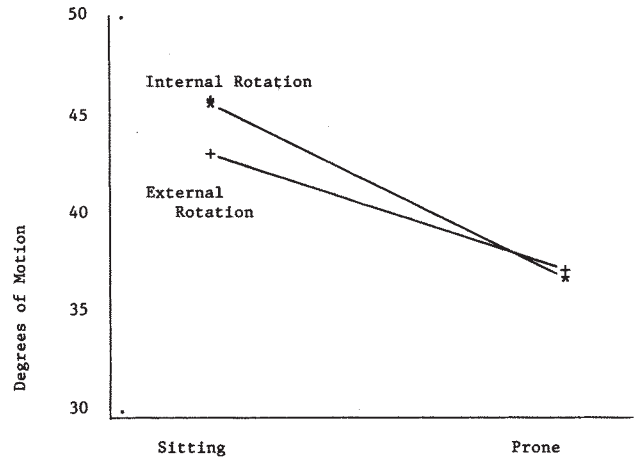

FIGURE 8. Paradigm—interaction A × C.

is beyond the scope of this study and is not supported by prior research.[4]

Both dancers and nondancers showed variability in rotation values from sitting to prone, although dancers showed less variation from one position to the other than nondancers. It would seem logical to assume that dancers would have nearly equal hip rotation values in the two test positions, due to their persistent stretching of anterior structures.

CONCLUSION

Based on our results, the investigators conclude that dancers have increased external rotation and decreased internal rotation when compared to nondancers and that dancers have less positional variability of hip rotation than do nondancers. This concurs with the pilot study's findings of decreased internal rotation in dancers.

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