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Lower extremity flexibility patterns in classical ballet dancers and their correlation to lateral hip and knee injuries

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ABSTRACT

Knee and hip problems account for up to 40% of injuries in classical ballet. Despite apparent flexibility, many dancers appeared to have tight iliotibial bands that contributed to lower limb problems. Thirty senior female ballet dancers were contrasted with thirty age-matched active volunteers for hip and knee range of motion, and the information derived was correlated with their orthopaedic medical histories. Dancers spent a reasonable period of time warming up, but it was usually with an unbalanced routine that emphasized hip abduction and external rotation to the exclusion of adduction work. This was reflected in the significantly lower range of passive hip adduction and internal rotation compared to the controls. Furthermore, the older and more experienced the dancer, the more this trend was exaggerated. This unbalanced flexibility may play a role in the production of lateral knee pain (30% of the dancers) and anterior hip pain (33% of the dancers). It is suggested that more attention should be given to a balanced stretching regimen as part of the dancers' warmup in an effort to reduce the frequency of some of the chronic hip and knee complaints.

Knee and hip problems make up 20% to 40% of the injuries sustained by ballet dancers.[9] Recently, several classical ballet dancers were seen with pain, tenderness, and snapping at the lateral aspect of the hip or knee. After examination and investigation, a diagnosis of greater trochanteric bursitis, external clicking hip syndrome, or iliotibial band friction syndrome was made. Iliotibial band tightness has been implicated as a predisposing factor in each of these conditions. The tightness results in increased friction as the band crosses over the greater trochanter and lateral femoral condyle. Stretching of the iliotibial band has been commonly recommended as part of the treatment of these syndromes. Despite showing remarkable flexibility in most lower extremity muscle groups, passive hip adduction (Ober's test) in the dancers presenting with lateral hip and knee pain was generally limited. Galabert[2] states that ballet is unique among sports in that its inherent bilateral development and perfect symmetrical balance produces efficient muscle power and coordination. However, like Galabert, we question whether this perfect symmetry is uniformly present.

These observations prompted a study to determine: 1) the commonly practiced flexibility routines performed by classical ballet dancers; 2) the prevalence of lateral hip and knee pain and snapping problems among dancers versus nondancers; and 3) the flexibility patterns in the lower extremities of classical ballet dancers compared to an age-matched nondancing population.

METHODS

Cooperation was obtained from a local ballet school and its associated ballet company to observe, interview, and measure flexibility in 30 of its more senior female students (Table 1). The standard warmup and flexibility portions of several classes were observed and visually analyzed. Each

TABLE 1
Dancers training profile

	Mean	Range
Years dancing	9.6	5.0–13.0
Days/week practicing	5.2	5.0–7.0
Hours/week practicing	18.2	10.0–45.0
Weeks/year practicing	48.0	40.0–50.0
Hours/week warming up or stretching legs	4.8	2.5–13.0

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dancer was individually interviewed to determine her age, dance experience, and duration of dancing per week and over the year. Special attention was given to the duration of each practice devoted to warmup and stretching, duration per week devoted to stretching outside dance practice, and to the occurrence of lateral or anterior hip pain, and snapping of lateral knee pain. Those who had pain or snapping problems were questioned as to its qualities, onset, treatment and associated disability.

Thirty age-matched, active, nonballet dancing females were interviewed to determine the time per week spent on lower extremity stretching and to note any occurrence of lateral hip and knee pain or snapping and its severity and treatment.

Each subject was measured prior to warming up and stretching. The passive hip flexion, extension, abduction, adduction, internal rotation, external rotation, and knee extension of each leg were measured using a long arm goniometer that was specially adapted with a spirit level on the ends of each arm one on the vertical axis and one on the horizontal axis (Fig. 1). This allowed the determination of the horizontal and vertical positions for the stationary arm of the goniometer.

Placement of the joints at the limits of their passive range and goniometric measuring were done by the same investigators for all subjects. Intraobserver reliability was calculated by measuring the same subject on 3 alternate days. The average percentage of error for all measurements was 4.3%, suggesting a high intraobserver repeatability value.[10]

The protocol for goniometric measuring was selected specifically to assess muscle tightness and was set up as follows:

Flexion. With the subject supine and the pelvis stabilized by hanging the contralateral lower leg over the side of the table, the hip and knee were flexed passively in the sagittal plane to the limit of range or until the pelvis began to rotate. The stationary arm of the goniometer was placed along the horizontal axis while the moving arm was placed parallel to the long axis of the thigh between the greater trochanter and the lateral epicondyle of the femur (Fig. 2A).

Extension (Thomas test). With the subject in the supine position, the contralateral hip and knee were flexed maximally and held against each subject's chest. The angle of hip flexion of the ipsilateral hip was measured with the stationary arm of the goniometer horizontal and the measuring arm parallel to the long axis of the thigh between the greater trochanter and the lateral femoral epicondyle (Fig. 2B).

Abduction. With the subject supine, the pelvis was stabilized by hanging the contralateral lower leg over the table. The leg to be measured was maintained in neutral rotation with the foot perpendicular to the floor. It was then abducted passively in the frontal plane to the extreme of range. Range was measured with the stationary arm of the goniometer on a line between the two anterior superior iliac spines (ASIS) and the moving arm along the long axis of the abducted thigh between the ASIS and the midpatella (Fig. 3A).

Adduction (Ober's test). With the subject lying on her side, the leg underneath was flexed for balance and to eliminate lumbar extension. The testing hip of the subject was brought into full extension and abduction with the knee flexed to 90° (Fig. 3B). The leg was then allowed to drop (adduct) by the pull of gravity with only enough support on the foot by the examiner to keep the knee flexed to 90°, hip extended to neutral and the thigh in neutral rotation. The flexibility was quantitated with the stationary arm of the goniometer parallel to the horizontal axis and the moving arm along the long axis of the adducting thigh as measured from the ASIS to the midpatella. The zero position wa

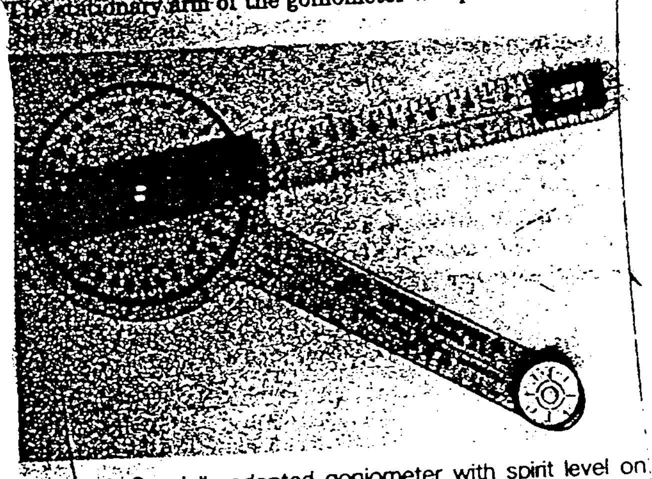

Figure 1. Specially adapted goniometer with spirit level on each arm to permit accurate placement in horizontal and vertical planes.

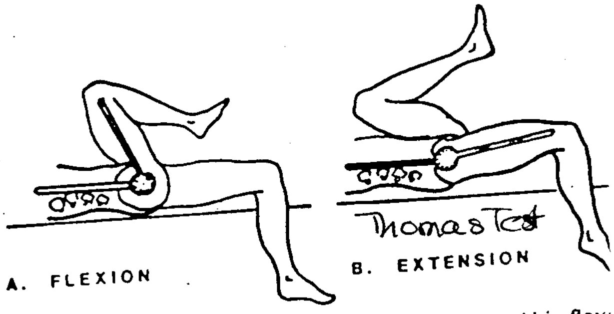

Figure 2. A, pelvis secured by contralateral leg and hip flexe to maximum. Reference point is horizontal. B, Thomas te for hip extension. Pelvis is fixed by flexing hip. Referen point is the horizontal plane.

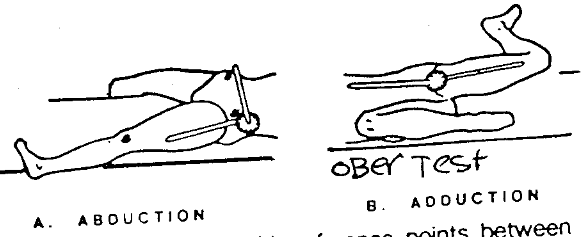

Figure 3. A, abduction with reference points between anterior superior iliac spines. B, Ober's test for adduc tightness with reference point in the horizontal plane.

Full extension
+ Abduction
Knee bent 90°

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taken to be when the thigh was horizontal; positive values were recorded if the thigh was adducted to a position past horizontal; negative values were recorded if the thigh adducted to a position short of horizontal.

Internal rotation. With the subject sitting on the edge of the table with the knee flexed 90° and the pelvis stabilized, the foot was maximally abducted. The stationary arm of the goniometer was placed perpendicular to the floor and the moving arm was placed along the axis of the tibial shaft (Fig. 4).

External rotation. The position was the same as for internal rotation, except that the foot was passively adducted to the limit of range (Fig. 4).

Knee

Extension. From the position of full hip flexion used for measuring hip flexion, the knee was maximally extended and the angle measured with the stationary arm of the goniometer on the long axis of the thigh and the moving arm along the long axis of the lower leg (Fig. 5).

Statistical analysis included calculation of the means, standard deviations, and *t*-tests. Percent errors and average deviations were used to test reliability of observations.[7]

RESULTS

The mean age of the dancers was 15.4 years (range, 13 to 19) and that of the control group 15.1 years (range, 13 to 18). The dancers were devoting significant amounts of time to their dancing, averaging 18.2 hours per week (Table 1). The nondancing population was spending an average 0.37 hours per week on lower extremity stretching (0 to 2.5 hours) as compared to the 4.8 hours per week by the dancers.

The ballet dancers' warmup consisted of 30 to 60 minutes of various active dance maneuvers performed to music at the barre. These included maneuvers such as the plié (demi and grand), the tendu in first and fifth position, the glissé, rond de jambe, frappé, fondu, petit and grand battement, and adage and battement en clouche. All of these exercises were, in effect, range of motion movements for the hip and knee. The common feature observed in all the warm-up maneuvers was the propensity to hip abduction and external rotation. The positions were also held for only brief periods of time. These barre exercises were followed by 5 to 10 minutes of unstructured static stretching of the dancers' choice and duration. Again, the emphasis was on external rotation and abduction of the hip as well as hip and knee extension.

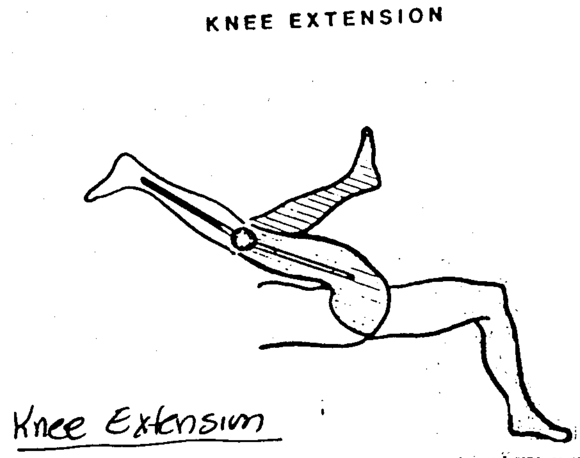

Figure 5. From the point of maximum hip flexion, the thigh position is held and is the reference point. The starting position shaded, and the knee is then extended from this position. This emphasizes hamstring tightness.

Nine of the dancers (30%) had experienced lateral hip or knee problems, whereas only five of the nondancers admitted to similar problems. None of these five required formalized treatment other than slight temporary modification of activity. In contrast, seven of the nine dancers required some treatment and three of these required more than 1 week off dancing. This was also the case with 2 of the 3 lateral knee pain problems. Ten dancers (33%) had problems with anterior hip snapping (seven were painless and three painful) whereas only one of the thirty nondancers interviewed had experienced this. In no case of anterior hip snapping did the dancer require any more treatment than modifying her dance technique (Table 2).

When range of motion comparisons were made between the 30 dancers (60 legs) and 30 nondancers (60 legs), the dancers were found to have significantly greater passive hip external rotation, flexion, extension, abduction, and knee extension (Table 3). However, the dancers had significantly less passive hip adduction and internal rotation than the control group (Fig. 6).

The ranges of motion of the 13 and 14-year-old dancers ($N = 11$) were compared to those of the 17 to 19-year-old dancers ($N = 9$), who had an average of 7.3 years and 10.8

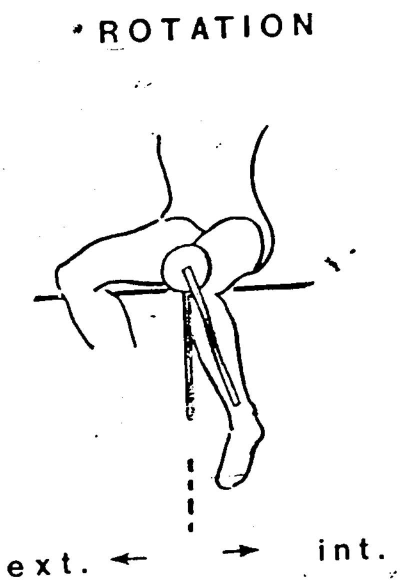

Figure 4. Internal and external rotation with reference point perpendicular to floor.

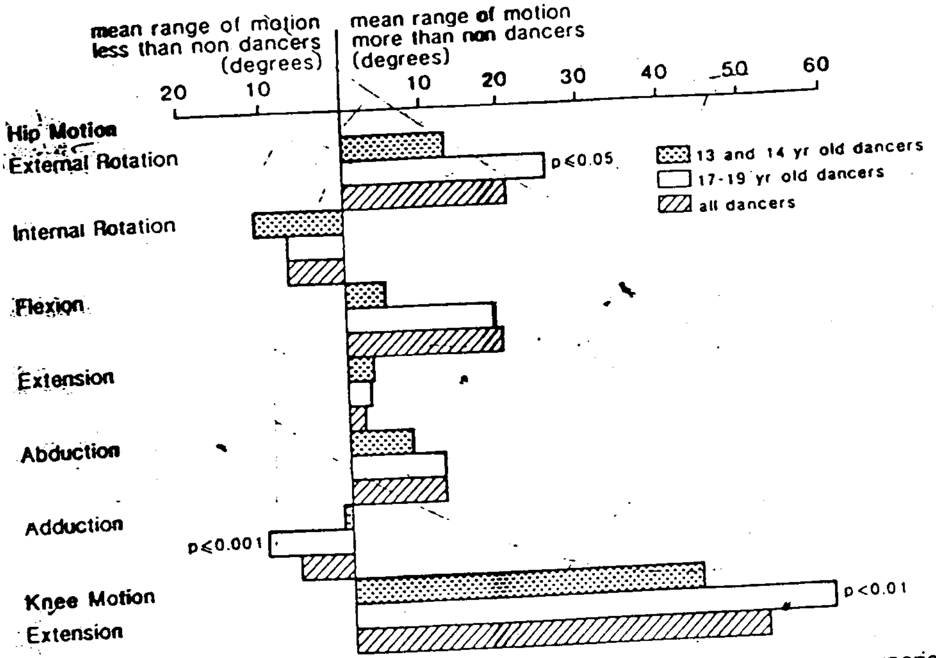

Figure 6. The difference in mean ranges of motion for all movements between young dancers, more experienced dancers, and the control group

TABLE 2
Injury profile of dancers versus nondancers

Complaint	No. Dancers	Treatment	Nondancers	Treatment
Anterior hip snapping		Modified technique	0	
Painful	3	None kept from dancing	1	None
Painless	7	None	0	
Lateral hip pain (no snapping)	3	Physiotherapy, stretching, no time off dancing		
Snapping lateral hip		Modification of routines	2	None
Painful	3	Rest, physiotherapy, and stretching	3	Slightly modified training
Painless	3	No treatment	5	Slightly modified training
Lateral knee pain	3	Rest, stretching, NSAID, modified routine		

TABLE 3
Lower extremity range of motion

Movement	Dancers Mean (Deg)	SD	Nondancers Mean (Deg)	SD	Significance (*P* value)
Hip					
External rotation	84.0 ±	16.2	63.0 ±	14.6	0.001
Internal rotation	49.0 ±	8.4	56.0 ±	9.1	0.001
Flexion	167.0 ±	7.6	147.0 ±	8.3	0.001
Extension	−0.4 ±	1.2	−2.2 ±	4.3	0.01
Abduction	55.0 ±	7.7	43.0 ±	4.7	0.001
Adduction	−2.3 ±	8.7	4.0 ±	7.1	0.001
Knee					
Extension	172	14.4	120	12.0	0.001

years of dancing experience, respectively. It was noted that the overall flexibility pattern seen in the dancer population (i.e., greater hip external rotation, flexion, abduction, knee extension, and less hip adduction and internal rotation) was even more exaggerated in the older ballet dancers (Table 4, see Fig. 6). This was especially true of the relative inflexibility in passive hip adduction.

When the range of motion of the nine dancers with lateral hip or knee pain or snapping was compared to the range of motion of the rest of the dancers without lateral symptoms, it was found that passive hip adduction was significantly reduced in the dancers with a history of lateral pain or snapping (Table 5).

No statistical difference could be found for range of motion between dancers with anterior hip pain or snapping and dancers without anterior symptoms.

DISCUSSION

The traditional classical ballet warmup consisted of dancing maneuvers done at the barre to the rhythm of music. Th

TABLE 4
Range of motion in dancers of different age groups

Movement	Dancers 13–14 yr Mean (Deg)	SD	Dancers 17–19 yr Mean (Deg)	SD	Significance (P value)
Hip					
External rotation	76.0 ±	20.1	89.0 ±	5.9	0.05
Internal rotation	45.0 ±	6.2	49.0 ±	8.0	NS[a]
Flexion	162.0 ±	8.6	166.0 ±	5.7	NS
Extension	1.0 ±	3.5	0.5 ±	1.6	NS
Abduction	51.0 ±	7.3	55.0 ±	7.9	NS
Adduction	+4.0 ±	9.5	−6.1 ±	6.5	0.001
Knee					
Extension	164.0	20.4	180.0	0.0	0.01

[a] Not significant.

TABLE 5
Snapping or pain in lateral hip and knee

Motion	Present Mean (Deg)	ROM	Absent Mean (Deg)	ROM	Significance (P value)
Hip adduction	−5.6 ±	8.4	+0.3 ±	9.5	0.05

would serve to increase core body temperature; however, the emphasis on prolonged static stretching was surprisingly little. On the other hand, attesting to the efficacy of the ballet warmup is the extreme flexibility achieved for hip flexion, external rotation, abduction, and knee extension. These are the prime hip and knee motions in classical ballet. Rarely adopted are the positions of hip internal rotation and adduction. Even when hip adduction is used, such as with feet in the fifth position, the feet incompletely cross; the heel of the front foot touches the toe of the back foot (French and Russian method).[3] Therefore, the frequency and extent to which the hip abductors are put through the range of adduction is minimal. It is theorized that adaptive shortening of the soft tissue structures limiting hip internal rotation (i.e., lateral hip capsule and external rotators) and adduction (i.e., gluteus medius and iliotibial tract or band) occurs. This trend was probably exaggerated in the older, more experienced dancers because of the natural tendency of soft tissue flexibility to decrease with age when it is not stretched, and the increasing flexibility with age in the more frequently stretched soft tissue structures.

In view of the marked tightness of the iliotibial band and the rigorous training program of these professional and preprofessional dancers, it is surprising that lateral hip and knee overuse syndromes are not a greater problem, such as has been documented in runners.[1] Perhaps this is because dancers spend most of their practice and performance time in hip abduction and external rotation, which tends to decrease the tension of the iliotibial band over the bony prominences. Also, dancers are unlikely to put their knees and hips through as high a number of repetitions of flexion and extension as runners, who do so 800 to 2,000 times per mile. This point was graphically illustrated by one professional dancer/instructor who had only occasional twinges of lateral hip pain while actively dancing. Within 2 days of taking a job as a mail carrier, which required 6 to 8 hours a day of walking, she developed severe and incapacitating bilateral iliotibial band friction syndrome.

In the questionnaire portion of the study, 10 of the 30 dancers reported lateral hip and/or knee pain or snapping It is possible that these symptoms represented greater trochanteric bursitis, external snapping hip syndrome, or iliotibial band friction syndrome.

Recently, the etiology of snapping around the hip has been clarified.[8] Anterior hip snapping, which was known to be prevalent (although according to our study, less of a problem than lateral hip snapping) was investigated by Schaberg et al.[8] using clinical, iliopsoas bursography, cadaveric, and surgical findings. They found that the snapping felt anteriorly with active extension of the flexed abducted and externally rotated hip could be caused by the iliopsoas tendon moving over an osseous ridge on the anteromedial lesser trochanter, or by a tight iliopsoas tendon moving over either the iliopectineal eminence or the anterior inferior iliac spine. This mechanism is probably present in joggers. We found the incidence and magnitude of hip flexion contracture to be greater in the nondancing population. This implies that hip flexor tightness does not play a role in causing anterior hip snapping, which was found to be present 10 times more commonly in dancers than nondancers. Quirk[6] has stated that this anterior snapping or popping is probably a capsular or suction phenomena due to the wide range of motion at the dancers' hips allowing partial subluxation.[6]

The lateral snapping hip syndrome presents as a snapping that is felt on the lateral aspect of the hip, usually when going from extension to flexion, while weightbearing. It has been traditionally explained as the snapping of a thickened posterior border of the iliotibial band or anterior border of the gluteus maximus as it moves over the greater trochanter.[7] Jacobs and Young[4] have suggested that this may be accentuated by a narrow biiliac width.

CONCLUSIONS

- Warmup and stretching in classical ballet dancers usually consists of barré exercise and brief unstructured periods of static stretching with emphasis on maneuvers involving external rotation and abduction of the hip.
- Lateral hip and knee pain and snapping was a significant problem in the dancers interviewed.
- Classical ballet dancers are significantly more flexible than the nondancing population in passive hip external rotation, flexion, abduction, and knee extension, but less flexible than nondancers in passive hip adduction and internal rotation.
- This flexibility pattern of greater passive hip external rotation, knee extension and less hip adduction is more pronounced in older, more experienced dancers.
- The dancers who had experienced lateral hip and knee pain or snapping had significantly less flexibility in hip adduction than the dancers who had not experienced lateral hip and knee pain or snapping.

These observations give evidence for the hypothesis that iliotibial band tightness is a contributing factor in lateral hip and knee soft tissue "friction syndromes" such as the iliotibial band syndrome, external snapping hip syndrome, and greater trochanteric bursitis. We therefore recommend that classical ballet dancers include a structured static iliotibial band stretch in their warmup and stretching routines.

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