Lower Extremity Alignment and Injury in Young, Preprofessional, College, and Professional Ballet Dancers

Part I. Turnout and Knee-Foot Alignment

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Abstract—Three-hundred-fifty dancers participated in this study: 22 young (< 13 years old) attending a school associated with a local company, 171 preprofessional, 58 college dancers in an advanced ballet class, and 99 professional dancers. Of these, there were 14 males in the preprofessional group and 50 males in the professional group. Functional turnout angle and knee-foot alignment were assessed in three classical ballet positions (first, right-fifth, and left fifth) during a demi-plie. The knee-foot alignment (angle of deviation—AOD) was assessed by measuring where the tibial tuberosity aligned with respect to the center of the foot. The angles of deviation indicated that the tibial tuberosity most often aligned toward the inner border of the foot. The young dancers had the largest turnout angle and the college dancers had the smallest angle. The deviation angles reflected these data, since the young dancers had the largest AOD and the college dancers had the smallest deviations. These data suggest that young dancers may be forcing turnout by altering knee-foot alignment (i.e., forcing turnout at the ankle). Turnout angle was larger in right and left fifth position than in first position. This was most likely due to the ability in fifth position to brace one leg (or foot) against the other and force turnout at the ankle. The large AOD in fifth position is consistent with this explanation. Thus, turnout in first position may be more representative of a dancer's functional turnout generally used during movement. The techniques developed to assess turnout angles and knee-foot alignment are quantitative and can easily be used in a clinical setting. *Med Probl Perform Art 4:148–153, 1989.*

Ballet is one of the most physically demanding activities when compared to other sports.[1, 2] What sets ballet training apart from other forms of activity or other styles of dance is the demand for a "high degree of turnout." Turnout refers to the rotation of the legs such that when the heels are together, the toes point outward. In the ideal turned-out position, a straight edge could be placed along the inner borders of the feet. Ballet requires this outward rotation of the legs in all five of the basic foot positions first through fifth.

A good turnout is critical to a successful career in ballet.[3, 4] If properly executed, the turnout will occur at the hip joint, and the knee will then be aligned close to the center of the foot.[5] Certain anatomical conditions such as ligament laxity, a long femoral neck, a low femoral neck-shaft angle, and a low angle of femoral anteversion must be present in the architecture of the hip joint if it is to have the degree of outward rotation required of ballet.[6] This combination of anatomical structures is rare.[6]

When the hip socket is limited in its range of outward rotation, a dancer may try to compensate by incorrectly turning-out from the knee and/or ankle.[7] This will cause the knee to align considerably in front of the medial border of the foot. Many medical experts believe that incorrect turnout leads to chronic problems in the knees, ankles, and feet because of the resulting torsion on these structures.[5–9]

Despite the importance of turnout and its purported relationship to injury, there are no quantitative data on the functional angle of turnout (i.e., the angle of turnout used in dance position) in ballet dancers, nor are there quantitative data on knee-foot alignment as it relates to turnout. Part I of this study assesses the functional turnout angle and knee-foot alignment in young dancers, preprofessional dancers, college dancers, and professional dancers. The techniques developed to assess turnout and knee-foot alignment in this study are quantitative and can easily be used in a clinical setting.

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METHODS

Three-hundred-fifty dancers participated in this study and each signed an informed consent document consistent with University policy. Of this group, 22 were classified as young but not preprofessional (less than 13 years old, who were attending a school associated with a local company), 171 were classified as preprofessional (at least 13 years old and a member of a local company or attending a professional summer dance school), 58 were college dancers who were in an advanced ballet class, and 99 were professional dancers. Of these, there were 14 males in the preprofessional group and 50 males in the professional group.

Young, preprofessional, and professional dancers were from the Massachusetts, Connecticut, Washington (D.C.), and Montreal areas. College dancers were from Smith College, Mt. Holyoke College, and the University of Massachusetts. In the total sample of dancers, five ballet schools and preprofessional companies, three colleges, and four professional companies are represented. The dancers were given a questionnaire to determine their training status and history, as well as their injury history of the lower extremities. The questionnaire was based on that used to assess musculoskeletal injuries in theatrical dance students.[10] These data were used for Part II of this study, which will report on injuries and compare injury rate and type with alignment characteristics. The tibial tuberosity of each leg was found by palpation and marked. Then each dancer's turnout and knee-foot alignment were measured.

To assess turnout and alignment, each dancer stood barefoot or in tights in the ballet position on a sheet of white paper and an outline of the feet was traced. The dancers were asked to perform their typical demi-plie position (i.e., what they would normally use at the barre), looking straight ahead. A plumb line was then dropped from the tibial tuberosity of each leg and the "deviation point" was marked on the paper (Fig. 1A). This procedure was used for the following ballet positions: first, right fifth (the right foot was front), and left fifth (the left foot was front). Three repeated measures (three plies) were taken at each position for each leg.

To determine the knee-foot deviation, the width of the heel was measured on the paper tracing of each foot position, and the midpoint of the heel and the midpoint of the forefoot were marked (Fig. 1B). These points were easy to measure accurately and, from results of a pilot study, were determined to be reliable measures. The pilot study was performed using 15 dancers, and each investigator measured every dancer. Correlations were greater than $r = 0.78$ among the measurements of the investigators for turnout angle and angle of deviation (AOD), and there was no significant difference among investigators. Therefore, for the present study it was decided that each dancer would be measured by only one of the investigators. One investigator, however, performed all the measurements and calculations from the paper tracings.

The midpoint of the heel was determined by measuring a fixed distance (40 mm) from the back of the heel and then determining the center of the heel width at that point. The mid-forefoot point was determined as the center of the width of the foot taken at the notch of the 5th metatarsal. In the next step, a reference line, which bisected the mid-heel and the mid forefoot points, was drawn. The angle of turnout was taken to be the angle between the reference lines of the two feet. Another line, called the deviation line, was then drawn from the deviation point to the mid-heel point. The angle formed by the reference and deviation lines was taken as the AOD. A positive value for AOD would indicate that the deviation line (with respect to the reference line) fell toward the medial border of the foot.

An analysis of variance (ANOVA) was calculated to determine differences in physical characteristics, training status, turnout, and AOD among the four female groups and between the two male groups. A Scheffe's *post hoc* test was used to determine specific between-group differences. Regression analysis was performed to predict turnout angle from the other criteria measures that were assessed.

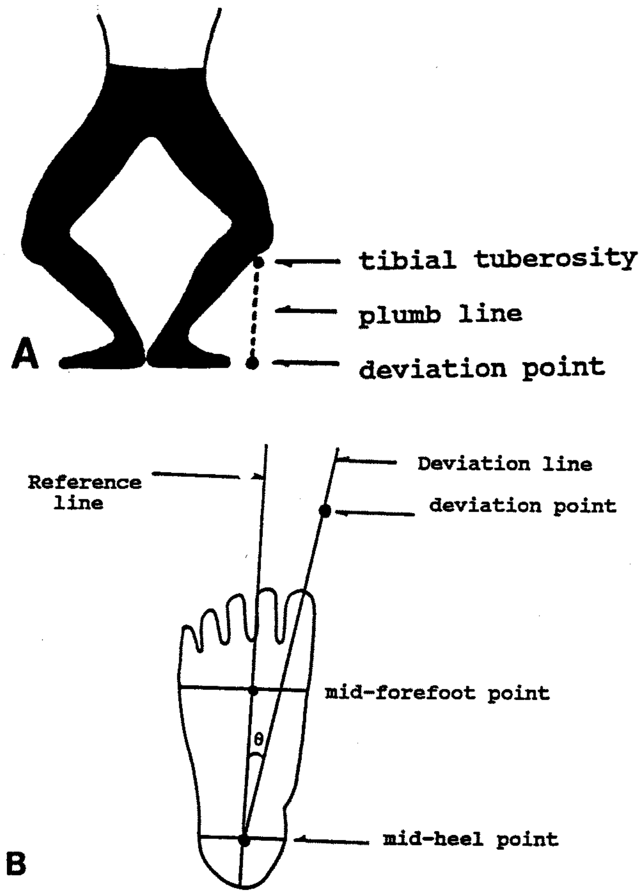

FIGURE 1. Measurement technique to assess: A, the deviation point and B, and angle of deviation. The angle of deviation is the angle formed by the reference line and the deviation line (θ). The turnout angle is the angle formed by the reference line for one foot and the reference line for the other foot.

RESULTS

The age, height, and weight of the subjects are presented in Table 1. For the females, the young group was significantly shorter than the other groups, who did not differ significantly in height. The young group weighed significantly less than the other groups, whereas college dancers weighed significantly more. This pattern was the same when weight was expressed per height squared (Wt/Ht^2). For the males, the preprofessional group weighed significantly less than the professionals but were the same heights. Also, Wt/Ht^2 was significantly greater for the professional male dancers.

Figure 2A presents the training status of the female groups. The years of dance training, years of ballet training with three or more classes per week, and years on pointe parallel the ages of the four groups. There was a highly significant difference among groups for each variable ($p < 0.01$). The hours of rehearsals per week as well as number of performances per year were significantly greater for the professional dancers and significantly less for the college dancers compared with young and preprofessional dancers ($p < 0.05$). The number of hours of class per week was significantly greater for the young and the preprofessional dancers compared with the college and professional dancers ($p < 0.05$).

Figure 2B presents the training status of the two groups of male dancers. The years of training paralleled age. The professional male dancers had significantly greater rehearsal hours per week and performances per year but spent less class time per week compared with the preprofessional dancers ($p < 0.05$).

The angle of turnout for the female dancers is presented in Figure 3A. There was a significant difference in turnout angle for first position among the groups ($p < 0.01$). The *post hoc* test showed that the college dancers had significantly less turnout than the other groups ($p < 0.05$). The greatest turnout was found for the young group compared to the other groups ($p < 0.05$). This pattern among groups was also found for right fifth and left fifth (Fig. 3A).

Turnout data for the males are presented in Figure 3B. The preprofessional dancers and the professional dancers did not differ significantly in turnout. It is interesting to note that for the professional male dancers the angle of turnout for all positions is almost identical to that for female professional dancers. However, for the preprofessional dancers, the males had a slightly greater turnout than the female preprofessionals in all three positions.

The AOD data for the females are presented in Figure 4A. Positive values indicate that the deviation line fell

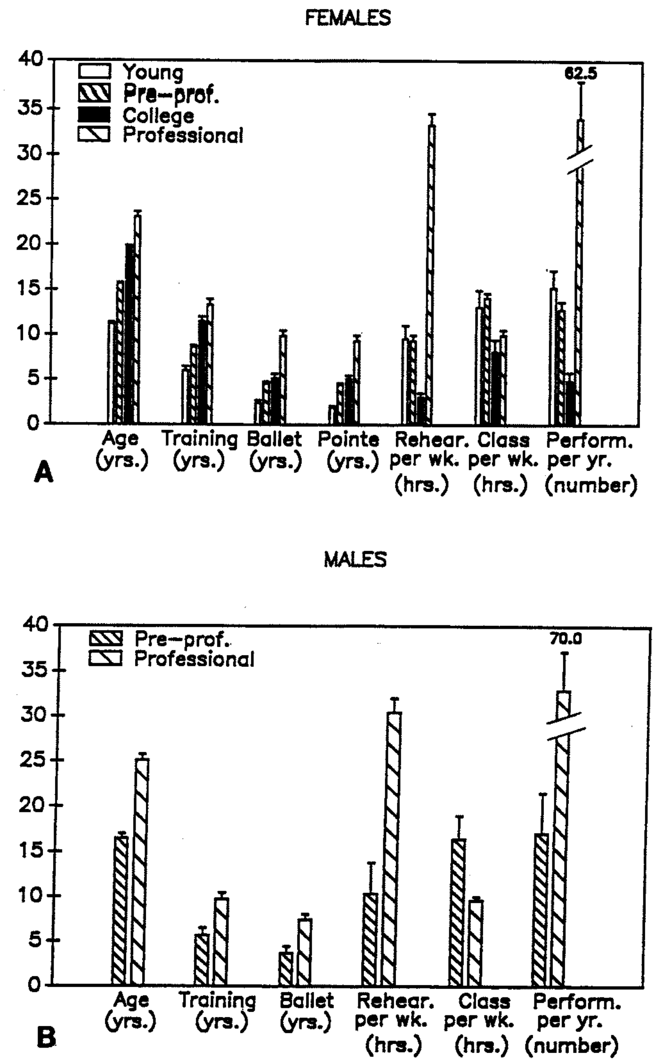

FIGURE 2. Age and years of dance training for (A) females and (B) males. Years of ballet refers to the number of years that dancers took three or more classes per week.

TABLE 1. **Physical Characteristics of Dancers (means and standards deviations)**

	Age (years)	*Height (cm)*	*Weight (kg)*	*Wt/Ht²*
Females				
Young (n=22)	11.1 (0.8)	146.0 (8.6)	34.8 (5.1)	.023 (.002)
Preprof. (n=157)	15.6 (1.6)	163.2 (5.5)	48.6 (5.3)	.026 (.002)
College (n=58)	19.8 (1.6)	164.6 (6.6)	54.5 (5.6)	.029 (.002)
Profession. (n=49)	23.2 (4.1)	165.8 (6.5)	50.0 (5.3)	.026 (.001)
Males				
Preprof. (n=14)	16.5 (2.0)	176.8 (8.1)	64.3 (9.7)	.029 (.002)
Profession. (n=50)	25.1 (4.6)	177.0 (6.2)	67.5 (5.5)	.031 (.002)

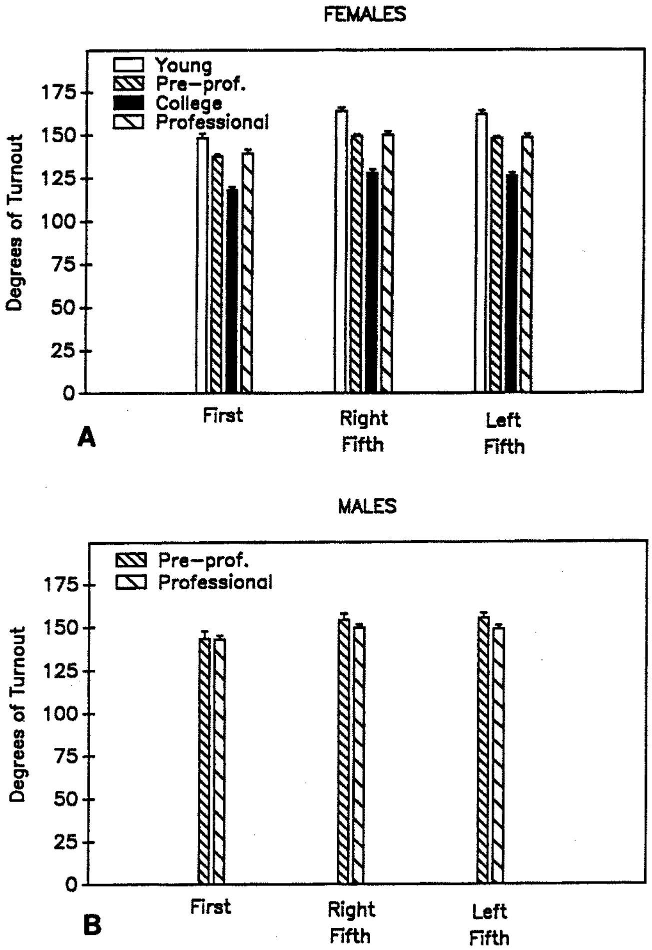

FIGURE 3. Turnout angle in degrees for (A) females and (B) males. The turnout angle is the angle formed by the reference line for one foot and the reference line for the other foot (see Fig. 1).

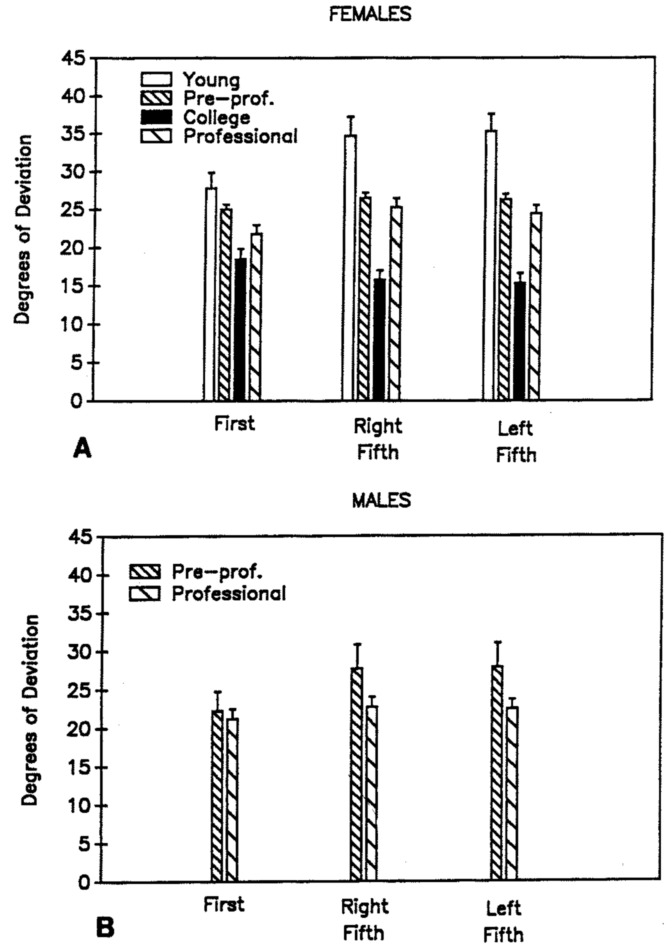

FIGURE 4. Angle of deviation in degrees for (A) females and (B) males. The angle of deviation is the angle formed by the reference line and the deviation line (see Fig. 1). These data indicate values for the right and left side combined.

toward the inner borders of the feet. A certain amount of positive deviation is expected due to the natural tendency for tibial torsion. Using different methodology, where the thigh-foot angle was measured in a non-weight-bearing, relaxed position, Staheli et al.[11] reported a deviation in the thigh-foot angle such that the axis of the foot is turned outward relative to the axis of the thigh.

In first position, the AOD (the sum of deviations for the left and right sides) was significantly greater for the young group than for the other groups ($p < 0.05$). The college dancers had the smallest AOD. In right and left fifth, this pattern was exaggerated; the young group had a considerably greater AOD than the other groups ($p < 0.05$), and the college group had a significantly smaller AOD ($p < 0.05$). The AOD data for the male dancers are presented in Figure 4B. The preprofessional dancers tended to have a larger AOD than the professionals, but this only approached statistical significance ($p < 0.10$).

For each of the groups, turnout in first position was significantly less than turnout in either right fifth or left fifth ($p < 0.05$). Although the turnout for right fifth was significantly greater ($p < 0.05$) than left fifth, this difference was not large (146.8° vs. 145.7°—means for all subjects combined). When the groups were analyzed separately, only the male subjects did not fit this pattern, i.e., there was no significant difference in their turnout between right and left fifths.

The AOD of the right leg in first position (Fig. 5—mean of all subjects combined) was significantly greater than the AOD of the left leg ($p < 0.01$), and this was true for each group when analyzed separately. In both right and left fifths, the AOD for the right leg was significantly greater than the left ($p < 0.05$ and $p < 0.01$). When the groups were analyzed separately, the AOD for the right leg was significantly greater than that for the left leg in first position and left fifth position, but not right fifth.

For the preprofessional and professional female dancers, Wt/Ht^2, years of ballet training, and age significantly predicted turnout. For example, turnout in first position was predicted ($p < 0.01$) by the equation : $TO_1 = -1241\ Wt/Ht^2 + 1.6\ BALL - 1.89\ AGE$, where TO_1 is turnout in first position and BALL is years of ballet training. This

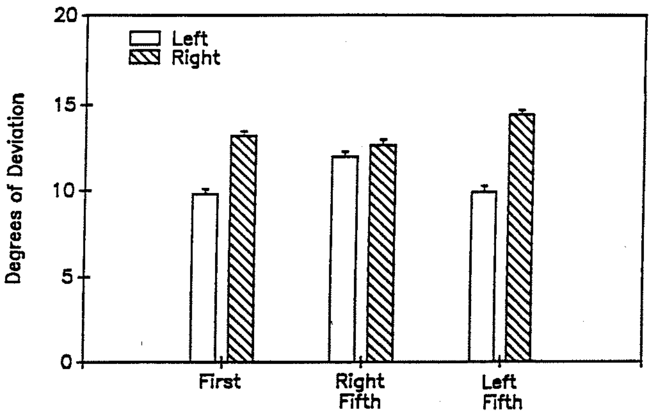

FIGURE 5. Angle of deviation in degrees for the left and right foot.

indicates that females with less weight for height, more ballet training, and of younger ages had more turnout. Turnout in right fifth was predicted by only Wt/Ht^2 in these groups and turnout in left fifth was predicted by Wt/Ht^2, BALL, and AGE in similar equations. Because of the possible interactions of age, years of training, and Wt/Ht^2, these prediction equations should be viewed with caution.

The AOD was significantly affected by the angle of turnout. For the sample tested, the best predictor of deviation in any position was the angle of turnout in the same position ($p < 0.01$), with the larger angle of turnout predicting the larger AOD. Age was also a significant predictor ($p < 0.01$), with the young dancers having greater deviation.

Pearson product moment coefficients were calculated to assess the relationship between degree of turnout and AOD. Turnout in first position correlated with AOD in first position ($r = 0.38$, $p < 0.01$). Turnout in right fifth correlated with AOD in right fifth ($r = 0.60$, $p < 0.01$), and turnout in left fifth correlated with AOD in left fifth ($r = 0.61$, $p < 0.01$). Thus, the greater the degree of turnout, the greater the AOD.

DISCUSSION

The 21 young dancers who ranged in age from 9 to 12 years and the 143 preprofessional dancers were spending approximately 23 hours per week in either class or rehearsal. These data are consistent with data from other groups of young dancers.[12,13] Considering that these youngsters were in school for the greater part of the day, 23 hours is a large amount of time devoted to dance training.

Each group had less turnout in first compared to either fifth position. In fifth position, dancers are able to brace the front leg against the back, allowing them to force their turnout at the knee and ankle. The angle of deviation was also greater in fifth compared with first position (except for the college dancers), suggesting that the dancers were forcing turnout. The AOD for the college dancers may be explained by the fact that the dancers were enrolled in dance programs that advocate against forced turnout. Therefore, they may have been particularly conscious of their knee-foot alignment. Measurement of turnout angle in first may be a more realistic measure of a dancer's functional turnout than turnout angle in fifth position. Perhaps dancers should use this as a guide when establishing their fifth position.

The data on turnout and AOD suggest that the young dancers may not have been using proper alignment. Their degree of turnout was greater than the professional dancers and therefore greater than what would seem to be required for successful performance. Because turnout is negatively related to Wt/Ht^2, the body type of young dancers may allow for greater turnout. However, more importantly, the AOD was substantially larger for the young dancers than for other groups. Whether the young dancers are forcing turnout at the ankles or other age-related factors such as joint laxity contribute to the greater AOD for the young dancers cannot be determined from this study. However, teachers and clinicians should be aware that young dancers may have the propensity to achieve the turned-out position by forcing turnout at the ankle, thereby placing undue stress at the knee.

It is apparent that by the time the female dancers are at a preprofessional level, the alignment characteristics are much the same as those for the professional dancers. In contrast, the college dancers had a smaller angle of turnout and a smaller deviation than the other groups. They were also heavier. These college dancers, although they were enrolled in advanced ballet, were in dance programs that were weighted towards modern and jazz dance. These idioms do not require the large turnout or the excessively slim body type necessary for classical ballet.

Young dancers may have the propensity to achieve the turned-out position by forcing turnout at the ankle, thereby placing undue stress at the knee.

Textbooks for dance pedagogy and injury prevention give only general information about correct knee-foot alignment and how to assess it. Opinions vary as to whether the knee should align over the center of the foot[14–16] or over the second toe.[5] These descriptions are based solely on visual inspection. The data in the present study show that for the majority of dancers, the tibial tuberosity aligned with the big toe rather than between the second and third toes.

For all of the subjects, the AOD is largest for the right side. If poor knee-foot alignment is related to injury, then we may expect to see greater injury to the right leg. Turnout is generally developed and specifically practiced during the barre exercises. In most barre exercise, one leg works while the other maintains the stationary position. It is common to begin these barre exercises with the right leg as the working leg. Therefore, the first time an exercise is performed, concentration is divided between remembering the sequence and executing the movement correctly. When the exercise is repeated on the other side, the sequence has been learned and the dancer can pay more attention to correct execution of the movement. Perhaps the greater AOD on the right side is related to the fact that barre exercises are first performed on the right side (right leg as the working leg), and errors in controlling turnout become habitual.

SUMMARY

Turnout angle was assessed in three standard classical ballet positions in young, preprofessional, professional, and college ballet dancers. The young dancers had the largest turnout angle and the college dancers had the smallest angle. The deviation angles reflected these data, since the young dancers had the largest angle of deviation and the college dancers had the smallest deviations. These data suggest that young dancers may be forcing turnout by altering knee-foot alignment. Turnout angle was larger in right and left fifth position than in first position. This was most likely due to the ability in fifth position to brace one leg (or foot) against the other and force turnout at the ankle. Also, in fifth position, the knee may be slightly flexed, which would release the knee and allow for forced turnout at the ankle. The large angle of deviation in fifth position is consistent with this explanation. Thus, turnout in first position may be more representative of a dancer's functional turnout normally used during movement when no bracing can occur.

Instructors, physicians, and physical therapists can easily use the techniques developed in this study to provide a general assessment of turnout and knee-foot alignment in dancers. Because the present study was a field investigation, we recommend further examination of this technique in a controlled laboratory setting to confirm its usefulness as a criterion measurement for research investigations of lower extremity alignment.

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