ORIGINAL ARTICLE

Dance training intensity at 11–14 years is associated with femoral torsion in classical ballet dancers

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14 November 2005**Objective:** To examine in a cross sectional study the influence of femoral torsion (FT) and passive hip external rotation (PER) on turnout (TO). Starting age, years of classical ballet training, and current and past dance training intensity were assessed to determine their influence on FT, PER, and TO in pre-professional female dancers.**Methods:** Sixty four dancers (mean (SD) age 18.16 (1.80) years) were recruited from four different dance training programmes. They completed a dance history questionnaire. FT was measured using a clinical method. PER was measured with the subjects prone, and TO was measured with the subjects standing.**Results:** Mean TO was 136°, mean unilateral PER was 49.4°, and mean FT was 18.4°. A positive correlation was observed between PER combined (PERC) and TO ($r = 0.443$, $p < 0.001$). A negative association was found between FT combined (FTC) and PERC ($r = -0.402$, $p = 0.001$). No association was found between starting age or years of classical ballet training and FTC, PERC, or TO. Dancers who trained for six hours a week or more during the 11–14 year age range had less FT than those who trained less (mean difference 6°, 95% confidence interval 1.4 to 10.3). Students currently training for longer had higher levels of TO ($p < 0.001$) but comparable PERC and FTC.**Conclusion:** FT is significantly associated with PERC. Dancers who trained for six hours a week or more at 11–14 years of age had significantly less FT. FTC had a significant influence on PERC, but no influence on the execution of TO.

Turnout (TO) is the most fundamental framework of classical ballet technique.¹ It refers to external rotation of the lower limbs, the ideal position being with the feet at 180°. Ideally TO should occur primarily as external rotation at the hip joints, with small amounts of additional range being achieved by external rotation of the tibias and feet.^{2–3} However, not all dancers are able to achieve ideal TO, and compensatory strategies such as anterior pelvic tilt, screwing the knees, and pronating (rolling in) the feet are common.^{2–3} Compensated TO is a common phenomenon in ballet,^{4–5} and has been strongly linked to overuse injuries in dancers.^{2–3–6}

It is generally accepted that the ability to perform TO is largely influenced by soft tissue extensibility, muscle strength, and bony anatomy. Passive external rotation of the hip (PER) has been found to account for as much as 70–77% of the total range of TO.⁶ Femoral torsion (FT), also referred to as femoral version, is the angle between the femoral neck axis and the dorsal border of the femoral condyle.⁷ FT has a strong relation to PER in normal children.⁸ As greater PER may be of critical importance for dancers to achieve the ideal TO, FT may well have a significant value for dancers, especially if it could positively influence their performance.

When dancers were compared with the normal population, there appeared to be an increased PER range and a decreased internal rotation (PIR),⁹ possibly due to a training effect. Similar findings have been observed in the throwing arm of professional baseball pitchers.¹⁰ In pitchers there is increased range of external rotation and decreased range of internal rotation in the dominant arm relative to the non-dominant arm. These differences are associated with increased humeral retroversion in the dominant arm.^{10–11} This was attributed to skeletal modelling caused by the repetitive external rotation forces created by the throwing arm. Despite a similar assumption being proposed in classical dancers as a result of repetitive TO training,^{4–12} FT in dancers has been reported

as comparable to that of the general population.^{13–14} These observations, however, may not be definitive as there were clear limitations to the designs of these studies.

The age at which ballet dancers begin their training has been considered an important factor in the development of the ideal TO.^{12–14–15} Longitudinal studies have shown that, in terms of bone mineral accrual, bone is at its most responsive to mechanical loading between the ages of 11 and 14 years.¹⁶ Furthermore, it has been shown that vigorous physical activity, such as jumping and classical ballet training, have a positive modelling effect on the femur in prepubertal and peripubertal girls.^{17–19} Although the actual intensity required to gain these skeletal changes is not known, it has been found that tennis players training an average of six hours a week in the prepubertal period have increased bone mineral content and bone size in their dominant arms.²⁰

To our knowledge, no studies have investigated the effect of dance training intensity (hours of dance training a week) on the passive hip components of TO. The purpose of this study was to investigate in classical ballet dancers whether:

- FT is associated with PER and therefore TO
- starting age of dance training has an effect on FT
- there is a critical age at which dance training intensity is most strongly associated with FT moulding.

METHODS

Subjects

For this cross sectional study, 64 full time pre-professional female dancers between the ages of 14 and 25 years were recruited from WA Academy of Performing Arts (Diploma

Abbreviations: FT, femoral torsion; FTC, FT combined; PER, passive external rotation of the hip; PERC, PER combined; PIR, passive internal rotation of the hip; TO, turnout

Figure 1 Turnout in first position.

and Bachelor of Arts - Dance), Terri Charlesworth School of Dance, and the Graduate College of Dance, in Perth Western Australia. Volunteers were recruited after an information presentation at their respective schools. Students participated in six ($n = 23$), 13.5 ($n = 14$), or 20 ($n = 27$) hours a week of classical training depending on which programme they attended.

No volunteers had undergone surgery to the lower limb or had congenital hip disorders or any injury that prevented measurement of their hip. Three volunteers were excluded on the basis of age (>25) or body mass index (weight (kg)/height (m)²; >28).

This study was approved by the human research ethics committee at Curtin University of Technology. All subjects and their parent/guardian, where appropriate, provided written informed consent.

Measurement protocol

Before measurement, the subjects completed a dance history questionnaire. Tossing a coin determined which hip was measured first. The assessor measuring FT, PER, and PIR was blinded to the inclinometer readings. A second assessor, screened from the measuring proceedings, recorded the findings from the inclinometer. A third assessor recorded the TO, height, weight, and body mass index. No formal warm up was performed before testing.

Dance history questionnaire

We constructed a dance history questionnaire to gain information on starting age of classical ballet, hours of dance training a week throughout career, career breaks, and the different styles of dance training undertaken at different ages.

Table 1 Descriptive statistics of ballet dancers ($n = 64$)

	Mean (SD)	Range
Age (years)	18.16 (1.80)	14.0–25.0
Starting age (years)	7.3 (3.9)	3.0–16.0
Years of dance training	11.8 (3.3)	3.0–18.0
Classical ballet	11.0 (4.3)	1.0–18.0
Contemporary	5.3 (2.5)	0.0–13.0
Other dance styles	7.1 (4.7)	0.0–18.0
Age of menarche	13.7 (1.5)	11.0–17.0
Body mass index	20.4 (1.8)	17.0–24.0
Femoral torsion (°)		
Right	19.3 (4.86)	9.1–32.5
Left	17.6 (5.02)	7.3–29.4
Combined	36.9 (9.02)	19.1–57.4
External hip rotation (°)		
Right	48.8 (11.04)	28.0–73.7
Left	49.9 (10.33)	27.4–72.1
Combined	98.7 (20.20)	57.0–143.8
Internal hip rotation (°)		
Right	35.1 (9.97)	11.1–53.7
Left	33.3 (8.88)	13.5–62.3
Turnout (°)	136.2 (21.69)	88.0–172.0

FT

FT was measured clinically as described by Tamari *et al.*⁷ using an electronic digital inclinometer (FAS-A; MicroStrain, Burlington, Vermont, USA) with 0.1° increments. Subjects were placed prone with the leg to be measured in 90° of knee flexion and the hip in a neutral position. The inclinometer was attached using Velcro straps distal to the knee and was aligned with the knee joint line, which was defined as the dorsal border of the femoral condyles (distal reference). The neck of the femur was placed in the horizontal position using Nelaton's line.⁷ This is a line from the anterior superior iliac spine to the ischial tuberosity bisecting the acetabulum and was drawn on the volunteers using chalk and a ruler. The proximal tip of the greater trochanter can be palpated as it intersects Nelaton's line during rotation of the hip joint, to identify when the axis of the femoral neck is positioned horizontally.⁷ The angle between the horizontal femoral neck axis and the axis of the knee joint line represents FT. A positive value is given for ante-torsion of the femur, and a negative value for retro-torsion. This technique has good intrarater reliability (intraclass correlation coefficient = 0.89) and a strong correlation with FT measured using magnetic resonance imaging ($r = 0.81$).⁷ FT combined (FTC) was calculated as the sum of left and right FT.

Passive hip external and internal rotation

PER and PIR were also measured with the subject lying prone using the inclinometer attached in the same manner to the tibia and using knee joint line as the moving axis reference point. The hip was rotated externally and internally until elevation of the ipsilateral or contralateral posterior superior iliac spine signalled the end of available PER and PIR respectively. Combined external rotation (PERC) was calculated as the sum of left and right PER.

TO

TO was measured as described by Negus *et al.*⁶ Subjects stood on a piece of paper and were asked to adopt their "first position" (fig 1) as they do in ballet class. A line was then drawn around their feet. On this tracing, a line bisecting the foot was drawn from the middle of the second toe to the mid point of the heel on each foot. The angle formed between the two lines of bisection was measured using a universal goniometer (fig 1).

Dance training intensity

The number of hours a week of formal classical ballet training was defined as dance training intensity. Subjects were grouped according to the weekly hours trained over the four year periods 7–10, 11–14, and 15–18 years of age.

Data analysis

SPSS version 12.0 statistical package was used for data analysis. Descriptive statistics were used to summarise the data. As TO is a measurement of both legs, PERC and FTC were used in the analyses. Associations between variables were calculated using Pearson's and Spearman's correlations. Differences between those who started dancing before and after 11 years of age were analysed using an independent *t* test.

To investigate the effect of current dance training intensity, students were grouped according to hours of current classical ballet training (six, 13.5, and 20+ hours a week). The differences in FTC, PERC, and TO between these three groups were analysed using one way analysis of variance. To investigate the effect of previous dance training intensity (hours a week) the dancers were dichotomised according to hours trained a week at different ages (7–10 years, 11–14 years, and 15–18 years). A cut-off point of six hours a week

Table 2 Comparison of femoral torsion combined (FTC), passive external rotation of the hip combined (PERC), and turnout (TO) between those starting classical ballet training before and after 11 years of age

	Before 11 years (n = 52)	11 years and after (n = 12)	t Value	p Value
FTC (°)	36.92 (8.87)	36.65 (10.06)	0.09	0.929
PERC (°)	100.05 (20.37)	92.9 (19.2)	1.108	0.272
TO (°)	138.33 (20.13)	126.75 (26.41)	1.691	0.096

Values are mean (SD).

was selected a priori, as this duration of training had previously been observed to have an effect on skeletal modelling. These differences were analysed with and without correction for current level of training using one way analysis of variance and analysis of covariance.

RESULTS

Table 1 summarises age, body mass index, dance training history, and degrees of FT, hip range of motion, and TO.

There was a negative correlation between FTC and PERC ($r = -0.402$, $p < 0.001$), and a positive correlation between PERC and TO ($r = 0.443$, $p < 0.001$). However, there was no association between FTC and TO ($r = -0.147$, $p = 0.246$).

There was no association between starting age of classical ballet training and FTC ($p = 0.016$, $p = 0.898$), PERC ($p = -0.149$, $p = 0.241$), or TO ($p = -0.189$, $p = 0.135$). Furthermore, years of classical training had no association with FTC ($p = -0.035$, $p = 0.786$), PERC ($p = 0.126$, $p = 0.326$), or TO ($p = -0.049$). FTC, PERC, and TO were comparable between those who started dance training before 11 years of age and those who started later (table 2).

Hours of training a week at the time of data collection were dependent on the student's programme of study. TO differed between the three groups ($F_{2,62} = 56.035$, $p < 0.001$), and there was a significant dose-response effect (post hoc pairwise comparisons $p < 0.02$) (fig 2). FTC and PERC did not differ according to current hours of training a week, and visual examination of the data (fig 2) suggests that the increased range of TO achieved by dancers who trained more hours a week was predominantly from compensatory strategies.

Only one volunteer participated in an average of more than six hours of training a week during the 7–10 years age range, invalidating this comparison in this age range. In the age range 11–14 years, those who trained more than six hours a week had less FTC ($F_{1,62} = 5.7$, $p = 0.02$) and greater TO ($F_{1,62} = 6.35$, $p = 0.01$) than those who trained less (fig 3), but the difference in TO was not significant after correction

for current hours of training. There was a consistent trend in PERC, but the differences were not significant either with or without correction for current training level (fig 3).

In the 15–18 year age range, 40 dancers in the study trained more than six hours a week on average. These dancers had significantly less TO ($124 (20)^\circ$ v $143 (20)^\circ$; $p < 0.001$), but there were no differences in PERC or FTC ($94 (20)^\circ$ v $102 (20)^\circ$ and $39 (10)^\circ$ v $36 (8)^\circ$ respectively; $p > 0.13$). The difference in TO was not significant after correction for current hours of training.

DISCUSSION

Several studies have investigated TO in ballet dancers. Values reported vary from $93 (5)^\circ$ to 136° .^{2–4 6 21} In the dancers we measured, the average TO was 136° , very similar to the values of 133° and 136° reported by Negus *et al*⁶ and Watkins *et al*²¹ respectively. The lower measures of TO reported by Bennell *et al*⁵ and Gilbert *et al*³ are probably due to differences in the methods used to measure TO. Bennell *et al*⁵ measured active TO with subjects pivoting on their heels to the TO position. Gilbert *et al*³ used qualitative criteria such as knee alignment over the foot and alignment of weight bearing to minimise compensatory movements during measurement. This monitoring probably reduced the functional TO angle achieved by the dancers in that study. In our study and the one by Negus *et al*,⁶ subjects were asked to “stand in first position as they would in a normal class”. A noteworthy observation in our study was that many of the subjects performed a demi-plié before assuming their first position. This was not corrected as it was considered to be a common variant when assuming first position. Friction with the floor may anchor the feet allowing the dancer to use compensatory strategies resulting in greater absolute TO.

We observed a moderate association between PERC and TO ($r = 0.443$, $p < 0.001$), consistent with a previous report for younger novice dancers.⁵ This could be relevant clinically as it suggests that dancers vary considerably in how much they

Figure 2 Comparison of femoral torsion combined (FTC), passive external rotation combined (PERC), and turnout (TO) according to hours of training a week. * $p < 0.02$ compared with other training hours.

Figure 3 Differences in femoral torsion combined (FTC), passive external rotation combined (PERC), and turnout (TO) in the age range 11–14 years in those training more than six hours a week compared with those training less than six hours a week. * $p \leq 0.05$.

can and do compensate. This does not mean, however, that PER is not important for dancers. By increasing their PER they are increasing the potential for ideal TO without using compensatory strategies and stressing other tissues.

We found a moderate negative correlation between FTC and PERC. Kozic *et al*⁸ also reported an association between FT and PER. The consequence of this is that a retroverted femur may increase the dancer's potential for PER and reduce the need for compensatory strategies, and therefore reduce the risk of injury. Nonetheless, the contribution of FT to TO appears to be small overall, and we found no independent correlation between FTC and TO. Two previous studies have measured FT in the ballet dancing population.^{13, 14} Both concluded that the increased range of PER commonly observed in ballet dancers was not related to differences between dancers and non-dancers in femoral neck version angle. These studies did not concurrently collect and measure controls, but made comparisons between dancers and data from other sources; moreover, sample sizes were small for between group comparisons. Consequently, larger studies with concurrent non-dancing populations matched for age and sex are needed to confirm this finding.

Our results show that the girls who trained for six hours or more a week at 11–14 years of age had significantly less FT than those who trained less at this age. Although no studies have shown that ballet dancers can influence their FT, several have shown that baseball pitchers and handball players have more retroversion in the humerus of their dominant arm than the non-dominant arm.^{10, 11} These differences have been attributed to the effect of repetitive mechanical loading on the humerus.^{10, 11} The femoral neck has been shown to have increased bone mineral density in prepubertal, early pubertal, and retired classical ballet dancers when compared with controls, suggesting that the femur may respond to loading during classical ballet training.^{18, 22} Indeed the forces involved in many of the jumping and landing manoeuvres in classical ballet dancing have been suggested to be as high as 3.5–5 times body weight.²³ Jumping activities have been shown to augment significant bone modelling in the hip region in children.^{24–26} Therefore it is conceivable that the training of classical ballet dancers may lead to adaptive changes in the osseous anatomy resulting in a change in FT.

Evidence of an intensity of training effect in the 11–14 year age range is consistent with previous reports. A longitudinal study on healthy 9–19 year old children showed that the rate of skeletal modelling in girls was particularly pronounced between the ages of 11 and 14 years. Moreover, this effect was dramatically reduced after the age of 16 and/or two years after menarche.¹⁶ Two studies have shown significant bone gains in the femoral neck in early pubertal (Tanner stage II and III) compared with prepubertal (Tanner stage I) girls.^{24, 27} Other studies have shown that prepubertal (Tanner stage I) and premenarcheal (Tanner stage I and II) girls taking part in an exercise intervention had a significant increase in bone mineral density compared with maturity matched con-

What this study adds

- Training for more than six hours a week at 11–14 years of age is associated with more retro-torsion of the femur
- This skeletal geometry is associated with greater external rotation range of motion at the hip joint, which may enable dancers to achieve ideal turnout using fewer compensatory strategies and consequently reduce the risk of injury

trols.^{28, 29} In most girls, menarche is achieved after Tanner stage III and immediately after peak height velocity, which can happen anytime between the ages of 10.5 and 15.5.³⁰ Bailey *et al*¹⁷ estimated that over 27% of the bone mineral at the femoral neck was laid down in the four years surrounding peak height velocity. This critical time period relates to the ages of 11.5–13.5 (Tanner stages II–IV) in girls.³⁰

The level of activity required to create these bony adaptations is yet to be determined. Studies examining the effect of physical activity on bone have used different loading activities at various intensities. No previous studies have compared the effects of training hours on FT. Our data suggest that dance training for at least six hours a week between the ages of 11 and 14 confers some advantage in terms of FT, but we have no data to show whether a higher training load would be even more advantageous.

An inverse relation between the age at which dancing was started and PER and TO has been suggested.^{14, 31} Sammarco¹² suggests that starting ballet before the age of 11 would allow the ballet dancer to mould the shape of the femur as well as develop their TO. Our study found no association between starting age and FTC, PERC, or TO. Nor did we find a difference between those starting before and after 11 years of age, with regard to FTC, PERC, and TO. It should be noted, however, that, before age 11, very few participants in our study were doing more than one or two classes a week, so the training load may not have been sufficient to demonstrate this effect if it exists.

Although years of classical training would logically seem to be a factor influencing PER and TO, the results from our study suggest otherwise. This is supported by similar findings by Bennell and coworkers.⁵ In contrast, years of ballet significantly predicted TO in pre-professional and professional female dancers in another study.²¹ In the latter study, only the years in which the dancer took three or more classes a week were counted. This would be consistent with the intensity of training being an important predictor of skeletal modelling and may explain why the relation between years of dance and TO was not evident in our sample, a considerable proportion of which took less than three classes a week for many of their years of training before the age of 15.

CONCLUSION

The findings of this study are not consistent with the conventional wisdom that starting dance training before 11 years of age advantages the dancer in the development of ideal TO. The data do suggest, however, that physical activity during childhood is associated with skeletal modelling. Specifically, the data show that training for more than six hours a week at 11–14 years of age is associated with more retro-torsion of the femur. This skeletal geometry is associated with greater external rotation range of motion at the hip joint, which may enable dancers to achieve ideal TO using fewer compensatory strategies and consequently reduce the risk of injury.

What is already known on this topic

- Turnout is the fundamental framework of classical ballet technique and the ability to perform it is influenced by soft tissue extensibility, muscle strength, and bony anatomy
- Femoral torsion has a strong relation to passive external rotation of the hip in normal children and therefore may be of critical importance for dancers in achieving ideal turnout

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COMMENTARY

Turnout is a key component of the physique of the classical ballet dancer. A lack of turnout can predispose to injury, diminish classical ballet technique, and may cause a dancer to pursue another form of dance or cease dance altogether. Sound scientific research into the ideal turnout for classical training and ways in which this turnout may be influenced is increasing, but remains sparse. This research adds to our understanding of factors that may allow us to influence the development of turnout in those without ideal turnout. The paper provides a clear description of some of the skeletal features of turnout and compensatory mechanisms so commonly used by dancers lacking ideal turnout. Various methods of measuring turnout are well described and highlighted, explaining conflicting information in the literature on turnout measurements. The contrasting findings in this paper with some other studies on years of ballet training and turnout development is also well explained. This paper also adds positively to our understanding of skeletal changes that may occur with repetitive physical activity.

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