

Atraumatic tears of the ligamentum teres are more frequent in professional ballet dancers than a sporting population

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Abstract

Objectives To compare the frequency of atraumatic ligamentum teres (LT) tear in professional ballet dancers with that of athletes, and to determine the relationship with clinical and imaging findings.

Methods Forty-nine male and female professional ballet dancers (98 hips) and 49 age and sex-matched non-dancing athletes (98 hips) completed questionnaires on hip symptoms and physical activity levels, underwent hip rotation range of movement (ROM) and hypermobility testing, and 3.0-Tesla magnetic resonance imaging (3 T MRI) on both hips to detect LT tears, acetabular labral tears, and articular cartilage defects, and to measure the lateral centre edge angles (LCE).

Results A higher frequency of LT tear was found in dancers (55 %) compared with athletes (22 %, $P=0.001$). The frequency and severity of LT tears in dancers increased with older age ($P=0.004$, $P=0.006$, respectively). The Hip and Groin Outcome Score (HAGOS) pain scores or hip rotation

ROM did not differ significantly among participants with normal, partial, or complete tears of LT ($P>0.01$ for all). Neither the frequency of generalised joint hypermobility ($P=0.09$) nor the LCE angles ($P=0.32$, $P=0.16$, left and right hips respectively) differed between those with and those without LT tear. In most hips, LT tear co-existed with either a labral tear or a cartilage defect, or both.

Conclusion The higher frequency of atraumatic LT tears in professional ballet dancers suggests that the LT might be abnormally loaded in ballet, and caution is required when evaluating MRI, as LT tears may be asymptomatic. A longitudinal study of this cohort is required to determine if LT tear predisposes the hip joint to osteoarthritis.

Keywords Hip joint · Ligamentum teres · Magnetic resonance imaging · Ballet · Lateral centre edge angle · Hypermobility

Introduction

The ligamentum teres (LT) is a pyramidal shaped, intra-articular ligament of the hip, with bands arising from the acetabular notch and the transverse ligament of the acetabulum, and inserting into the fovea of the femoral head [1–3]. The importance of the function of LT in adults has been debated since the 19th century [4]. Its role as a source of hip pain or in joint stability has been investigated, but remains controversial [5–13]. It has been suggested that in people such as dancers with capsular laxity or insufficient acetabular coverage, LT may play a more important role in joint stability [14–16].

In any sport, LT tears can occur because of traumatic hip dislocation [17]. However, LT injury is more commonly

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atraumatic and has been associated with joint instability [18, 19]. Ballet dancers are thought to be at risk of LT injury owing to the repetitive, extra-physiological range of movements they perform, especially involving external rotation with axial loading [16]. Abnormality of the LT has been identified in young gymnasts, and is thought to be an adaptation to mechanical loading that is similar to that used in ballet [20, 21]. LT tears have been reported to be the third most common cause of hip pain in athletes, and have been identified as a potential source of hip pain in ballet dancers [18, 22].

Gray and Villar [2] documented the clinical presentation and arthroscopic classification of LT lesions, and since then advances in hip arthroscopy, along with greater clinical awareness, has led to an increased diagnosis [23, 24], with LT tear prevalence ranging from 4 % to 65 % in arthroscopy studies [2, 23, 25–32]. Arthroscopy remains the gold standard for diagnosing LT abnormality [28]. However, recent improvements in magnetic resonance imaging (MRI) technology and imaging techniques have enhanced the evaluation of LT pathology [14, 29, 33].

Isolated tears of LT have been associated with the premature onset of hip osteoarthritis (OA) [1]. Even though most LT tears co-exist with labral tears and cartilage damage, the exact relationship is still unknown [17, 19, 23, 30]. The risk of hip OA in ballet dancers remains unclear, and the investigation of LT tears in a ballet population has to our knowledge not been reported [34–37].

The objectives of this study were to determine the frequency of atraumatic LT tears in male and female professional ballet dancers compared with a sporting control group, to evaluate any associations between LT tears and clinical signs and symptoms, and to determine if LT tears are associated with inadequate acetabular roof coverage, articular cartilage defects or acetabular labral tears in this population.

Materials and methods

This case–control study investigated 98 participants with a median age of 30 (range 18–64 years), including 49 ballet dancers and 49 sporting controls (21 men and 28 women in each group; Table 1). Dancers were either current ($n=33$) or retired ($n=16$) professional classical ballet dancers from the national ballet company. Retired dancers were all actively teaching ballet. Control participants played tennis, basketball or netball. These sports were chosen, as both male and female participants commonly participate for a similar duration of years to ballet, and are the most commonly played sports in the region. However, these sports do not employ such extreme, repetitive ranges of movement (ROMs) as those used in ballet. The 49 controls were matched with dancers with regard to gender and age (± 2 years), and, in an attempt to standardise the activity levels of the control group, were included if they had played their sport more than three times a week from at least 10 years of age and were still playing at least 2–3 times a week. Any participants with a history of hip trauma or serious injury, hip surgery, congenital hip disease, inflammatory joint disease, or systemic, metabolic, or neurological disorders were excluded, along with those with contraindications for MRI (pregnancy, claustrophobia, metal implants). Ethics approval was granted and participants provided written informed consent.

Participants completed a questionnaire about their years of activity (ballet or sport) and their medical and injury history. Participants also completed the International Physical Activity Questionnaire-Long Form (IPAQ), from which the metabolic minute energy expenditure estimate per week (MET min/week) was calculated [38]. The HAGOS, designed to assess the perception of hip pain or dysfunction of physically active

Table 1 Participant characteristics

	Ballet dancers ($n=49$)	Control group ($n=49$)	<i>P</i> value
Gender, % men	43	43	1.00
Age, years	30 (25–47.5)	30 (25.5–45)	0.99
Years of activity	22 (18.5–27)	20 (16.25–30)	0.23
BMI, kg/m ²	20.58 (18.83–22.28)	23.26 (22.2–25.41)	<0.001
IPAQ MET, min/week	10,951 (7,047–20,080)	5,508 (2,809–8,209)	<0.001
HAGOS pain score	100 (90–100)	100 (92.5–100)	0.77
ER at 0° hip flexion, °	61.2 (9.5)	50.6 (10.9)	<0.001
IR at 0° hip flexion, °	38.3 (10.4)	39.6 (10)	0.54
ER at 90° hip flexion, °	63.7 (8.4)	52.5 (9.5)	<0.001
IR at 90° hip flexion, °	36.5 (29–42.5)	39.5 (34.5–44)	0.02
Beighton score (% ≥ 5)	33	4	<0.001

Hip rotation data for right hips are presented

Data are presented as mean (standard deviation, SD) or median (interquartile range, IQR) unless otherwise indicated

BMI body mass index, IPAQ International Physical Activity Questionnaire, HAGOS hip and groin outcome score, ER external rotation, IR internal rotation

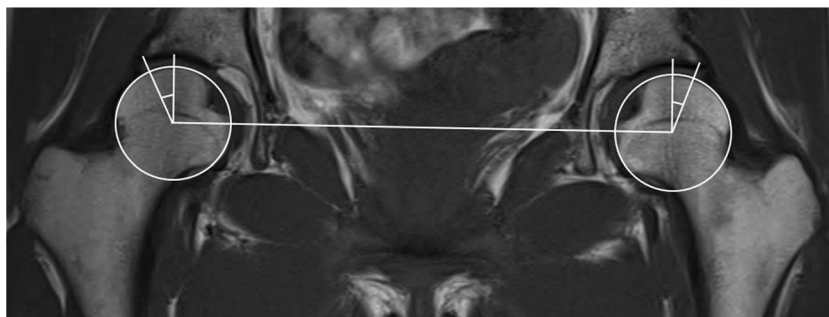


Fig. 1 Coronal T1 MRI of the whole pelvis demonstrating lateral centre edge angles (LCE). A line joins the centre of the femoral heads and represents the transverse pelvic axis. The LCE is the angle between a

line drawn through the centre of the femoral head perpendicular to the transverse pelvic axis, and a line extending from the centre of the femoral head to the lateral margin of the acetabular roof

participants, was completed [39]. The pain subscale score was used, from which a normalised score was calculated, ranging from 100 (no pain) to 0 (extreme pain). Body mass index (BMI) was calculated from the height and weight measurements of each participant.

Passive hip internal rotation (IR) and external rotation (ER) at 0° and 90° of hip flexion were measured in the supine position and sitting, as previously described [40]. Generalised joint hypermobility (GJH) was assessed using the Beighton nine-point scoring system, with a score of ≥ 5 considered hypermobile, as forward flexion can be a trained manoeuvre [41, 42].

Participants were scanned in the supine position, with straps and padding to maintain neutral spine and hip alignment. All studies were performed with a 3-Tesla Trio scanner (Siemens, Erlangen, Germany), using an eight-channel phased array body coil. Left and right hips were imaged separately. The following sequences were part of the MRI protocol: coronal T1 (whole pelvis) sequence (repetition time (TR)=403 ms, echo time (TE)=22 ms, slice thickness/slice gap=6.0 mm /2.4 mm, field of view (FOV)=330 x 350 mm, matrix=512 x 384, number of signal averages=1); coronal proton density-weighted (PD) fat-saturated sequence (TR=2,640 ms, TE=30 ms, slice thickness/slice gap=3.5 mm /1.0 mm, FOV=200 x 200 mm, matrix=320 x 288, number of signal averages=1); oblique axial PD fat-saturated sequence (TR=2,700 ms, TE=30 ms, slice thickness/slice gap=3.5 mm /1.0 mm, FOV=200 x 200 mm, matrix=384 x 288, number of signal averages=1); and sagittal PD fat saturated sequence (TR=3100 ms, TE=30 ms, slice thickness/slice gap=3.5 mm /1.0 mm, FOV=200 x 200 mm, matrix=384 x 256, number of signal averages=1). The LT, acetabular labrum, and articular cartilage were evaluated in all planes. Lateral acetabular coverage was evaluated by measuring the lateral centre edge angle (LCE) on mid-coronal images (Fig. 1) [43]. For ethical reasons contrast agent was not injected for image enhancement. The total time for the MRI, including patient positioning, was approximately 50 min. Images were stored in a picture archive and communication system (PACS) for online analysis.

The LT was evaluated using MRI and classified into three groups; LT was considered normal if there was continuity of all fibres, a homogeneous, hypointense signal on MRI images, with smooth margins, and a normal insertion (Fig. 2); partial tears were scored if there was partial discontinuity of fibres with heterogeneous or hyperintense signal within LT, with or without irregularity or frayed margins (Fig. 3); complete tears were scored if there was a complete loss of ligament continuity, with no normal fibres in the expected location of LT, the attachment sites into the fovea capitis or the transverse ligament were not visible or were a shortened, thickened stump (Figs. 4, 5) [14, 29, 33, 44]. The appearance of LT was also divided into two groups: normal or LT tear (partial or complete).

The presence or absence of labral tear or cartilage defect on MRI was scored using previously validated methods [45]. Absence of a labral tear was scored if a homogeneous, hypointense signal of the labrum was identified with the base sitting flush with the acetabulum or focally increased signal confined to the labrum. Presence of a labral tear was scored if a line of hyperintense signal was detected coursing from the



Fig. 2 Coronal proton density-weighted MRI with fat saturation shows a normal ligamentum teres (arrow)

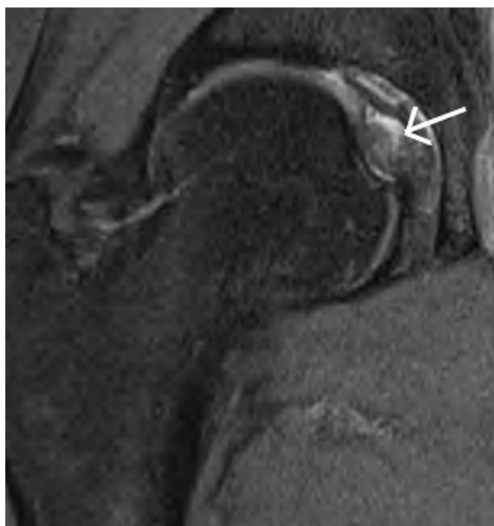


Fig. 3 Coronal proton density-weighted MRI with fat saturation shows a partial tear of the ligamentum teres (*arrow*)

articular side through the base or into the substance of the labrum, with or without distraction of the labrum [45]. The articular cartilage was scored as intact if no cartilage defect was present, or if there was only signal alteration within the cartilage [45]. A cartilage defect was classified as present if there was cartilage loss that could range from focal partial thickness defects such as superficial ulceration, fissuring, or fibrillation, to full-thickness cartilage loss with exposure of subchondral bone of either the acetabular or femoral surface [45]. Hips were categorised into three groups; a normal hip had a normal LT and no labral tear or cartilage defect; an isolated LT tear had a LT tear but no evidence of a labral tear or cartilage defect; and combined pathology was scored if there was a LT tear with a labral tear or cartilage defect or both.

All MRIs were scored by one radiologist with 22 years of MRI experience, including 19 years of musculoskeletal MRI expertise. The LCE was measured by the primary author who had been trained by the radiologist. Both assessors were



Fig. 4 Coronal proton density-weighted MRI with fat saturation shows a complete tear of the ligamentum teres (*arrow*)



Fig. 5 Coronal proton density-weighted MRI with fat saturation shows a superior labral tear (*white arrow*) and an acetabular cartilage defect (*grey arrow*)

blinded to all participant data. Test–retest reliability was established in 30 hips, measured approximately 12 months following the initial scoring.

Data were analysed using statistical software (SPSS version 21, SPSS, Chicago, IL, USA). All data were assessed for normality using the Shapiro–Wilk test. Mann–Whitney test or independent *t* tests were used to evaluate continuous data, and categorical data were analysed using Pearson’s Chi-squared test. One-way ANOVA or Kruskal–Wallis tests were used to compare age, ROM, and HAGOS scores among the three classifications of LT. One-way ANOVA or Kruskal–Wallis tests were also used to compare ROM among three groups; normal; isolated LT tear; and those combined with a labral tear, cartilage defect or both. Owing to multiple comparisons the *P* value was set at <0.01.

Cohen’s kappa statistics and ICCs (two-way mixed, absolute agreement) were used to calculate the intra-rater reproducibility of scoring MRI features. There was 83 % agreement in categorising LT tears, 87 % agreement in categorising labral tears, 83 % agreement in categorising a cartilage defect as absent or present, and substantial intra-rater reliability with kappa values of 0.64 (95%CI 0.36–0.92, $P < 0.001$) for LT, 0.73 (95%CI 0.49–0.97, $P < 0.001$) for labrum and 0.68 (95%CI 0.43–0.92, $P < 0.001$) for cartilage scoring. There was 73 % agreement and moderate intra-rater reliability with a kappa value of 0.49 (95%CI 0.35–0.61, $P < 0.001$) for categorising LT tears into three groups; normal; partial tear; and complete tear [46]. The intra-rater reliability of measuring LCE was excellent, with the ICC (two-way mixed, absolute agreement) demonstrating agreement of measures (ICC = 0.95; 95 % CI: 0.94–0.98).

Table 2 Comparison of participants with and without ligamentum teres (LT) tears in either hip

	LT % (<i>n</i>)		Total, <i>n</i>	<i>P</i> value
	Normal	Tear		
Dancers	45 (22)	55 (27)	49	0.001
Controls	78 (38)	22 (11)	49	
Female dancers	43 (12)	57 (16)	28	0.006
Female controls	79 (22)	21 (6)	28	
Male dancers	48 (10)	52 (11)	21	0.06
Male controls	76 (16)	24 (5)	21	

Results

Dancers and controls were matched with regard to age, years of activity, and gender. BMI and IPAQ measures were significantly different between groups (Table 1). However, IPAQ scores did not significantly differ between retired dancers and their matched sports participants ($P=0.32$). Hip ROM did not differ between left and right hips ($P>0.01$ for all), and the data for right hips are presented (Table 1). Hip ER was significantly greater in dancers than in controls ($P<0.001$), but there was no difference in hip IR ROM between the groups. A higher percentage of dancers had Beighton score ≥ 5 than controls ($P<0.001$). An MRI-defined LCE angle of less than 25° was considered to be undercoverage of the acetabular roof [43]. The mean LCE angles were normal in dancers (L = 29.45 ± 4.6 , R = 29.63 ± 5), and did not differ significantly from controls (L = 30.86 ± 5 , R = 31.55 ± 5.5), ($P=0.15$, $P=0.06$, for the left and right hips respectively).

The frequency of an LT tear in at least one hip in dancers (55 %) was higher than in controls (22 %; $P=0.001$; Table 2). The frequency of LT tear in female dancers (57 %) was higher than in female controls (21 %; $P=0.006$), with a similar trend in men ($P=0.06$; Table 2). The frequency of partial and complete tears of LT in at least one hip was higher in dancers than in controls ($P=0.002$; Table 3). There was no difference in the overall frequency of LT tear between men (38 %; 16) and women (39 %; 22; $P=0.91$). There was also no difference in the classification of an LT tear between the sexes ($P=0.59$).

Table 3 Comparison of ligamentum teres (LT) classification between groups*

Group	Normal LT	Partial tear	Complete tear	Total
Dancers	22	16	11	49
Controls	38	9	2	49

Values are expressed as the number of participants with normal LT, partial or complete LT tear in at least one hip. The more severe classification of LT tear was used when both hips had a pathological condition

* $P=0.002$

Table 4 Ligamentum teres (LT) classification in both hips (all participants)

Left hips	Right hips		
	Normal	Partial	Complete
Normal	60	11	0
Partial	5	8	2
Complete	0	2	9

Values are expressed as the number of hips

All participants with complete LT tears in one hip had some abnormality in their other hip (Table 4).

Participants with LT tears were older than those without LT tears; however, the difference in median age was only significant in dancers ($P=0.004$; Table 5). It has been suggested that over time, partial tears often progress to complete tears [28]. Even though the frequency of LT tears did not differ significantly between retired and current dancers ($P=0.05$), the severity of LT tears increased with increasing age ($P=0.006$). There was no association between age and the LT tear classifications in controls ($P=0.5$).

There was no difference in HAGOS pain subscale scores between the groups (Table 1). Frequency of hip pain, as indicated by HAGOS pain subscale scores less than 100, was found in 49 % of dancers (24) and 45 % of controls (22; $P=0.69$). The HAGOS pain subscale scores did not significantly differ between the classifications of LT tear in dancers or controls, and were high in the LT tear groups, indicating low levels of pain (Table 6). Hip rotation ROM was similar in those with and without LT tears (Table 7), and in the classifications of LT ($P>0.01$ for all). There was no significant difference in the frequency of Beighton scores ≥ 5 between those with ($n=4$) or without ($n=24$) LT tears ($P=0.09$). The LCE angle did not differ between those with and those without LT tears ($P=0.32$, $P=0.16$, left and right hips respectively).

Tears of LT were not associated with the presence of labral tear in dancers (left $P=0.93$, right $P=0.03$) or controls (left $P=0.91$, right $P=0.03$), or with cartilage defects in dancers (left $P=0.09$, right $P=0.03$) or controls (left $P=0.08$, right $P=0.13$). However, in the majority of hips, LT tears co-

Table 5 Comparison of age between participants with and those without ligamentum teres (LT) tears

	Ligamentum teres		<i>P</i> value
	Normal	Tear	
All participants	28 (23–42)	33 (29–51)	0.01
Dancers	27 (22–33)	34 (29–51)	0.004
Controls	29 (25–45)	31 (28–52)	0.53

Values are expressed as median age (IQR)

Table 6 Comparison of HAGOS pain subscale scores between classifications of ligamentum teres (*LT*)

Group	Side	LT classification			<i>P</i> value
		Normal	Partial tear	Complete tear	
Dancers	Left	100 (99.38–100)	100 (70.63–100)	100 (100)	0.62
	Right	100 (100–100)	100 (100–100)	97.5 (80–100)	0.04
Controls	Left	100 (100–100)	92.5 (76–100)	87.5 (83–93)	0.02
	Right	100 (100–100)	100 (72–100)	n/a	0.02

Values are expressed as median (IQR) score

n/a no complete tears

existed with labral tears or cartilage defects, or both (Table 8). The ROM in hips with isolated LT tears did not differ from that of hips with concomitant pathological conditions or hips with a normal LT ($P > 0.01$ for all). There was no association between BMI ($P = 0.25$) or IPAQ scores and LT tears ($P = 0.67$).

Discussion

This study found a higher frequency of atraumatic LT tears on MRI in professional ballet dancers compared with an age- and sex-matched sporting population, suggesting that LT might be a passive restraint to the extreme hip ROM used in ballet. The frequency and severity of LT tears increased with age in dancers. Tears of the LT were not related to pain, hip rotation ROM, lateral acetabular coverage, or generalised joint hypermobility. Labral tear or cartilage defects co-existed with LT tears in the majority of hips.

Similar to ballet, extreme joint loading in young asymptomatic gymnasts may account for the increased frequency of LT abnormality compared with a non-sporting control group [21]. The LT is maximally tensioned in flexion combined with abduction and ER [5–7], but may only support the role of the capsular

ligaments in limiting movement [13]. Hip joint capsular laxity could result from repetitive stretching of the anterior hip capsule or GJH, and predispose a ballet dancer to LT tears [18]. In support of previous findings, hip ER ROM was higher and GJH more common in our cohort of professional ballet dancers [35, 47]. However, we found that LT tears were prevalent in dancers regardless of their ER ROM and hypermobility scores, and therefore, joint laxity does not appear to predispose a dancer to LT tears.

Repetitive stretching of the LT and hip joint microinstability may cause partial rather than complete LT tears [48]; however, the frequency of complete tears and that of partial tears in dancers were similar. This study showed that nearly twice as many dancers had a partial tear compared with the sporting group, and the prevalence in the general population is similar to this sporting group [49]. Complete tears, either bilateral or associated with a partial tear in the opposite hip, were almost exclusively in the dancers, and complete LT tears have rarely been reported in other populations [14, 27, 29, 33, 49]. A partial LT tear may progress over time to a complete tear [48], as increasing age was associated with an increased severity of LT tear in dancers in this study. The frequencies of LT tears were

Table 7 Hip rotation range of movement (ROM) in participants with and without ligamentum teres (*LT*) tears

ROM	Side	Ligamentum teres		<i>P</i> value
		Normal	Tear	
ER at 0° hip flexion	Left	52.5 (45.5–60)	59.3 (52.9–64)	0.08
	Right	53.9 (11.4)	59.8 (10.7)	0.02
IR at 0° hip flexion	Left	40.3 (12.5)	42.2 (9.4)	0.48
	Right	39.7 (10.9)	37.4 (8.4)	0.30
ER at 90° hip flexion	Left	54.7 (9.7)	55.5 (12.7)	0.75
	Right	57 (10.4)	60.5 (10.7)	0.13
IR at 90° hip flexion	Left	36.5 (10.8)	37.3 (10.4)	0.77
	Right	39 (34.3–44)	33.5 (29.1–34.3)	0.18

Values are expressed as ROM in degrees: median (IQR) or mean (SD)

Table 8 Frequency of isolated ligamentum teres (LT) tears and tears combined with acetabular labral tears, cartilage defects or both

	Side	Normal LT	Isolated LT tear	Combined with ALT and/or cartilage defects
Dancers	Left	30	4	15
	Right	25	3	21
Controls	Left	41	2	6
	Right	41	1	7

Values are the numbers of hips
ALT acetabular labral tear

similar in current and retired dancers, but older dancers were more likely to have a torn LT [23, 30].

Inadequate acetabular coverage may predispose a dancer to LT tears, as people with lower LCE angles had a higher prevalence of atraumatic LT tears [23]. However, we reported no significant difference in the lateral acetabular coverage in dancers compared with the sporting population, and no association with LT tears. Therefore, LT tears appear to be due to ballet-specific loading.

Free nerve endings responsible for pain and inflammation have been detected in the LT, supporting its role as a source of pain [10–12]. Low levels of hip pain were reported in 49 % of dancers in this study, lower than the 60 % reported previously in elite ballet dancers [34]. Neither pain nor rotation ROM were related to LT tears in this or other studies [23, 30, 49]. It is possible that concomitant pathological conditions, such as labral and cartilage lesions, constituted a confounding factor, influencing both pain and ROM [50]. None of the dancers with isolated LT tears reported pain, and rotational ROM did not differ from those with co-existing labral or cartilage lesions.

Ligamentum teres tears have been shown to co-exist with labral and cartilage lesions, and recurrent instability due to LT tears may lead to labral tears, cartilage defects, and subsequent osteoarthritis [23, 30, 32]. The majority of hips with LT tears in this study had either a labral tear or a cartilage defect, or both. Arthroscopic studies have found that LT tears are related to larger sized labral tears, higher grades of acetabular cartilage injury, and femoral head cartilage defects [23, 30, 32]. The temporal relationship among LT tears, labral tears, and cartilage defects requires prospective studies [23].

Treatment of LT tears with surgical debridement and reconstruction has been recommended for dancers who present with persistent pain and instability following failed conservative management [16, 18]; however, capsular tightening and LT reconstruction can limit ER ROM, which is incompatible with elite dance [1, 16, 28]. The lack of functional consequences of LT tears in this cohort of ballet dancers could be due to a superior proficiency of hip control achieved at this elite level. Good conservative restoration of hip control may compensate for a torn LT, and obviate the need for surgery.

Hip arthroscopy remains the gold standard for diagnosing LT tears [28]. A limitation of this study was the use of MRI to

evaluate LT. Compared with arthroscopy, MRI has good specificity for detecting LT tears, but lower sensitivity, and it is possible that we have missed tears of the LT in this study [14]. Contrast enhancement used in magnetic resonance arthrography (MRA) has been found to augment detection of partial LT tears compared with MRI [33]. However, MRI is as accurate as MRA in detecting complete LT tears [33]. Both MRA and hip arthroscopy are invasive, and were deemed unethical for this study. Substantial intra-rater reliability was found for differentiating between normal LT and tears of the LT [49]; however, we found only moderate agreement in differentiating between the classifications of LT. We used a single radiologist to ensure consistency. Inter-rater reliability has been tested previously, demonstrating substantial agreement when diagnosing LT abnormality, and fair agreement when distinguishing among normal, partial or complete tears [33, 49].

Sporting participants were chosen for a control group in an attempt to evaluate the effects of extreme loading on LT, while controlling for the effects of exercise. Although our controls were high-level athletes who had participated in their sport from a similar age to the dancers, their activity levels at the time of testing were not matched, because the dancers were engaged in full rehearsal days and nightly performances. The IPAQ scores did not differ between retired dancers and their matched controls, and our findings were similar in the two groups. Although the BMIs of dancers were lower than those in the sporting group, neither BMI nor IPAQ scores were related to LT tears [23, 30].

Our ROM testing was limited to rotation in two positions, and future research could evaluate more complex positions that are relevant to ballet.

Conclusion

The frequency of atraumatic tears of the LT on MRI was high in professional ballet dancers compared with an age- and sex-matched sporting population. The findings of this study suggest that extreme loading of the hip, over a prolonged duration, might result in LT tears, and caution is required when evaluating MRI, as LT tears may not be the source of symptoms. Labral tears and cartilage defects co-existed with LT tears in the majority of hips, and a longitudinal study is

required to establish if a LT tear is a precursor to symptomatic hip OA in this population.

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Compliance with ethical standards

Conflicts of interest Susan Mayes is employed by The Australian Ballet and declares a potential conflict of interest. The other authors declare that they have no conflicts of interest.

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