Abstract
A cross-sectional design was employed retrospectively to evaluate injuries self-reported by 71 pre-professional ballet dancers over one season. Some of the descriptive findings of this survey were consistent with those of previous research and suggest particular demographic and injury trends in pre-professional ballet. These results include gender distribution, mean age and age range of participants, training hours, injury location, acute versus overuse injuries, as well as average number of physiotherapy treatments per dancer. Other results provide information that was heretofore unreported or inconsistent with previous investigations. These findings involved proportion of dancers injured, average number of injuries per dancer, overall injury incidence during an 8.5 month period, incidence rate by technique level, mean time loss per injury, proportion of recurrent injury, and activity practiced at time of injury. The results of univariate analyses revealed several significant findings, including a decrease in incidence rate of injury with increased months of experience in the pre-professional program, dancers having lower injury risk in rehearsal and performance than in class, and a reduced risk of injury for dancers at certain technique levels. However, only this latter finding remained significant in multivariate analysis. The results of this study underscore the importance of determining injury rates by gender, technique level, and activity setting in addition to overall injury rates. They also point to the necessity of looking at both overall and individual dancer-based injury risks.

Ballet is a theatrical pursuit that is well known for its high volume and intensity of training and relatively young age of initiation. Pre-professional ballet training may start as early as ages 8 to 10 years, with a professional career being up to 10 years away. Published studies on professional ballet schools report hours of preparation ranging from 6 to 30 hours per week. Top-level ballet students typically train 5 to 6 days a week as they approach the professional level. Physical activity, including ballet, provides many health-related benefits to those who participate. However, engaging in athletic activity at a young age also involves risk of injury. Young ballet dancers may be particularly vulnerable to injury due to the presence of still-maturing growth plates and the growth process itself. Most young ballet dancers, particularly those who progress to elite levels of training and performance, typically do not pass through their ballet careers without incurring injuries. Concern has been raised regarding the incidence, severity, and long-term effects of injury sustained in ballet. Five cohort studies were found that report incidence and distribution of injury affecting pre-professional ballet students. Overall incidence rate of injury in these studies ranged from 0.8 to 4.7 injuries per 1,000 hours of training. The information provided in these studies, however, is insufficient and makes comparative analysis difficult for two reasons:

1. They did not use the same method for defining injury. One study reported only on overuse injury. Three studies counted only injuries that were seen by a...
healthcare professional. Only one study included injuries seen by a physical therapist and injuries that were self-reported.

2. Studies provided limited and inconsistent exposure information (i.e., denominator data). In two studies, exposure was estimated based on group training records and not on individual exposure to risk of injury. One study did not describe how exposure data were obtained.

The incidence of dance injuries in the aforementioned articles may be underreported, as ballet dancers suffer both traumatic and overuse injuries. Dancers may modify or not discontinue their training due to minor musculoskeletal complaints, choosing to ignore the injury or hide it from health professionals. Less serious injuries that do not result in cessation of dance activity may progress to overuse or more severe injuries.

Given the limits of current data on the incidence and distribution of injury among pre-professional ballet students, there is a need for continued epidemiological study of injury in this aesthetic and athletic endeavor. The present study was undertaken to better define and update information on these aspects of ballet injuries at different ages and levels of pre-professional training and performance. Data were also collected on factors associated with injury, with the aim of assisting in the development of injury prevention strategies.

Methods and Materials

Subjects

The subjects for this study were drawn from a premier training venue for aspiring ballet dancers that is affiliated with a world-renowned professional ballet company. “Pre-professional” is defined in this study as a level of training for a professional career in ballet, usually under the auspices of a professional ballet company that includes a rigorous academic and dance training schedule. “Aspirant” refers to ballet dancers at the advanced, post-secondary training level, who are making the transition from student to professional dancer.

A total of 76 pre-professional ballet students were invited to participate in this study. They ranged in age from 11 to 21 years and represented technique levels 1 to 7 plus the Aspirant program as defined by their school. Seventy-one students (44 females, 27 males) accepted the invitation.

Study Design

A cross-sectional design was employed retrospectively to evaluate injuries affecting the 71 participants for a period of 8.5 months. The Institutional Review Boards at two universities reviewed and approved this study. A memo of understanding regarding study protocol was developed between the faculty representatives of these universities and the ballet school Director of Operations. For the purposes of this study, injury was defined as “a dance-related incident that resulted in the dancer missing all or part of a practice or performance.” “Practice” included technique classes and rehearsals. The survey captured injuries incurred between September 5, 2013, and May 22, 2014.

Study Procedures

An injury questionnaire was adapted with permission from O’Kane and coworkers and initially piloted with dance students for ease of comprehension and time efficiency. Following this pilot study, pre-professional ballet students were invited to participate through a letter distributed by the instructors at the ballet school. Participation was completely voluntary without consequence for those who chose to decline the invitation. Students who expressed an interest in participating were provided with a letter explaining the study and a consent form to be signed by a parent or legal guardian or the student if he or she was 18 years of age or older. Participants under the age of 18 with a signed parental or legal guardian consent form were also asked to complete an assent form expressing their personal willingness to participate.

The ballet school scheduled the injury survey sessions near the end of the ballet school year, before summer break. Students were scheduled for a 1 hour session to fill out the questionnaire and came as a cohort according to their age and technique level. The instructions requested students to self-report the frequency and characteristics of all injuries sustained during the previous school term (8.5 months). Information requested for each injury included body part injured, injury type, new or recurring injury, time loss, circumstances associated with injury, and health care professionals seen.

In addition to the research assistant, and in accordance with the ballet school’s policy on supervision, instructors for each technique level were present to serve as supervisors and to answer any questions the students might have regarding the survey instrument or their past injuries. For reference purposes, instructors brought a binder that contained information about reported musculoskeletal complaints seen by a school physiotherapist as well as related activity restrictions, how long those restrictions were or should be in place, and (where applicable) when the next physiotherapist or doctor follow-up was scheduled.

Each time a physiotherapist changed the restrictions a new form was submitted. The information on the form was standardized, with lists of dance techniques that could be circled to identify restrictions imposed, for how long, and whether follow-up treatment was scheduled. The binder served as a central depository for these forms, so all instructors associated with each student had access to activity restrictions that were in place for that student. Upkeep of injury logs by instructors on each student throughout the study period was mandatory.

Students attended on-site physiotherapy clinics for consultation on their own initiative or on the advice of their teachers if an injury was suspected. Students were encouraged to report to the on-site physiotherapy clinic for consultation but had the option of seeking off-site consultations. It is unclear how many, if any, dancers were lost to physiotherapy follow-up.
or went privately to a family physician or physiotherapist without disclosing this information to the school. Given privacy of information legislation, these injuries were available only if the student chose to include them in the survey.

A database of student names was generated from the assent forms onto an Excel spreadsheet, and subject numbers were assigned to each student. The students’ responses to the survey questions were then transcribed from the survey form to the spreadsheet and subject numbers replaced student names.

Data Analysis
Rates of injury were calculated per 1,000 hours of dance and per 1,000 dance exposures (DEs). A DE was defined as one dancer participating in a training or performance session.17,18 Individual injury rates were first calculated for each dancer, dividing the number of injuries by hours of dance exposures, and then averaged (mean) across either all dancers or specific cohorts of dancers according to technique level and gender. This allowed for the construction of 95% confidence intervals around these average injury rates. Exposure data used in these calculations were retrospectively determined for each dancer in relation to administrative records: specifically, individual ballet school attendance record and corresponding record of class, rehearsal, and performance hours and DEs for all dancers, as well as by technique level and gender.

We also calculated the proportion of dancers who sustained one or more injuries. Rate ratios were calculated using standard methods to compare between sex and technique level.19 Frequency and percentage of injuries relative to anatomical location, activity setting, and injury type were reported. The severity of injury according to the number of days required for a dancer to return to full participation following the day of injury was described. We also recorded the number of injuries requiring physiotherapy treatment, referral to a medical practitioner, and surgery. Confidence intervals for proportion estimates were calculated using the Agresti-Coull method.20

Because of multiple injuries in some dancers, Poisson regression models of individual injury rates relative to 1,000 hours exposure versus risk factors were fitted using generalized estimating equations. Odds ratios were not calculated, as it is beneficial to estimate injury incidence directly and via the generalized estimating equations, thereby controlling for multiple injuries per dancer. The risk factors considered were as follows:

- Age;
- Gender (with female designated as the reference);
- Technical level (with levels 1 and 2 combined and used as the reference level, and the Aspirant program considered the final level);
- Months in pre-professional training; and
- Activity setting where an injury occurred, with “classes” used as the reference.

Unadjusted injury rates and associated confidence intervals were estimated from Poisson regressions with a single risk factor. For adjusted rates a multiple-Poisson regression with all risk factors except for technical level due to strong correlations within the data was used.

Poisson regressions were run in R,21 and the “gee” package was used for the generalized estimating equations.22

Significance level for all analyses was set at $p < 0.05$. For rate ratios, statistical significance was also evaluated according to whether or not the 95% confidence intervals contained the null value.

Results
Seventy-one of 76 dancers completed the questionnaire for a response rate of 94.7%. The sample consisted of 44 (62%) females and 27 (38%) males. The subjects ranged in age from 11.04 to 22.33 years at the outset of the study. The mean age of all students was 16.77 years (95% CI: 16.11 to 17.43) with female mean age of 16.41 (95% CI: 15.69 to 17.12) and male mean age of 17.37 (95% CI: 16.07 to 18.67). The breakdown of number of students participating at each technique level is shown in Table 1. Technique levels 1 and 2 were combined for analyses since they trained together.

The dancers trained 6 days per week, with class hours ranging from 12.5 to 20 hours per week, depending on technique level. Aspirant dancers trained 25 to 30 hours per week, which included classes with the professional company.

Sixty-seven of 71 dancers (95.8%) reported their height. Mean (95% CI) height for both genders combined was 65.9 inches (64.9 inches to 66.9 inches), with a minimum of 55 inches and a maximum of 79 inches. The female mean (95% CI) height was 64.7 inches (63.9 inches to 65.5 inches), with a minimum of 58 inches and a maximum of 70 inches. Two females did not report height. The male mean (95% CI) height was 68.0 inches (65.9 inches to 70.2 inches), with a minimum of 55 inches and a maximum of 79 inches. Two males did not report height.

Sixty-one of 71 dancers (85.9%) chose to include their height in the questionnaire for a response rate of 80.5%. Mean (95% CI) height for both genders combined was 54.9 inches (54.0 inches to 55.8 inches), with a minimum of 46 inches and a maximum of 65 inches. The female mean (95% CI) height was 54.6 inches (53.7 inches to 55.5 inches), with a minimum of 46 inches and a maximum of 64 inches. The male mean (95% CI) height was 55.2 inches (54.3 inches to 56.1 inches), with a minimum of 50 inches and a maximum of 62 inches.

### Table 1 Distribution of Ballet Students by Technique Level and Aspirant

<table>
<thead>
<tr>
<th>Age range</th>
<th>Levels 1 and 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Level 5</th>
<th>Level 6</th>
<th>Level 7</th>
<th>Aspirant</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-12</td>
<td>11-12</td>
<td>12-13</td>
<td>13-16</td>
<td>14-18</td>
<td>15-19</td>
<td>16-19</td>
<td>18-21</td>
</tr>
<tr>
<td>Female (N = 44)</td>
<td>7</td>
<td>2</td>
<td>7</td>
<td>14</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Male (N = 27)</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Total (N = 71)</td>
<td>12</td>
<td>4</td>
<td>7</td>
<td>21</td>
<td>5</td>
<td>8</td>
<td>14</td>
</tr>
</tbody>
</table>
reported weight. Mean (95% CI) weight for both genders was 117.3 lbs. (111.2 lbs. to 123.4 lbs.), with a minimum of 84 lbs. and a maximum of 190 lbs. The female mean (95% CI) weight was 106.3 lbs. (102.3 lbs. to 110.2 lbs.), with a minimum of 85 lbs. and a maximum of 125 lbs. Ten females did not report weight. The male mean (95% CI) weight was 131.2 lbs. (120.1 lbs. to 142.2 lbs.) with a minimum of 84 lbs. and a maximum of 190 lbs. All males reported weight.

During the 2013 to 2014 season 5 of 71 dancers (4 females, 3 level five and 1 level four; 1 male level two) discontinued training with the ballet school, resulting in an attrition rate of 0.07 (95% CI: 2.7 to 15.9). Two of these dancers had experienced recurring injuries that impacted their progress and raised concerns about their future in ballet. Sixty-six of the original 71 dancers returned for the 2014 to 2015 season.

Frequency and Incidence of Injury
During the study period 61 of 71 dancers reported 114 partial and full time-loss injuries that occurred in supervised dance practice and performance. An additional seven dance-related injuries that occurred in unsupervised settings were also reported. These seven injuries were not included in the analyses.

The incidence proportion of injured students was 0.859 (95% CI: 0.757 to 0.923). Ten dancers (14.1%) experienced no injuries during the study period. The average number of injuries per dancer was 1.61 (95% CI: 1.34 to 1.87) and ranged from 0 to 5. By gender, the average number of injuries per female dancer was 1.61 (95% CI: 1.27 to 1.96) and 1.59 (95% CI: 1.15 to 2.03) per male dancer. The average number of injuries for the Aspirant dancers (N = 14), regardless of sex, was 2.00 (95% CI: 1.30 to 2.70). Table 2 provides a summary of how many students were affected by 0 or more injuries. The majority of dancers (73.2%) had 1 to 2 injuries.

Table 3 shows a breakdown of overall injury rates and by technique level. The overall mean incidence of injuries was 3.82 (95% CI: 2.24 to 5.40) injuries per 1,000 DEs and 3.06 (95% CI: 1.99 to 4.13) injuries per 1,000 hours. The average (95% CI) injury rate for males of 2.37 (1.63 to 3.12) injuries/1,000 hours or 2.82 injuries per 1,000 DEs was not significantly different from the females at 3.48 (1.79 to 5.17) injuries/1,000 hours or 4.43 (1.92 to 6.94) injuries per 1,000 DEs. As indicated, injury rates were highest for Aspirant dancers, both in terms of DEs and per 1,000 hours, followed by technique levels 5 and 4, and 1 and 2 combined.

Anatomical Location of Injury
As shown in Table 4, the lower extremity (LE) was the body region most affected by injury (85.96%), followed by the head, spine, and trunk (H/S/T; 7.89%) and upper extremity (UE: 3.51%). The three most common injury locations were the hip (17.54%), knee and ankle (14.91%), followed by the tibia and foot (8.77%). Although not statistically significant, females suffered a greater percentage of LE injuries, while males incurred a greater proportion of H/S/T and UE injuries (Table 4: *X*² = 4.156, df = 2, *p* = 0.1252).

Activity at Time of Injury
A comparison of overall mean injury rates by activity is shown in Table 5. Although the largest proportion of injuries (90.6% with CI: 81.2 to 94.6) occurred during class, the risk of injury in rehearsal was 7.66 injuries per 1,000 hours of exposure (95% CI: 0.58 to 14.75), followed by class at
2.28 injuries per 1,000 hours of exposure (95% CI: 1.77 to 2.79), and then performance at 1.05 injuries per 1,000 hours of exposure (95% CI could not be calculated as N = 1).

Overuse Versus Acute Onset
Almost two-thirds (65.8%) of all injuries (N = 114) were gradual onset or overuse in nature (95% CI: 57% to 74%), and 34.2% were sudden onset or acute (95% CI: 26% to 43%). Dancers who reported an injury were asked if they had had this injury before (same location, type, and onset). Fifty-four percent of injuries were recurrent (95% CI: 45% to 63%), while 46% were new (95% CI: 37% to 55%). Slightly more than 60% (61.3%) of overuse injuries were recurrent, compared to 41% of new injuries. However, this difference was not statistically significant ($X^2 = 3.486$, df = 1, $p = 0.0619$). There was also no statistically significant relationship between injury location and acute versus overuse injuries ($X^2 = 4.842$, df = 2, $p = 0.0885$).

Injury Outcome
Table 6 provides a summary of types of injury. As shown, the three most common types of injury were tendinitis (22.81%), sprain (16.67%), and strain (14.91%). The next most common type of injury was “other,” which included ankle pain or soreness, snapping psoas syndrome, torn labrum, periostitis of the tibia, swelling or bruising, “popped rib” or pulled muscle, overstretch, tension, and sacral bone contusion. Two of 114 injuries resulted in surgery, for a proportion of 0.018 (95% CI: 0.001 to 0.067).

Students who were treated by the ballet school physiotherapists and had restrictions imposed on their dance activity had to be cleared before being able to participate in class or rehearsal. The average (95% CI) time loss per injury as reported by the students was 14.0 days (9.83 to 18.19). The median time loss was 7 days, and maximum time loss for an injury was 180 days. Fifty-eight percent of injuries were considered mild (less than 7 days’ time loss), 26% moderate (8 to 21 days’ time loss), and 16% severe (greater than 21 days’ time loss).

Sixty-three of 71 dancers (88.7%) received a total of 562 physiotherapy treatments, which were provided by two physiotherapists employed by the ballet school and company. Eight of 71 dancers (11.3%) did not seek treatment. Dancers who did seek treatment received from 1 to 36 treatments for a range of musculoskeletal complaint- and injury-related conditions. Each treated dancer received an average of 9.43 (95% CI: 7.34 to 11.52) treatments. The number of treatments per type of musculoskeletal complaint or injury was 4.04 per condition.

The range of musculoskeletal complaint- and injury-related conditions that were treated included abrasion,
bursitis, contusion, joint dysfunction, fasciitis, periostitis, physeal injury, sprain, strain, stress fracture, subluxation, and tendonitis. Of these, the three conditions that required the greatest proportion of treatments were tendonitis (28.6%), strain (28.2%), and sprain (17.4%). Notably, these were also the three most commonly reported injury types.

Conditions treated with common diagnoses were cross-tabulated. The three most common locations treated for tendonitis were peroneal (N = 57), rectus femoris (N = 34), and Achilles (N = 31). The three most common strains treated by the physiotherapists were lumbar (N = 20), gastrocnemius (N = 17), and midfoot (N = 10).

Body parts in need of physiotherapy included a broad range of anatomical sites, although there was a preponderance of lower extremity locations. The three most common anatomical locations treated by the physiotherapists were the lower leg (23.5%), foot (15.4%), and knee (13.45%).

**Injury Risk factors**

Unadjusted (simple Poisson regression) and adjusted (multiple Poisson regression) estimates of rate ratios for injuries per 1,000 hours of exposure to practice and performance are provided in Table 7. Shaded cells represent variables that could not be run in the multiple regression model because Aspirant dancers were not included due to missing data. All variables are categorical except for age and months training, which are continuous. As such, the rate ratio refers to the multiplicative decrease in risk per year of age or total number of months in the program, respectively. For example, based on the simple Poisson regression in Table 7, for every year of age the risk of injury drops by approximately 5.4%.

In univariate (unadjusted) analyses, significant predictors of injury risk (total) included technical level, months training, and environmental location. Compared to the first technical level (levels 1 and 2), levels 3 and 6 had significantly lower injury rates, while the remaining levels were not significantly different from the first. Dancers with more months experience in the pre-professional program had a lower injury rate. Dancers in rehearsal and performance had a significantly lower injury rate than dancers in class. This is in contrast to looking at activity setting using an overall injury rate calculated by summing injuries and exposure across all dancers and then dividing total injuries by total exposure (as reported in Table 5). The difference here is due to how the injury rate was calculated, with the data in Table 7 producing an individual injury rate using injury number corrected for multiple injuries per dancer and exposure. Only one predictor, technical level 3, remained significant in

**Table 5** A Comparison of Injury Rates (95% CI) for Technique Levels 1 to 7 by Activity

<table>
<thead>
<tr>
<th>Activity</th>
<th>Total No. of Injuries*</th>
<th>Total No. of DEs</th>
<th>Average Rate (95% CI): No. of Injuries/1,000 DEs</th>
<th>Total No. of Hours</th>
<th>Average Rate (95% CI): No. of Injuries/1,000 Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>77</td>
<td>28,425.5</td>
<td>2.71 (2.10 - 3.31)</td>
<td>33,803.13</td>
<td>2.28 (1.77 - 2.79)</td>
</tr>
<tr>
<td>Rehearsal</td>
<td>7</td>
<td>736.0</td>
<td>9.51 (0.71 - 18.31)</td>
<td>913.25</td>
<td>7.66 (0.58 - 15.75)</td>
</tr>
<tr>
<td>Performance†</td>
<td>1</td>
<td>894.0</td>
<td>1.12</td>
<td>950.95</td>
<td>1.05</td>
</tr>
<tr>
<td>Overall‡</td>
<td>85</td>
<td>30,055.5</td>
<td>2.83 (2.33 - 3.43)</td>
<td>35,667.58</td>
<td>2.38 (1.88 - 2.89)</td>
</tr>
</tbody>
</table>

*As exposure data were not available for dancers in the Aspirant category, these analyses exclude those injuries. †Confidence intervals could not be calculated as there was only one injury. ‡Activity was not provided in two injury reports.

**Table 6** Frequency and Percent Distribution of Injury Types

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blisters</td>
<td>5</td>
<td>4.39</td>
</tr>
<tr>
<td>Bruise/swelling</td>
<td>5</td>
<td>4.39</td>
</tr>
<tr>
<td>Bursitis</td>
<td>5</td>
<td>4.39</td>
</tr>
<tr>
<td>Concussion</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Corns</td>
<td>2</td>
<td>1.75</td>
</tr>
<tr>
<td>Cut/scrape</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dislocation</td>
<td>1</td>
<td>0.88</td>
</tr>
<tr>
<td>Fracture</td>
<td>1</td>
<td>0.88</td>
</tr>
<tr>
<td>Knee cap-related pain</td>
<td>5</td>
<td>4.39</td>
</tr>
<tr>
<td>Muscle spasm</td>
<td>2</td>
<td>1.75</td>
</tr>
<tr>
<td>Other</td>
<td>14</td>
<td>12.28</td>
</tr>
<tr>
<td>Shin splint</td>
<td>7</td>
<td>6.14</td>
</tr>
<tr>
<td>Sprain (ligament)</td>
<td>19</td>
<td>16.67</td>
</tr>
<tr>
<td>Strain (torn muscle)</td>
<td>17</td>
<td>14.91</td>
</tr>
<tr>
<td>Stress fracture</td>
<td>3</td>
<td>2.63</td>
</tr>
<tr>
<td>Subluxation</td>
<td>2</td>
<td>1.75</td>
</tr>
<tr>
<td>Tendonitis</td>
<td>26</td>
<td>22.81</td>
</tr>
<tr>
<td>Torn knee cartilage</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>114</td>
<td>100</td>
</tr>
</tbody>
</table>
the multivariate analysis. This finding supports the univariate analyses which showed a decreased risk of injury for level 3 in the technique program.

**Discussion**

In several previous injury studies of young ballet dancers, the proportion of female to male dancers ranged from 58% to 87%.1-3,10,15 The majority of students (44/71) in our study were also female (62%). The mean age (16.77 years; CI: 16.11 to 17.43) and age range (11 to 21 years) of students in our study were also similar to previous studies, where the mean age and age range were 14.7 to 17.2 and 10 to 22 years, respectively.1-3,10,15

A 4-year prospective study of pre-professional ballet dancers reported a drop-out rate of 20% per year during the first 2 years of the study and 15% during years 3 to 4.18 First year drop-outs were characterized by a significantly greater proportion of major injuries as compared with their peers. In our study, 7% of dancers stopped training during the study period. Although none were injured at the time they discontinued ballet, recurrent injuries were a consideration in two cases.

**Frequency and Incidence of Injury**

Previous studies report that 42.1% to 77% of ballet dancers were injured during the study period, with some incurring multiple injuries.1-3,10,23,24 The incidence proportion of injury in our study was slightly greater, with 61/71 (85.9%) of the participants reporting at least one injury during the study period. However, only nine dancers sustained more than two injuries.

As shown in Table 3, the overall mean incidence of injury in our study was 3.06/1,000 hours of exposure and 3.82/1,000 DEs, which is slightly higher than overall injury rates reported in previous research (Table 8). Overall injury rates ranged from 0.8 to 2.4 injuries/1,000 hours and 1.09 to 3.52 injuries/1,000 DEs in previous studies.1-3,15 These findings may, in part, reflect a difference in approach to defining injury and exposure across studies. They may also reflect the more inclusive definition of injury in our study, which included all dance-related incidents that resulted in the dancer missing all or part of a practice or performance. In several studies, only injuries that were seen by a physical therapist, licensed healthcare practitioner, or orthopaedic surgeon were included.1,3 However, identifying injuries that the dancer self-perceives (and that relate to time loss) may help detect problems and prevent them from worsening, translating into less time away from dance and decreased health care costs.10

Table 3 also shows that the incidence rates for injury, both in terms of hours and dance exposures, were highest for the Aspirant group, followed by technique levels 5, 4, and 1 and 2 combined. Differences in injury rates across technique levels have not been reported in previous studies, but may reflect a number of factors that...
would be worthy of further consideration. For example, differences in instruction, training, or scheduling may help to explain the disparity. Differences in injury rates relative to technique level may also result from some dancers having relatively high individual injury rates. For example, in our study, the higher rate of injury among the Aspirant group may be explained, in part, by the high individual rate of injury of one of the Aspirant dancers. This tendency is accounted for in the Poisson regressions with the generalized estimating equations that were employed in our analysis of risk factors (Table 7).

In our study, the average injury rate for females was higher than for males; however, this difference was not statistically significant. Injury rates were higher for males than females in two other studies, but these differences were not tested for significance. In one study, male students did incur a significantly greater rate of self-reported injuries than females, in spite of the fact that the females danced more hours than the males. In addition to different physical demands in ballet, possible explanations for gender differences in injury rates may be hormonal in nature or anatomically based, such as increased joint laxity in female dancers and differences in motor control of knee function.

**Anatomical Location of Injury**

Identifying the anatomical location of injury is important for instructors and health care professionals who work with young ballet dancers. Such information highlights body parts most likely to be injured and thereby directs attention for developing possible preventive measures. Although definition of injury and exposure differed among previous studies involving pre-professional ballet dancers, the majority of injuries consistently involved the lower extremity (LE: 69% to 91%), followed by the head, spine, and trunk (H/S/T: 4.6% to 24.0%). Similarly, in our study (Table 4), the majority of injuries affected the LE (85.96%), followed by the H/S/T (7.89%) and upper extremity (UE: 3.51%). In fact, the three most common injury sites—hip, knee, and ankle—were all LE. Although statistically not significant, comparison of injured body region by gender showed a somewhat different distribution of injury among males and females, with females showing a greater percentage of LE injuries and males a greater percentage of H/S/T and UE injuries. Gender differences in location and type of injury are not uncommon in gender-comparable sports and likely relate to the different physical demands of a given sport combined with gender differences in anatomy and physiology.

**Activity at Time of Injury**

Previous research reported overall injury rates but did not distinguish rates during class, rehearsal, and performance. A comparison of injury rates by activity for technique levels 1 to 7 dancers is shown in Table 5. Although the largest proportion of injuries (90.6% with CI: 81.2 to 94.6) occurred during class, the risk of injury, calculated by comparing total injuries for all dancers against total exposure for all dancers, was greatest in rehearsal at 7.66 injuries/1,000 hours of exposure (95% CI: 0.58 to 14.75), followed by class at 2.28 injuries/1,000 hours (95% CI: 1.77 to 2.79) and then performance at 1.05 injuries/1,000 hours (95% CI could not be calculated, as N = 1 after removing the Aspirant group due to lack of exposure data). This finding underscores the importance of considering injury rates by activity as well as overall injury rates.

**Overuse Versus Acute Onset Injuries**

Studies concerned with injury onset in young ballet dancers indicate a range of 53.6% to 85% for gradual onset injuries and from 12% to 45% for acute injuries. In our study, the majority of injuries were also overuse (65.5%), and the majority of those (61.3%) were recurrent injuries. Notably, Ekegren and colleagues observed that 86.2% of 29 pre-professional ballet students in their study had current overuse injuries. Whether it be young ballet dancers or youth sports athletes, overuse injuries are common, particularly among those participants involved from an early age in year-round high-level training and performance. Understanding the factors that contribute to these injuries and providing comprehensive management protocols are central to ensuring successful treatment outcomes.

**Injury Outcome**

Data on the most common types of injury vary across ballet injury studies. However, it is evident that pre-professional ballet dancers frequently incur sprains and strains as well as stress-related injuries such as tendinitis. In our study, the three most common types of injury were tendinitis, sprain, and strain.

Ekegren and colleagues reported a mean of 7.02 (95% CI: 6.19 to 7.86) physiotherapy treatments for 378 injuries over an academic year. This was a total of 2,655 treatments, the approximate equivalent of 10 treatments in each of their 266 dancers. Recognizing possible differences in treatment protocol, 63 dancers (87.7%) in our study received physiotherapy treatment on 562 occasions for an average of 8.92 treatments per dancer, which is similar to Ekegren and colleagues’ results.

A useful measure of severity of injury is the duration of restriction from dance training and performance subsequent to injury. There is a paucity of data on time loss as a result of injury affecting pre-professional ballet dancers. Ekegren and colleagues reported a mean time loss of 28.7 days due to injury (95% CI: 22.23 to 34.18). Hamilton and associates suggested an average length of disability of 54 days for young elite ballet students following injury. In contrast, the average (95% CI) time loss per injury in our study was 14.0 days (9.83 to 18.19). In another study, Krasnow and coworkers reported on 16 ballet dancers (ages 12 to 18 years) and found one-third of injuries (29%) required 3 to 7 days of training modification, 47% required 1 to 4 weeks, 6% required 1 to 3 months, and 18% more than 3 months at reduced train-
<table>
<thead>
<tr>
<th>Study</th>
<th>Study Design</th>
<th>Age</th>
<th>Injury Definition</th>
<th>Exposure</th>
<th>No. of injuries</th>
<th>No. of injuries/1,000 DEs*</th>
<th>No. of injuries/1,000 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present Study</td>
<td>Cross-sect. 8.5 mos.</td>
<td>Range: 11.04-22.33 Mean: 16.1</td>
<td>Self-report of any dance-related incident that resulted in the dancer missing all or part of a practice or performance</td>
<td>Access to individual attendance records</td>
<td>11†</td>
<td>3.82 (95% CI: 2.24 - 5.40)</td>
<td>3.06 (95% CI: 1.99 - 4.13)</td>
</tr>
<tr>
<td>Bowerman et al., 2014</td>
<td>Prosp. 6 mos. N = 46</td>
<td>Range: n/a Mean: 16 ± 1.58</td>
<td>Physiotherapist report of any physical harm resulting in pain or discomfort that required a dancer to alter activity during one or more classes or which required a dancer to cease all dance activity</td>
<td>Not reported</td>
<td>59</td>
<td>3.52 (95% CI: n/a)</td>
<td>2.40 (95% CI: n/a)</td>
</tr>
<tr>
<td>Ekegren et al., 2014</td>
<td>Prosp. 1 yr. N = 266</td>
<td>Range: 15-19 Mean: 17.2 ± 1.21</td>
<td>An anatomic tissue-level impairment as diagnosed by a licensed health care practitioner that results in full-time loss of activity for one or more days beyond the day of onset</td>
<td>Hours and athletic (dance) exposures provided on a weekly basis from student's attendance records</td>
<td>378</td>
<td>1.87 (95% CI: 1.68 - 2.06)</td>
<td>1.38 (95% CI: 1.24 - 2.52)</td>
</tr>
<tr>
<td>Leanaderson et al., 2011</td>
<td>Retrosp. 7 yrs. N = 476</td>
<td>Range: 10-21 Mean: n/a</td>
<td>All injuries for which students received orthopaedic care were included</td>
<td>Hours exposure obtained from attendance records</td>
<td>337</td>
<td>n/a</td>
<td>0.8</td>
</tr>
<tr>
<td>Gamboa et al., 2008</td>
<td>Retrosp. 5 yrs. N = 359</td>
<td>Range: 9-20 Mean: 14.7 ± 1.9</td>
<td>An injury was considered to have occurred when a dancer sought at least one treatment session from a physical therapist</td>
<td>Rate of injury was calculated per dancer, per 1,000 athletic exposures, and per 1,000 hours of dance. Information on how exposures and hours were documented was not provided.</td>
<td>198</td>
<td>1.09</td>
<td>1.77</td>
</tr>
<tr>
<td>Luke et al., 2002†</td>
<td>Prosp. 9 mos. N = 39</td>
<td>Range: 14-18 Mean: 15.8 ± 1.0</td>
<td>(a) Self-reported injuries determined every 2 weeks via survey; and (b) Reported injuries gathered by the physical therapist at each dancer visit</td>
<td>Exposure hours determined by using the sum of the averaged reported hours of dance per 2-week blocks and the sum of the previous one-day recall of hours danced.</td>
<td>112 SRIs 71 RIs-PT</td>
<td>n/a</td>
<td>4.7 SRI (CI: 3.8 - 4.6) 2.9 RI-PT (CI: 2.2 - 3.6)</td>
</tr>
</tbody>
</table>

*One dance exposure = one ballet dancer involved in one training or one performance session. †There were seven dance-related injuries reported that occurred in unsupervised dance settings; they were eliminated from our analyses. SRIs = self-reported injuries. RI-PT = reported physical therapy injuries.
risk of injury and different in nature (58%), requiring less than 7 days' time loss; however, 42.1% of injuries required more than 8 days' time loss before return to full participation.26

Fifty-four percent of injuries sustained in our study were recurrent. Percentage estimates for re-injury in two other studies of pre-professional ballet dancers were 14% and 43.7%.2,10 By comparison, youth sport data indicate a range of 6.4% to 49% of all injuries are recurrent.1 It is generally recognized that unresolved residual symptoms from a previous injury predispose an athlete to re-injury at the same and different sites.30

Few studies document the proportion of injuries requiring surgery. Bowerman and colleagues15 reported that 23 of 326 injuries (7.1%) in their study of adolescent dancers required surgery during a 1-year period of injury surveillance. Luke and coworkers10 noted that 5 of 39 dancers (12.8%) had a history of lower extremity surgery related to ballet participation. In our 8.5 month study, surgery was performed in only two of the 114 recorded injuries (1.75%). Our data, thus, indicate less severe injury with regard to time loss and surgery compared to the two previous studies.10,15 Determining the reasons for this discrepancy awaits further research, including standardized injury reporting in dance.17

Risk Factors

One purpose of our study was to report on the incidence and distribution of injuries sustained by pre-professional ballet dancers over a period of one season (8.5 months). To that end, we have reported data related to those aspects of injury. In addition, we employed univariate and multivariate statistics to investigate possible risk factors. In univariate analyses, age was not significantly related to injury. This finding is in contrast to those of Leanderson and associates,2 who reported an increase in injury incidence with increased age, and Luke and colleagues,10 who found a significant association between older age and increased risk of both self-reported and medically recorded injury (p = 0.004). Luke and colleagues19 speculated that this finding may be explained by older dancers having more demanding roles.

In our study, univariate analyses showed months of experience in the pre-professional program to be associated with a decreased risk of injury. However, this variable did not remain significant in multivariate analysis. This finding suggests that the risk of injury decreased with increased months of experience and may be explained by such factors as improved skill level, better preventive strategies, and ballet selection, or survival of the strongest and fittest over time.24 However, injury causation is multifactorial in nature, and it may well be that the injury profile of these dancers changed over time. Unlike those who dropped out of the program, adaptations in the continuing dancers may have occurred due to continued training, thus positively changing their risk profile.31 Notably, in their 6-year follow-up of Swedish professional ballet dancers Ramel and associates32 observed that in spite of an increased workload and age over time, their dancers appeared to be less prone to incapacitating pain.

Relative to technique levels 1 and 2, levels 3 and 6 experienced a reduced risk of injury, although only the reduction in level 3 remained significant in multivariate analyses. Although the sample size in groups 3 and 6 is relatively small, this is likely a true effect since the result is statistically significant. These findings underscore the importance of considering injury rates by training level as well as overall rates.

In the univariate analysis, dancers had lower injury risk in rehearsal than in class. This seems to contradict the overall mean injury rates for each activity when calculating injury rates by summing injuries and exposure across all dancers (Table 5). However, the Poisson regression determines injury risk for each individual dancer (while correcting for dancers with multiple injuries during the study), which differs from the overall mean injury rate. This points to the necessity of looking at both overall and individual dancer-based injury risks.

Study Limitations

Our study had several limitations. First, sample selection was non-random. It is possible that schools most concerned with safety may be more likely to participate in a study of injuries. Second, requesting young ballet dancers to report on injuries retrospectively may have resulted in recall bias, especially for less serious injuries. However, instructors at the school had individual student binders with them during data collection to assist students who had difficulty recalling specific information related to injuries sustained during the past year. A minor injury might easily have been forgotten, but any significant injury causing time loss or modification in training would have appeared in the student's binder, as in most cases the disruption caused by the injury would have affected the remainder of the season in some manner. Conversely, confidential self-reporting gave dancers the opportunity to disclose injuries they otherwise might not have reported to the medical staff for fear of not being allowed to participate in class or performance.

Calculating exposure time may be problematic in a dance study using retrospective data collection; however, access to individual attendance records and schedules for technique classes, rehearsals, and performances established a reliable basis for estimating individual injury rate for each dancer in our study. Finally, our assessment of significant risk factors was limited by our relatively small sample size of dancers. Future ballet research will benefit from prospective cohort studies, including multiple ballet schools to establish temporal relationships between injuries and risk factors.

Conclusion

Our study provides a needed update on the epidemiology of injury affecting pre-professional ballet dancers. Some of the descriptive findings of this investigation were consistent
with those of previous research and suggest particular demographic and injury trends in pre-professional ballet. Other results disclosed information that was heretofore unreported or inconsistent with prior investigations, including:

- A greater proportion of dancers in our study were injured than was the case in previous studies. We also recorded a slightly higher overall rate of injury. This is likely because we elected to use a broader definition of injury in this study than did the investigators of the studies to which we compared our data.
- Mean time loss per injury is half what was reported elsewhere in the ballet literature; however, methods of determining these data between studies were not standardized.
- Injury rates relative to class, rehearsal, and performance were reported, as well as those relative to technique and training levels.
- A description of the frequency and distribution of musculoskeletal complaints and injury-related conditions treated by the ballet school physiotherapists was provided.
- More than half of all recalled injuries (54.2%) were recurrent.

We set out to expand and update information on the incidence and distribution of ballet injury at different ages and levels of pre-professional training and performance. We also attempted to identify factors associated with injury that might assist in the development of injury prevention strategies. We believe future studies are needed to further develop our findings. Most essentially, a multi-year longitudinal study of ballet dancers would ensure stability of injury data. Determining the specific circumstances surrounding injuries (e.g., injury mechanism) would assist in developing effective injury prevention strategies. Age, technique level, and prior injury may reveal injury risk factors that can be addressed with injury prevention programs. Longitudinal anthropometric data should be used to estimate growth rates every 6 months, given that young athletes experiencing rapid growth are believed to be at greater risk of injury. Prospective assessment of exposure time will assist in determining and evaluating more precise injury rates in training and performance.

Acknowledgments

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20. Agresti A, Coull BA. Approximate is better than “exact” for interval estimation of binomial proportions.


