An Injury Prevention Program for Professional Ballet

A Randomized Controlled Investigation

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Background: Few investigations have examined dance-specific injury prevention programs (IPPs), and no published randomized controlled trials are available that evaluate IPPs for dance.

Hypothesis: The implementation of an IPP will significantly reduce the risk of injury in professional ballet dancers.

Study Design: Randomized controlled trial; Level of evidence, 2.

Methods: A randomized controlled trial was designed that entailed a superiority model for the intervention group. All professional dancers from a single ballet company were eligible to participate. Randomization and allocation were performed before the start of the season. The control group practiced and performed without change to preexisting standard operating practice. The IPP group was instructed to perform a 30-minute exercise program 3 times per week over the 52-week study period. Injuries were recorded. Standard continuous and categorical data comparisons and correlations were used. Cox proportional hazards regression models for recurrent failures were used wherein the hazard ratio indicates the relative likelihood of injury in the control versus intervention groups.

Results: Of the 52 eligible dancers, 75% (n = 39) participated. Of these 39 dancers, 19 (9 males, 10 females; mean age, 26.6 ± 4.0 years) were randomized to the control group and 20 (11 males, 9 females; mean age, 25.1 ± 5.1 years) to the IPP group. No significant ($P > .05$) difference was found in baseline demographics between groups. A total of 116 injuries were recorded for the entire study population (49 IPP; 67 control). Traumatic and chronic injuries accounted for 54% and 46% of injuries, respectively. The injury rate was 82% less (IPP hazard ratio, 0.18; $z = -2.29$; $P = .022$) in the IPP group after adjustment for confounding variables, and time between injuries was 45% longer (IPP hazard ratio, 0.55; $z = -2.20$; $P = .028$) than for controls.

Conclusion: The present study is the first prospective randomized controlled investigation of an IPP for professional ballet. The results showed an 82% decrease in injury rate for the intervention group and an extended period from previous injury to subsequent injury.

Registration: NCT04110002 (ClinicalTrials.gov identifier).

Keywords: ballet; dance; injury prevention; injury rate; Brighton; Beighton

Dancers experience a variety of musculoskeletal injuries, and most dancers will experience at least 1 significant injury in their career.[13,42,48] The type and incidence of dance injuries are relatively well-represented in the literature, but limited literature is available regarding the cause of those injuries.[‡] The most common injuries that dancers sustain are those of the lower extremity and lower back.[42,48] The most common diagnoses include lumbar strain, ankle sprain, Achilles tendinitis, metatarsal stress fracture, posterior tibialis strain, and hip strain.[42] Causes of injury are thought to include muscular fatigue, muscular imbalance, and balance deficits.[3,12,14,26,27,32,45] Dancers

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have higher rates of certain anatomic conditions such as hypermobility, hip dysplasia, and hip microinstability.[16,17,36] Prior reports from the same dance company have shown hip instability and dysplasia in nearly 90% of dancers.[17,36] These conditions induce abductor fatigue and hip microinstability, which can be improved by strengthening the core and periarticular musculature.[16,25] Core strengthening also has been shown to decrease rates of back and lower extremity injury.[22,25,45,57] Furthermore, improved balance and lower extremity muscular strength are associated with decreased lower extremity injury rates.[3,12,14,41,43] Thus, a program to reduce muscular fatigue and muscular imbalances and improve balance in dancers would be expected to reduce injury.

Injury prevention protocols in the literature focusing on individual sports have been shown to be effective. FIFA 11+ for soccer is one of the most well-known and well-studied programs.[6,10,24,40] The FIFA 11+ has been shown to reduce muscle strain and tears,[40] noncontact injuries,[24] rates of lower extremity injuries, risk of overuse injuries, risk of severe injuries, time lost to injury, and risk of overall injuries.[6] Many other studies have investigated reduction of a particular injury, such as anterior cruciate ligament tears,[19,31,39] hamstring strain,[32,37] and elbow injury.[11,18] The few ballet dance-specific injury prevention studies in the literature either were inconclusive with regard to reducing injuries or did not use a control group.[2,35,46] At present, no published randomized controlled trials are available evaluating an injury prevention program (IPP) for dance.

We designed an IPP (see the Appendix) to target the core, hip abductor, hip flexor, and hip extensor muscles. The primary purpose of the study was to evaluate the effectiveness of this IPP for professional ballet. We hypothesized that the use of an IPP would significantly reduce the risk of injury in professional ballet dancers.

METHODS

Institutional review board approval was obtained for this study. All male and female professional ballet dancers, 18 years of age or older, from a single metropolitan ballet company were eligible. Eligible sample size was predetermined by the number of company members (n = 52). Exclusion criteria included those who chose not to participate, were pregnant, and were younger than 18 years. Informed consent was obtained from all participants. Baseline demographics and measurements were gathered at the annual company physical examinations, which took place at a tertiary care facility over 1 day. Data gathered included body mass index (BMI), age, sex, previous injury, years dancing professionally, rank, single-leg balance, turnout (in degrees based on rotation boards), Beighton score,[7] Brighton criteria,[15] International Hip Outcome Tool (iHOT-12) score, and American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score.

Dancers were separated into 3 rank groups based on their position in the company. Principals and first soloists were designated as rank 1, soloists and demi-soloists as rank 2, and corps de ballet and apprentices as rank 3. The dancers were randomized to 1 of 2 groups through use of Microsoft Excel's random function stratified by rank to ensure that each rank was equally represented in the intervention and control groups. The random allocation sequence, enrollment, and assignment of participants were executed by the first author (A.M.V.). Funding was provided internally by Houston Methodist Orthopedics and Sports Medicine.

Injury Prevention Program

Participants in the control group were instructed to continue their current dance and exercise practices as usual per standard operating practice for training and performances. The experimental group was instructed to perform as much of a prepared exercise program as they could (details in Appendix). Compliance was measured and defined as having completed at least 4 consecutive weeks of the IPP. No explanation regarding participants' noncompliance was elicited. The program consisted of three 30-minute exercise programs that the participants were to perform each week for 52 weeks unsupervised unless they requested specific guidance from the athletic training staff. They were not given allotted time by the company to complete these exercises. However, most exercises could be performed without cumbersome equipment. Thus, the exercises could be completed at times and locations that the participants found convenient. They had access to a fully equipped athletic training facility at the company's combined class, rehearsal, and performance space. Dancers were given a booklet with written (see the Appendix) and graphic descriptions of each exercise. Additionally, custom video descriptions of each exercise were available on YouTube (https://www.youtube.com/channel/UCOrCu9zLaVMsEpPxFqVhqjw). The dancers were instructed to turn in weekly adherence assessments. The program was based

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Ethical approval for this study was obtained from Houston Methodist Research Institute (study ID: Pro00022554).

TABLE 1
Injury Prevention Program for Professional Ballet

Day 1	Fire hydrants
	Side plank clam
	Side step with resistance band
	Side plank
	Resistance band toe points
	Star drill
	Heel stretch
	Iliotibial band stretch
Day 2	Nordic hamstring
	Bird dog
	Double-leg bridge
	Prone leg lift
	Glute kicks
	Resistance band pointed eversion
	Plank
	Hamstring stretch
Day 3	Progressive lunges
	Wall sits
	Decline squats
	Step-downs
	Single-leg stance
	Resistance band foot flexion
	Dead bug
	Quad stretch

on preventing the most common injuries as well as the rehabilitation and prevention protocols that have been shown to target those issues in athletes.

The weekly program was designed for 3 days, each day with different exercises. It was recommended that the dancers choose 3 nonconsecutive days on which to perform these exercises, and they were instructed not to consolidate days. All exercises had progression options that included increasing resistance with elastic bands or free weights. The dancers were to progress through the outlined protocol when each exercise was no longer challenging enough for them. Wherever possible, eccentric aspects of the exercises were emphasized. All exercises are listed in Table 1 (detailed in the Appendix).

Injury Data

Injury was defined in 2 ways. The first definition was based on the Standard Measures Consensus Initiative from the International Association of Dance Medicine and Science (IADMS).[30] The second definition was an adaptation of the National Aeronautics and Space Administration (NASA) injury guidelines,[51] as listed in Table 2. Injuries were diagnosed by either a certified athletic trainer or a physician. Injuries were recorded on a physical form created specifically for the study and in an electronic medical record system (Athletic Trainer System).

Additional information collected included injury type (traumatic vs overuse), affected body part, diagnosis, mechanism, duration of time to full activity, and treatment. Information on where the injury occurred (class, rehearsal, performance, other), activity (classical, contemporary ballet, modern, other), and number of hours danced in the preceding week was also collected. Return to full activity was defined as return to unrestricted class, rehearsal, and performance.

TABLE 2
Injury Definitions[a]

Injury Classification	Definition	No. (%) of Injuries
International Association of Dance Medicine and Science (IADMS)	The term *injury* refers to anatomic, tissue-level impairment as diagnosed by a licensed health care practitioner that results in full-time loss from activity for 1 or more days beyond the day of onset. For those events that do not rise to the level of a reportable injury event within the surveillance system, the term *musculoskeletal complaint* should apply.	45 total
Adaptation of NASA injury guidelines		116 total
Class I	Minor injury that would not impede performance; no long-term health risks.	71/116 (61.2)
Class II	Moderate injury that may impede performance; requires activity modification; possible short-term health risks.	33/116 (28.4)
Class III	Significant injury that would require cessation of activity for a period of time; possible long-term health risks.	11/116 (9.5)
Class IV	Severe injury and possible threat to career as a dancer; probable long-term health effects.	1/116 (0.9)

[a]The table provides the IADMS injury definition and total number of injuries among both groups, as well as an adaptation of the National Aeronautics and Space Administration (NASA) injury guidelines used to define injury, total number of injuries among both groups, and the percentage of total injuries based on classification.

Statistical Analysis

Statistical analysis on treatment group differences for continuously scaled baseline and outcome variables was

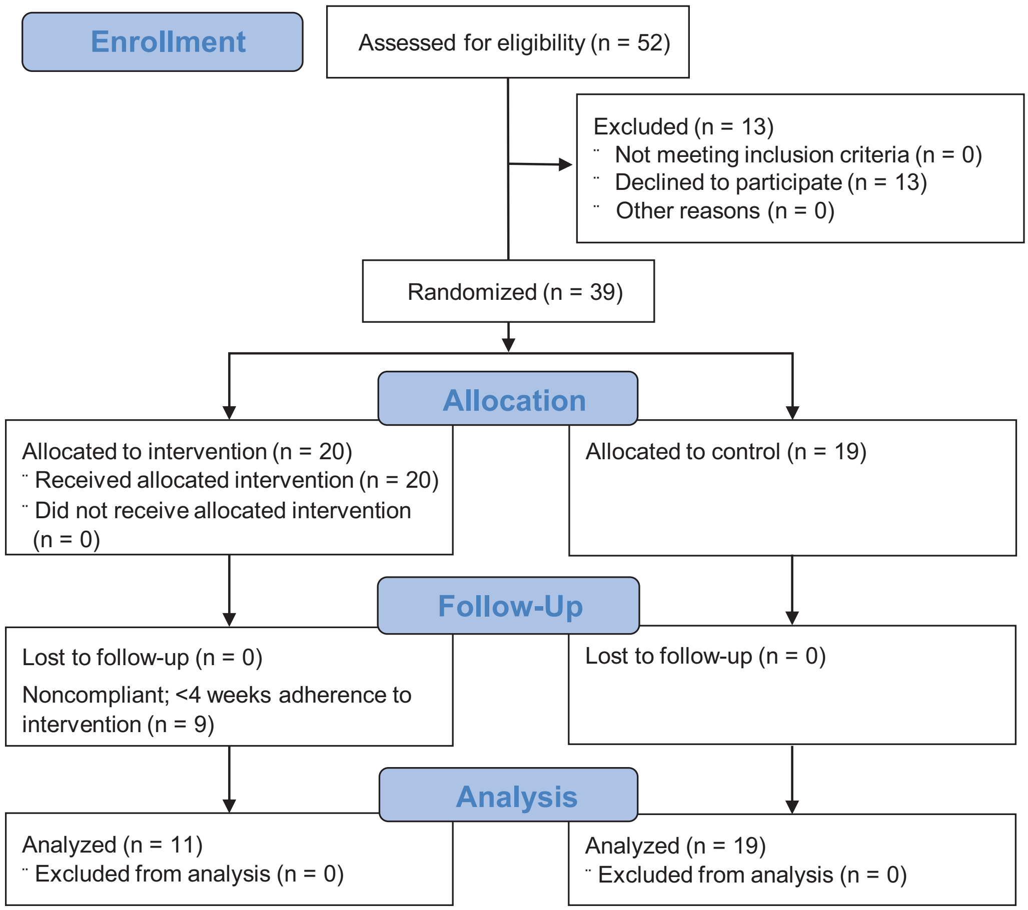

Figure 1. CONSORT (Consolidated Standards of Reporting Trials) flow diagram.

conducted by use of the Student *t* test, with results presented in the form of groupwise mean and standard deviation and tail probability (*P* value). As commonly used in outcomes for interventional studies,[52] Cox proportional hazards (PH) regression models for recurrent failures were used, where the hazard ratio (HR) indicates the relative likelihood of injury in the control versus intervention group. Modeling included compliant participants in the IPP group and all controls. Confounders significant across arms and whose *P* values were less than .25 in univariate models were added to multivariable models that included the IPP treatment effect (0,1) to identify the adjusted HR. The adjusted HR controls for influence by confounders, which are defined as factors associated with both the exposure (IPP) and disease (injury). All statistical analyses were performed using Stata Version 14.

RESULTS

Of 52 eligible dancers, 75% (n = 39) chose to participate. The remaining 13 declined participation because they believed they did not have the time to commit, and none were excluded for not meeting inclusion criteria (Figure 1). Of the 39 dancers, 19 (9 males and 10 females; mean age, 26.6 ± 4.0 years) were randomized to the control group and 20 (11 males and 9 females; mean age 25.1 ± 5.1 years) to the IPP group. No significant ($P > .05$) differences in age, BMI, and company rank were found among the groups (Table 3). This remained true when the noncompliant individuals were removed from the analysis (Table 4). We noted that 11 participants (11/20; 55%) were compliant with the program, based on the fact that they performed at least 4

TABLE 3
Demographics for Control and Intervention Groups (Including Noncompliant Participants)

Demographic Parameter	Intervention	Control	*P* Value
Age, y	25.1 ± 5.1	26.6 ± 4.0	.32
Sex, n			.64
Male	11	9	
Female	9	10	
Height, in	67.8 ± 3.0	66.8 ± 3.2	.32
Weight, lb	136.2 ± 21.4	127.0 ± 27.2	.26
Body mass index, kg/m^2	20.7 ± 1.9	19.8 ± 2.6	.22
Rank, n			.91
Rank 1	4	5	
Rank 2	4	2	
Rank 3	12	12	

[a]Values are expressed as mean ± SD unless otherwise noted.

TABLE 4
Demographics for the Control Group and Compliant Dancers Within the Intervention Group[a]

Demographic Parameter	Compliant	Control	P Value
Age, y	27.2 ± 5.7	26.6 ± 4.0	.79
Sex, n			.92
Male	5	9	
Female	6	10	
Height, in	66.3 ± 2.42	66.8 ± 3.2	.69
Weight, lb	129.2 ± 19.4	127.0 ± 27.2	.26
Body mass index, kg/m^2	20.5 ± 1.8	19.8 ± 2.6	.38
Rank, n			.78
Rank 1	3	5	
Rank 2	2	2	
Rank 3	6	12	

[a]Values are expressed as mean ± SD unless otherwise noted.

TABLE 5
Frequency of All Injuries by Anatomic Location (Including Control Group and All Intervention Group Participants)[a]

Location of Injury	% (n)
Head/face	0.9 (1)
Wrist	1.7 (2)
Hip/groin	8.6 (10)
Neck/cervical spine	6.0 (7)
Hand/finger/thumb	1.7 (2)
Thigh	6.9 (8)
Shoulder/clavicle	6.0 (7)
Sternum/ribs	3.4 (4)
Knee	4.3 (5)
Upper arm	0.9 (1)
Thoracic spine	8.6 (10)
Lower leg/calf	8.6 (10)
Elbow	0 (0)
Abdomen	1.7 (2)
Ankle	9.5 (11)
Forearm	0 (0)
Lower back/pelvis/sacrum	13.8 (16)
Foot/toe	17.2 (20)
Other	0 (0)

[a]N = 116.

weeks of the IPP. Reasons for noncompliance were not elicited from participants. If participants were not compliant, their data were not included in the Cox PH statistical analysis of injury rate and subsequent injury. However, other aspects of their injuries were included, as discussed below.

For all participants, 45 injuries were sustained based on the IADMS Standard Measure Consensus Initiative over 52 weeks. Based on the modified NASA guidelines, 116 injuries were sustained (Table 2). The number of injuries by anatomic location can be seen in Table 5. The setting of all injuries was as follows: class, 10.3%; rehearsal, 67.2%; performance, 16.4%; and other, 6.0%. The style danced at the time of injury was contemporary ballet (49%), followed by classical ballet (41%), modern dance (3%), and other activities (7%). Traumatic injuries made up 54% of all injuries, whereas overuse injuries made up 46%. All mechanisms of injury are listed in Table 6. The IPP group had 49 injuries (compliant and noncompliant), whereas the control group had 67 total injuries during the study period. The mean number of days to full activity after injury was not statistically significant between the control and IPP groups (11.9 ± 43.7 vs 14.6 ± 25.2, respectively; $P = .49$). During the study period, 4 participants underwent surgery. Of these, 1 dancer from the IPP group underwent abdominal wall reconstruction, adductor longus compartment decompression, and tendon release for a chronic abdominal wall injury sustained in the prior season. A further 2 dancers underwent arthroscopic anterior labral repair for chronic shoulder instability; 1 of these dancers was in the IPP group and the other dancer was in the control group, and both had initial episodes of ipsilateral instability in prior seasons. The fourth dancer who underwent surgery was in the IPP group but was noncompliant. He underwent ankle arthroscopy with os trigonum resection.

TABLE 6
Frequency of All Injuries by Mechanism (Including Control Group and All Intervention Group Participants)[a]

Mechanism of Injury	% (n)
Overuse	26.7 (31)
Landing	6.9 (8)
Stretching	9.5 (11)
Floor surface	0.9 (1)
Collision	0 (0)
Slip	0.9 (1)
Twisting	8.6 (10)
Props	0.9 (1)
Lift	6.9 (8)
Fall	0.9 (1)
Turning	4.3 (5)
Lighting	0 (0)
Jump	18.1 (21)
Partnering	7.8 (9)
Shoes	3.4 (4)
Other	4.3 (5)

[a]N = 116.

The median time to injury for compliant IPP participants was 219 days, whereas for control participants the median time to injury was 130 days. See Table 7 for hypothesis testing results. Prior injury, rank, balance left, and iHOT-12 score were not significantly different across the treatment groups. In the univariate Cox PH models for injury rate, the variables female, years dancing, turnout left, turnout right, average Beighton score, and AOFAS ankle-hindfoot scores resulted in $P \leq .25$ (indicating significant confounding variables). In the univariate Cox PH models for subsequent injury, the variables years dancing, turnout left, turnout right, average Beighton score, and Brighton criteria resulted in $P \leq .25$ (Tables 8 and 9). Participants without values for the confounding variables were excluded from this analysis by statistical necessity. A total of 3 participants from the IPP group and 4 participants from the control group refused to be measured for 1 or more of the confounding variables.

TABLE 7
Hypothesis Testing Results for Potential Confounders Used in Multivariable Failure-Time Models[a]

Variable	Significant ($P < .05$) Across Intervention (IPP vs Control)	Predicts Injury Rate With $P \leq .25$	Predicts Subsequent Injury With $P \leq .25$
Prior injury (0,1)	N	NA	NA
Female (0,1)	Y ($P = .031$)	Y ($P = .003$)	N
Years dancing	Y ($P = .014$)	Y ($P = .052$)	Y ($P = .195$)
Rank	N	NA	NA
Balance left	N	NA	NA
Balance right	Y ($P < .001$)	N	N
Turnout left	Y ($P < .001$)	Y ($P = .005$)	Y ($P = .033$)
Turnout right	Y ($P < .001$)	Y ($P = .002$)	Y ($P = .046$)
Total turnout (L+R)	Y ($P < .001$)	N	N
Beighton score	Y ($P = .007$)	Y ($P = .032$)	Y ($P = .071$)
Brighton criteria (0,1)	Y ($P = .028$)	N	Y ($P = .211$)
iHOT-12 score	N	NA	NA
AOFAS ankle-hindfoot score	Y ($P = .003$)	Y ($P = .196$)	Y ($P = .029$)
IPP		N	N

[a]AOFAS, American Orthopaedic Foot and Ankle Society; iHOT-12, International Hip Outcome Tool; IPP, injury prevention program; L, left; N, no; NA, not applicable; R, right; Y, yes.

TABLE 8
Injury Rate Cox Proportional Hazards Regression Hazard Ratio (HR) for the Injury Prevention Program (IPP)[a]

Variable	HR	z	P Value	95% Confidence Limit Lower	95% Confidence Limit Upper
IPP	0.18	–2.29	.022	0.04	0.78
PC1	0.52	–2.78	.005	0.33	0.83
PC2	0.90	–0.43	.667	0.55	1.46
PC3	0.53	–2.51	.012	0.32	0.87

[a]The regression was adjusted by the top 3 principal components (PC) from correlation of years dancing, turnout right, turnout left, mean Beighton score, American Orthopaedic Foot and Ankle Society ankle-hindfoot score, and female confounders. The model was based on 77 recurring injury times for 23 participants. Only the control group and compliant IPP participants were included in this analysis. Thus, the HR for the compliant IPP group is 0.18 ($P = .022$; 95% CI, 0.04-0.78), implying a rate of injury that is 82% lower than controls.

TABLE 9
Subsequent Injury Cox Proportional Hazards Regression Hazard Ratio (HR) for the Injury Prevention Program (IPP)[a]

Variable	HR	z	P Value	95% Confidence Limit Lower	95% Confidence Limit Upper
IPP	0.55	–2.20	.028	0.32	0.94
PC1	0.78	–2.67	.007	0.65	0.94
PC2	0.75	–3.25	.001	0.63	0.89
PC3	0.94	–0.65	.516	0.77	1.14

[a]The regression was adjusted by the top 3 principal components (PC) from correlation of years dancing, turnout right, turnout left, mean Beighton score, American Orthopaedic Foot and Ankle Society ankle-hindfoot score, and Brighton criteria confounders. The model was based on 77 values of time from previous injury for 23 participants. Only the control group and compliant IPP participants were included in this analysis. Thus, the HR for the compliant IPP group is 0.55 ($P = .028$; 95% CI, 0.32-0.94), implying that the time between injuries (subsequent injury) is prolonged by 45%.

The results of the injury rate Cox PH model as shown in Table 8 suggest an HR of 0.18 ($P = .022$; 95% CI, 0.04-0.78), implying a rate of injury that is 82% lower in the compliant IPP group than in controls. The results shown in Table 9 suggest that the time between injuries (subsequent injury) is prolonged by 45% (HR, 0.55; 95% CI, 0.32-0.94) among the compliant IPP group compared with controls.

DISCUSSION

The present study is the first prospective randomized controlled investigation of an injury prevention program for professional ballet. The results showed an 82% decrease in injury rate for the intervention group and an extended period from previous injury to subsequent injury. This confirmed our hypothesis. These results suggest that an IPP performed for as little as 4 weeks may reduce injury rate and increase injury-free time over the course of 1 year.

As used in clinical trials to test the efficacy of an intervention on reducing disease,[52] the Cox PH regression model was used in the present study. This allowed us to adjust for several confounding factors that are thought to contribute to injury, including sex, hypermobility, and turnout. Thus, the present study provides a reliable test of treatment efficacy, which is of upmost interest to the clinician.[52] The results of this investigation confirmed the impression that an IPP program would be beneficial to participants. However, due to the relatively small number of participants included in the statistical analysis, further research is warranted to allow applicability to the larger dance population. Compliance was measured and defined as having completed at least 4 consecutive weeks of the IPP. Nearly half of the IPP participants were compliant. However, this resulted in exclusion of potentially 25% of the baseline and injury follow-up data for the Cox PH data analysis. We conducted dimensional reduction using principal components analysis of significant confounders in failure time models in order to prevent violation of the rule of thumb requiring the addition of 10 records for each potential confounder and outcome measurement made.

Although many reports are available regarding injury prevention techniques for team sport athletes,[§] very few intervention trials for prevention of injuries in dancers have been conducted. Only 3 studies have attempted to reduce injuries in dancers. Mistiaen et al[35] and a later study by Roussel et al[46] were structured around the same preprofessional dance program. Although those investigators found reduced injuries with an IPP, they did not use a randomized controlled model nor did they include professional dancers. Allen et al[2] reported the effects of individualized conditioning programs on the injury rate of a professional ballet company. Those investigators found significant reduction in injury rates for their population based on using the prior year's injury data as the control comparison. Their IPP was customized to each dancer. The development of the individualized program was not explained in detail, making replication of the program difficult, and the report does not provide the amount of time each dancer had to commit each week or the duration of the intervention. Additionally, the conditioning sessions were supervised by a professional from the medical team. The present study found a reduction in injury rates using a generalized IPP for ballet based on common weaknesses in the ballet dancer. Although an individualized and supervised program may be ideal for injury prevention, this is difficult for most dance companies to provide. The IPP in the present study can be easily adopted by all ballet dancers. Furthermore, the randomized control group used in the present study takes dancer differences and repertoire into consideration, which is not possible when using prior season data.

Injury data collected in the current investigation are consistent with reports from other studies with regard to when injuries most commonly occurred and the anatomic location for injuries.[13,20,23,38,42] However, the present population had a higher proportion of traumatic injuries (53%) than previously reported in the literature.[13,20,42,47] This is likely due to the implementation of a new annual winter program, requiring dancers to learn entirely new staging, props, costuming, and choreography, which was significantly more physically demanding. Furthermore, another production performed that year required some of the men to dance en pointe, which is highly unusual.

Limitations of this study include poor compliance over the year-long period. This may have been attributable to lack of motivation or time on the dancer's part. This is a common plight in studies evaluating IPPs, especially in elite athletes.[35,49,50,53,55] The 3 prior dance-specific IPPs either do not reveal compliance rates at all[2,46] or do not reveal the compliance of the dancers used in their final analysis.[35] However, in the present investigation, when viewed in a per-protocol analysis, the intervention group was found to have a decreased rate of injury. This suggests a protective effect from even a short duration of an IPP for professional ballet dancers. The poor compliance rate also results in selection bias within the cohort. The present study required dancer self-motivation to implement, which may have been the reason for low compliance. We tried to limit all hindrances to compliance by providing multiple modes of instructional delivery, availability of an in-house athletic trainer with full knowledge of the IPP, little need for extra equipment, availability of equipment on-site if needed, freedom to work exercises into the participants' individual schedules, detailed prelabeled adherence records requiring only checkmarks to indicate completed exercises, and weekly text messages and monthly emails from the athletic trainer with reminders to complete and turn in adherence forms. A scheduled supervised time allotted by the company administration may have increased compliance. The reduction in injury seen with limited compliance during the season argues that greater reductions could be seen if this IPP became a required part of the dancers' training. The evaluation of professional classical ballet dancers limits the IPP's applicability to students and other styles of dance.

Other limitations include the small number of participants, which was dictated by the company size and not by a power analysis. However, the uniqueness of the population adds significant value to this study, as it is very difficult to get professional athletes to participate in a randomized controlled trial for an IPP. The ability to gather this type of information on professional athletes is both rare and invaluable. Although 52 dancers were eligible to participate, only 39 choose to do so. This could lead to selection bias in the dancers who chose to participate, who may have been more motivated to comply or already performing their own cross-training regimen. The length of the study was only 1 year; however, 2 years is the standard in most level 1 randomized controlled trials. Diagnoses of most injuries were made by a certified athletic trainer, not an orthopaedic surgeon. Thus, diagnostic accuracy was not confirmed for all injuries unless the injury was severe enough to warrant further investigation. Last, because IPP sessions were not supervised, the level of compliance may have been overestimated by the dancers self-reporting to appease investigators. However, assessment documentation provided by the dancers was made anonymous with the use of participant identification numbers.

CONCLUSION

The present study is the first prospective randomized controlled investigation of an injury prevention program for professional ballet. The results showed an 82% decrease

[§]References 4-6, 11, 22, 33, 34, 37, 39, 40, 43, 44, 54.

in injury rate for the intervention group and an extended period from previous injury to subsequent injury.

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APPENDIX

Injury Prevention Program

The goal for all exercises is to maintain a stable and level pelvis and engaged core. Work in front of a mirror if possible to ensure proper form. As exercises become less challenging, advance them as indicated below.

Day 1—Abductors/core/foot and ankle (~30 minutes):

Fire Hydrants. On your hands and knees, lift your right leg directly out to the side without rotating your pelvis, and return to the starting position. Perform 15 lifts, keeping the knee pointing forward, core engaged, and pelvis stable. Repeat on the left. Perform a total of 3 sets on each side, alternating sides. (4 minutes)

- Advance by adding a resistance band around the knees.

Side Plank Clam. Lying on your right side, support your body with your right elbow and forearm and right knee. Lift your pelvis off the floor and maintain a straight line between your right shoulder and right knee. Lift the left knee out to the side, keeping your hips stacked directly on top of each other and your core engaged. Perform 15 repetitions and switch sides. Complete 3 sets each side, alternating sides. (3 minutes)

- Advance by adding a resistance band around the knees.

Side Step With Resistance Band. Stand in parallel with your feet together and place a resistance band around your ankles. Keep your knees over your toes and take a wide side step with the right leg, maintaining the parallel position. Slowly allow the left leg to meet the right leg. Maintain an upright posture with the core engaged. Repeat for a total of 15 repetitions. Switch sides for a total of 3 sets per side. (5 minutes)

- Advance by increasing the strength of the resistance band.

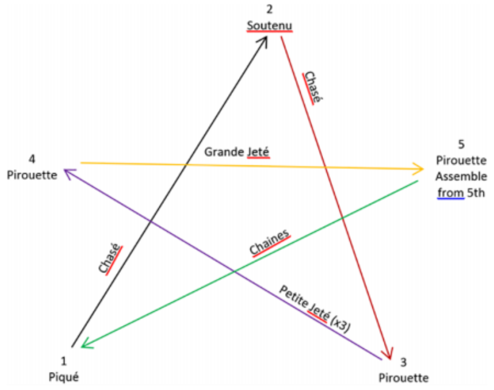
Side Plank. Lying on your right side, support your body with your right elbow and forearm and your right foot. Lift your pelvis and legs off the floor and maintain a straight line from head to toe. Ensure your shoulders and hips are stacked directly on top of one another, and engage your core. Hold this position for 30 seconds. Rest for 30 seconds. Repeat for a total of 2 sets on each side. (6 minutes)

- Advance by increasing the hold time by 15-second intervals until you can hold for 90 seconds.

Resistance Band Toe Points (eccentric focus). While sitting, place a resistance band around your toes and hold the ends with your hands. Roll through the foot to a demi-pointe position. Point the toes and **slowly** allow just the toes to flex, returning to a demi-pointe position. Repeat for a total of 30 repetitions. Alternate sides for a total of 3 sets on each side. (3 minutes)

- Advance by increasing the resistance of the band.

Star Drill. Set up 5 objects in the shape of a large star. Designate a number to each object, 1 through 5, so that the numbers are not next to each other (ie, the consecutive number is diagonal to the previous number; see diagram). Start at object 1 and perform a right turn of your choice (ie, soutenu, pique, pirouette, etc) and then advance to object 2, performing a traveling movement of your choice leading with your right leg (ie, chaînés, chassé, jeté, etc). At object 2, perform another turn and then advance to object 3, performing a different traveling movement. Continue through the star until you reach object 5. At that point, repeat the pattern reversing the order; start with a turn at object 5 and advance to object 4, then 3, and so on. When you return to object 1, start the entire exercise over, leading with the left leg. Complete 2 sets on each side. Try to make the transitions seamless and quickly. Focus on good technique and keeping your core engaged. (5 minutes)



Heel Stretch. Use an incline board or step to allow the heel to fall toward the floor, stretching the Achilles tendon and calf muscle. Hold the stretch on the right for 15 seconds and switch to the left leg for 15 seconds for a total of 3 sets each leg. (2 minutes)

Iliotibial Band Stretch. While standing, cross the left leg behind the right and lean your upper body to the left. This will stretch the outside of the right hip. Hold the stretch on the right for 15 seconds and switch to the left leg for 15 seconds for a total of 3 sets each.

Day 2—Hamstrings/glute/core/foot and ankle (~30 minutes):

Nordic Hamstring. Sit on your knees, stabilize your feet, and hold your arms across your chest. Slowly allow your body to lean forward. Maintain a straight line from your shoulders to your knees the entire time. When you get to a point you can no longer hold your body up, extend your arms and slowly fall into a push-up position. Your goal is to be able to control your body all the way to the floor. Repeat for a total of 10 repetitions. Rest for 30-60 seconds and repeat for a total of 3 sets. (4 minutes)

- Advance by increasing by 2 repetitions per set.
- Advance further by holding a weight in your arms.

Bird Dog (opposite arm/leg lift). On your hands and knees, extend your right arm in front of you and left leg behind you, slowly return to the starting position. Keep your core engaged and your pelvis parallel to the floor. Perform 20 repetitions. Switch sides. Alternate sides to complete a total of 3 sets on each side. (4 minutes)

- Advance using a weight in your hand and a resistance band on the legs.

Double-Leg Bridge. Lying on your back, place your feet on the floor with your knees directly above your heels. Hold a weighted ball between your knees. Lift your pelvis off the floor to make a straight line from your shoulders to your knees. Engage your core and glutes and keep your pelvis level, hold, and slowly return to the starting position. Perform 15 repetitions. Repeat for a total of 3 sets. (2 minutes)

- Advance to **Single-Leg Bridge**: Without the weighted ball, use the same instructions as the double-leg bridge, but extend 1 leg so the foot comes off the floor. The thighs should remain parallel to one another. Engage your core and glutes and keep your pelvis level, hold, and slowly return to the starting position. Perform 15 repetitions. Then repeat with the other leg. Alternate sides to perform a total of 2 or 3 sets per side.
- Advance to **Stability Ball Double-Leg Bridge**: Place both heels on a stability ball. Lift your pelvis off the floor to make a straight line from your shoulders to your heels. Engage your core, keep the pelvis level, hold for 30 seconds, and slowly return to the starting position. Repeat for a total of 3 sets.
- Advance to **Stability Ball Single-Leg Bridge**: Perform as the stability ball double-leg bridge but lift 1 leg off the stability ball. Engage your core, keep your pelvis level, and hold for 30 seconds. Rest and then repeat with the other leg. Perform a total of 2 or 3 sets per side.

Prone Leg Lift. The key to this exercise is keeping both hip bones pressed into the floor for the entire duration. Lying on your belly, engage your core and keep both hip bones on the floor; lift the right leg off the floor about 6 inches. Keep the leg parallel so the heel is directed toward the ceiling. Hold for 5 seconds and then release. Perform 10 repetitions. Repeat on the left for a total of 3 sets with each leg. (6 minutes)

- Advance by performing 5 pulses instead of a 5-second hold for each repetition.
- Advance further by adding a resistance band around the ankles.
- Advance further by placing a stability ball under the feet. Place both hands on the floor and extend your

legs behind you and place them on a stability ball so you are in a plank-like position. Maintain a straight line with your body from your shoulders to your heels. Keep your pelvis level and core engaged. Lift 1 leg off the ball about 6 inches without rotating your pelvis. Keep the leg straight and parallel so the heel is directed toward the ceiling. Hold for 5 seconds and then release. Perform 10 repetitions. Repeat on the left for a total of 3 sets with each leg.

Glute Kicks. On your hands and knees, lift 1 leg so the thigh is parallel to the floor. Then bend the knee to 90° and keep the thighs parallel with the heel directed toward the ceiling. Keep your pelvis level and your core engaged. Lift the heel to the ceiling, hold, and return to the starting position. Perform 10 repetitions. Switch to the other leg. Alternate sides for a total of 3 sets on each side. (4 minutes)

- Advance by increasing the number of repetitions by 5 each set until you reach 20 repetitions per set.
- Advance by adding a resistance band around the ankles/feet. Advance the repetitions as above.

Resistance Band Pointed Eversion (eccentric focus). Wrap the resistance band around the ball of your right foot and hold the ends in your left hand. Place your left foot on the band to create resistance for your right foot. Point your right foot and "wing" it as much as possible. Slowly allow it to come into a sickled position. Quickly wing your foot again and repeat for a total of 10 repetitions. Switch sides. Alternate feet for a total of 3 sets on each side. (3 minutes)

- Advance by adding 5 repetitions to each set until you reach 20 repetitions per set.
- Advance further by increasing resistance band strength.

Plank. Lying face down on the floor, prop yourself up on your toes and forearms. Keep your shoulders above your elbows. Engage your core and keep your pelvis level. Make a straight line with your body from your head through your heel, like a wood plank. Hold this position for 45 seconds. Take a 30-second break. Repeat for a total of 4 sets. (3-5 minutes)

- Advance by increasing the hold time to 60 seconds with a 30-second break for a total of 3 sets.
- Advance further by increasing the hold time to 75 seconds with a 30-second break for a total of 2 sets.
- Advance further by increasing the hold time to 90 seconds with a 30-second break for a total of 2 sets.
- Continue increasing hold time by 15 seconds until you can hold the plank for 3 minutes.

Hamstring Stretch. While sitting on the floor, bend forward at the hips and grab your ankles/toes and lower your elbows to the floor. Flex the feet and elongate your spine as much as possible. Hold for 15-30 seconds. Complete 2 sets.

Day 3—Quadriceps/proprioception (~30 minutes):

Progressive Lunges. Stand with feet parallel and hands on your hips. Engage your core and keep your pelvis level throughout the exercise. With your right leg, lunge forward slowly until your leg forms a 90° angle at the knee. Bring your back leg to meet the front leg. Repeat with the left leg. Lunge forward with the right leg again but add 2 pulses when you get to the bottom of the lunge. Bring your back leg to meet the front leg. Repeat with the left leg. Lunge forward with the right leg again but pulse 3 times at the bottom of the lunge. Bring your back leg to meet the front leg. Continue in the same manner, increasing the pulses by 1 on each side until you reach 10 pulses. Rest. Repeat the entire progression for a total of 2 sets. (4 minutes)

- Advance by increasing the number of sets.
- Advance further by holding weights in your hands.
- Advance further by increasing weight.

Wall Sits. Stand with your feet hip-width apart in a parallel position with your back against a vertical wall. Walk your feet away from the wall as your back slides down the wall and your legs form a 90° angle at the hips and knees. Engage your core by attempting to flatten your lower back against the wall. Hold this position for 30 seconds. Straighten up and break for 30 seconds. Repeat 3 times. (3 minutes)

- Advance by increasing your hold time to 45 seconds for 3 sets.
- Advance further by holding for 60 seconds for 2 sets.

Decline Squats. Stand on an incline board in parallel position with your hands on your hips. Engage your core and keep your pelvis level throughout the exercise. Keep your chest upright, ensure your knee stays in line with your toes, and keep your weight in your heel so you can freely move your toes. Slowly bend your legs until they create an approximately 60° angle at the knee. As you straighten back up, focus on contracting your glutes. Repeat for a total of 10 repetitions. Repeat to complete 3 sets. (3 minutes)

- Advance by performing **Single-Leg Decline Squats**: The exercise is the same as above only with 1 leg lifted off the board; hence, you are standing on 1 leg. Repeat for a total of 10 repetitions. Alternate sides to complete 3 sets on each leg.
- Advance further by switching to **Eccentric Box Jumps**: Place a stable elevated surface (plyometric box or aerobic step) about 6 inches in front of you. Place your feet in a parallel position hip-width apart. Keep your knees over your toes and keep your spine lengthened and core engaged without collapsing in the chest. Bend your knees and jump up onto the box with both feet. Straighten your knees, hips, and back to complete the upward portion. Then slowly jump forward off the other side of the box and land softly through the feet, keeping

the arches lifted, in first position. Turn around and repeat.

- Start with a 6- to 12-inch box and 5 jumps. Increase by 2 jumps until 10 repetitions are not challenging enough. Progress to 10 repetitions × 2 sets, then 10 repetitions × 3 sets. When that has become comfortable, increase the size of the box.

Step-Downs. Stand on a step or other elevated stable surface (start with something ∼6-8 inches high). Stand on 1 leg with your toe at the edge of the step and the other leg extended over the edge of the step. Keep your core engaged, chest lifted, pelvis level, and standing knee over your toes. Slowly bend the standing leg until the extended leg touches the floor below the step. Straighten your standing leg and repeat for a total of 10 repetitions. Alternate legs to complete a total of 3 sets on both sides. (3 minutes)

- Advance by increasing the height of the step.

Single-Leg Stance. Begin on a stable surface. Place a penny under your big toe and the end of a pen under the arch of your foot. Engage your core and glutes and maintain a level pelvis. Maintain proper ballet posture. With feet parallel, stand on 1 foot and close your eyes. Hold for 30 seconds. Your standing toe should hold the penny to the floor. Keep the arch of your standing foot lifted; it should not touch the pen. Switch to the other leg. Alternate legs and complete a total of 3 sets on each leg. (4 minutes)

- Advance by adding a port-de-bra sequence of your choice.
- Advance by standing in a doorway, extending your arms in front of you, and rotating your upper body so your hands touch the doorway; then, rotate back to the other side.
- Advance by performing the single-leg stance in a turned-out position.
- Advance further by adding adage, rond de jambe en l'air, or frappé combinations with the lifted leg.
- Advance further by performing the single-leg stance en relevé with eyes open and then eyes closed, and start the advancement protocol as above.
- Advance to a flat-footed stance on a foam pad or Bosu ball and advance as above.

Resistance Band Foot Flexion (eccentric focus). Loop a resistance band around a table leg or some other stable surface. Loop the other end over the top of your flexed foot. Create tension in the band by moving away from its fixed point. From the fully flexed position, slowly allow the foot to come to a demi-pointe position. Flex the foot quickly and repeat the slow release to demi-pointe. Perform a total of 10 repetitions. Switch to the other foot and repeat. Alternate feet to complete a total of 3 sets per foot. (3 minutes)

- Advance by adding 5 repetitions to each set until you reach 20 repetitions per set.
- Advance further by increasing the resistance band strength.

Dead Bug. Lying on your back, lift your legs so your hips and knees are at 90° angles. Lift your arms straight to the ceiling. Engage your core by flattening your lower back onto the floor. Your lower back should be in contact with the floor through the entire exercise. Keep your pelvis level. Allow your right arm to slowly fall backward until it reaches the side of your head. Simultaneously, straighten and lower your left leg to about 2 inches off the floor. Return to the starting position and perform the same movement with the left arm and right leg. Repeat for a total of 20 repetitions. Rest and complete a total of 2 sets. (2 minutes)

- Advance by completing 3 sets.
- Advance further by adding a weighted ball to your hand while performing the exercise.

Quadriceps Stretch. While in a lunge position, grasp your right leg behind you at the ankle with the right hand, press the hips forward while pulling the foot closer to your glutes, and hold the stretch for 15 seconds. Switch sides. Repeat for a total of 3 sets per side.