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Prevalence of injuries and training correlates in Brazilian young rhythmic gymnastics athletes

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ABSTRACT
Purpose. Rhythmic gymnastics is a popular sport with great acceptance throughout the world. However, the combination of repetitive movements of extreme flexibility and stress/tension on the musculoskeletal system during intense training are potential risk factors for injuries. The objective of the study was to collect retrospective data on the prevalence of self-reported injuries in Brazilian young rhythmic gymnastics athletes. In the sequence, correlates equivalent to the training history for injuries were identified.
Methods. The study included 236 girls aged 9 to 17 years from 23 teams registered in the São Paulo State Federation of Rhythmic Gymnastics practicing rhythmic gymnastics for at least two years. A questionnaire with structured questions was applied to collect data on training history and injuries occurred in the last 12 months.
Results. The prevalence of self-reported injuries was 62.3% [95% CI: 57.9–67.0]. The most exposed body region was the lower extremities, predominantly tendinitis and sprains, with a higher incidence during training. Sport experience and volume/weekly training were identified as independent predictors of injuries. Young athletes who trained/competed ≥ 9 years presented twice as high chances of being injured (OR = 1.94 [95% CI: 1.52-3.36]) and training ≥ 26 hours/week almost tripled the chances of the gymnasts presenting some type of injury (OR = 2.91 [95% CI: 2.23–4.74]).
Conclusions. Significant inverse associations between injury incidence and training history correlates reinforce the need for implementing different targeted injury-risk mitigation strategies in young rhythmic gymnastics athletes.
Key words: overuse injuries, epidemiology, risk factors, training, youth sports, Brazil

Introduction

The practice of sports at young ages has increased in recent decades [1]. This phenomenon is not surprising, given the evidence of its benefits to the physical and psychosocial health of children and adolescents [2]. In this context, rhythmic gymnastics has been widely accepted among girls, gaining popularity worldwide, translating into rapid growth in participation rates [3].

However, this greater demand for sport, together with the decrease in the age of beginning and specialisation, the dramatic increase in the degree of difficulty of the specific skills and the highest demands for intensity/volume of physical efforts in training, tend to expose young gymnasts to a higher risk of injury, which raises major concerns about their severity and harmful effects in the medium and long term [4].

The marked demand for strength, resistance, muscle power, agility and extreme flexibility to perform movement routines that request jumps, spins, throwing, rotations, pirouettes with grace and elegance, accompanied by a reduced amount of body fat, considering that an aesthetic body is considered a fundamental element of this sport [5], characterise rhythmic gymnastics as a sport that results in a unique spectrum of injuries.

In fact, rhythmic gymnastics requires a high level of proprioceptive control, extreme impact on the extremities, hyperlordosis positioning and highly dynamic displacements that can be aggressive and difficult to absorb by the young organism still in the process of maturation and development of the locomotion apparatus and musculoskeletal system. These factors combine to differentiate the young gymnast in terms of potential injury risks [6].

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Considering the costs of treatment and rehabilitation, the time away from training and competitions, the risk of temporary or permanent disabilities and the consequent impairment in quality of life, sports injuries can burden the young athlete and her or his team, besides presenting a broad social effect [7]. In view of this, researchers recognise the importance of surveys on sports injuries in young athletes and highlight the need to gather adequate epidemiological data for planning, implementing and monitoring preventive actions [8].

The first objective of the study was to collect retrospective data on the prevalence rate of self-reported injuries by young athletes from a representative sample of rhythmic gymnasts. Subsequently, correlates equivalent to the training history identified as predictors of injuries were identified in the same sample.

Material and methods

Participants

A sample of young female athletes practicing rhythmic gymnastics for at least two years and who participated in youth competitions in the state of São Paulo, Brazil, in the year 2019 was selected to carry out the study. It is estimated that approximately 700 young athletes, members of 23 teams, participated in the seven official competitions held that year. The non-probabilistic casual method was used to select the participants. To this end, prior to the beginning of the competitions, all the coaches and managers of the teams participating in the competitions were contacted and informed about the nature, objectives of the study and the principle of confidentiality. In sequence, permission was requested to contact and invite the young athletes to participate in the study. Upon confirmation by the Free and Informed Consent Term, previously approved by the Ethics Committee in Research from the University of Northern Parana and signed by the parents/guardians of the young athletes, 236 girls aged 9 to 17 years agreed to participate in the study, which represented around 1/3 of the above-mentioned universe of competition participants.

Data collection

Data collection was carried out using a two-part questionnaire with structured questions: indicators equivalent to the training history and self-reports on injuries that occurred in the last 12 months during the rhythmic gymnastics practice. Additional information regarding chronological age, menarche age and body weight and height measurements were also collected to calculate the body mass index.

In the case of training history, information equivalent to the sport experience in the modality (year/months), the duration of the training sessions (hours/minutes), the weekly frequency of the sessions and the competition modality (individual and team) were obtained. Using the duration and weekly frequency of the sessions, the training volume in hours/week was calculated (duration of sessions × weekly frequency). In the segment referring to self-reported injuries, data equivalent to type (muscle/tendon, joint/ligament and bone), location (spine, upper and lower extremities), occurrence event (training and competition) and post-treatment return conditions (symptomatic and asymptomatic) were collected.

The questionnaire was applied through face-to-face interview, at a single point in time, individually for each young athlete, by a single researcher and at the location and time of the competitions. The reliability and anonymity of the reports of the young athletes were guaranteed and the average duration of the interviews was approximately 15 minutes.

Data analysis

For the analysis of continuous data, the mean and standard deviation calculations were used. Prevalence estimates equivalent to self-reported injuries were presented in specific proportions (%), accompanied by the respective 95% confidence intervals ($CI_{95\%}$). For the analysis of the associations between the self-reported injuries and the potential correlates, the prevalence ratio calculations were used. Statistical differences among the strata under investigation were confirmed using the chi-square test (χ^2). In the sequence, to control confounding variables, correlates that showed at least marginally significant associations ($p \leq 0.20$) in the bivariate analysis were selected to be included in stepwise multiple logistic regression procedures, in order to derive the estimated probability of injuries according to the independent predictors. All those correlates that showed statistical significance at $p < 0.05$ remained in the multivariate model.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and, as integrated into an institutional project, has been approved by the Research Ethics Committee of the University of Northern Parana, Brazil (approval No.: 3,412,665/2019).

Informed consent

Informed consent has been obtained from all individuals included in this study. The rights of all participants were safeguarded by the free and informed consent form signed by the gymnasts and their guardians.

Results

Descriptive data of the sample selected in the study are available in Table 1. The gymnasts had a mean age of 13.4 ± 1.9 years. Considering the values of body mass index for gender and age, 40.3% of young athletes showed low body weight and 8.2% were overweight. At the time of data collection, around 1/3 of the sample revealed that they had not yet menstruated (34.2%), and the mean age of menarche was 12.3 ± 1.5 years. Approximately half of the sample reported training regularly between 5 and 8 years (49.1%), while a lower concentration of gymnasts presented sport experience ≥ 9 years (10.6%). Most young athletes reported training 4–5 times/week (59%) with a duration equivalent to 4–5 hours/session (62.3%). As for training volume, a higher proportion of gymnastics reported training 16–20 hours/week (32.2%). The proportion of gymnasts who declared competing in individual modalities, team or both, was comparable.

The prevalence of self-reported injuries by the gymnasts was equivalent to 62.3% [95% CI: 57.9–67.0], of which 40.3% [95% CI: 37.9–42.9], 16.1% [95% CI: 14.8–17.8] and 5.9% [95% CI: 5.1–6.9], respectively, reported having been affected by one, two or three injuries in the 12 months up to data collection. Table 2 summarises the distribution of prevalence according to selected strata of interest. Of the total number of self-reported injuries by the gymnasts, a predominance of minor injuries (49%) was identified, however, 20.4% of self-reported injuries were severe and required medical attention and temporary removal from training for at least two weeks. The lower extremities of the body (58.8), especially the ankles/feet (31.2%) and knees (17.6%), were more exposed to the occurrence of injuries, wherein tendinitis (36.3%) and sprains (22.1%) were the most prevalent self-reported injuries. The injuries occurred more frequently in the training environment (95%) and in the execution of the jumping (43.7%) and spin elements (28.1%). One in every three gymnasts (33.7%) reported training with signs and symptoms of previous injuries.

Estimates of prevalence of self-reported injuries with stratification by chronological age, body mass index, menarche age and selected indicators of training history are shown in Table 3. Results of bivariate analyses showed that, from the list of potential correlates considered, body weight and modality in which they train/compete in rhythmic gymnastics were not statistically indicated ($p < 0.20$).

Results of the stepwise multiple logistic regression are available in Table 4. By controlling the other correlates selected in the study, the final model confirmed the sport experience and the volume/weekly training as independent and significant predictors of injuries in the gymnasts. The results showed that young athletes who trained/competed ≥ 9 years presented approximately twice the odds of injury to their peers who trained/competed ≤ 4 years (OR = 1.94 [95% CI: 1.52–3.36]). In the case of the volume/week training, training ≥ 26 hours/week almost tripled the odds of the gymnasts presenting some kind of injury (OR = 2.91 [95% CI: 2.23–4.74]).

Table 1. Descriptive information of the sample selected in the study (n = 236)

	Mean ± *SD*	Distribution in Strata (%)
Chronological age (years)	13.4 ± 1.9	≤ 12 years: 34.7 13–15 years: 50.5 ≥ 16 years: 14.8
Height (cm)	155.7 ± 7.8	
Body weight (kg)	45.8 ± 7.6	
Body mass index (kg/m^2)	18.8 ± 2.2	Low weight: 40.3 Eutrophic weight: 51.5 Overweight: 8.2
Age of menarche (years)	12.3 ± 1.5	Did not menstruate: 34.2 ≤ 11 years: 19.6 12–13 years: 33.9 ≥ 14 years: 12.3
Sport experience (years)	5.6 ± 2.7	≤ 4 years: 40.3 5–8 years: 49.1 ≥ 9 years: 10.6
Weekly frequency (number of sessions)	4.4 ± 1.1	≤ 3 sections: 25.4 4–5 sections: 59.0 ≥ 6 sections: 15.6
Duration of sessions (hours)	4.1 ± 1.3	≤ 3 hours: 27.1 4–5 hours: 62.3 ≥ 6 hours: 10.6
Training volume (hours/week)	18.4 ± 7.5	≤ 10 hours/week: 13.5 11–15 hours/week: 25.8 16–20 hours/week: 32.2 21–25 hours/week: 16.6 ≥ 26 hours/week: 11.9
Competition Modality		Individual: 31.8 Team: 34.3 Both: 33.9

Table 2. Distribution of the prevalence ($CI_{95\%}$) of self-reported injuries by young rhythmic gymnastics athletes according to selected strata of interest

	Numbers of injuries	
	n	%
Degree of severity		
Minor	95	49.0
Moderate	76	30.6
Severe	28	20.4
Location		
Spine	35	17.6
Low back	30	15.1
Cervical/neck	5	2.5
Upper extremity	47	23.6
Shoulder	11	5.5
Elbow/forearm	15	7.5
Wrist/hand	21	10.6
Lower extremity	117	58.8
Hip	7	3.5
Thigh/leg	13	6.5
Knee	35	17.6
Ankle/foot	62	31.2
Type		
Muscle/tendon	50	25.1
Bruise	3	1.5
Strain	11	5.5
Cramp/muscle fatigue	36	18.1
Joint/ligament	127	63.9
Tendinitis	72	36.3
Sprain	44	22.1
Luxation	11	5.5
Bone – fractures	8	4.0
Unspecific pain	14	7.0
Event		
Training	189	95.0
Competition	10	5.0
Elements		
Jumps	87	43.7
Spins	56	28.1
Hyperextension	33	16.6
Others	23	11.6
Post-rehabilitation return		
Asymptomatic	132	66.3
Symptomatic	67	33.7

Table 3. Prevalence ($CI_{95\%}$) and prevalence ratio ($CI_{95\%}$) of self-reported injuries by young rhythmic gymnastics athletes with stratification for potential correlates

Correlates	Prevalence ($CI_{95\%}$)	Prevalence ratio	*p*-value
Global prevalence	62.3% [57.9–67.0]		
Chronological age			0.027
≤ 12 years	56.9 [52.9–61.2]	Reference	
13–15 years	61.4 [57.1–66.0]	1.16 [1.01–1.61]	
≥ 16 years	68.8 [63.9–73.9]	1.39 [1.17–2.07]	
Body mass index			0.332
Low weight	63.8 [59.3–68.6]	1.14 [0.98–1.64]	
Eutrophic weight	60.1 [55.9–64.6]	Reference	
Overweight	63.4 [58.9–68.2]	1.11 [0.96–1.69]	
Age of menarche			0.037
No menstruation	56.0 [52.0–60.2]	Reference	
≤ 11 years	67.9 [63.1–73.0]	1.43 [1.19–2.24]	
11–13 years	64.6 [60.0–69.5]	1.28 [1.09–1.97]	
≥ 14 years	61.1 [56.8–65.7]	1.17 [1.00–1.81]	
Training history			
Sport experience			0.032
≤ 4 yars	57.9 [53.8–62.3]	Reference	
5–8 years	61.4 [57.1–66.0]	1.13 [0.99–1.68]	
≥ 9 years	67.8 [63.0–72.9]	1.36 [1.16–2.06]	
Weekly frequency			0.024
≤ 3 sessions	55.9 [52.0–60.1]	Reference	
4–5 sessions	62.7 [58.3–67.4]	1.25 [1.08–1.91]	
≥ 6 sessions	68.9 [64.0–74.1]	1.46 [1.21–2.42]	
Duration of sessions			0.008
≤ 3 hours	54.6 [50.7–50.5]	Reference	
4–5 hours	61.5 [57.2–66.1]	1.26 [1.07–1.98]	
≥ 6 hours	71.1 [66.1–76.5]	1.63 [1.31–2.84]	
Training volume			0.013
≤ 10 hours/week	54.2 [50.4–58.3]	Reference	
11–15 hours/week	57.5 [53.4–53.2]	1.14 [0.97–1.78]	
16–20 hours/week	63.3 [58.8–68.1]	1.43 [1.17–2.56]	
21–25 hours/week	67.6 [62.8–72.7]	1.62 [1.29–2.94]	
≥ 26 hours/week	69.9 [65.0–64.6]	1.78 [1.39–3.21]	
Competition modality			0.375
Individual	61.1 [56.8–56.5]	Reference	
Team	63.4 [58.9–68.2]	1.09 [0.95–1.68]	
Both	62.9 [58.5–67.6]	1.06 [0.93–1.61]	

Discussion

The objective of the study was to provide updated information on the prevalence rate of self-reported injuries by young athletes of a sample of rhythmic gymnasts from the state of São Paulo, Brazil, and their predictive correlates equivalent to the training history. Although some systematic reviews have already reported the prevalence of injuries in elite rhythmic gymnastics athletes in Europe and the United States [6, 8, 9], the data available from other regions and cultures are still quite scarce.

The main findings revealed a high burden associated with injuries, with six out of ten participants (62.3%) reporting at least one type of injury in the last year. Many of these injuries were minor to moderate in severity and did not result in an interruption in the training routines. However, 20.4% of the gymnasts re-

Table 4. Hierarchical multiple logistic regression for correlates associated with the history of training of self-reported injuries by young rhythmic gymnastics athletes

Correlates	OR_{Crude} ($CI_{95\%}$)[a]	$OR_{Adjusted}$ ($CI_{95\%}$)[b]
Training history		
Sport experience		
≤ 4 years	Reference	
5–8 years	1.51 [1.25–2.37]	1.34 [1.13–2.05]
≤ 9 years	2.16 [1.69–3.74]	1.94 [1.52–3.36]
Training volume		
≤ 10 hours/week	Reference	
11–15 hours/week	1.70 [1.31–2.87]	1.52 [1.17–2.56]
16–20 hours/week	2.15 [1.68–3.57]	1.94 [1.52–3.22]
21–25 hours/week	2.71 [2.14–4.45]	2.47 [1.95–4.06]
≤ 26 hours/week	3.23 [2.47–5.26]	2.91 [2.23–4.74]

[a] Odds ratio not adjusted
[b] Odds ratio adjusted by the other variables included in the model

ported severe injuries that required time off for treatment and rehabilitation, thus adversely affecting training and competition performance. For this reason, it becomes imperative to identify predisposing correlates to the occurrence of injuries in this sample of young gymnasts.

Comparisons among studies available in the literature revealed considerable differences in the prevalence rates of injuries in rhythmic gymnastics athletes. It quickly becomes clear that these variations can be attributed to the definition of injuries used in the studies. Some considered only those injuries sufficiently severe that medical attention was required [3, 10]; others defined injuries as any type of trauma that would interfere in the gymnasts' performance, therefore also considering those lighter injuries [6, 8, 9]. Another factor that makes comparisons difficult is the level of competition of the study participants. Some studied only elite gymnasts, with extensive experience in international competitions [3, 11], while others included beginner gymnasts in the sample or those who have not yet reached higher levels of training and competition [6, 10]. Clearly, these differences are related to the duration of exposure to injuries, considering that the training volume tends to change according to the gymnasts' level of competition [13].

In addition to divergences in the definition of injuries and the nature of the samples, two other additional characteristics may make comparisons among the studies difficult. The fact that the data come from retrospective or prospective approaches and represent small samples or epidemiological surveys are also not inconsequential. In view of this, comparisons among studies should be carried out with extreme caution. Beyond this, when confronted with international data, the prevalence of injuries observed in the present study was similar to that found in Italian gymnasts [11], lower than that described in North American gymnasts [4] and higher than that found in gymnasts from Romania [14] and Greece [15]. To the best of our knowledge, no previous survey to date has been performed in Brazilian young athletes of rhythmic gymnastics.

A marked majority of the gymnasts (95%) reported that the injuries occurred in training, which corroborates evidence from previous studies [6, 8, 9]. This data warns about the importance and need to control the methods employed, since greater exposure to training routines tends to increase the risk of injuries in this sport. On the other hand, consistent with the results found by other studies [12, 14, 15], it was found that the most frequent injuries reported by young athletes were sprains and tendinitis, followed by muscle contractures. In this regard, no gymnast participating in the study reported the occurrence of a concussion. However, it is noteworthy that, in child and youth sports, any injury resulting from impact with obstacles or objects, causing partial or complete loss of some function, especially in the head region, should be investigated in detail, and attempts to reduce this type of injury are critical [7]. Specifically in rhythmic gymnastics, concussions may result from collisions with other athletes in team events and as a result of falls.

Regarding the most vulnerable body segment, the data from the present study indicated that, although high prevalence was identified in the spine (17.6%), particularly in the low back (15.1%), injuries occurring in the lower extremities of the body were predominant (58.8%), especially in the ankles/feet (31.2%) and knees (17.6%). These findings contrast the results of surveys performed in rhythmic gymnastics initiation groups, which indicated an increased risk to the low back [16]; however, they coincide with data presented in studies that gathered samples of young athletes with greater competition experience [14, 15].

Regarding the specific gestures of rhythmic gymnastics, similar to what was observed in systematic review studies [6,9], the elements with the highest incidence of injuries were jumps and spins. For specialists in the area, repeated actions to the exhaustion of these elements, added to the execution technique incompatible with the ability demonstrated by the gymnast, may be the main causes [17]. Hence the importance of greater attention in the domain of these elements, insisting on progressive learning through appropriate methodological procedures until achieving the cor-

rect technique, and on proper monitoring of the workload (volume and intensity) in the training.

The higher prevalence of tendinitis in the lower extremities is probably related to the repetitive jumping techniques performed in all rhythmic gymnastics routines, especially in rope events. The imbalance of muscle-tendon units predisposes gymnasts to overuse injuries and the physical growth spurt at pubertal age can often compromise the relative capacity for muscle stretching [18]. Specifically, in the case of sprains, especially of the ankle, rhythmic gymnastics puts the athlete at risk of this type of injury due to movements that request jumps and spins. In this context, some sprains can most likely be avoided by strengthening the peroneal muscles. It is noteworthy that, generally, inadequate rehabilitation of ankle sprains results in recurrence of the injury; therefore, specific strength training and proprioceptive exercises become essential after ankle sprains [19].

Knee injuries are quite prevalent in young female athletes in many other sports. This is related to several factors, including anatomic misalignments (*genu valgum* and an increase of femoral anteversion), harder training surface, muscle imbalances and errors in the training load dosage (volume, intensity and frequency incompatibilities) [20]. In addition, attempts to improve the turn-out by increasing external tibial torsion and ankle pronation impose excessive stress on the patellofemoral joint [18]. This stress increases the risk of injury to the knee extensor mechanism. In the last year, 17% of the gymnasts included in the study reported knee injuries. Ensuring adequate stretching capacity of the quadriceps and hamstring muscles and increasing the strength of the vastus medialis oblique may decrease the susceptibility to knee injuries [21].

A disturbing finding was the prevalence of low back injuries reported by the study participants (15.1%). Although only 1.4% of the gymnasts reported fractures in the spine, it is possible that other gymnasts experienced undiagnosed bone stress reactions or early spondylosis. Rhythmic gymnastics provides a high-risk environment for this type of injury because, in training, ballistic movements of extreme spine hyperextension are repeatedly requested. Previous findings attributed the high rate of spondylolysis in gymnasts to increased lordosis and dynamic hyperextension of the spine [22]; in addition, there is a higher incidence of spondylosis in gymnasts with low back pain [23]; therefore, there should be consistent suspicion when gymnasts exhibit these symptoms.

The spine was only one of the regions where fractures occurred. Overall, 4% of the gymnasts reported some type of fracture, particularly in the ankles/feet. In this regard, it is important to highlight that the previous study identified a higher risk of stress fractures as the weekly training volume increases [24]. As a rule, stress fractures occur when the cellular mechanism is insufficient to restore bone tissue microtrauma caused by repetitive external forces during training [25]. Risk factors for stress fractures include a harder surface training, poor nutrition, anatomical misalignment, inappropriate training load for the current condition of the gymnast, muscle-tendon unit imbalances [18] and menstrual irregularities, including amenorrhoea and oligomenorrhea, which contribute to the onset and development of premature osteoporosis [15].

The sport experience and the volume/weekly training were identified as independent predictors of injuries in the young rhythmic gymnastics athletes selected in the study. Etiologically, by increasing the number of years and hours/week of training, the structures and tissues are subjected to progressively higher stress, with less time to repair microscopic damage that may eventually occur in muscles, bones, tendons and joints, consequently increasing the risk of injury onsets [24].

In view of this, it is suggested that the cost-effectiveness of the weekly training volume should be carefully examined in the search for a balance between improving performance in the modality and reducing the risk of injuries. In this context, a previous study identified a close relationship between weekly training volume and achievements or success in youth sports [26]; however, limiting the training volume to a maximum of 20 hours/week may significantly decrease the number of injuries and the dropout rate in young athletes, while still allowing for elite performance [27].

The position of the International Society of Sport Psychology on excessive training in children and adolescents suggests that the search for maximum performance at any cost should be ethically and clinically condemned [28]. While elite and beginner gymnasts in countries with a tradition in international rhythmic gymnastics competitions train 25–30 and 9–12 hours/week, respectively [8], the gymnasts included in the present study reported training on average approximately 18 hours/week.

Among the limitations of the present study, it stands out that, although the sample size can be considered smaller, it represents 1/3 of the entire delimited population; therefore, in this case, the results should only be extrapolated to other young rhythmic gymnastics athletes with identical training and competition characteristics. Similarly, the retrospective analysis of the data makes its findings less reliable, due to the possible

memory bias or even by biased statements towards the desirable; however, the results found provide relevant information on the relationships between historical training indicators and injury risk that justify additional prospective investigations. Also, the cross-sectional approach of the data does not allow us to perform causality inferences in the association between susceptibility to injuries and the investigated correlates, due to the outcome and the other variables being identified at the same time. On the other hand, the main strength of the study is the fact that potential topics for further investigations have been identified in an attempt to minimise the risk of injury in this technically challenging and extremely demanding sport.

Conclusions

In conclusion, the study findings highlight the pronounced vulnerability to injuries among the emerging talents in rhythmic gymnastics. Notably, the lower extremities emerged as the primary locus of these injuries, characterised primarily by tendinitis, sprains, and muscle contractures. These injuries were found to occur more frequently during training sessions. While the majority of injuries were categorised as minor to moderately severe, necessitating immediate attention and treatment, they carry lasting implications. These implications encompass not only the imperative to expedite the return of gymnasts to training and competitive arenas, but also the imperative to mitigate the potential evolution into more debilitating injuries in the long term. These long-term repercussions not only jeopardise athletes' continued participation in their sport but also pose substantial threats to their overall health and quality of life, both in their youth and as they transition into adulthood. The study's notable discovery of inverse associations between the athletes' injury rates and training history, such as greater sports experience and weekly training volume, underscores the importance of crafting training schedules that prioritise injury prevention.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

References

1. Bergeron MF, Mountjoy M, Armstrong N, Chia M, Côté J, Emery CA et al. International Olympic Committee consensus statement on youth athletic development. Br J Sports Med. 2015;49(13):843–851; doi: 10.1136/bjsports-2015-094962.
2. Turska-Kmieć A, Neunhaeuserer D, Mazur A, Dembiński Ł, Del Torso S, Grossman Z et al. Sport activities for children and adolescents: The Position of the European Academy of Paediatrics and the European Confederation of Primary Care Paediatricians 2023-Part 1. Pre-participation physical evaluation in young athletes. Front Pediatr. 2023;11:1125958; doi: 10.3389/fped.2023.1125958.
3. Edouard P, Steffen K, Junge A, Leglise M, Soligard T, Engebretsen L. Gymnastics injury incidence during the 2008, 2012 and 2016 Olympic Games: analysis of prospectively collected surveillance data from 963 registered gymnasts during Olympic Games. Br J Sports Med. 2017;52(7):475–481; doi: 10.1136/bjsports-2017-097972.
4. Gulati R, Rychlik K, Wild JT, LaBella CR. Rhythmic gymnasts' injuries in a pediatric sports medicine clinic in the United States: a 10-year retrospective chart review. Phys Sportsmed. 2022;50(5):454–460; doi: 10.1080/00913847.2022.2040890.
5. Douda HT, Toubekis AG, Avloniti AA, Tomakidis SP. Physiological and anthropometric determinants of rhythmic gymnastic performance. Int J Sports Physiol Perform. 2008;3(1):41–54; doi: 10.1123/ijspp.3.1.41.
6. Hart E, Meehan WP, Bae DS, d'Hemecourt P, Stracciolini A. The young injured gymnast: a literature review and discussion. Curr Sports Med Rep. 2018;17(11):366–75; doi: 10.1249/JSR.0000000000000536.
7. Junge A, Engebretsen L, Alonso JM, Renström P, Mountjoy M, Aubry M et al. Injury surveillance in multi-sport events: the International Olympic Committee approach. Br J Sports Med. 2008;42(6):413–421; doi: 10.1136/bjsm.2008.046631.
8. Caine D, Harringe ML. Epidemiology of injury in gymnastics. In: Caine DJ, Russell K, Lim L (eds). Handbook of Sports Medicine and Science – Gymnastics. Oxford: Wiley-Blackwell, 2013. 111–124; doi: 10.1002/9781118357538.ch10.
9. Thomas RE, Thomas BC. A systematic review of injuries in gymnastics. Phys Sportsmed. 2019;47(1):96–121; doi: 10.1080/00913847.2018.1527646.
10. Kruse D, Lemmen B. Spine injuries in the sport of gymnastics. Curr Sports Med Rep. 2009;8(1):20–28; doi: 10.1249/JSR.0b013e3181967ca6.
11. Cupisti A, D'Alessandro C, Evangelisti I, Umbri C, Rossi M, Galetta F et al. Injury survey in competitive sub-elite rhythmic gymnasts: results from a prospective controlled study. J Sports Med Phys Fitness. 2007;47(2):203–207.
12. Vernetta M, Montosa I, López-Bedoya J. [Analysis of sports injuries in Young athletes of competitive rhythmic gymnastics in the infantile category]. Rev Andal Med Deporte. 2016;9(3):105–109; doi: 10.1016/j.ramd.2015.11.001.

13. Bahr R, Clarsen B, Derman W, Dvorak J, Emery CA, Finch CF et al. International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020 (including STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS)). Br J Sports Med. 2020;54(7):372–389; doi: 10.1136/bjsports-2019-101969.
14. Oltean A, Rusu MM, Copoiu N, C ălin MF. Incidence of injuries in rhythmic gymnastics. Ovidius Univ Ann Ser Phys Educ Sport Sci, Mov Health. 2017;17(2,Suppl):427–432.
15. Paxinos O, Mitrogiannis L, Papavasiliou A, Manolarakis E, Siempenou A, Alexelis V et al. Musculoskeletal injuries among elite artistic and rhythmic Greek gymnasts: a ten-year study of 156 elite athletes. Acta Orthop Belg. 2019;85(2):145–149.
16. Piazza M, Di Cagno A, Cupisti A, Panicucci E, Santoro G. Prevalence of low back pain in former rhythmic gymnasts. J Sports Med Phys Fitness. 2009;49(3):297–300.
17. Westermann RW, Giblin M, Vaske A, Grosso K, Wolf BR. Evaluation of men's and women's gymnastics injuries: a 10-year observational study. Sports Health. 2015;7(2): 161–165; doi: 10.1177/1941738114559705.
18. Caine DJ, Nassar L. Gymnastics Injuries. In: Caine DJ, Maffulli N (Eds.). Epidemiology of pediatric sports injuries. Individual sports. Med Sport Sci. Basel, Karger. 2005;48:18–58; doi: 10.1159/isbn.978-3-318-01179-1.
19. Trikha R, Greig DE, Shi BY, Schroeder GG, Chernoff DJ, Jones KJ et al. Multicenter analysis of the epidemiology of injury patterns and return to sport in collegiate gymnasts. Orthop J Sports Med. 2023;11(2):2325967 1231154618; doi: 10.1177/23259671231154618.
20. Blatnik TR; Briskin S. Bilateral knee pain in a high-level gymnast. Clin J Sport Med. 2013;23(1):77–9; doi: 10.1097/JSM.0b013e31825c464d.
21. Hinds N, Angioi M, Birn-Jeffery A, Twycross-Lewis R. A systematic review of shoulder injury prevalence, proportion, rate, type, onset, severity, mechanism and risk factors in female artistic gymnasts. Phys Ther Sport. 2019;35:106–115; doi: 10.1016/j.ptsp. 2018.11.012.
22. Fett D, Trompeter K, Platen P. Back pain in elite sports: a cross-sectional study on 1114 athletes. PLoS One. 2017; 12(6):e0180130; doi: 10.1371/journal.pone. 0180130.
23. Cupisti A, D'Alessandro C, Evangelisti I, Piazza M, Galetta F, Morelli E. Low back pain in competitive rhythmic gymnasts. J Sports Med Phys Fitness. 2004;44(1): 49–53.
24. Cavallerio F, Wadey R, Wagstaff CRD. Understanding overuse injuries in rhythmic gymnastics: A 12-month ethnographic study. Psychol Sport Exerc. 2016; 25:100–109; doi: 10.1016/j.psychsport.2016.05.002.
25. Kox LS, Kuijer PP, Kerkhoffs GM, Maas M, Frings-Dresen MH. Prevalence, incidence and risk factors for overuse injuries of the wrist in young athletes: a systematic review. Br J Sports Med. 2015;49(18):1189–1196; doi: 10.1136/ bjsports-2014-094492.
26. Fabricant PD, Lakomkin N, Suguimoto D, Tepolt FA, Stracciolini A, Kocher MS. Youth sports specialization and musculoskeletal injury: a systematic review of the literature. Phys Sportsmed. 2016;44(3):257–262; doi: 10.1080/00913847.2016. 1177476.
27. Jayanthi NA, Post EG, Laury TC, Fabricant PD. Health consequences of youth sport specialization. J Athl Train. 2019;54(10):1040–9; doi: 10.4085/1062-6050-380-18.
28. Côté J, Lidor R, Hackfort D. ISSP position stand: To sample or to specialize? Seven postulates about youth sport activities that lead to continued participation and elite performance. Int J Sport Exerc Psychol. 2009;7(1):7–17; doi: 10.1080/1612197X.2009.9671889.