Injuries and training recommendations in elite rhythmic gymnastics

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ABSTRACT

Objective: To identify risk factors for injury in rhythmic sportive gymnastics and to provide recommendations for reducing the risk of injury.
Methods: A one-year retrospective survey of injuries in twenty national-level rhythmic gymnasts (ages 14.8 to 18.8 years; mean age 17.1 years). Hours of rhythmic gymnastics (RG) training per week, minutes of stretching per day, and hours of conditioning per week, were analyzed as potential risk factors for injury. Main outcome measures were injuries that required time off, major injuries (at least 7 days off), injuries to muscle-tendon units, and fractures.
Results: Thirteen (65%) of 20 gymnasts sustained time-loss injuries, and 4 gymnasts (20%) reported major injuries. Seventeen (85%) gymnasts reported muscle-tendon unit injuries and 5 (25%) suffered fractures. Sixteen (80%) of the gymnasts reported back pain or stress fractures of the back, 8 of whom required time off training. One gymnast (5%) incurred a concussion. Logistic regression indicated that rhythmic gymnastics training and stretching were associated with muscle-tendon unit injury. On multivariate analysis, stretching was found to be the only independent predictor of muscle-tendon unit injuries with each additional minute lowering the risk by approximately 10% ($p \leq 0.01$). Conditioning and stretching were both independent predictors of fractures. The risk of fracture was estimated to increase by over 60% for each additional hour of weekly conditioning (odds ratio = 1.62; $p = 0.03$) and decrease by almost 20% for each additional minute of daily stretching (odds ratio = 0.81; $p = 0.04$). None of the variables studied were predictive of back pain or injury.
Conclusions: Injuries in rhythmic gymnastics may be reduced by increasing the amount of time spent stretching per day (at least 40 minutes), and limiting conditioning to a maximum of 6 hours per week.

KEY WORDS: Sports. Injury prevention. Adolescent. Elite. Rhythmic gymnastics.

RESUMEN

Objetivo: Identificar los factores de riesgo en gimnastas de rítmica de alto nivel y aconsejar recomendaciones para prevenir el riesgo de lesiones.
Métodos: Encuesta retrospectiva de un año de historial deportivo en 20 gimnastas que competían en el ámbito nacional (media de edad, 17,1 años; rango, 14,8-18,8 años). Las horas de entreno por semana, los minutos de estiramientos por día y horas de entrenamiento aeróbico por semana se analizaron como un riesgo potencial de factores de riesgo para lesiones deportivas. La mayoría de lesiones registradas requería dejar los entrenamientos (*time off*); las lesiones más severas (mínimo de 7 días sin actividad deportiva) eran lesiones de partes blandas: tendón y/o músculo y fracturas.
Resultados: De las 20 gimnastas, 13 (65%) tuvieron lesiones que obligaron a dejar los entrenamientos y otras actividades deportivas, 4 (20%) fueron lesiones más severas. Diecisiete (85%) contestaron que presentaron lesiones musculotendinosas y 5 (25%) sufrieron fracturas. Dieciséis sujetos (80%) de la muestra presentaron lumbalgia o fracturas de estrés lumbar, 8 de los cuales requirieron reposo. Una gimnasta tuvo una conmoción cerebral. La regresión logística indica que el entreno y los estiramientos en gimnasia rítmica están asociados a lesiones de la unión musculotendinosa. En el análisis multivariante se halla que los estiramientos eran el único predictor independiente de las lesiones de la unión musculotendinosa; con cada minuto adicional se disminuye el riesgo aproximadamente un 10% ($p \leq 0{,}01$). Los ejercicios de estiramiento y de acondicionamiento son los 2 factores independientes de predicción de fracturas. El riesgo de fractura fue estimado > 60% por cada hora semanal adicional de entrenamiento (*odds ratio* [OR] = 1,62; $p = 0{,}03$) y decrece casi al 20% por cada minuto adicional de estiramientos diarios (OR = 0,81; $p = 0{,}04$). Ninguna de las variables estudiadas fue predictiva de dolor o lesión lumbar.
Conclusiones: Las lesiones en la gimnasia rítmica se podrían reducir incrementando el tiempo que se dedica a los estiramientos por día (al menos 40 min), y limitando el entrenamiento a un máximo de 6 h por semana.

PALABRAS CLAVE: Deporte. Prevención de lesiones. Adolescente. Elite. Gimnasia rítmica.

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INTRODUCTION

With its inclusion in the 1984 Olympic Games in Los Angeles, Rhythmic Sportive Gymnastics has gained popularity worldwide. The sport is based on precision, grace, originality and coordination with music[1]. It combines the movements of dance with the use of five small hand apparatuses: hoop, ball, clubs, ribbon, and rope. Four of these five apparatuses are identified every two years as official events for international competitions.

Aesthetics plays a critical role in the success of rhythmic gymnasts. Rhythmic gymnasts need low body fat and increased flexibility and strength for success[2]. In fact, extreme flexibility is required for execution of many of the movements of rhythmic gymnastics. Because of the difficulty of the sport, countless hours are required to perfect routines lasting 75 to 90 seconds each in individual competition and from 2 minutes 15 seconds to 2 minutes 30 seconds for group events (www.usa-gymnastics.org). Training occurs on a 13 m × 13 m carpet. Elite rhythmic gymnasts in Canada train 25 to 30 hours per week[2]. The combination of low body fat, movements that require extreme flexibility, and the repetitive stresses on the musculoskeletal system from intensive training are all potential risk factors for overuse injuries. Unfortunately, until now, little research has been conducted to identify the risk of injury in rhythmic gymnastics, or to establish recommendations for the reduction of injuries in this sport.

METHODS

Subjects

A one-year retrospective survey on gymnastics-related injuries was distributed to national-level rhythmic gymnasts of a single country. The nature of the study was explained to the subjects, and participation in the study was voluntary. There were a total of 20 surveys analyzed, which represented 100% of the national team members. The average age was 17.1 years, ranging from 14.8 to 18.8 years.

Survey

The survey consisted of four sections: personal data, conditioning (i.e. strength training; aerobic training), stretching, and injuries. Personal data included age, number of years of training in rhythmic gymnastics and number of hours of training per week. The sections on conditioning and stretching determined how much time was spent per week, on average, doing each activity. The injury section was a checklist grouped by body region. For each self-reported injury, gymnasts indicated how much time off was required and whether or not casting or surgery was necessary. Each self-reported injury was then graded into minor (no time off), moderate (< 7 days off), or major (at least 7 days off). Any injury which required cast or surgery was considered major. "Time-loss" injuries were those requiring any time off from training (i.e. moderate or major)[3]. All self-reported injuries were included in analysis of body regions affected as well as in analysis of types of injuries.

Statistical analysis

Continuous data were compared using an unpaired Student's t-test. Logistic regression analysis was conducted to identify risk factors and the likelihood ratio test was used to assess the significance of each variable. To control for confounding, stepwise multiple logistic regression was used to establish the independent predictors for each binary outcome with the adjusted odds ratio as the measure of association[4]. The amount of stretching was used to derive the estimated likelihood of fractures and muscle-tendon unit injuries, whereas weekly levels of conditioning were used to estimate the likelihood of fractures. A two-tailed $p \leq 0.05$ was considered significant for all statistical tests. Data analysis was performed with SPSS for Windows (SPSS Inc., Chicago, IL).

RESULTS

Gymnasts had an average experience of 6.5 years in the sport (SD = 2.8) ranging from 3 to 13 years. They trained an average of 26.2 hours per week (SD = 7.5; range 14 to 36 hours), conditioned an average of 300 minutes per week (SD = 200; range 45-720), and stretched an average of 33 minutes per day (SD = 20; range 10-100). Ten of the gymnasts (50%) experienced abnormal menstrual function. Five (25%) had oligomenorrhea and five (25%) had amenorrhea.

Although all of the gymnasts reported having sustained some type of injury during the year preceding the study, only 13 (65%) of 20 gymnasts sustained a time-loss injury, as defined as an injury that required time off from any portion of regular training. Four gymnasts (20%) sustained major injuries that required at least seven days off training. Seventeen (85%) gymnasts reported having sustained injuries to muscle-tendon units and five (25%) had suffered injuries to the bone (fractures). Also of note, 16 (80%) of gymnasts indicated that

Table I Distribution of injuries

	Mild (no time off)	Moderate (< 7 days off)	Major (≥ 7 days off)	Total (self-reported)	Total (significant)
Head and neck	3	2	0	5	2
Upper extremities	16	3	0	19	3
Lower extremities	42	13	2	57	15
Trunk/back	13	7	7	27	14
Total	74	25	9	108	34

they had experienced back pain or stress fractures of the back and eight of these required time off for this problem. Although only one gymnast sustained a knee injury that required time off during the year, nine (45%) of the gymnasts experienced knee pain. One gymnast (5%) incurred a concussion during the course of training. Table I summarizes the distribution of self-reported injuries by body region.

Muscle-tendon unit injuries

Hours of RG training per week ($p = 0.034$) and minutes of stretching per day ($p = 0.006$) were found to be significant predictors of self-reported injuries to muscles and tendons. For each additional hour of RG training per week, the estimated risk of injury increased 29%. Gymnasts who did not sustain muscle-tendon injuries trained an average of 18.7 hrs/wk (SD = 2.3) while those who did trained an average of 27.5 hrs/wk (SD = 7.4) ($p \leq 0.05$). For each additional minute of stretching per day, the risk of injury decreased 11%. On multivariate analysis, stretching was found to be the only independent predictor of muscle-tendon unit injuries ($p \leq 0.01$). Figure 1 illustrates the relationship between amount of stretching per day and likelihood of fracture or injury to muscle-tendon units. There does not appear to be a protective benefit of stretching on reduction of muscle-tendon unit injuries until daily stretching exceeds approximately 40 minutes. Additional time spent stretching beyond 40 minutes per day is associated with a steep reduction in likelihood of muscle-tendon unit injury.

Fractures

On univariate analysis, minutes of conditioning per week ($p = 0.002$), hours of RSG training per week ($p = 0.005$) and minutes of stretching per day ($p = 0.003$) were all significant predictors of fractures. The risk of fracture increased 1% for each additional minute of conditioning per week, and increased 32% for each additional hour of RG training per week. Subjects who did not sustain fractures trained an average of 23.8 hrs/wk (SD = 7.1) and those who indicated that they had had a fracture trained an average of 33.4 hrs/wk (SD = 2.1) ($p \leq 0.01$). The risk of fracture decreased by 19% for each additional minute of stretching per day. Both conditioning ($p = 0.03$) and stretching ($p = 0.05$) were found to be independent multivariate predictors of fractures. Figure 1 illustrates the protective benefit of stretching as the likelihood of fracture approaches zero when daily stretching exceeds 40 minutes. In figure 2 it is apparent that the likelihood of fracture steeply increases when weekly conditioning exceeds 6 hours. Although none of the variables analyzed were found to

Figure 1 Association between the amount of conditioning per week and likelihood of fracture.

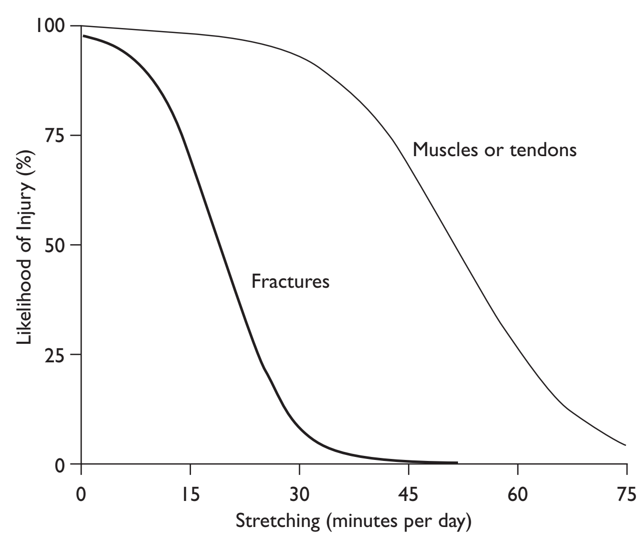
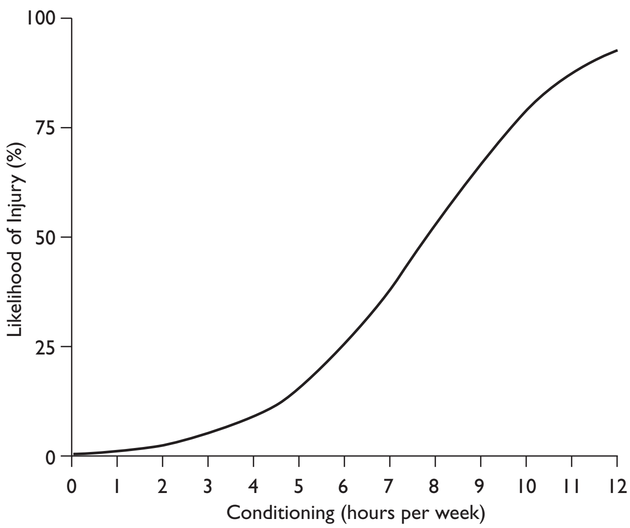


Figure 2 Increase in the probability of fracture due to conditioning sessions lasting more than 6 h.



be significant predictors of either time-loss injuries or major injuries, there does appear to be a trend toward greater incidence of major injuries with increasing time spent conditioning ($p = 0.076$).

Discussion

This study reveals a high burden of injury among elite rhythmic gymnasts, with 100% of national team members reporting at least one injury per year. Many of these injuries were mild and resulted in no disruption of training. Unfortunately, 65% of gymnasts required some time off training during the preceding 12 months due to their injuries. This can adversely affect training as well as performance in competition. For this reason, it is imperative that we develop an understanding about the risk factors for injury and subsequently make recommendations to reduce injuries among these high-performance athletes.

The most disconcerting result is the extremely high rate of low back pain reported by these athletes. Eighty percent described pain that was exacerbated by hyperextension of the spine. Although only two gymnasts reported actual stress fractures of the spine, it is possible others may have had undiagnosed bony stress reactions or early spondylolytic lesions. Rhythmic gymnastics provides a high-risk environment for such injuries, with many of the techniques requiring repetitive, ballistic, extreme hyperextension of the spine[5]. Many authors have attributed the high rate of spondylolysis among gymnasts and dancers to increased lordosis and dynamic hyperextension of the spine[6-12]. There is a high incidence of spondylolysis among gymnasts with low back pain[6,13]; therefore, there needs to be a high index of suspicion when a gymnast develops such symptoms.

Treatment of spondylolysis as well as other overuse syndromes of the posterior elements of the spine involves specific exercises to increase abdominal strength, improve hamstring and lumbodorsal fascia flexibility and antilordotic postural exercises[7-9,11]. These treatment principles can be applied prophylactically in an attempt to reduce the incidence of significant spine injuries[8]. Also, a proper warm-up with stretching and slow, progressive increase in techniques over 20 to 30 minutes has been recommended by other authors[8,14]. Early recognition of a developing spondylolytic lesion facilitates more rapid healing and less time off training. If lumbar pain develops during the course of training, the gymnast should be allowed to rest or change to pain-free techniques until the pain resolves. This approach, in conjunction with the preventative exercises may help reduce the rate of spondylolysis in these gymnasts.

The spine was only one of the regions where gymnasts reported fractures. Twenty-five percent of the team members sustained fractures and several gymnasts required some time off training for these injuries. This was particularly true of fractures of the fibula and foot. Stress fractures occur when the cellular mechanism of repair fails to keep pace with the microscopic damage to bone caused by repetitive forces during training[6,15]. Risk factors for stress fractures include hard training surfaces, poor nutrition[15], anatomic malalignments, training errors such as rapid increases in training frequency or intensity, muscle-tendon unit imbalances[11], and menstrual irregularities such as amenorrhea and oligomenorrhea[16]. Our study determined that 50% of elite rhythmic gymnasts have some form of menstrual dysfunction, which is consistent with research conducted by Lindboe and Slettebo in 1984[17]. This leads to premature osteoporosis and increased risk of stress fracture[16]; however, because of the small numbers in our study, no significant relationship between menstrual dysfunction and fractures was noted.

A very interesting finding of this study was the correlation between increased stretching and decreased fractures. Many authors feel that stretching helps reduce the risk of stress fractures[8,11,15,18] and that other overuse injuries can be prevented by correcting muscle imbalances[19,20]. Our results support this contention and provide specific recommendations for reduction of fractures based on time spent stretching each day. Increased conditioning, on the other hand, results in a higher incidence of fractures. Up to a certain point, strength exercises reduce the risk of fracture[8,9,11,15]. Our study shows that at the elite rhythmic gymnastics level, there is an increased risk of fracture as hours of conditioning per week increases. This means that the cost-benefit ratio of conditioning needs to be examined and a balance between performance enhancement and reduction of injuries must be found. Finally, although not as important a predictor of injury, the total number of hours of rhythmic gymnastics training per week appears to be a factor in the etiology of fractures. This likely relates to increased exposure time for acute fractures and increases the repetitive microtrauma leading to stress fractures. The International Federation of Sports Medicine (FIMS) position statement on excessive physical training in children and adolescents contends that training for maximum performance at any price should be condemned ethically and medically[19]. Once again, the cost-benefit ratio must be evaluated. While sub-elite rhythmic gymnasts in Canada train between 9 and 12 hours per week, elite rhythmic gymnasts train between 25 and 30 hours per week[2]. A strong relationship between volume of training per week and attainment or success in the sport has been identified[21]. Limiting training to a maximum of 30 hours per week may decrease the number of fractures sustained among national team gymnasts, while still allowing for elite-level performance. At a sub-elite level where volume of training may be more flexible, a further restriction of training to a maximum of approximately 20 hours per week may be associated with a lower risk of muscle-tendon unit injuries. Imbalances of muscle-tendon units predispose athletes to overuse injuries and growth can often lead to relative decreases in flexibility[11]. Contrary to the findings of other authors[22-24] who concluded that stretching does not reduce injury in sport, we found a very strong correlation between increased stretching and decreased injuries of muscles and tendons. One possible explanation for this discrepancy is that previous studies did not involve athletes whose sports demand excessive muscle length, which pre-exercise stretching may facilitate. Many rhythmic gymnastics techniques are accomplished at just such excessive muscle lengths. The stretching reported in this study was not limited to pre-exercise stretching. Rather, it reflected total daily stretching which likely exerts some of its protective benefit through increased overall flexibility. Furthermore, although elite rhythmic gymnasts exhibit extreme flexibility in general, specific demands of the sport may result in relatively more flexible agonist muscle groups than antagonist groups.

Injuries to muscle-tendon units were reported in 85% of gymnasts. Most of these injuries to the upper extremities were of a mild nature, but 25% of gymnasts sustained time-loss injuries to muscles or tendons of the lower extremities. The hamstrings, groin and ankle were the most common sites of injury that required time off from training. Hamstring and groin injuries occur during ballistic movements such as split leaps and kicks that are performed frequently during training and often stress the muscle-tendon units at the extremes of flexibility[1]. Tendinitis of the foot and ankle is likely related to the repetitive jumping techniques executed in all routines, but primarily in the rope event. Imbalances of muscle-tendon units predispose athletes to overuse injuries and growth can often lead to relative decreases in flexibility[11]. We found a very strong correlation between increased stretching and decreased injuries of muscles and tendons. Although elite rhythmic gymnasts exhibit extreme flexibility in general, specific demands of the sport may result in relatively more flexible agonist muscle groups than antagonist groups. For example, techniques such as scales and split leaps require greater flexibility of hamstrings than quadriceps. Ballet dancers have much stronger ankle plantarflexors than dorsiflexors because of the amount of time spent jumping and “en pointe”. Because of many similarities between dance and rhythmic gymnastics, similar muscle imbalances may occur in the latter. It is possible that additional time spent stretching each day reduces the flexibility imbalances inherent in a sport such as rhythmic gymnastics; therefore, injury to muscles and tendons is reduced. According to Kulund and Tottossy, stretches should be slow and graceful and should be held for 30 seconds[14]. Bouncing during stretching precipitates a reflex contraction of the muscle and may result in injury[14].

Number of hours of rhythmic gymnastics training per week was also found to be a significant predictor of injury to muscle-tendon units; however, this was not an independent predictor. By increasing the number of hours of training each week, the tissues are placed under greater and greater stress, with less time for reparation of microscopic damage to the muscles and tendons. The resultant increase in injuries to muscles and tendons must be taken into consideration when determining training schedules for elite gymnasts.

Knee injuries are quite prevalent among female athletes in many different sports. This is related to a number of factors including anatomic malalignments (genu valgus, increased femoral anteversion), hard training surfaces, muscle imbalances and training errors (sudden increase in intensity or frequency)[25]. In addition, attempts to increase turn-out by increasing external tibial torsion and ankle pronation place excess stress on the patellofemoral joints[11]. This stress increases risk of injury to the extensor mechanism of the knee. Forty-five percent of our gymnasts complained of knee pain in the preceding year, most of which was attributed by the athlete to tendinitis. Ensuring adequate flexibility of quadriceps and hamstring muscles, as well as building strength of the vastus medialis obliquus (VMO) may reduce the incidence of knee pain[24].

Sprains of the foot and ankle occurred frequently among the national team members. Rhythmic gymnastics places the athlete at risk for such injuries because of techniques such as jumps and turns. Leaping ability is essential for success in the sport[26]. Rehabilitation of ankle sprains involves strengthening of the peroneal muscles. Perhaps some sprains can be prevented by developing greater peroneal strength in all gymnasts. Inadequate rehabilitation of ankle sprains often results in re-injury, so adequate strength and proprioception training is essential after ankle sprains.

The one gymnast who reported a concussion should be highlighted. This injury required some time off training, but less than one week. Any head injury in youth sports must be taken seriously, and attempts to reduce such injuries are critical. Although the mechanism of injury was not identified on the survey, head injuries could occur as a result of collision with other athletes, the hard training surface, or the clubs. Only one gymnast reported such an injury in our study; therefore, it was not possible to identify risk factors. A larger study is necessary to make recommendations for evaluating the risk of head injuries in this sport.

Limitations of the study

Although the sample-size of this study was small (N = 20), this represented 100% of study country's national team members; therefore, results can only be extrapolated to other national-level rhythmic gymnasts and not to the entire rhythmic gymnastics population. In addition, the small study group makes retrospective analysis of data less reliable; however, the findings of this study suggest important, significant relationships between variables examined (volume of training, stretching, conditioning) and injury-risk that warrants additional, prospective investigations.

Due to the small sample size, all self-reported injuries were used in analysis of body region and types of injuries. Definition of injury in the wider scientific literature varies from self-reported injuries, to injuries that disrupt normal training (time-off or modification of training), to injuries for which medical attention has been sought. As result, a comparison of injury rates between this study and others is more difficult. Nevertheless, this study has identified potential areas for further study in an attempt to reduce injuries in this graceful and technically challenging sport.

Conclusions

In summary, and with the above limitations in mind, the authors advocate the following recommendations to reduce the risk of injury in Rhythmic Gymnastics:

1. Stretch a minimum of 40 minutes per day.

2. Limit conditioning to a maximum of 6 hours per week. This may reduce likelihood of fracture.

3. Limit training to a maximum of 30 hours per week, which may reduce likelihood of fracture; a further restriction of training to a maximum of 20 hours per week may reduce muscle-tendon unit injuries.

4. Measures to reduce the prevalence of low-back pain and knee pain should be sought. For example, a prophylactic regimen of abdominal strength exercises, antilordotic exercises, vastus medialis obliquus strength exercises, and quadriceps stretches could be incorporated into training. Reduction of the number of repetitions of back hyperextension techniques could be considered.

5. Further evaluation of the etiology of menstrual abnormalities in rhythmic gymnasts is warranted and risk factors identified should be addressed, in view of the association between menstrual abnormalities and osteoporosis identified elsewhere in the literature[16].

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