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A TWO-YEAR EPIDEMIOLOGICAL STUDY OF YOUNG ARTISTIC GYMNASTS' ANKLE INJURIES

DVOLETNA EPIDEMIOLOŠKA ŠTUDIJA POŠKODBE GLEŽNJA PRI MLADIH ŠPORTNIH TELOVADCIH

ABSTRACT

The most injured body parts in artistic gymnastics (AG) in the lower extremities are ankle sprains. The purpose of this study was to investigate young artistic gymnasts' risk factors of ankle injuries over a two-year period. Two hundred artistic gymnasts aged 9-13 years who compete in the recruits group participated in this study. The results showed that landing and take-off were the phases with the greater frequency of injuries that constitute a factor of danger for the likely appearance of ankle injuries with the majority of ankle injuries being observed during dismounts and floor exercises. Further, the duration of daily training and the considerable repetition of jumps constituted risk factors. Ligament sprains of the ankle during landing are the most common injuries that usually occur after exercises with back rotation and particularly after back somersaults. The number of take-offs and more than 10 elements daily on the vault affect the appearance of ankle injuries with the most common injuries being Achilles tendinitis that occur after front rotation exercises. Conclusively, young gymnasts experience a great number of ankle injuries especially during dismounts. To prevent injuries and restrict pressure on the lower extremities, they must use supplementary soft pits and mats during training on the landing phase.

Keywords: gymnastics; risk factors, injury prevention

IZVLEČEK

Najpogostejša poškodba spodnjih okončin v športni gimnastiki je izvin gležnja. Namen te študije je bil raziskati dejavnike tveganja pri poškodbah gležnja pri mladih športnih telovadcih v obdobju dveh let. V študiji je sodelovalo dvesto športnih telovadcev, starih od 9 do 13 let, ki tekmujejo v skupinah novincev. Rezultati so pokazali, da je pogostost poškodb, ki predstavljajo dejavnik tveganja za verjetni nastanek poškodbe gležnja, večja v fazah doskoka in odskoka, pri čemer je bilo največ poškodb gležnja ugotovljenih pri sestopih in pri vajah na parterju. Poleg tega sta bila med dejavniki tveganja tudi trajanje dnevnega treninga in veliko število ponovitev skokov. Nateg vezi v gležnju med doskokom je najpogostejša poškodba, ki se običajno pojavi po vajah z obrati nazaj in zlasti po saltu nazaj. Število odskokov in več kot deset prvin dnevno na preskoku vplivajo na nastanek poškodb gležnja, pri čemer je najpogostejša poškodba vnetje ahilove tetive, ki se pojavi po vajah z obratom naprej. Zaključimo lahko, da mladi telovadci utrpijo veliko število poškodb gležnja, zlasti pri sestopih. Da bi preprečili poškodbe in zmanjšali pritisk na spodnje okončine, morajo med treningom faze doskoka uporabljati mehkejše gimnastične jame in blazine.

Ključne besede: gimnastika, dejavniki tveganja, preprečevanje poškodb

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INTRODUCTION

Artistic gymnastics (AG) is a spectacular sport in which gymnasts participate in various events incorporating skills based, in most cases, on the ability of the lower limbs such as in floor exercises (FE), vaulting (V), balance beam (BB), and during dismounts on all apparatuses. The degree of difficulty of the gymnastic skills practised and performed increases progressively from when gymnasts are young and continues through their growth years. In addition, the intensity and volume of training give rise to a concern about the risk of injury in these gymnasts. Further, gymnastics is a sport where there is always a real and present danger of physical injury. Sports injuries are a phenomenon with a variable interaction of risk factors. Injury has been defined as any gymnastic-related incident that resulted in the gymnast missing any portion of a practice or competitive event, beginning on the day of the injury (Caine et al., 1989). Several authors have examined injury patterns in artistic gymnastics in more traditional forms (Caine et al., 2003; Kolt & Kirkby, 1999; Bak et al., 1994). Injuries such as those that occur in AG generally result from the culmination of a pre-existing condition and/or a particular set of circumstances (Meeuwisse, 1994). The answer to what causes sports injuries has rarely been studied (Lysens et al., 1984). Take-off and landing are important phases in gymnastics routines. Numerous studies show that the most injured body parts in AG are the lower extremities (Kolt & Kirkby, 1999; Bak et al., 1994; Andrish, 1985; Hutchison & Ireland, 1995), especially in the ankle and knee joints (Bale & Goodway, 1990; Kirialanis et al., 2015; Marshall & Covassin, 2007; Tenvenrget et al., 1992) with ankle sprains being the most commonly reported injury (Caine et al., 2003; Marshall & Covassin, 2007; Caine & Nassar, 2005). Between 55%–65% of injuries in AG that occur on the lower extremities are related with high repetition frequencies, with 50%–70 % of lower limb injuries occurring in the tibiotalar and knee joints (Arampatzis et al., 2003). In addition, most injuries are related to the landing phase (Kirialanis et al., 2002; Kirialanis et al., 2003; Meeusen & Borms, 1992) that not only affects gymnasts' final rank during competition (Leskosek et al., 2010), but entails a high risk of injury mainly due to the high impact magnitudes of 14 to 18 body weight (BW) applied to one leg (Panzer, 1987) and to the mat's instability (Arampatzis et al., 2002; Arampatzis et al., 2003). Landing imposes forces on the body that must primarily be absorbed by the musculoskeletal components of the lower extremities. If the loads become too great for the body to accommodate, a potential injury situation arises (Dufec & Bates, 1990). In this sense, as Gervais (1997) stated, drawing up programmes with exercises for good landing, separated from the entire routine, would help reduce the impact forces during landing in gymnastics.

Previous studies showed that the magnitude of impact forces tends to increase with the skill complexity and with an increase in the falling height (Marinsek, 2010; Panzer, 1987) ranged from 3.9 to 14.4 times the gymnast's BW (Panzer, 1987). Take-off is also a phase used primarily in the vault, floor exercise (FE) and balance beam (BB) exercises. The take-off imposes forces on the body, especially in the musculoskeletal components of the lower extremities. Takei (1989) reports that the average horizontal and vertical forces during periods were 2970 N, which translated to 4.9 times the BW of the subjects. In addition, forces at take-off during different somersaults can be up to 13.9 times the participant's BW, whereas forces at the ankle required during tumbling take-offs and landings range from 5.0 to 17.5 times BW (McNitt, 1991). However, there is a lack of studies about the risk factors causing injuries during these two phases. This is one of the first studies to investigate lower limb injuries not only during competition but during training in a gymnasium. Accordingly, the purpose of this study was to examine young competitive artistic

gymnasts' risk factors for ankle injuries especially during the landing and take-off phases over a two-year period.

MATERIALS AND METHODS

Subjects

A total of 200 artistic gymnasts (100 males and 100 females), aged 9–13 years that compete in the recruits group participated in this study. Anthropometrics and training data are shown in Table 1. This study covers two 11-month seasons (September to July) and includes injury registration by all Northern and Southern Greece artistic gymnastics clubs. Informed consent for participation in the study was obtained from the parents of all gymnasts.

Table 1: Anthropometric characteristics and training data (mean values ± SD) of the sample (n=200).

	Male gymnast (n=100)	Female gymnast (n=100)
Age (years)	13 ± 3.3	11.53 ± 2.1
Body height (cm)	38.8 ± 13.8	32.4 ± 8.6
Body mass (kg)	144.8 ± 17.0	138.2 ± 13.1
Gymnastics experience (years)	6.0 ± 0.3	6.2 ± 0.2
Training sessions/week	6	6

Any injury was recorded through direct observation by the authors and a physiotherapist during practice in the gymnasium or during competition irrespective of the need for medical attention or time loss. In the majority of cases, the authors were in the gymnasium when the injury occurred, and an examination and interview with the gymnast was conducted at the time of the injury with respect to the injury mechanism and diagnosis. Any injury that occurred outside gymnastics was not included in this study. During the examination, the gymnast was asked about their injury history to be able to distinguish the injury type (acute injury or re-injury). However, in cases where they were not present the gymnast and the coach filled out an injury protocol and contacted a physiotherapist for a clinical examination within 24 hours of the injury occurring. One advantage was that our study reports the incidence of injuries that happened during competition and during training in the gymnasium where the gymnasts usually spent much more time preparing for competition. A weakness is that no sex differences regarding injuries were reported and that the injuries were not distinguished in practice and competition separately. The study was approved by the local Ethics Committee for Medical Research.

Statistical Analysis

An analysis of frequencies was used for the statistical treatment of the data and the level of significance was set as $p< 0.05$. Moreover, an analysis of correspondence was applied to determine the relationships between the categorical dependent variables.

Results

The analysis of frequencies showed that the gymnasts sustained 42.6% of ankle injuries during landing and 32.9% during take-off. The analysis of correspondence revealed that two factors explain 78.05% of the total variance of the variables included in the analysis (Table 2).

Table 2: Eigenvalues, % of variance explained and % cumulative variance of the factors explained the ankle injuries

Factors	eigenvalue	% of variance explained	cumulative variance
1st factorial axis (landing – fall - other)	0.0470	49.64	49.64
2nd factor factorial axis (landing-take off)	0.0269	28.42	78.05

The first factorial axis, which explained 49.64% of the total variance of all dependent variables, was created by the variables related to ankle injuries during take-off and are presented in Table 3 (Table 3). Ankle injuries in the take-off phase occurred mainly, in FE and V, during exercises with a front rotation (forward salto), and combinations of forward and backward saltos with pirouettes, causing tendonitis in the Achilles tendon. A gymnast sustained one ankle injury during the season, the time loss associated with the injury was more than two months and they usually engage in sustained physiotherapy care during the rehabilitation programme. Moreover, it is clear that the daily training duration (>4 hours), the repetition of blocking (> 20), the repetition of elements on the vault (>10) and the lack of a springboard floor can be risk factors for the appearance of ankle injuries at take-off, and there are usually re-injuries.

Table 3: Variables loaded in the 1st factor axis and related with ankle injuries during the take-off phase

Phase of injury	Variables	Coordinates	Absolute Contribution	Relative contribution
Take-off	Vault	0.39	8.0	0.92
	Exercises with front rotation (front salto)	0.29	5.3	0.73
	Floor Exercise	0.16	3.9	0.78
	One (1) time injured	0.08	1.0	0.36
	Tendinitis	-0.35	12.8	0.84
	Combination of exercises with front and backward rotation	-0.25	6.7	0.80
	Re-establishment in more than 2 months	-0.16	2.6	0.78
	Physiotherapy as a rehabilitation	-0.11	1.3	0.42
	Re-injury	-0.19	3.6	0.50
	Lack of acrobatic floor	-0.14	0.8	0.10
	Training above 4 hours daily	-0.11	2.2	0.38
	20 – 29 take-offs	-0.10	1.6	0.11
	10 – 19 vaulting elements	-0.07	1.3	0.38
	Not selected gymnasts	-0.06	0.8	0.96

The second factorial axis, which explained 28.42% of the total variance of all dependent variables, was created by the variables which are related with ankle injuries during the landing phase and are presented in Table 4 (Table 4). Ankle injuries during landings mainly occurred during forward saltos on the parallel bars (PB), horizontal bar (HB), rings (R) and uneven parallel bars (UB), causing ligament sprains. The time loss associated with the injury was less than a month for most gymnasts, they sustained one ankle injury during the season and did not need medical care. Further, ankle injuries upon landing usually occurred during practice in the gymnasium, with gymnast who do not practise specific landing exercises, with a daily training duration of 2 to 4 hours, and where the repetition of elements on the vault exceeds 20. Usually, they do not present with a re-injury when they continue training after the injury and they undertake physiotherapy for rehabilitation.

Table 4: Variables loaded in the 2nd factor axis and related with ankle injuries during landing

Phase of injury	Variables	Coordinates	Relative Attendance	Relative Attendance
Landing	Parallel Bars, Horizontal bar, Rings,			
	Uneven bars	0.51	21.3	0.74
	Backward rotation (salto backward)	0.20	6.4	0.60
	It needed physiotherapy	0.23	5.2	0.80
	Type of injury: ligaments or sprains	0.15	5.0	0.79
	Medical care	0.17	4.6	0.70
	Training 2 -4 hours daily	0.22	4.4	0.94
	Does not exist re-injury	0.24	4.3	0.74
	They don't execute special landing elements	0.13	3.0	0.50
	Re-establishment in less than 1 month	0.12	2.8	0.86
	Continuation of training after injury	0.12	2.2	0.58
	One (1) time injured	0.09	2.1	0.45
	They execute 20 – 30 vault elements	0.14	1.2	0.18
	Injuries at training period	0.07	1.2	0.88

Discussion

According to the analysis of correspondence (tables of frequencies), landing and take-off are the phases with a greater frequency of injuries that constitute a risk factor for the likely appearance of ankle injuries. It is obvious that the ankle joint is exposed to high loads because most events are performed with the take-off and landing on the feet. Our results support the data of Wadley and Albright(1993) who report that chronic diseases of laquers of molecules in the ankle are particularly due to the large number of repetitions of acrobatic back saltos and during the landing phase in FE and V. Further, our results are consistent with the findings of Kolt and Kirkby (1999) who report that the ankle joint of elite gymnasts was the most common location of injury and those of Caine and Nassar (2005) who found that ankle sprains were the most commonly reported injury in US female gymnasts and Caine et al. (2003) who report that the lower extremities are the most frequently injured body region in gymnasts.

ANKLE INJURIES DURING TAKE-OFF

Our results show that the take-off phase mainly influences the appearance of ankle injuries. Some gymnastics' apparatuses like the V for ankle injuries, and FE for ankle injuries during take-off, seem to have a greater risk of injury than other apparatuses. No previous studies have examined the relationship between the incidence of ankle injuries at take-off and the gymnastics apparatuses upon which they appear.

According to McAuley et al. (1987), the few injuries observed in vaulting could be due to the small time spent on this apparatus, a finding in conflict with those of Vergouwen (1986) who reported that most injuries occur on the vault. On the contrary, in the ankle joint at take-off the most common injury is Achilles tendinitis and it usually occurs after exercises with a front rotation (forward salto) and a contra salto. No report on the probability of ankle injuries during take-off supports this suggestion. This can be explained by the fact that in FE and on the vault a great number of take-offs are executed in which the ankle joint plays a more important role due to the particularity of the step on the springboard or the ankle at take-off where the calf muscles act more than the other muscles. Because these jumps are repeated many times, tendinitis occurs, particularly in the Achilles tendon, which needs a long time and particular care to ensure the right rehabilitation. Taunton et al. (1988) agree that repeated jumps can create injuries in new gymnasts but the most frequent type in this case are a*pophysitis* and Osgood Schlatter's disease. Further, ankle injuries during take-off are more serious than injuries upon landing. These results are strengthened by the finding that with ankle injuries at take-off a longer time is required for rehabilitation (>2 months) than ankle injuries during landing (<1 month), and they also need physiotherapy for rehabilitation and, despite that, when gymnasts with an injured ankle have tried to continue training after the injury they have incurred a re-injury.

Perhaps, this is due to the special impact forces imposed on the ankle joint at take-off which range from 1.9 to 4.9 times BW [31]. Moreover, the great number of take-offs (> 20) and more than 10 elements per day on the V apparatus affect the appearance of ankle injuries at take-off, a finding in agreement with those of Taunton et al. (1988). Further, Hudash and Albright (1993) report that because of the large number of repetitions on the springboard there are chronic injuries particularly in the ankle joint. The relationship of the time of training and the likely appearance of injuries has been investigated generally for injuries in gymnastics and not specifically for ankle injuries in particular phases.

Our result showing that a great number of take-offs leads to the appearance of injuries is in relation with other studies (Hudash & Albright, 1993; Taunton et al., 1988). Finally, it is realised that 'selection' is not only a factor which determines an athletic career but also plays an important role in the likely appearance of injuries, which can be interpreted from the fact that 'selected' gymnasts will also have suitable mobility characteristics and fitness, which several researchers believe constitute risk factors that affect the appearance of injuries (Meeusen & Borms, 1992; Micheli, 1985; Steele & White, 1986).

ANKLE INJURIES UPON LANDING

The analysis of equivalences revealed that the greater number of ankle injuries on landing has a stronger cross-correlation with gymnastics apparatuses that have a certain height, such as the PB, HB, rings and UB, a finding that partly agrees with the data of Wadley and Albright (1993) according to which 7 out of 18 ankle injuries occur during landing in FE, or after dismounts from gymnastics apparatuses. This means that the majority of ankle injuries resulted from falls during dismounts and FE where gymnasts constantly land from a great height while rotating and/or twisting, leading to high rates of both initial and recurrent ankle injuries. Ligament sprains in the ankle during landing are the most common injuries that usually occur after exercises with a back rotation and particularly after back somersaults. This finding verifies the valuable data of Caine et al. (1989) and Vergouwen (1986), but contradicts the results of Pettrone and Ricciardeli (1987) which state that 16 out of 51 ankle injuries occurred upon dismount during backward somersaults with twists. Further, Andrish (1985) shows that ligament sprains are in second place in terms of frequency but are the most serious and need surgical intervention. In gymnasts with ankle injuries, in many cases there was a continuation of training without particular relapse problems being presented. This finding agrees with those of Bos and Sol (1982) who report that landing during exercise on the vault and after dismounts can create large forces in the ankle joint and particularly in the ligaments.

Other factors which contribute to the appearance of injury increasing the frequency of ankle injuries upon landing are the duration of daily training (> 4 hours daily). However, no reports exist for ankle injuries upon landing in relation to the time of training. Our results are partly consistent with the findings of Goodway et al. (1989), which show that inadequate safety equipment is related with a great number of injuries, whereas Lowry and Le Veau (1982) show that the presence of safety equipment does not ensure that it will actually be used. In line with previous aspects, Meeusen and Borms (1992) report that various spotting equipment is used for protection from various injuries, while emphasising that it remains a question for investigation how much that really happens. In contrast with the data of Pettrone and Ricciardelli (1987) who did not find a significant relationship between injuries and safety equipment, our results do not confirm this relationship for ankle injuries. However, Wilson et al. (1989) found that peak VGRF was reduced by 50% with the use of a mat and a sprung floor, compared with a mat placed directly on a concrete floor. In their review, Daly et al. (2001) report that no formal controlled studies had evaluated the effectiveness of matting, sprung floors, padded vaults, or other protective devices and suggest that safety devices and protective equipment are designed to reduce the magnitude of the impact forces imposed on the musculoskeletal system and thereby the potential for injury.

Gymnasts who do not use special exercises for landing in the 'training season' and involve a large number of jump repetitions (>20 jumps daily on the vaulting horse) have increased probabilities of ankle injuries, a finding that is confirmed by the value and relative attendance in the analysis of correspondence.

The lack of relevant reports does not allow the making of a finding in the present research on the particular relationship. However, our results resemble those of Hudash and Albright (1993) who state that the high number of jumps on the springboard and landings create particular problems for the ankle joint. Nevertheless, some researchers have characterised certain characteristics as risk factors that affect the appearance of injuries, such as a big height and weight (Steele & White, 1986).

CONCLUSION

The findings of this study indicate that young gymnasts experience a large number of ankle injuries with most injuries being related to landing, especially during forward salto dismounts from apparatuses. It was mentioned that all gymnasts were a member of the Hellenic Gymnastic Federation and belonged to different gymnastic clubs. For this reason, it is possible that the factors affecting injuries may differ between clubs, thus affecting the generalisability of our study results. Several factors such as training methods, equipment and coaching may vary from one gymnastics club to another. In addition, coaches must primarily use supplementary soft pits and mats during training to restrict pressure on the lower extremities in the landing phase. Further, strict control and recording of the amount of exercises performed in daily training must be undertaken to regulate the progressive volume of training, especially in this particular age group of gymnasts. In addition, injuries related with the take-off phase occur in FE and V, causing tendonitis of the Achilles tendon.

RECOMMENDATIONS

1. To incorporate special landing exercises to increase proprioception of the lower limbs.
2. Gymnasts must do strengthening exercises for the ankle joint that resemble the take-off phase.
3. To use foam mats to enhance proprioception of the ankles via strengthening exercises.
4. To avoid injuries, mental training could be a component of preparing a new skill.

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