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INJURIES AND ILLNESSES AMONG COMPETITIVE NORWEGIAN RHYTHMIC GYMNASTS DURING PRESEASON: A PROSPECTIVE COHORT STUDY OF PREVALENCE, INCIDENCE AND RISK FACTORS

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ABSTRACT

Objectives: Rhythmic gymnastics is an Olympic sport that demands high training volume from early age. We investigated the extent of, and risk factors for, injuries among competitive Norwegian rhythmic gymnasts.

Methods: One-hundred and seven of 133 (80.5%) female rhythmic gymnasts (mean age: 14.5 years (SD 1.6), mean BMI: 18.9 (SD 2.2)) participated. All gymnasts completed a baseline questionnaire and the "Triad-Specific Self-Report Questionnaire". Injuries, illnesses and training hours were recorded prospectively for 15 weeks during preseason using the "Oslo Sports Trauma Research Center Questionnaire on Health Problems" (OSTRC-H2).

Results: Response rate to OSTRC-H2 was 97%. Mean overuse and acute injury prevalence were 37% [95% CI: 36 – 39%] and 5% [95% CI: 4 – 6%], respectively. Incidence was 4.2 overuse injuries [95% CI: 3.6 – 4.9] and 1.0 acute injuries [95% CI: 0.5 – 1.6] per gymnast per year. Overuse injuries in knees, lower back and hip/groin represented the greatest burdens. Previous injury increased the odds of injury (OR 30.38, [95% CI 5.04 – 183.25]), while increased age (OR 0.61 per year, [95% CI: 0.39 – 0.97]) and presence of menarche (OR: 0.20, [95% CI: 0.06 – 0.71]) reduced the odds of all injuries and substantial injuries, respectively.

Conclusions: Overuse injuries were common among Norwegian rhythmic gymnasts. Younger gymnasts had higher all-injury risk. Gymnasts who were not menstruating had higher substantial injury risk. Injury prevention interventions should start at an early age and focus on preventing knee, lower back, and hip/groin injuries.

SUMMARY BOX

“What are the new findings?”

1. Overuse injuries are the most common injury type.
2. Overuse injuries in knees, lower back and hip/groin represented the greatest burdens among competitive Norwegian rhythmic gymnasts.
3. Rhythmic gymnasts’ injury risk over time was substantially increased if they had a previous injury at baseline. In addition, younger gymnasts had higher all-injury risk, while non-menstruating gymnasts had higher substantial injury risk.

“How might it impact on clinical practice in the near future?”

1. Injury prevention interventions should start at an early age to avoid the first injury.
2. Future preventive programs should focus on knees, lower back and hip/groin.
3. Knees, lower back and hip/groin are anatomical areas that need attention in future clinical studies.

INTRODUCTION

Rhythmic gymnastics (RG) debuted as an Olympic sport at the 1984 Olympic Games. It is a female sport, combining movements from classical ballet with strength and fitness from artistic gymnastics and modern dance. The gymnasts perform routines with music, containing difficult bodily maneuvers coordinated with manipulation of hand-held apparatus; rope, hoop, ball, clubs and ribbon. All routines include leaps, turns, balances and acrobatic maneuvers, and most elements require extreme flexibility and strength[1]. The gymnasts compete either as individuals or in groups of five. To reach elite level, high training volume is required from early age—usually as early as 5-6 years in the dominant Eastern European nations and 8 – 10 years in other nations[2, 3].

To date, there are few high-quality prospective studies of injuries among rhythmic gymnasts[4, 5]. These state that the most common injury locations in RG are the lower back and lower limb, with prevalence rates of 86% and 22% for lower back injuries and 39% for lower limb injuries[4, 5]. RG is governed by the Federation Internationale de Gymnastique (FIG), which designs the competition rules; Code of Points (CoP). The Code of Points is renewed in every Olympic cycle, and each Code of Points defines different mandatory elements with the body and hand-held apparatus. These elements change the pattern of movements and training load.

Previous Code of Points mostly honoured body elements with repeated lower back hyperextensions; the lower back has been the most commonly reported location of overuse injuries in previous studies[1, 4-10]. The current Code of Points (2017) honours more body elements with split leg positions, as well as more complex manipulation of the hand-held apparatus. The Code of Points has changed three times since the latest prospective study of injuries was published in 2007[5]. Those results may not be generalized to rhythmic gymnasts performing in the early 2020s.

Previous studies suggested that a weekly training volume exceeding 20 – 30 hours, hypermobility, poor technique and inappropriate training load were potential risk factors for injuries in RG[10-12]. In addition, rhythmic gymnasts commonly have low BMI (<18.5) and percentage of body fat, low energy availability, disordered eating and menstrual dysfunction[13, 14], which increase athletes' vulnerability to injuries[15, 16].

Our aim was to investigate the extent, location and potential risk factors (age, BMI <18.5, previous injury, weekly training load, hypermobility, lack of menarche and disordered eating) of injuries among competitive Norwegian rhythmic gymnasts. To record acute injuries, overuse injuries and illnesses the "Oslo Sports Trauma Research Center Questionnaire on Health Problems" (OSTRC-H2)[17] was distributed once a week.

MATERIALS AND METHODS

We invited all competitive rhythmic gymnasts in Norway (133 gymnasts from 22 clubs) to participate in a prospective cohort study. To be eligible for inclusion, gymnasts needed to be born in 2005 or earlier, compete at the highest national or international level of RG in Norway, and understand the Norwegian language. All gymnasts (or legal guardians of those under 16 years of age) gave written informed consent to participate. The study was approved by the Regional Ethics Committee (2018/1047/REK Sør – Øst B, 09.08.2018) and the Norwegian Centre for Research Data (NSD: 148616, 10.10.2018). Data were collected between September and December 2018.

Main outcome measurement

Prevalence and incidence of injuries and illnesses were registered weekly for 15 weeks during preseason using the OSTRC-H2[17]. A hyperlink to the OSTRC-H2 was sent automatically by SMS to the gymnasts' cell phones every Sunday using an online platform (AthleteMonitoring, Fitstats Inc., New Brunswick, Canada), and daily reminders were sent to non-responders.

The OSTRC-H2 starts with four questions on symptoms and consequences of injury and illness the past 7 days[17, 18]. Based on the gymnast's answers, extra information was recorded such as the type of health problem (acute injury, overuse injury or illness – all defined in an information box within the OSTRC-H2), injury location and mechanism, illness symptoms, date and time loss and medical attention. In addition to information on health problems, we recorded gymnasts' weekly hours of training/competition and use of analgesic medications. Injury was defined as a physical complaint or observable damage to body tissue produced by the transfer of energy, regardless of whether it received medical attention or its

consequences with respect to impairments in training or competition[17-19]. Acute injury is caused by a single, clearly identifiable energy transfer (e.g. fall or collision)[17-19], while overuse injury is caused by multiple accumulative bouts of energy transfer without a single, clearly identifiable event responsible for the injury[17-19]. Illness was defined as a complaint or disorder experienced by the gymnast not related to injury, regardless of whether it received medical attention or its consequences with respect to impairments in training or competition[17-19]. Illness can be either physical or psychological. A psychological illness can be a response to psychological trauma suffered during sport (i.e. abuse, harassment, post-traumatic stress disorder, response to sport injury) or suffered outside of sport[17, 18]. Health problems were categorized as substantial if they led to moderate or severe reductions in sports performance or participation, or time loss. To assure data quality, the principle investigator contacted gymnasts who registered ambiguous responses within five days of their response.

Each week, we calculated the prevalence of each type of health problem by dividing the number of reported problems by the number of questionnaire responses. Incidence was expressed as the rate of new cases per gymnast year. Using previously-described methods[20], we calculated a severity score of 0 – 100 for each health problem, each time it was reported. These scores were summed for each type of health problem to reflect its relative burden[21]. To illustrate the burden we plotted the severity (cumulative severity scores) and incidence of each injury location and illness type[21].

Risk factor analyses

We identified a number of potential risk factors based on previous literature in similar sports[22-27] and focus group discussions with experienced RG coaches and gymnasts. These included demographic and background variables (age, BMI <18.5, previous injury), weekly hours of training, hypermobility and the female athlete triad. Previous injury was defined as an injury that had led to absence from training/competition and/or medical attention before inclusion. All gymnasts completed a baseline questionnaire in August 2018, and hypermobility was assessed clinically using a Beighton score[28]. Beighton score consists of nine tests evaluated for reliability and recommended by the British Society of Rheumatology[29]. The rhythmic gymnasts were categorized as hypermobile if they scored positive on five or more of the nine tests[30]. One examiner, a trained sports physiotherapist

(MCDG), performed all clinical assessments. Data on the female athlete triad were assessed by the “Triad-Specific Self-Report Questionnaire”[16] at the time of the clinical assessment. The "Triad-Specific Self-Report Questionnaire" examines the three components involved in the female athlete triad; 1) low energy availability with or without disordered eating, 2) menstrual dysfunction, and 3) low bone density[16]. In addition, two questions from the “Low Energy Availability in Females Questionnaire” (LEAF-Q)[31] was used to cover menarche.

Statistical analysis

All statistical analyses were performed in R[32] using the Ime4 package[33]. Demographics, background variables and potential risk factors are presented as mean with standard deviation (SD) and frequency with percentage. Kolmogorov-Smirnov and Shapiro-Wilk tests were used to assess the normal distribution[34]. Potential risk factors were entered into generalised linear mixed-effects models with both all injuries and substantial injuries as outcomes. Univariate analyses of potential risk factors were made before multivariable models were built. The multivariable model with the lowest AIC (Akaike information criterion) for both outcomes were chosen as the final model and included the risk factors previous injury, age and menarche. The results are reported as odds ratios (OR) with 95% CI.

RESULTS

One-hundred and seven (80.5%) of the 133 invited gymnasts consented to participate in the study, and none were lost to follow-up. Reasons for not participating were unknown in 22 cases, while two assigned to the study too late, and two had retired from the sport or changed to a lower competition level not included in the study. In total, 1605 questionnaires were sent to the gymnasts and 1564 were completed, resulting in a response rate to the OSTRC-H2 of 97%. The response rate to the baseline questionnaire, the “Triad-Specific Self-Report Questionnaire” and clinical examination was 100%, and the results are shown in Table 1. Mean hours of weekly training measured prospectively in the OSTRC-H2 was 15.7 (7.8), while the baseline questionnaire found a mean of 18.4 (7.2). Weekly prevalence of medication use (analgesic) was 7% [95% CI 7 – 8%].

Table 1: Results of the baseline questionnaire, the "Triad-Specific Self-Report Questionnaire" and clinical examination of all included rhythmic gymnasts (n=107).

	Mean (± SD)
Age (years)	14.5 (1.6)
Height (cm)	162.6 (7.0)
Weight (kg)	50.1 (8.7)
BMI (kg/m^2)	18.9 (2.2)
Age when started RG (years)	7.5 (1.9)
Years as a competitive gymnast	4.3 (1.5)
	Proportion of gymnasts (%)
BMI ≤ 18.5	47 (43.9)
Previous injury	82 (76.6)
Acute injury at inclusion	9 (8.4)
Overuse injury at inclusion	54 (50.5)
Hypermobility (Beighton score ≥5)	50 (46.7)
Numbers with female athlete triad	
Bone health	
Stress fracture[1]	6 (5.6)
Low bone density	0 (0.0)
Menstrual function	
Menarche	70 (65.4)
Age at menarche	13.0 (1.2)
Energy availability	
Disordered eating[2]	10 (9.3)
Diet	13 (12.1)
Worried about own body weight	14 (13.1)
Attempts to change body weight	22 (20.6)
Recommended to change body weight	23 (21.5)

[1] Present or previous stress fracture. [2] Present or previous disordered eating.

Prevalence and incidence of injuries and illnesses

During the registration period, 116 substantial injuries (22 acute and 94 overuse) were reported by 85 gymnasts. The weekly mean overuse injury prevalence was 37% [95% CI: 36 –39%], of which 21% [95% CI: 20% - 23%] was categorized as substantial. The weekly mean acute injury prevalence was 5% [95% CI: 4 – 6%], with 3% [95% CI: 2% - 3%] representing

substantial injuries. The incidence rate was 4.2 new overuse injuries [95% CI: 3.6 – 4.7] and 1.0 new acute injuries [95% CI: 0.5 – 1.6] per gymnast per year. The incidence rate for substantial injuries was 2.6 [95% CI: 2.1 - 3.6] and 0.5 [95% CI: 0.5 - 1.0] for overuse and acute injuries, respectively. For illness, the weekly mean prevalence was 7% [95% CI 5 – 9%] with 4% [95% CI 3 – 5%] categorized as substantial. The incidence rate for illness was 2.6 [95% CI 2.1 – 3.1] per gymnast per year, of which 1.6 [95% CI 1.0 – 2.1] was substantial. Fig. 1 shows an overview of the prevalence.

Injury and illness locations and time-loss

Table 2 shows locations for acute injuries, overuse injuries and illnesses as well as time-loss. The knees, lower back and hip/groin were the most common injury locations. The majority of health problems were characterized as slight or mild.

Table 2: Injury and illness locations and time-loss in rhythmic gymnasts (n=107). The cut-off points for the injury categories is based on the IOC consensus statement[19].

Injuries	Cases	Slight (0 days)	Mild (1-7 days)	Moderate (8-28 days)	Severe (>28 days)	Total time-loss (days)
Total	171	109	48	13	1	363
Acute injury	33	13	18	2	0	65
Ankle	6	1	5	0	0	11
Foot	7	6	1	0	0	2
Hand	4	2	2	0	0	2
Head	2	2	0	0	0	0
Hip/groin	2	0	1	1	0	23
Knee	3	1	2	0	0	3
Lower leg	1	0	1	0	0	3
Neck	3	0	3	0	0	5
Pelvis	1	0	1	0	0	2
Shoulder	1	0	1	0	0	2
Thigh	3	1	1	1	0	12
Overuse injury	138	96	30	11	1	298
Ankle	7	4	2	1	0	11
Ribs/upper back	4	4	0	0	0	0
Foot	14	13	1	0	0	2
Hip/groin	23	17	5	1	0	31
Knee	33	22	5	5	1	169
Lower back	27	17	6	4	0	55
Lower leg	11	8	3	0	0	6
Neck	2	1	1	0	0	4

Pelvis	7	3	4	0	0	10
Shoulder	5	4	1	0	0	6
Thigh	4	2	2	0	0	4
Wrist	1	1	0	0	0	0
Illness	Cases	Slight (0 days)	Mild (1-7 days)	Moderate (8-28 days)	Severe (>28 days)	Total time-loss (days)
Total	85	22	59	3	1	193
Gastrointestinal	6	2	3	1	0	17
Neurological	5	2	3	0	0	3
Respiratory	62	16	43	2	1	152
Undiagnosed	12	2	10	0	0	21

Relative burden and risk matrix

Overuse injuries represented 75% of the total cumulative severity score number, while acute injuries represented 9% and illness the remaining 16%. Fig. 2 shows that overuse injuries in knees, lower back and hip/groin represents the greatest burdens.

Risk factors

Table 3 shows univariate analyses of potential risk factors associated with all injuries and substantial injuries. Previous injury was statistically significant alone for both outcomes, while menarche was statistically significant only for substantial injuries.

Table 3: Univariate analyses of potential risk factors associated with all injuries and substantial injuries in rhythmic gymnasts (n=107)

Outcome: All injuries			
Risk factor	Odds Ratios	95% CI	p-value
Previous injury	21.43	3.65 – 125.85	0.001*
Age (per year)	0.72	0.45 – 1.14	0.165
BMI (>18.5)	0.83	0.66 – 1.03	0.092
Hypermobility	1.15	0.30 – 4.48	0.837
Menarche	0.29	0.07 – 1.20	0.088
Disordered eating	1.88	0.17 – 20.53	0.604
Outcome: Substantial injuries			
Risk factor			
Previous injury	11.21	2.14 – 58.61	0.004*
Age (per year)	0.75	0.50 – 1.21	0.161
BMI (>18.5)	0.85	0.71 – 1.02	0.085

Hypermobility	1.52	0.42 – 5.53	0.529
Menarche	0.22	0.06 – 0.78	0.019*
Disordered eating	2.72	0.31 – 23.82	0.366

*Statistically significant, p<0.05.

Table 4 shows the final multivariate model for risk factors associated with all injuries and substantial injuries. Since age and menarche are highly correlated, they were not combined when assessing potential multivariable models. The best model fit for all injuries included age, while the best model fit for substantial injuries included menarche.

Table 4: Final multivariate model showing odds ratios with 95% confidence intervals for risk factors associated with injuries and substantial injuries in rhythmic gymnasts (n=107).

Outcome: All injuries			
Risk factor	Odds Ratios	95% CI	p-value
Previous injury	30.38	5.04 – 183.25	<0.001*
Age	0.61	0.39 – 0.97	0.035*
Time	0.97	0.94 – 1.01	0.170
(Intercept)	49.31	0.08 – 31630.57	0.237
Outcome: Substantial injuries			
Risk factor			
Previous injury	11.09	2.26 – 54.37	0.003*
Menarche	0.20	0.06 – 0.71	0.013*
Time	1.00	0.96 – 1.04	0.864
(Intercept)	0.03	0.01 – 0.16	<0.001

*Statistically significant, p<0.05

DISCUSSION

Norwegian rhythmic gymnasts have high prevalence and incidence of overuse injuries during preseason. Knees, lower back and hip/groin were the most common injury locations in our study and represented the greatest burdens. Previous injury and younger age were risk factors for injury, and previous injury and lack of menarche were risk factors for reporting a substantial injury. Illness rates were very low, and represented a small part of the overall burden of health problems.

Injury prevalence and methodology

The use of OSTRC-H2 represents a new and different methodology within epidemiological research[17]. Compared to other instruments traditionally used, OSTRC-H2 has been shown to better document injuries and illness among athletes, especially overuse injuries, due to the use of more variables then time-loss alone as a cut-off for registration[17, 20]. Several athletes continue to train and compete despite having an injury[35]. To our knowledge, this is the first study within RG where OSTRC-H2 is used to document different types of health problems. Hence, comparisons of prevalence and incidence rates with previous studies within RG are challenging.

We were only able to identify one study within RG that report injury prevalence. Mørk et al found an injury prevalence of 38% at training and 6.5% in competitions[36]. This study was not conducted during the latest CoP, nor specify the prevalence of overuse and acute injuries separately[36]. The present study found higher overall prevalence of injuries than Mørk et al[36], possibly because their measurement method focused more on acute injuries than overuse injuries with a time-loss definition[36]. When comparing our prevalence rates with a study using OSTRC-H2, conducted among female elite sport athletes from Sport Academy High Schools in Norway including endurance, technical and team sports, our study shows higher prevalence rates for all injuries, and especially overuse injuries (37.0% vs 19.0%)[37]. This is also the case when comparisons are made only with the technical sports (37.0% vs 20.0%)[37].

Injury incidence

We have not been able to find published studies which state the incidence of overuse and acute injuries separately, and the three identified studies within RG are not from the latest CoP[4-6]. Hutchinson et al reported an incidence of 474 injuries per 490 training sessions and 68 (21 – 94) injuries during seven weeks[4], Cupisti et al found an injury incidence of 1.08 new injuries per 1000 hours of training[5], while Edouard et al stated an incidence of 73.4 ± 30.2 injuries per 1000 registered gymnast during the course of the 2008, 2012 and 2016 Olympic Games[6]. Different calculation methods of incidence, in addition to use of both prospective and cross-sectional study designs, prevents direct comparison with our results.

Injury locations

Knee injuries have been frequently reported in previous studies among rhythmic gymnasts[4-6, 10], however, this is the first study were knee is the most frequently reported injury location. FIG adjusted the CoP in 2009, removing stressful elements for the knee joint after an increase in reported knee injuries in the early 2000[4, 5, 10]. The present high rates of knee injuries might be explained by high training volume while the skeleton is still growing and developing, resulting in stress of the many growing zones of the knee joint [42].

Low back pain remains a major challenge among competitive rhythmic gymnasts, although the current Code of Points does not demand body elements with hyperextension of the lumbar spine to obtain a high score. Even so, many gymnasts still hyperextend their lower backs, especially in acrobatic maneuvers and leaps. Some of these elements contain simultaneous hyperextension and rotation, which may be even more harmful to the lower back then isolated hyperextensions.

The current Code of Points has given body elements with split leg positions equally high values as elements with lower back hyperextension. Split positions demand great range of motion of the hip joints, and can therefore lead to compression/impingement of structures close to the joint or overloading of the muscles in the area. This may explain why hip/groin is the third most frequently reported location of injury in the present study. A study conducted during the latest CoP supports this finding with hip/groin being the second most frequently injured area lateral to lower back[6].

Training and competing despite pain—par for the course

A majority of gymnasts in this study continued training and competing, and had often few days of time-loss (0 – 7 days), despite a high prevalence and incidence of injuries. Previous research within RG shows the same tendency with most injuries categorized as negligible or mild, with 0 – 14 days of time-loss as the most common[4, 5, 10, 36]. Our study also showed that analgesic use was prevalent, but not in an amount that can be used as a plausible explanation for continuing training in spite of reported injuries. One could speculate that cultural values and unwritten norms on how to deal with pain and injuries in the rhythmic gymnasts' environment can be an explanation. A qualitative study showed that a common

attitude among rhythmic gymnasts were that “gymnasts who want to reach elite level must withstand pain and do not skip training because of pain or injuries”[38]. This study was conducted among gymnasts at the same age and competition level as in our study.

Burden of injury, the risk matrix and risk factors

Several studies within RG support the findings that overuse injuries are more common and represents a greater burden than acute injuries[4, 6, 11]. This is the first study of rhythmic gymnasts to visualise burden as a risk matrix. Overuse injuries in knees, lower back and hip/groin posed the greatest risk because they occurred frequently and had the greatest consequences. Existing injury prevention programs designed for RG contain several exercises for the lower back, but there is little focus on exercises for the knees and hip/groin[7].

We have not been able to identify studies within RG that supports our finding that previous injury increases the odds of injury. Previous injury as a risk factor of musculoskeletal injuries is, however, well known in other sports [39, 40]. To our knowledge, this is the first study within RG to find an association between age and lack of menarche and injuries. Increased age as a risk factor reducing the odds of injury in the present study might be explained by the fact that the majority of the included gymnasts were under 16 years of age. In general, the physeal growth is not complete until between the ages of 16 and 20, and a large amount of training while the skeleton is still growing and developing makes the musculoskeletal system more vulnerable to injuries [42]. Furthermore, age as a risk factor might be an expression of selection bias. If some gymnasts stop the sport due to injuries, gymnasts older than 16 years may represent the “survivors” in their age groups (i.e. those less prone to injury). Since age and menarche are closely related, it is likely that the explanation used for age (degree of maturation) also is applicable as explanation on why presence of menarche seems protective of substantial injuries.

Tringali et al[12] found that hypermobility increases the odds of injury in RG[12], but there was no association between hypermobility and injury in the present study. A possible explanation may be the use of different measurement methods to diagnose hypermobility. Tringali et al analyzed buccal swab tests to quantify the frequency of common polymorphisms

linked to genes correlated with joint mobility[12], while the present study used Beigthon score to diagnose hypermobility.

Strengths and limitations

The strengths of the present study are the prospective design and that relevant risk factors expressed in focus groups were analysed. We included 80.5% of the total population of competitive rhythmic gymnasts in Norway, and achieved a consistently high response rate throughout the study. This ensured both high internal and external validity, with the potential to generalize the results to all competitive Norwegian rhythmic gymnasts. The use of reliable and valid measurement methods for prevalence and incidence of injuries and illnesses, as well as for hypermobility, can also be considered a strength of the study.

Limitations of the present study are the relatively small population of rhythmic gymnasts in Norway with subsequent increased risk of type 2 error and low statistical power. The latter resulted in wide confidence intervals in the risk factor analyses. In addition, the OSTRC-H2 is not validated specifically for youth athletes, and the definitions of certain health problems used at the time (e.g. psychological illness vs mental health problems) were unfortunate and probably contributed to underestimation the problem. The use of the “Triad-Specific Self-Report Questionnaire" also made it difficult to accurately diagnose factors related to the female athlete triad. The registration period was short and restricted to the preseason. A recent study of rhythmic gymnasts found that training load was higher and recovery time was shorter during the competitive season[41]. Registration of injuries throughout the whole year might have revealed higher prevalence and incidence rates, as well as other anatomical locations affected by injuries and risk factors. We note that as results are based on self-reported data, conclusions on risk factors and preventive measures should be interpreted with caution. The results from competitive Norwegian rhythmic gymnasts can probably be generalized to gymnasts in the other Nordic countries, but may not be generalizable to rhythmic gymnasts with higher training dosage.

Conclusion

Competitive Norwegian rhythmic gymnasts have a high prevalence and incidence of overuse injuries during preseason. Our data provide a rationale for injury prevention interventions to start at an early age—we suggest as early as before 10 years of age. The gymnast's injury risk over time was substantially increased if they had a previous injury at baseline. In addition, younger gymnasts have higher all injury risk over time, while non-menstruating gymnasts have higher substantial injury risk. Based on the results from the present study the knees, lower back and hip/groin are anatomical areas that need attention in future clinical studies and preventive programs within rhythmic gymnastics.

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COMPETING INTERESTS:

None declared.

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CONTRIBUTORSHIP:

All authors participated in the study design and development, analysis and interpretation of data, and writing of the manuscript.

DATA SHARING:

Please contact the authors with requests to access anonymised data.

PATIENT INVOLVEMENT:

A focus group, containing three experienced coaches and three active gymnasts, discussed the risk factors included in the present study. The focus group found that no changes were necessary to the study.

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LEGENDS OF FIGURES

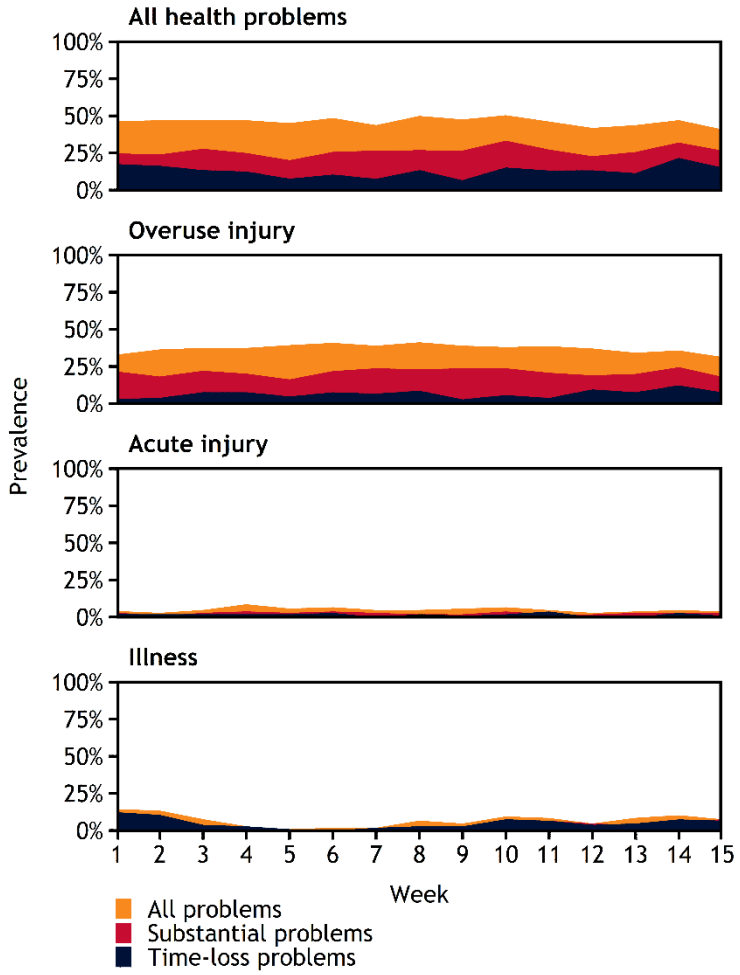

Fig. 1: Prevalence of all health problems, overuse injuries, acute injuries and illness.

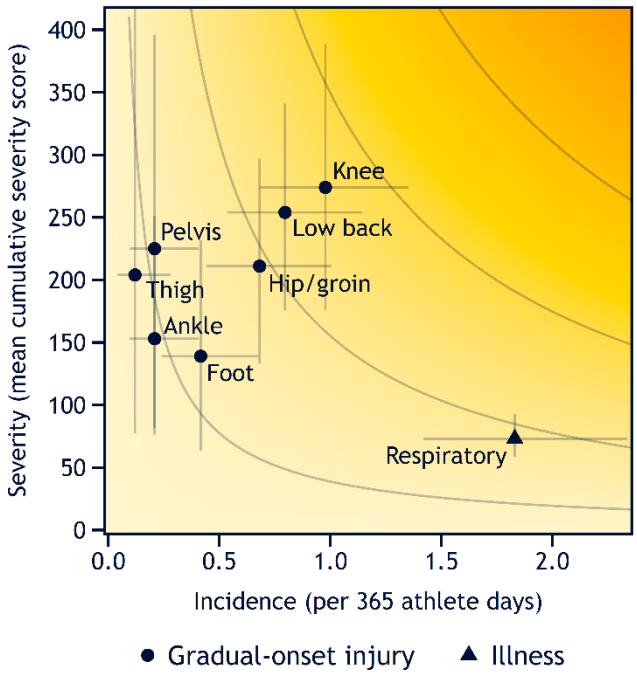

Fig. 2: Risk matrix illustrating the incidence and average cumulative severity scores of the 8 highest-burden injury locations/illness types.