**Appendix C: Studies examining the influence of sport, exercise, training load and competition on the incidence of illness**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Reference** | **Study design** | **Sport** | **Population (number, level, sex, age)** | **Illness definition / measure** | **Study duration** | **Measurements / monitoring** | **Load monitoring** | **Load studied** | **Multiple risk factors for illness included** | **Analysis** | **Main findings** |
| **Ext** | **Int** | **Absolute** | **Change in training load** | **Competition** | **Single risk factor model** | **Multiple risk factor model** |
| Svendsen et al 2016 [[1](#_ENREF_1)] | Prospective cohort | Cross country skiers | 39 Elite (medal winners=16)M=22, F=17> 18 years | UR infectionsGIT infections | 7-8 years | UR and GIT infectionsTraining monitored using daily logs over 7-8 yearsNumber of competitionsNumber of days at altitudeNumber of international flights  | Y | Y | Y | Y | Y | Y |  | Y | * UR infections more prevalent in winter/spring than summer
* OR for illness increased by competition (2.9) and international travel (4.9)
* Training load did not influence odds ratio for illness
* Athletes with higher training monotony had 13% lower risk of illness
* Medal-winning athletes have lower illness rates than their less successful counterparts
 |
| Raysmith et al, 2016 [[2](#_ENREF_2)] | Prospective cohort | Track and filed athletes | 33Elite> 18 years | Illness episodes | 5 seasons (years) | Illness episodes (medical support team diagnosis)Training load (weekly)Illness burdenPerformance goals | Y | Y | Y |  | Y | Y |  | Y | * Most illnesses (50%) occurred in the two months prior to competitions
* Increased illness burden is associated with a reduction in achieving performance goals
 |
| Thornton et al 2015 [[3](#_ENREF_3)] | Prospective cohort | Rugby League | 32Professional rugby league playersMales26 ± 4.8 years | Illness episodes | 29 weeks | Illness episodes. Overall well-being and muscle soreness.Multi-component self-reported questionnaire weekly  |  | Y |  | Y | Y |  |  | Y | * Internal training load (TL) measures predict self-reported illness
* Weekly TL >2765 AU, monotony >0.78 AU and strain >2282 AU were strong predictors of the incidence of illness
* Perceptual ratings of overall wellbeing and muscle soreness are related to the incidence of self-reported illness
 |
| Veugelers et al 2015 [[4](#_ENREF_4)] | Prospective cohort | Australian football | 45EliteMale> 18 years | Illness episodes (not system specific) | 15 weeks | Illness episodes recorded by team doctorTraining load (daily) (session RPE) (low and high training load) | Y | Y | Y | Y |  |  |  | Y | * The odds of illness was significantly lower in the high training load (RPE field)
 |
| Svendsen et al 2015 [[5](#_ENREF_5)] | Prospective cohort | Cross country skiers | 44EliteM=27, F=1718-32 years | URS episodes | 2-3 years | URS episodesTraining monitored using daily logs Effect of participating in a competition (11-day Tour de Ski) | Y | Y | Y |  | Y | Y |  | Y | * 48% of those who took part in Tour de Ski became ill during or after the event vs. 16% of those who did not participate
 |
| Hellard et al 2015 [[6](#_ENREF_6)] | Prospective cohort | Swimmers | 28 Elite (International=8 and national=20)M=14, F=1416-30 years | URS episodesOther illnesses | 4 years | URS episodesOther illness (pulmonary, GIT, urogenital)Training monitored weekly  | Y | Y | Y | Y | Y | Y |  | Y | * URS episodes more prevalent in winter
* Odds of illness 50-70% higher during intensive training periods than in normal training and competition (10% increase in URS risk with 10% increase in training load)
* Illness rates lower among international vs. national level athletes
 |
| Hausswirth et al 2014 [[7](#_ENREF_7)] | Randomised controlled trial (RCT) | Triathletes | 27 (Control=9, Overload training=18)Non-elite (regular training) Male | URS episodes | 3 weeks | URS episodesTraining loadOther: POMS, Performance, Sleep | Y | Y | Y |  |  | Y |  | Y | * Higher incidence of URS episodes in overreached (67%) vs. non-overreached (22%) and control athletes (11%)
 |
| Martensson et al 2014 [[8](#_ENREF_8)]  | Retrospective cohort | Endurance athletes (cross country skiers, biathletes, distance runners) | 11 Elite endurance athletes M=8, F=317-24 years | Illness days (exercise constrained) | 3-16 years | Illness (“sick”) days (exercise constrained)Training logs (hours) over years (varied between 3-16 years) | Y |  | Y |  |  |  |  | Y | * Training volume (hours per year) negatively correlated to number of days training missed due to illness
 |
| Gleeson et al 2013 [[9](#_ENREF_9)]  | Cross-sectional study | Endurance athletes (running, cycling, swimming, triathlon, team games, racquet sports) | 75 Recreational student athletesM=44, F=3118-35 years | URS episodes (questionnaire) | 4 months | URS episodes (weekly)Training load (hours per week) in three groups (high, medium, low)Blood samples for haematological and immune parameters | Y |  | Y |  |  |  | Y |  | * Incidence of URS 2.5 fold higher in those training 7-10 hours/week or >11 hours/week vs. those training 3-6 hours/week
* High training loads were associated with higher IL-2. IL-4 and IL-10 production in response to antigen challenge
 |
| Rama et al 2013 [[10](#_ENREF_10)] | Case control | Swimmers | 30 (19 elite swimmers, 11 sedentary controls)M=20, F=1014-21 years | URS episodes | 7 months | URS episodes (daily)Training load (volume, intensity) dailyCompetitionsBlood samples for haematological and immune parameters | Y | Y | Y | Y |  |  | Y |  | * Highest incidence of URS (67%) during period of highest training load with 0% incidence of URS in sedentary controls at same time
 |
| Brink et al 2012 [[11](#_ENREF_11)]  | Prospective cohort | Soccer players | 94 Elite Males15-18 years | Symptoms of illness suggestive of overreaching | 2 seasons | Symptoms of overreaching (n=7) recorded by medical staff Training load (RESTQ-Sport scores) monthlyPerformance (Interval Shuttle Run Test) | Y | Y | Y |  |  |  | Y |  | * Physical training load related to illness (OR=1.12)
* Multinomial regression demonstrated that physical stress was related to both injury and illness (range OR: 1.01-2.59)
* Psychosocial stress and recovery were related the occurrence of illness (OR: 0.56 -2.27)
 |
| Gleeson et al 2012 [[12](#_ENREF_12)] | Prospective cohort | Endurance athletes (running, cycling, swimming, triathlon, team games, racquet sports) | 80 Recreational student athletesM=46, F=3418-35 years | URS episodes (questionnaire) | 4 months | URS episodes (weekly)Training load (IPAC weekly)Blood samples for haematological and immune parametersSaliva (IgA) | Y |  | Y |  |  | Y |  |  | * Illness-prone athletes (n=24; >3 URS episodes in 4 months) had higher training load than 30 healthy athletes (0 URS in 4 months)
* Illness-prone athletes (n=24; >3 URS episodes in 4 months) had higher SIgASR than 30 healthy athletes (0 URS in 4 months)
 |
| Cunniffe et al 2011 [[13](#_ENREF_13)] | Prospective cohort | Rugby union | 31 Elite Males20-34 years | URS episodes (questionnaire) | 11 months | URS episodes (weekly) web-based diaryTraining load (RPE based, daily using web-based diary)Saliva (IgA, cortisol) | Y | Y | Y | Y |  | Y | Y |  | * Peaks in URS incidence in were preceded by periods of increased training load (intensity)
 |
| Moreira et al 2011 [[14](#_ENREF_14)] | Prospective cohort | Basketball | 15 Sub-eliteMales 18-21 years | URS episodes (WURSS-21 questionnaire) | 4 weeks | URS episodes (WURSS) weeklyTraining load daily (DALDA, session-RPE)Saliva (IgA, cortisol) | Y | Y | Y | Y |  | Y | Y |  | * Highest incidence of URS during weeks with highest training load
 |
| Matthews et al, 2010 [[15](#_ENREF_15)] | Prospective cohort | Runners | 35 (12 highly trained runners, 23 students)M=17, F=18> 18 years | Symptoms of illness | 3 months | Illness episodes (AIS self reported daily illness log) Training load (duration and intensity) daily | Y | Y | Y |  |  |  | Y |  | * Frequency of illness episodes was similar in runners and controls
* Illness duration and load was higher in runners
* Runners who were prone to illness had marginally higher training loads
 |
| Main et al, 2010 [[16](#_ENREF_16)] | Prospective cohort | Triathletes | 30 (well trained, M=20; 27.1+9.1 years; F=10; 27.4+6.6 years) | URS episodes  | 45 weeks | Illness episodes (10 point symptom and sign (SAS) checklist weekly; injuries weekly)Training load (weekly session number, duration, intensity, perceived effort)Psychological (stress, mood, training stress, burnout) | Y | Y | Y |  |  | Y |  | Y | * UR illness episodes were significantly associated with increases in training factors (p<0.05)
* UR illness episodes were significantly associated with psychological stressors (p<0.001)
* Common symptoms of overtraining were significantly affected by increased training and psychological stressors (p<0.001)
 |
| Spence et al 2007 [[17](#_ENREF_17)] | Prospective cohort | Endurance athletes (triathletes and cyclists) and sedentary controls | 83 (32 elite athletes, 31 recreationally active, 20 sedentary controls)Male and female18-34 years | URS episodes (WURSS-44 questionnaire) | 5 months | URS episodes (WURSS) dailyTraining load daily (distance, duration, intensity)Nasopharyngeal throat swabsSaliva (IgA, cortisol)Blood (serology) | Y | Y | Y |  |  | Y | Y |  | * Incidence Ratio for URS episodes (elite athletes=4.5, recreationally active=1, sedentary controls=1.9)
 |
| Ekblom et al 2006 [[18](#_ENREF_18)] | Retrospective cohort | Runners (marathon) | 1694 recreational runners M=1354, F=34018-65 years | URS episodes (questionnaire)  | 3 weeks | URS episodes (retrospectively 3 weeks before, and prospectively 3 weeks after a 42.2-km race)Training volume (km/week) (retrospective 6 months before the race) questionnaire | Y |  | Y |  | Y | Y | Y | Y | * Incidence of URS episodes similar pre-race (17%) and post-race (19%)
* Incidence of URS episodes higher post-race in those who had pre-race URS episodes (33%) vs. those who did not have pre-race URS episodes (16%)
* Pre-race training volume was not related to pre- or post-race URS episodes
* Younger age was a risk factor for pre-race URS episodes
 |
| Novas et al 2002 [[19](#_ENREF_19)] | Prospective cohort | Wide range of physical activities in high school or university students | 31 Wide range of physical activity (elite tennis to non-athletic students) Females14-21 years | URS episodes (questionnaire) | 3 months | URS questionnaire (daily)3-day physical activity record (3 blocks of weekdays and 1 weekend day) (total daily energy expenditure)(quartiles)Daily tennis training diary (tennis players sub-group)(session-RPE) | Y | Y (sub-group) | Y |  |  | Y |  |  | * URS symptom index higher in low training load quartile but highest in the highest training load quartile
 |
| Fahlman & Engels 2005 [[20](#_ENREF_20)] | Prospective cohort study | American football | 100 (75 college football players, 25 controls)Males18-25 years | URS episodes (questionnaire) | 12 months | URS questionnaire (weekly)Training (physical activity questionnaires) (8 times in the 12 month period)Training and Competition periods (defined)Saliva (IgA) | Y |  | Y |  | Y | Y | Y |  | * Incidence of URS episodes higher during training/competition periods vs. off-season
* Incidence of URS episodes associated with lower SIgASR
 |
| Fricker et al 2005 [[21](#_ENREF_21)] | Prospective cohort | Runners (800m to marathon) | 20 Elite (national and international level)Male24+3 years (mean+SD) | URS episodes (questionnaire) | 4 months | URS questionnaire (daily)Training load (weekly mileage and intensity)Performance testing (start and end) | Y | Y | Y |  |  | Y | Y |  | * Incidence of URS episodes was not associated with weekly training load
 |
| Novas et al 2003 [[22](#_ENREF_22)] | Prospective cohort | Tennis | 17 Elite Females14-21 years | URS episodes (questionnaire) | 3 months | URS questionnaire (daily)Training load (daily) (session-RPE)Competitions (matches per week)Saliva (IgA) | Y | Y | Y | Y | Y | Y | Y |  | * More URS episodes associated with higher training volume
* More URS episodes associated with increased matches per week
* More URS episodes associated with higher competition level
 |
| Anderson et al 2003 [[23](#_ENREF_23)] | Prospective cohort | Basketball | 12 (College level Females 18-22 years | Illness episodes | 20 weeks | Illness episodes (after each training session)Training load (session RPE, session duration), monotony, training strain | Y | Y | Y | Y | Y |  | Y |  | * No correlation between total weekly training load and illness rates)
 |
| Peters et al 1993 [[24](#_ENREF_24)] | Randomised controlled trial (RCT) | Runners (ultra-marathon) | 157 Recreational 84 runners (n=84, M=82, F=2:) Controls (n=73) > 18 years | URS episodes (questionnaire) | 2 weeks | URS questionnaire (2 weeks post race in the Vitamin C supplemented group and a Control group)Pre-race training history (training status: ratio of training distance to training speed) | Y |  | Y |  | Y | Y | Y |  | * Incidence of URS episodes was higher in runners (68%) vs. controls (45%)
* Incidence of URS episodes was higher in runners with higher training status (increased load)
 |
| Heath et al 1991 [[25](#_ENREF_25)] | Prospective cohort | Runners | 530 Recreational runnersM=447, F=8313-75 years | URS episodes (questionnaire) | 1 year | URS questionnaire (daily)Training log (monthly) (mileage, racing)Multiple other risk factors  | Y |  | Y | Y |  | Y |  | Y | * Increased mileage (training load) was an independent risk factor for URS episodes
* Other independent risk factors for URS episodes were living alone, increased BMI, and male gender
 |
| Nieman et al 1990 [[26](#_ENREF_26)] | Cross sectional | Runners (marathon) | 2311 Recreational (M=1992; F=319)Non finishers (n=295)> 18 years | URS episodes (questionnaire) | 2 months | URS questionnaire (once)URS episodes 2 month pre-race, and 7 day post race)Training history in 2 months before race Energy, stress levels, sleep (questionnaire) | Y | Y | Y |  | Y | Y |  | Y | * Pre-race URS risk was higher in runners training >97 km/week vs. 32 km/week (OR=2.0)
* Post-race URS risk was higher in finishers vs. non finishers (OR=5.9)
 |
| Peters 1990 [[27](#_ENREF_27)] | Case control | Runners (ultra-marathon) | 108 recreational runners (M=97, F=11)108 controls> 18 years | URS episodes (questionnaire) | 2 weeks | URS questionnaire (twice) – 7 days before and 2 weeks after a raceTraining history (distance / week) in preparation for the race | Y |  | Y |  |  | Y | Y |  | * The incidence of URS episodes was twice as high in runners (29%) vs. controls (13%)
* Less trained runners had a higher incidence of URS episodes
 |
| Nieman et al 1989 [[28](#_ENREF_28)] | Cross sectional | Runners (5km, 10km, 21km) | 273 Recreational runnersM=193, F=90)> 18 years | URS episodes (questionnaire) | 2 months | URS questionnaire (once)URS episodes 2 months pre-race and 7 days post 5-, 10- and 21-km racesTraining history in the 2 months before races | Y | Y | Y |  | Y | Y | Y |  | * URS incidence was lower in runners training 42 vs. 12 km/week
* Race participation (5km, 10km and 21km) was not associated with increased URS episodes
 |
| Linde et al 1987 [[29](#_ENREF_29)] | Prospective cohort | Orienteering | 44 Elite 44 controls19-34 years | URS episodes (questionnaire) | 12 months | URS questionnaire daily | Y |  | Y |  |  |  | Y |  | * Incidence of URS episodes was higher in orienteers (2.5) vs. controls (1.7)
 |
| Peters et al 1983 [[30](#_ENREF_30)] | Case control | Runners (marathon) | 150 Recreational runners (M=145, F=5)124 sedentary controls18-65 years | URS episodes (questionnaire) | 2 weeks | URS questionnaire (twice)URS episodes 2 months pre-race and 7 days post 56 km raceTraining history (distance / week) in preparation for the race  | Y |  | Y |  | Y |  | Y |  | * URS episodes were more common in runners training > 65km/week (40%) vs. those training < 65km/week (20%)
* The incidence of URS episodes after the race was higher in runners (33%) vs. sedentary controls (15%)
 |

M=Males

F=Females

UR = Upper Respiratory

URS = Upper Respiratory Symptom

URTI = Upper Respiratory Track Infection

GIT = Gastrointestinal

IgA = Immunoglobulin A

SIgA = Salivary IgA concentration

SIgASR = Saliva secretory immunoglobulin A secretion rate

RPE = Rating of Perceived Exertion

WURSS – Wisconsin Upper Respiratory Symptom Score

OR – Odds Ratio

TL = Training Load

AU = Arbitrary Units

**References**

1. **Svendsen IT, I. Tonnesen, E. Bahr, R. Gleeson, M.** . Training- and competition-related risk factors for respiratory tract and gastrointestinal infections in elite cross-country skiers. *Br J Sports Med*  2016;**(in press)**.

2. **Raysmith BP, Drew MK**. Performance success or failure is influenced by weeks lost to injury and illnes in elite Australian Track and Field athletes: a 5-year prospective study. *J Sci Med Sport* 2016;**(in press)**.

3. **Thornton HR, Delaney JA, Duthie GM, et al.** Predicting Self-Reported Illness for Professional Team-Sport Athletes. *Int J Sports Physiol Perform* 2015 Sep 21.

4. **Veugelers KR, Young WB, Fahrner B, et al.** Different methods of training load quantification and their relationship to injury and illness in elite Australian football. *J Sci Med Sport* 2015 Jan 23.

5. **Svendsen IS, Gleeson M, Haugen TA, et al.** Effect of an intense period of competition on race performance and self-reported illness in elite cross-country skiers. *Scand J Med Sci Sports* 2015 Dec;**25**(6):846-53.

6. **Hellard P, Avalos M, Guimaraes F, et al.** Training-related risk of common illnesses in elite swimmers over a 4-yr period. *Med Sci Sports Exerc* 2015 Apr;**47**(4):698-707.

7. **Hausswirth C, Louis J, Aubry A, et al.** Evidence of disturbed sleep and increased illness in overreached endurance athletes. *Med Sci Sports Exerc* 2014;**46**(5):1036-45.

8. **Martensson S, Nordebo K, Malm C**. High Training Volumes are Associated with a Low Number of Self-Reported Sick Days in Elite Endurance Athletes. *J Sports Sci Med* 2014 Dec;**13**(4):929-33.

9. **Gleeson M, Bishop N, Oliveira M, et al.** Influence of training load on upper respiratory tract infection incidence and antigen-stimulated cytokine production. *Scand J Med Sci Sports* 2013 Aug;**23**(4):451-7.

10. **Rama L, Teixeira AM, Matos A, et al.** Changes in natural killer cell subpopulations over a winter training season in elite swimmers. *Eur J Appl Physiol* 2013 Apr;**113**(4):859-68.

11. **Brink MS, Visscher C, Coutts AJ, et al.** Changes in perceived stress and recovery in overreached young elite soccer players. *Scand J Med Sci Sports* 2012 Apr;**22**(2):285-92.

12. **Gleeson M, Bishop N, Oliveira M, et al.** Respiratory infection risk in athletes: association with antigen-stimulated IL-10 production and salivary IgA secretion. *Scand J Med Sci Sports* 2012 Jun;**22**(3):410-7.

13. **Cunniffe B, Griffiths H, Proctor W, et al.** Mucosal immunity and illness incidence in elite rugby union players across a season. *Med Sci Sports Exer* 2011 Mar;**43**(3):388-97.

14. **Moreira AA, F. Lima-Arsati, Y. Simoes, A. De Araujo, V**. Monitoring Stress Tolerance and Occurrences of Upper Respiratory Illness in Basketball Players by Means of Psychometric Tools and Salivary Biomarkers. *Stress and Health* 2011;**27**:e166-e72.

15. **Matthews A, Pyne D, Saunders P, et al.** A self-reported questionnaire for quantifying illness symptoms in elite athletes. *Open Access J Sports Med* 2010;**1**:15-22.

16. **Main LC, Landers GJ, Grove JR, et al.** Training patterns and negative health outcomes in triathlon: longitudinal observations across a full competitive season. *J Sports Med Phys Fitness* 2010 Dec;**50**(4):475-85.

17. **Spence L, Brown WJ, Pyne DB, et al.** Incidence, etiology, and symptomatology of upper respiratory illness in elite athletes. *Med Sci Sports Exerc* 2007 Apr;**39**(4):577-86.

18. **Ekblom B, Ekblom O, Malm C**. Infectious episodes before and after a marathon race. *Scand J Med Sci Sports* 2006;**16**(4):287-93.

19. **Novas A, Rowbottom D, Jenkins D**. Total daily energy expenditure and incidence of upper respiratory tract infection symptoms in young females. *Int J Sports Med* 2002;**23**(7):465-70.

20. **Fahlman MM, Engels HJ**. Mucosal IgA and URTI in American college football players: a year longitudinal study. *Med Sci Sports Exerc* 2005 Mar;**37**(3):374-80.

21. **Fricker PA, Pyne DB, Saunders PU, et al.** Influence of training loads on patterns of illness in elite distance runners. *Clin J Sport Med* 2005 Jul;**15**(4):246-52.

22. **Novas AM, Rowbottom DG, Jenkins DG**. Tennis, incidence of URTI and salivary IgA. *Int J Sports Med* 2003;**24**(3):223-9.

23. **Anderson L, Triplett-McBride T, Foster C, et al.** Impact of training patterns on incidence of illness and injury during a women's collegiate basketball season. *J Strength Cond Res* 2003 Nov;**17**(4):734-8.

24. **Peters EM, Goetzsche JM, Grobbelaar B, et al.** Vitamin C supplementation reduces the incidence of postrace symptoms of upper-respiratory-tract infection in ultramarathon runners. *Am J Clin Nutr* 1993;**57**(2):170-4.

25. **Heath GW, Ford ES, Craven TE, et al.** Exercise and the incidence of upper respiratory tract infections. *Med Sci Sports Exerc* 1991;**23**(2):152-7.

26. **Nieman DC, Johanssen LM, Lee JW, et al.** Infectious episodes in runners before and after the Los Angeles Marathon. *J Sports Med Phys Fitness* 1990 Sep;**30**(3):316-28.

27. **Peters EM**. Altitude fails to increase susceptibility of ultramarathon runners to post-race upper respiratory tract infections. *S Afr J Sports Med* 1990;**5**:4-8.

28. **Nieman DC, Johanssen LM, Lee JW**. Infectious episodes in runners before and after a roadrace. *J Sports Med PhysFitness* 1989;**29** 289-96.

29. **Linde F**. Running and upper respiratory tract infections. *Scan J Sports Sci* 1987;**9** 21-3.

30. **Peters EM, Bateman ED**. Ultramarathon running and upper respiratory tract infections. An epidemiological survey. *S Afr Med J* 1983;**64**(15):582-4.