

Managing Immune Health in Sports – A Practical Guide for Athletes and Coaches

Infektprävention im Leistungssport – Ein praktischer Leitfaden für Trainer und Sportler

Summary

- › **The prevention of infectious diseases** is particularly important in athletes who need a good all-season health status to be optimally prepared for competition.
- › **Since the immune system** is highly responsive to exercise, periods of intensified training induce a transient immune dysfunction. Athletes regularly encounter additional challenges, such as low energy availability, oxidative stress, psychological stress, sleep disruption, long-haul travel, overreaching periods and an imbalance of exercise and recovery. Moreover, exercise training performed in specific environments, such as high altitude, cold or heat, represents an even higher than usual threat to the immune function.
- › **This review** summarizes various recommendations which should help to reduce the athlete's immune disturbances and the risk of infection. An appropriate management of external and internal exercise loads, adequate recovery, as well as maintaining energy homeostasis by sufficient energy, fluid, and macronutrient intake is recommended. The observance of sleep hygiene strategies, general vaccination advice and instructions for exercising in specific environments is beneficial. Compliance with fundamental hygiene strategies can also reduce pathogen exposure in athletes and thus contribute to maintaining health.
- › **It is concluded** that these main strategies of protection against infection should be included in the early education of coaches and young athletes, leading to more professional management of disease prevention.

KEY WORDS:

Immune System, Exercise, Training, Immune Disturbance, Upper Respiratory Tract Infections

Introduction

It is obvious that the prevention of infectious diseases is particularly important in athletes who need a good health status all-season to complete their training schedule to be optimally prepared for competition. While diarrhea or an upper respiratory infection (URTI) is commonly not a severe problem for a healthy young person, it can be very serious for an international athlete. Although there is no possibility to completely eliminate infections,

Zusammenfassung

- › **Ein wirksamer Schutz vor Infektionen** ist vor allem für Leistungssportler von besonderer Bedeutung, um eine optimale Trainings- und Wettkampfsaison ohne langanhaltende Zwangspausen aufgrund von Erkrankungen bestreiten zu können. Gleichzeitig sind Athleten einer Vielzahl interner und externer Stressoren ausgesetzt, welche die Immunabwehr temporär oder dauerhaft schwächen können.
- › **Das Immunsystem** reagiert sensibel auf Belastung und Training, und demnach können Phasen intensiven Trainings ohne vollständige Regeneration zu einer transienten Immunsuppression führen. Zusätzlich sind Leistungssportler vielen weiteren Herausforderungen ausgesetzt, wie beispielsweise Energiemangelzuständen, oxidativem Stress, psychologischen Belastungen, unregelmäßigem Schlaf, gegebenenfalls langen Reisen oder einer Kombination dieser Einzelstressoren. Eine besondere Belastung stellen dabei Trainingseinheiten oder Wettkämpfe unter speziellen Umweltbedingungen dar, die das Immunsystem zusätzlich schwächen können, sowie hygienische Verhältnisse in Mannschaftssportarten, in denen sich Infekte rasch ausbreiten können.
- › **Diese Übersichtsarbeit** fasst spezifische Empfehlungen zusammen, die dem Leistungssportler ein besseres Management der Aufrechterhaltung der Immunfunktion und Reduktion von Infektionsrisiken ermöglichen. Dazu gehören die Einhaltung adäquater Trainingslasten und Regenerationsmaßnahmen, spezifische Ernährungsstrategien, Möglichkeiten der Stressprävention, Kernaspekte einer wirksamen Schlafhygiene, Impfpfehlungen sowie Hinweise für das Training unter Bedingungen wie Höhe, Kälte und Hitze.
- › **Schlussfolgernd** wird festgestellt, dass zentrale Verhaltensweisen zum Schutz vor Infektionen früh in der Ausbildung von Athleten und Trainern implementiert werden sollten, so dass bereits junge Sportler ein professionelles Management zur Vermeidung von bakteriellen und viralen Infekten entwickeln.

SCHLÜSSELWÖRTER:

Immunsystem, Belastung, Training, Immunsuppression, Atemwegsinfekte

there are a number of strategies that can substantially reduce the number of infectious episodes. Currently, there is a lack of experimental studies that allow preparing official guidelines for athletes. However, using data of carefully chosen findings from exercise studies and related fields enables creating a cluster of helpful recommendations to practically support athletes and coaches to reduce the risk of infections (55, 56). ➤

REVIEW

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The immune system is highly responsive to acute bouts of exercise (55). Since the immune response to exercise depends on intensity and duration of effort, athletes engaging regularly in exhaustive endurance or resistance exercise bouts are at increased risk of upper respiratory tract infections (URTI). Especially, periods of intensified training loads combined with long duration, such as marathon or ultramarathon runs, have been shown to induce a transient immune suppression (12, 33). These observations might also be attributable to the various additional challenges athletes encounter during training and competition such as low energy availability, oxidative stress, psychological stress, sleep disruption, long-haul travel, and overreaching periods resulting from heavy exertion and an imbalance of exercise and recovery (40, 57). Unambiguously, in team sports, athletes often stay in crowded places, such as locker rooms, with a large number of people. Close contact between athletes is common increasing the risk of airborne infection (7). If competing or exercising in specific environments like extreme heat, cold or changing altitude, the risk of infections rises even further (26). Taken together, athletes represent a vulnerable target group in need of strategies to prevent infectious diseases by managing immune disturbance and reducing infection risk.

Managing Immune Disturbances

Training Load Management

Evidence suggests that the appropriate management of external and internal load helps an athlete to prevent illness incidence. External loads quantify the exercise or competition load itself, whereas internal loads apply to the experienced physiological and psychological load response. The first step to appropriate load management is the monitoring of exercise bouts to minimize the risk of illnesses due to non-functional overreaching or overtraining (46). External loads are easily and objectively quantified by training frequency, volume, duration, and intensity (4). Regarding internal loads, literature solely provides evidence for the sensitivity of subjective measures of stress or recovery, such as session rate of perceived exertion (RPE, Profile of Mood States (POMS) or Acute Recovery and Stress Scale (ARSS) (44).

For instance, ARSS was associated with some immune blood markers in youth athletes (41). However, validity for using objective measures, such as heart rate or biomarkers, is limited though e.g. salivary Immunoglobulin A (IgA) may be used in addition to subjective questionnaires (44, 46, 19). Accordingly, it is advised to record internal loads regularly by a sensitive subjective measure after listening carefully to the perceived load and coaches to regularly adjust external loads on this basis.

Coping well with high loads requires adequate recovery after exhaustive exercise (54). The exercise-related recommendation includes the reduction of training load the days after high-intensity exercise (54). Please refer to other sections of this review for sleep hygiene or nutrition recommendations to better guide the recovery process. Furthermore, data indicates merely heavy exertion, long duration or a combination of both increases immune depression (36) and consequently, athletes participating in competitions increase risk of infections, such as URTI (46). For safety reasons, coaches should stick to an increase of duration, volume or intensity below 10% (19).

When managing immune disturbances by adjusting exercise load keep in mind, exercising during an acute infection increases the risk of serious health problems and may lead to sudden death as a worst-case scenario (46). Athletes may use a simple

log with 7-items of symptoms related to URTI to monitor their actual health status (32) and report any alterations and health concern to their coaches. Furthermore, coaches may reduce the load for immunosuppressed athletes to allow immune markers to return to baseline (19).

Immunonutrition for Athletes

As there is a strong link between metabolism and immune function (5), maintaining energy homeostasis by sufficient energy intake via macronutrients is critical to support an athlete's overall health including the prevention of inflammatory processes (54). Therefore, we strongly recommend athletes to maintain energy availability (EA) in order to reduce immune disturbances and balance hormone levels by feeding immune and further cells. Sufficient EA is a key factor to prevent URTIs and immune depression as a result of strenuous or prolonged exercise (38). The recent IOC consensus statement (29) defines EA as the difference between energy intake and energy expenditure in relation to fat-free mass (FFM). Low EA, less than 30 kcal/kg/FFM per day, is very common in male and female endurance athletes and other weight-sensitive sports though the condition is similarly known in team sports (17, 21). Therefore, athletes and coaches should monitor individual energy intake and expenditure while considering FFM (29). Thus, for athletes, we recommend an EA of 45kcal/kg/FFM per day to safely maintain energy supply for physiologic function (21).

Conclusively, a balanced diet of carbohydrates (CHO), fat, and protein is another important factor for the athlete's immune wellbeing (54). We emphasize the importance of carbohydrates (CHO) and consider the ingestion of 3-5g/kg/day CHO during low-intensity times of training up to 8-12g/kg/day CHO during high-intensity times and/or long duration of training (28). Moreover, we endorse supplementing CHO during prolonged exercise (30-60g/h) (2). For instance, CHO in the form of a sugar beverage or banana maintains blood glucose levels, reduces stress hormone response and lowers post-exercise plasma levels of lipid-related metabolites (34). Athletes and their coaches without access to a sports nutrition professional could alternatively use a quick valid screen such as the 15-item questionnaire to monitor current CHO intake (15). Furthermore, protein balance is preserved by ingesting 1.2-1.6 g/kg/day (54) and the ingestion of at least 0.5-1.5 g/kg/day fat may help to better meet energy intake recommendations. Fat intake for high energy yield could be increased up to 50% during high volume training (20).

Scientific literature discusses multiple other supplements and their potential to boost immune function or reduce exercise-induced immune depression (2). However, clinically meaningful results on any immune promoter of immune health in non-deficient athletes are lacking and a well-balanced diet seems to be adequate to maintain immune health in athletes. Whether it is antioxidants, vitamin D, minerals, glutamine, and other amino acids, herbs (echinacea or ginseng), bovine colostrums, probiotics, or β -glucan, there is not enough evidence to recommend any supplementation (35).

Beyond, supplements modifying reactive oxygen species may blunt exercise adaptations (14). Under special circumstances, at least a moderate support for some supplements, such as 4000 UI/day vitamin D3 in times of low UVB skin exposure or 75 mg zinc lozenges during the first 24h of URTI, is present (2). Nevertheless, before athletes take or coaches praise any kind of supplementation, we endorse a risk-benefit analysis by a sports nutrition professional (25).

Finally, water ingested by food and fluids is an important nutrient that is needed to limit dehydration due to sweat loss

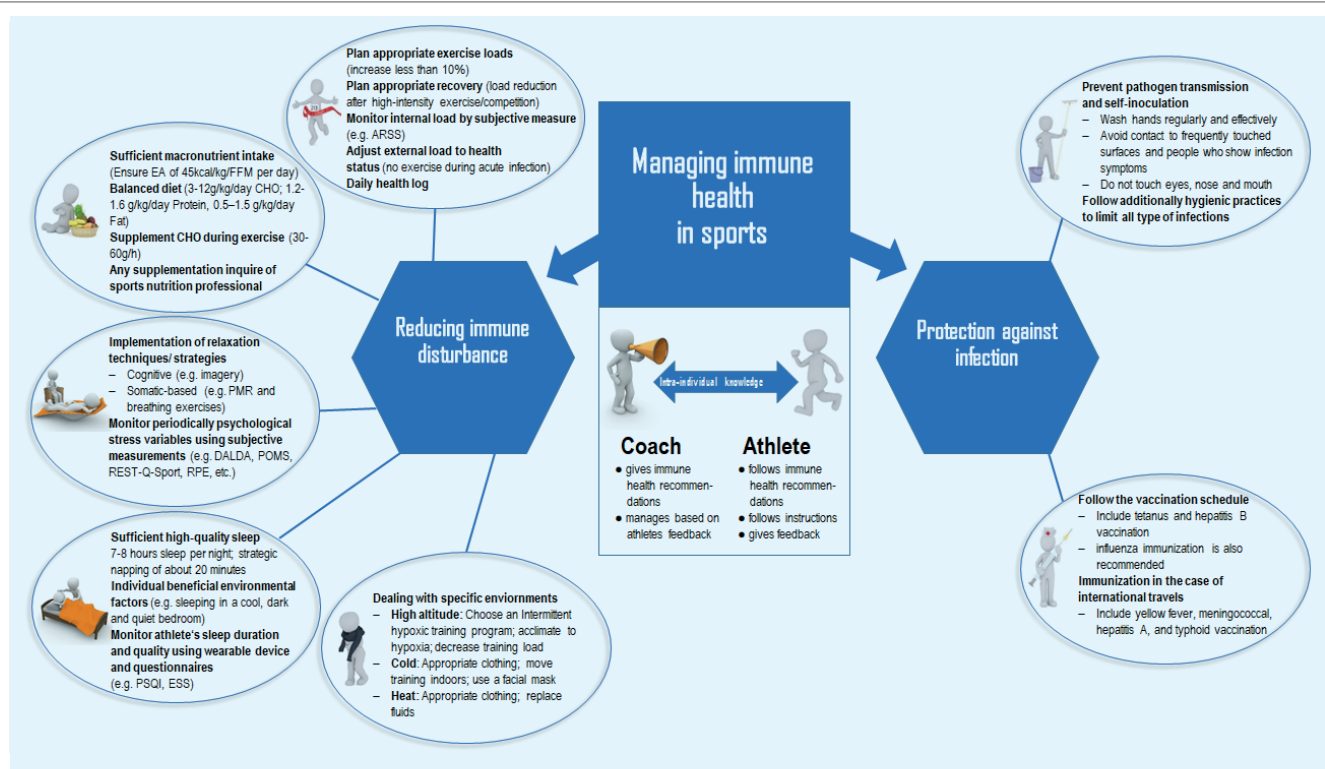


Figure 1

Managing immune health in sports: A close interaction between coaches and athletes is required to reduce immune disturbance and to protect against infection.

(20). However, moderate hypohydration by an acute exercise bout does not seem to influence the antigen-response e.g. after two hours of moderate endurance exercise (49). Please refer to the section heat in "Specific environments" for a recommendation to avoid immune decrements through dehydration when exercising in the heat.

Psychological Stress Management

As mentioned before, psychological stress is an internal load and receives increasing attention by professional athletes in order to withstand the enormous pressures at the international level (45). An imbalance between sport demands and the effectiveness of coping strategies negatively influence the immune system, especially during increased volume and intensity training phases (43). Conditions of inflammation, oxidative stress, or muscle damage, and increased risk for illness may aggravate feelings of depression or anxiety during training and/or competition loads (36).

In order to keep the immune system robust and manage immune disturbances, recommendations for the optimization of psychological well-being are needed. Coaches have to develop and employ psychological stress prevention programs to be used by their athletes to keep unnecessary life stress to a minimum (54). One example is the stress management model from Johnson et al. (2005) including six different subjects: goal setting skills, somatic and cognitive relaxation, stress management according to stress inoculation training (SIT), training of self-confidence, concentration skills and emotions in sport (18). Furthermore, resilience strategies can help athletes understand the relationship between personal traits, thoughts, and emotions, which in turn may help them minimize the internalized impacts of negative life events (47). Moreover, previous research has established the validity of relaxation techniques, such as cognitive strategies (e.g. imagery) or somatic-based strategies

(e.g. progressive muscle relaxation and breathing exercises) as useful psychological strategies to manage the stressors during recovery, and decrease acute stress measured by the change of salivary cortisol (8). Decreased levels of cortisol are associated with positive mood scores and an improvement in the individual's immune system. Astin et al. (1999) found that using psychological techniques has positive effects on health and the immune system (1). Most promising is the use of mindfulness meditation training for sport (MMTS), which shows beneficial results in studies for overall well-being, higher tolerance of negative experiences, and increased mental flexibility to reduce the perception of stress (39). Finally, it can be helpful for coaches to periodically monitor psychological stress variables of athletes using available instruments, like the daily analysis of life demands for athletes questionnaires (DALDA) or other subjective internal stress measurements like the POMS, the recovery-stress questionnaire for athletes (REST-Q-Sport), the psychological well-being scale (PWS), the sport coping approach questionnaire (ACSQ-1), the sport perceived autonomy scale, or the rate of RPE (43, 47, 54).

Sleep Hygiene

Sleep hygiene plays a vital role in overall human health and especially as an important bio-physiological variable for the athletes' well-being and recovery processes (53). Athletes show a high inter- and intra-individual variability of sleep characteristics and are often exposed to sleep disturbances because of excessive overload during training sessions and competitions with inadequate recovery (30). In addition, the variability of training and competition schedules may lead to inconsistent sleep quality in athletes (30). Chronic sleep deprivation, such as 10 nights with a sleep deficit of 50% (55), 21-months with an average sleep <8 h (37), or a sleep efficiency <85% (6) have a cumulative long-term negative effect on the human immune

system, resulting in increased susceptibility to infections and a higher prevalence of the common cold. Often athletes try to compensate for the sleep deficit during the competition phase within the recovery periods (54). This chronic variability in sleep quality should be avoided by better managing the strategies to improve sleep hygiene.

There are various sleep extension programs supporting athletes' sleep hygiene to reduce the risk of infections. One of the most important recommendations of these sleep extension studies is to employ sleep hygiene-related strategies to ensure adequate sleep after performing exercise and competitions sessions close to bedtime (53). 7-8 hours of sleep per night are required for psychological well-being, mood, and alertness and reduce susceptibility to respiratory infections (10, 52, 55). However, it is plausible that the optimum amount of sleep for athletes is an individual value and not a given number of hours of sleep per night (3). Furthermore, regular moderate training in the evenings, rather than high-intensity stimuli with increased core temperature, have positive effects on sleep efficiency and do not disrupt the thermo-physiological cascade (31). Strategic napping of about 20 minutes (alternatively 90 minutes for a complete sleep cycle) and determining individually beneficial environmental factors, e.g. sleeping in a cool, dark and quiet bedroom, are further methods to facilitate a regular, high-quality sleep (27, 37). Additionally, each athlete has a preferred sleep schedule that suits their circadian rhythm. Therefore, coaches should group together athletes exhibiting similar chronotypes in shared rooms during training camps in order to prevent sleep disturbances and bedtime procrastination. To mitigate interferences with sleep or other psychological strains, such as anxiety or competition stress, it may be beneficial to utilize self-confidence tools (i.e. meditation), which can help regulate sleep and avoid a dysregulation of the 24-hour cortisol rhythm (31). Habitual hormone dysregulation can also be prevented by avoiding blue light-emitting sources within 30 minutes before bedtime. Blue-enriched light is known to block the soporific hormone melatonin. In the context of intercontinental competitions or training camps, a pre-travel simulation of the new time-zone (e.g. waking and exposure to light at the new time and adoption of the new meal schedule) and exercise upon arrival can reduce the misalignment between body clock and local time (10). Furthermore, athletes should not take caffeinated beverages and/or alcohol within 4 hours of bedtime or consume non-steroidal anti-inflammatory drugs during recovery processes (27, 31). Lastly, it is recommended that coaches monitor an athlete's sleep duration by using a wearable device, and sleep quality with the Pittsburgh Sleep Quality Index Questionnaire (PSQI), Epworth Sleepiness Scale Questionnaire (ESS), or other applicable measurements to evaluate the psychophysiological state and estimate the susceptibility to infections (3, 50, 55).

Specific Environments

Physical activity performed in stressful environments is suggested to pose a higher than usual threat to immune function (56). This remains controversial, as the exercise stress in environmental extremes tends to be self-limiting due to accelerated fatigue and a reduced workload (54). Therefore, a more differentiated view on exercise in specific environments is required. At high altitude, the additive hypoxic stress during exercise decreases the cell-mediated immune function both in-vivo and in-vitro (9, 54). The resulting high prevalence of respiratory infections indicates the need for specific exercise recommendations at high altitude to maintain immune health (57). First of all, an acclimation to hypoxia and an ill-

ness-free state prior to altitude training is recommended (9, 54). Moreover, a transient reduction of training load combined with a slightly increased time for regeneration seems to be purposeful to prevent critical immunosuppression. This includes the avoidance of exhaustive exercise especially in the initial days at altitude, as well as a reduced interval-training intensity and an increased recovery time between interval sessions (9).

Cold environment is less-challenging for athletes, as long as they are appropriately clothed and getting cold and wet after exercise is avoided. Consequently, athletes should wear fabrics which transport moisture outwards fast to keep the wearer warm and dry (24). However, in the cold combined with wind and rain or snow, the risk for hypothermia rises, which is associated with an increased incidence of URIs including the 'common cold' (23). Therefore, in inclement weather, it should be considered to move the training indoors (42). If this is not possible and athletes train and compete in the winter, extra precautions must be taken to avoid prolonged periods of breathing cold, dry air. This inhalation has been shown to reduce upper airway ciliary movement and mucous flow (13). Furthermore, the human rhinovirus, a common cold-causing virus, replicates more robustly at cooler temperatures of 33 – 35°C found in the nasal cavity (23). Therefore, the protection of an athlete's airways from being directly exposed to very cold and dry air by using a facial mask is recommended (13).

Exercise in the heat has been associated with a reduction of T-cell mediated immunity (56). However, the overwhelming evidence supports that exercising in hot environments does not pose a greater threat to immune function compared to thermoneutral conditions (54). Nevertheless, a transient decrease in mucosal immunity due to dehydration should be avoided by appropriate clothing and replacement of fluids during exercise (42, 48, 57). Especially sportswear with 100% polyester fibres has a positive impact on athlete's overall performance at high temperatures. This is attributable to better moisture management as those fabrics are extremely breathable supporting the body's temperature regulation (16). Additionally, long distance and intercontinental flights seem to increase the incidence of URTI (22), though the exact causes are unreliable. Referring to the following section, the infection risk due to extended travel durations in extremely crowded areas like aeroplanes should be decreased by minimizing the contact to pathogens.

Protection against Infection

Hygienic Strategies

Infectious microorganisms gain access to the human body through orifices such as the nose, mouth, ears, anus, genital passage and skin injuries. Therefore, the best way to prevent infections is to block pathogens from entering the body. Compliance with fundamental hygienic strategies can reduce pathogen exposure and thus contribute to maintaining an athlete's health. This is particularly relevant throughout seasonal periods like training camps and competition phases, with augmented social contacts and increased exercise loads. First, athletes should wash their hands regularly and effectively, especially before meals, after contact with potentially contagious people, public places, and bathrooms. Subsequently, the usage of disposable paper towels, if available, is recommendable. During travel, it is advisable to avoid direct contact with frequently touched surfaces like door handles or banisters. Further, athletes should carry an alcohol-based hand-washing gel and prevent self-inoculation by not touching the eyes, nose, and mouth (13, 54). Besides the personal hygiene, coaches and athletes need

to be sensitized to strategic hygienic behaviour within their training group to prevent the transmission of pathogens. For example, coaches must be alert to athletes displaying infection symptoms and isolate them from others. Furthermore, athletes should refrain from exercise sessions in poorly ventilated gymnasium facilities and strictly use their own bottles, cups or towels. In line with this, athletes need to act responsibly by sneezing and coughing into the crook of the elbow as well as by minimizing contact with people who show infection symptoms (13). Moreover, the observance of additional hygienic practices is recommended to limit all type of infections. This includes, for example, wearing footwear when visiting public facilities, professional care and bandage of skin injuries, compliance with safe sex practices, as well as safe preparation and storage of foods. In conclusion, athletes should follow appropriate mouth hygiene with dental check-ups at regular intervals (54).

Vaccination

Due to the lack of official guidelines, some authors reported that athletes should undergo the recommended vaccination for the general population. However, there are some specific vaccines, which might have major importance for athletes. These include tetanus and hepatitis B, specifically for athletes who are at risk of lesions, contact to blood and body fluid, such as football, boxing, wrestling, and hockey (11). A suitable time for a not acutely indicated vaccination represents the resting periods or shortly prior to the winter and summer breaks. Regarding the annual influenza immunization, vaccination is usually recommended for older people or subjects who suffer from specific chronic diseases. However, since athletes regularly share overcrowded environments getting a real flu infection represents a string disruptive factor, athletes also – despite being young adults – should contemplate to get a flu vaccination (51).

Particularly, elite athletes have to travel a lot to join international events. Thus, they are prone to acquire infections not prevalent in their home countries. Accordingly, immunization against yellow fever, meningococcal, hepatitis A, and typhoid fever are recommended only in the case of international travels.

Future Directions

For the future, it is eligible that the central strategies for protection against infection are included in the early education of coaches and young athletes, leading to more professional management of disease prevention (Fig. 1). Furthermore, athletes and team players should be more extensively monitored during periods of intensified training, using combined methods of subjective assessments, such as questionnaires, and objective evaluation tools, such as measurement of salivary IgA. The results might be interpreted as early markers of immunosuppression or signals for starting training after successful regeneration. Finally, there is a high need for research trials in elite athletes on if and how these recommendations affect the individual infection risk. ■

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Conflict of Interest

The authors have no conflict of interest.

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