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Exercise in the Heat for Children and Adolescents. Statement from the Commission for Pediatric Sports Medicine, German Society for Sports Medicine and Prevention

Sport bei großer Hitze für Kinder und Jugendliche. Stellungnahme der Kommission Kinder- und Jugendsport der Deutschen Gesellschaft für Sportmedizin und Prävention e. V.

REVIEW

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Summary

- **Physical activity and exercise** are important for the physiological and psychological development of children and adolescents. They already play a significant role in enhancing and maintaining health in this age group. However, in adverse climatic conditions like heat and high humidity, intensive exercise, especially when involving large muscle groups, can be a risk for the health of children and adolescents, causing exertional heat illness.
- **The mechanisms of adaptation** to physical activity at high temperatures change during puberty. However, the thermoregulatory ability in children is as effective as in adults; comparable relative exercise intensity causes similar changes in body core temperature in both age groups.
- **The risk for exertional heat illness** in children and adolescents is highest when vigorous exercise is performed in hot and humid environment, but it may also occur at moderate temperatures. Tolerance for exercise in the heat shows great individual differences and can be influenced by training in adverse climatic conditions.
- **Exertional heat illness** in children and adolescents is preventable by different measures. There should be sufficient time for recovery between repeated exercise bouts. Children and adolescents should drink sufficient quantities regularly and provide for sun protection of head and skin. During all athletic events in the heat with participation of children and adolescents, trained personnel and facilities capable of effectively treating all forms of heat illness, should be readily available on site.

KEY WORDS:
Heat Tolerance, Heat Illness, Puberty

Zusammenfassung

- **Körperliche Aktivität und Sport** sind für die physiologische und psychische Entwicklung und für die Förderung und Erhaltung der Gesundheit von Kindern und Jugendlichen wichtig. Unter ungünstigen äußeren Bedingungen, wie z. B. bei großer Hitze, kann intensive körperliche Aktivität und Sport, insbesondere bei Einsatz großer Muskelgruppen, jedoch auch zum Risiko für die Gesundheit mit der Entwicklung einer Hitzekrankheit werden.
- **Die Anpassungsvorgänge** an körperliche Belastung bei Hitze vor der Pubertät unterscheiden sich von der Adaptation nach der Pubertät. Dennoch zeigt die Effektivität der Anpassung keine Unterschiede; gleiche Belastungsintensitäten führen in beiden Altersgruppen zu einem vergleichbaren Anstieg der Körperkerntemperatur. Möglicherweise wird eine geringere Schweißproduktion durch eine vermehrte Hautdurchblutung und eine damit verbundene bessere Wärmeabstrahlung kompensiert.
- **Das Risiko für die Entwicklung** einer belastungsinduzierten Hitzekranheit ist am größten wenn anstrengende körperliche Aktivitäten bei großer Hitze und hoher Luftfeuchtigkeit erfolgen, aber das Auftreten ist auch bei moderaten Temperaturen möglich. Hitzetoleranz zeigt große individuelle Unterschiede und kann durch Training unter ungünstigen klimatischen Bedingungen beeinflusst werden.
- **Zur Prophylaxe einer Hitzekrankheit** bei Kindern und Jugendlichen sind verschiedene Maßnahmen sinnvoll. So sollte auf ausreichende Pausen zwischen Wettkämpfen, adäquate Trinkmengen und auf einen guten Sonnenschutz geachtet werden. Darüber hinaus sollten bei Sportveranstaltungen mit Kindern und Jugendlichen Betreuer anwesend sein, die die Frühzeichen einer Hitzekrankheit erkennen und geeignete Therapiemaßnahmen einleiten können.

SCHLÜSSELWÖRTER:
Hitzetoleranz, Hitzekrankheit, Pubertät

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Introduction

Regular physical activity and exercise are important for physiological and psychological development of children and adolescents. They also play a significant part in early prevention of cardiovascular disease. However, in adverse environmental conditions like hot weather and high humidity, exercise can be a risk factor in the development of different types of exertional heat illness (EHI; Table 1). The risk for EHI is greatest when wet bulb globe temperature (WBGT) exceeds 28°C, but it also can occur in cool to moderate conditions (2). In high school athletes, an overall rate of 1.6 events per 100000 athletic exposures (AE), defined as one athlete participating in one game or practice, was reported (6). So, EHI occurs rarely, but it can cause relevant morbidity and even mortality, especially when diagnosis is delayed and adequate therapy is not initiated in time. Exertional heat stroke is the most frequent cause of ›

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Table 1

Definitions of Different Types of Heat Illness (1, 2).

	DEFINITION
Heat Stress	High air temperature, humidity, and solar radiation leading to discomfort and physiologic strain when children and adolescents are exposed to such environmental conditions, especially when they perform vigorous exercise or other physical activity.
Exertional Heat Illness	A spectrum of clinical conditions ranging from muscle (heat) cramps, heat syncope, and heat exhaustion to heat stroke and resulting from exercise or other physical activity in the heat.
Exertional heat cramps	Painful muscle contractions and muscle cramps, mostly affecting active muscle groups, caused by sweating, dehydration and electrolyte imbalance; core body temperature is normal in most cases.
Heat exhaustion	Moderate heat illness with the inability to continue to exercise, failing to maintain blood pressure and sustain adequate cardiac output, that results from strenuous exercise or other physical activity, environmental heat stress, acute dehydration, and energy depletion. Symptoms include weakness, dizziness, nausea, syncope due to orthostatic hypotension, and headache; core body temperature is <40°C.
Exertional heat stroke	Severe multisystem heat illness with central nervous system abnormalities like delirium, convulsions, or coma, endotoxemia, circulatory failure, and temperature-control dysregulation, potentially leading to organ and tissue damage, that results from an elevated core body temperature (>40°C), induced by vigorous exercise or other physical activity and typically high environmental heat stress.
Heat injury	Severe damage and dysfunction of the brain, heart, liver, kidneys, intestine, spleen, or muscle induced by long-lasting excessive rise of core body temperature associated with exertional heat stroke, especially for those athletes in whom symptoms are not promptly recognized and effective treatment by cooling is not initiated in a timely manner.

non-cardiovascular and non-traumatic death in athletes in the United States (14). Therefore, vigorous exercise in hot and humid environment needs special consideration, preparation and monitoring in order to prevent exertional heat illness in children and adolescents.

Prevalence of Exertional Heat Illness

There are controversial data concerning the frequency of EHI in children and adolescents. In an Australian study no case of heat illness in adolescent athletes was reported in medical records of emergency rooms in a ten-year period (4). A prospective study over a period of 9 months in primary school children in Bangkok showed a significant rise of core temperature during exercise, especially in children who did not drink enough, but no case of heat illness was observed (25). On the other hand, 55.000 cases of EHI were observed in a retrospective analysis of data from North American emergency rooms from the years 1997 to 2006. 75.5% of these cases were associated with sports and exercise, and 47.6% of the patients were younger than 20 years (16). In a prospective study in youth, high school and college athletes in Football rates of EHI were between 1.82/10000 AE in athletes aged 5-14 years and 0.57/10000 AE in high school athletes aged 14-18 years, with minor events like heat cramps, exhaustion or dehydration in about 90% of the cases (26). Similar results for the prevalence of EHI were found in the National Collegiate Athlete's Association (NCAA) injury surveillance system in college athletes aged 18-23 years with a rate of 0.47/10000 AE in 25 disciplines (27). Most events occurred in Football (1.55/10000 AE), in all other disciplines the event rates were between 0.05 and 0.59/10000 AE (27). In high school athletes in the USA, an overall rate of 1.6 events/100000 AE was reported, with 4.5/100000 AE in Football and rates between 0.2 and 0.9/100000 AE in seven other disciplines observed (6). The lower rate of EHI in the latter study by CDC is explained by different definitions; in the CDC study only cases of EHI resulting in one or more days of time loss from athletic activity were reported (6), whereas Yeargin et al. also collected data on less severe cases of EHI (26, 27). Although prepubertal athletes are considered more susceptible to EHI the rate in youth athletes aged 5-14 years was similar to the rate in college athletes aged 18-23 years and lowest in high school athletes aged 14-18 years (26). For Germany, no data on the epidemiology of exertional heat illness have been published.

Etiology of Heat Illness in Sports and Exercise

Physical activity and exercise cause an increased heat load, generated by repetitive contractions of large groups of muscle fibers. A relevant rise in body core temperature is prevented by physiological processes of thermoregulation like increased sweat production, causing heat loss by evaporation, and peripheral vasodilation, augmenting skin blood flow for better convective heat loss (19). Especially with high temperature and humidity, sustained exercise places high demands on thermoregulatory responses. In these conditions a critical rise in core body temperature can occur, leading to different types of EHI. A higher risk for the development of EHI is given in endurance workouts with submaximal efforts of large groups of muscles, repeated competitions with short breaks (qualification, semifinals and finals in one discipline on one day), or by wearing protective clothes (e. g. protection clothing in American Football, poorly ventilated helmets in cycling) (1, 2).

Other factors contributing to an increased risk of EHI are:

- Increased exposition to solar radiation cannot be avoided because of location and time of the competition
- Increased fluid loss by sweating
- Reduced fluid intake during physical activity
- Reduced resorption of fluids caused by reduced intestinal blood flow.

Maturational Differences in Thermoregulation

Because maturational differences in thermoregulatory mechanisms were observed in various studies, prepubertal children have traditionally been considered to have a reduced tolerance for exercise in the heat and to be at increased risk for EHI. More recent investigations with direct comparison of thermoregulatory responses in prepubertal children and adults have challenged these concepts. Although the differences in thermoregulation during maturation could be confirmed, the responses to exercise in the heat in children and adolescents has shown to be as effective as in adults (19). Exercise in the heat on a bicycle or a treadmill at a comparable relative intensity does not lead to a higher rise in core body temperature in prepubertal probands in comparison to postpubertal probands (3, 9, 12, 13, 21, 23).

However, prepubertal boys have a diminished sweat production in comparison to postpubertal boys and adult men (10, 11, 12, 15, 24). This difference cannot be demonstrated in female probands (17). Although sweating capacity in prepubertal boys is reduced, evaporative heat loss seems to be greater than in adult men (11). This observation may be explained by smaller sweat drops in children, leading to better evaporative cooling.

Only a few investigators studied skin blood flow in prepubertal children during exercise in the heat. They demonstrated a higher skin blood flow in prepubertal children in comparison to adults and greater skin vascular conduction (10, 24), leading to improved convective heat loss in this age group.

The cardiovascular system plays a central part in thermoregulation. It shifts heat away from body core and provides increased skin blood flow for better convective heat exchange as well as fluid supply for greater sweat production. Comparative studies between pre- and postpubertal athletes in respect to the adaptation of cardiovascular system to exercise in the heat did not show relevant differences in increase of cardiac output, stroke volume and mean arterial blood pressure (8, 18, 22).

Individual Factors Influencing Exercise Tolerance in the Heat

Although the risk is greatest with temperatures above 28°C WBGT, EHI can even occur at low temperatures (2). So, general environmental limits for temperature, relative humidity and sun exposure for safe participation in sports and exercise cannot be defined because exercise tolerance in the heat is influenced by individual factors. For example, 9-12 years old obese boys show a lower tolerance for exercise in the heat than lean boys of the same age (7). Gradual adaptation can reduce the risk of exertional heat illness (5), whereas protective clothing (e. g. American Football, goal keepers in field hockey, poorly ventilated bicycle helmets) can reduce convective heat loss and increase the risk for EHI. Successful heat acclimatization can improve tolerance for exercise in the heat (5), whereas recent illness can increase the risk for EHI by negative effects on hydration and regulation of body temperature (1).

Prevention of Exertional Heat Illness in Children and Adolescents

In most cases, healthy children and adolescents can safely participate in exercise and physical activity even in adverse climatic conditions like hot and humid weather. Adequate hydration, acclimatization to exercise in the heat, avoiding heat exposure when possible and external cooling during exercise breaks are effective measures to reduce physiological strain and improve exercise tolerance in hot weather (2, 5).

For prevention of EHI the following modifications and procedures are recommended (modified from (1, 2, 20) all recommendations are expert opinion, evidence class C):

- if possible, reschedule physical activity and exercise to cooler times, e. g. in the morning or in the evening
- reduce duration and intensity of exercise
- increase frequency and duration of breaks
- athletes should drink 5-7 ml/kg body weight 15-30 minutes before exercise
- when exercise lasts more than one hour, athletes should drink 10-13 ml/kg body weight per hour
- after exercise an additional fluid intake of 4 ml/kg bodyweight per hour of activity is recommended
- provide sufficient material for external cooling like cold water, ice or cool packs
- athletes should wear clothing that facilitates adequate cooling by convection and sweating
- in intensive solar radiation, parents, coaches or sports teachers should instruct exercising children and adolescents to care for adequate sun protection of exposed skin areas. In breaks between competitions athletes should wear a cap to protect the head and stay in shady areas
- Coaches, teachers and parents should regularly observe the young athletes for signs like weakness, nausea and vomiting, dizziness, headache, pallor or flush and changes of mental state. When these symptoms show up, exercise should be interrupted immediately
- In organized competitions personnel and facilities for effectively recognizing and treating EHI should be available on site.

Conflict of Interest
The authors have no conflict of interest.

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