

# Thermoregulation in Young People: Implications for the Physical Education Teachers, Sports Trainers and Activity Organizers

## 青少年的體溫調節：對體育教師、教練及 體育活動組織者的一點提示

Michael CHIA

Physical Education & Sports Science Group,  
National Institute of Education, Nanyang Technological University, SINGAPORE

謝永和

新加坡南洋理工大學教育學院體育與運動科學組



### Abstract

There are physical and physiological differences between how young people cope with exercise in hot and cold environments. Young people are especially disadvantaged when their thermoregulatory capabilities are compared to those of adults. Physically, young people have greater surface-area-to-mass ratio, have lower blood volume per unit of body surface area and smaller sweat glands compared to adults. Physiologically, young people are less energy efficient when it comes to locomotion, they have lower maximal cardiac output and also lower sweat gland sensitivity when compared to adults. These differences mean that young people have to tolerate a greater thermal load when they exercise in the heat or that they lose heat faster when they exercise in a cold environment compared to adults. Physical education teachers, sports trainers and activity organizers must be informed of these facts and take the appropriate actions to ensure that young people are sufficiently shielded from harsh environmental conditions when they are engaged in physical activity.

### 摘要

在熱環境與冷環境下運動，青少年的機體反應有其自身的特點。這是因為青少年的體溫調節功能比成年人弱。之所以較弱，有其形態結構與生理功能兩方面的影響因素。與成年人相比，青少年體表面積與體重比值較大；單位體表面積的血流量較少；運動時青少年產能能力較低；最大心輸出量較少；汗腺較小及汗腺的敏感性較弱等。這些差異致使青少年在熱環境下運動時將承受較強的熱負荷，而在冷環境下運動則散熱較快。因此，體育教師、教練和體育活動組織者應重視青少年體溫調節的特點，在這些非常環境下運動時應採取必要的預防保護措施，以確保青少年的健康與安全。

### Introduction

How adults thermoregulate<sup>1</sup> in a hot environment, at rest and during exercise, have been the subject of much research attention. The mechanisms involved in thermoregulation are therefore generally well understood. In contrast, the body of knowledge on young people's thermoregulatory capabilities is less secure. For instance, a wide gap still exists in our

understanding of young people's response to thermal stress and how growth and maturation affect the response. Data on sex differences in thermoregulation in prepubertal children and between girls and women are also scarce (Falk, 1998). Therefore, greater research attention in this area is recommended.

<sup>1</sup> Thermoregulation can be defined as the capability of the body to maintain a stable core temperature in various environments at rest and also during exercise.

## Factors Affecting Thermoregulation

Thermoregulation is affected by environmental condition as well as physical and physiological characteristics of the body. Depending on whether the medium is air or water, or a combination of both, environmental factors that affect thermoregulation include temperature, air or water velocity and humidity. The physical and physiological make up of the person also affect thermoregulation. Physical factors that affect thermoregulation include body dimensions, body composition and body surface area-to-mass ratio. Physiological factors affecting thermoregulation includes the sensitivity of the various organ systems to hot or cold stimuli and the person's state of acclimatization, aerobic fitness and state of hydration. During exercise, the heat produced by the exercising muscles can be as high as 20 times as that produced at rest (Falk, 1998). Exercising in a hot environment therefore places an added

stress on the thermoregulatory processes whilst exercising in the cold relieves some of the thermal stress.

## Physical and Physiological Differences in Thermoregulation in Young People and Adults

Young people are not 'adults-in-miniature'. The manner in which young people physiologically cope with heat and cold stresses are markedly different from that of adults. While young people attain 'thermoregulatory competence' with the attainment of adulthood, many physical and physiological changes occur during growth and maturation in young people that affect the manner in which young people respond physiologically to heat or cold stress. Table 1 outlines the salient physical and physiological differences between young people and adults and how these may influence thermoregulation.

**Table 1. Physical and Physiological Differences between Young People and Adults that Affect Thermoregulation.**

Difference	Effect on thermoregulation
<i>Physical</i>	
❖ Greater surface-area-to-mass ratio	Increased heat gain in hot environments Increased heat loss in warm and cold environments
❖ Lower blood volume per body surface area	Less blood flow to the skin, muscles & central nervous system
❖ Smaller sweat glands	Lower sweat output
<i>Physiological</i>	
❖ Greater oxygen cost of locomotion	Greater metabolic heat production per kg body mass
❖ Lower maximal cardiac output	Less blood flow to the skin, muscles & central nervous system during exercise
❖ Lower sweat gland sensitivity	Higher threshold of sweating Longer time to sweating onset Lower sweating rate

## Thermoregulatory Differences between Young People and Adults

Research informs us that thermoregulation during exposure to hot or cold environments differ between young people and adults. But these physical and physiological differences between young people and adults do not necessarily pose a health threat during exercise in a warm environment. Studies have demonstrated that in a thermoneutral<sup>2</sup> environment, young people's thermoregulatory abilities during exercise (Docherty, Eckerson & Hayward, 1986) are not compromised but difficulties arise when they exercise in very hot environments (Armstrong & Welsman, 1997).

The main physical difference between young people and adults is that young people have a larger surface area-to-body mass ratio. This simply means that for each unit of body mass, young people have a greater surface area that is exposed to the environment when compared to adults. While the amount of heat generated in an exercising person is proportional to amount of body mass involved in the exercise, heat transfer between the exercising person and the environment is dependent upon the surface area exposed to the environment. Therefore a young person who is smaller in size absorbs heat from a hot environment and loses heat in a cold environment more rapidly than an adult who is larger in size. For instance, the surface area-to-body

mass ratio of an eight-to-nine-year-old child (e.g. 1.3m, 20 kg, 0.87m<sup>2</sup>) can be 40% greater than that of an adult (e.g. 1.75m, 67 kg, 1.81 m<sup>2</sup>) (Falk, 1998). Hence, dry heat exchange (conduction, convection and radiation) is relatively greater in young people than in adults. Young people also face problems during exercise in water where their higher surface area-to-body mass ratio makes them vulnerable to rapid heat loss given that the heat conductance of water is 25 times that of air (Armstrong & Welsman, 1997). This can of course happen even in very hot ambient air temperatures.

Another thermoregulatory disadvantage that young people face is their higher production of heat per unit of body mass during walking and running activities. In other words, young people are less efficient when it comes to locomotion where they tend to expend more energy than adults do in accomplishing the same exercise task. For instance, Bar-Or (1989) demonstrated that at speed of 8 km/h, a seven-year-old child expends 15-20% more energy per unit of body mass than a 17 year-old adolescent does. When exercising in hot environments, this additional heat energy that is generated because of young people's comparative 'inefficiency' in locomotive tasks poses an additional strain on their less than mature thermoregulatory processes. The elevated metabolic heat production during submaximal and maximal exercise in the younger person however may be advantageous when exercising in the cold in the short term but during long duration exercise in the cold, less reserve in energy will be available (Smolander, Bar-Or & Korhnen, 1992).

Yet another physiological difference between young people and adults is that young people have a lower cardiac output (and therefore blood volume) during exercise and this may impede skin perfusion thereby limiting heat loss through convection and radiation from the skin surface (Armstrong & Welsman, 1997). The competition for blood flow to the skin to maintain adequate cooling may also result in reduced blood flow to the exercising muscles and the central nervous system, probably explaining in part the lower heat tolerance reported in children (Drinkwater, Kuppatt & Denton, 1977) and also their different subjective response to exercise in the heat (Falk, Bar-Or & MacDougall, 1992). However in a cold environment, the smaller blood volume reported in young people does not appear to affect the effectiveness of thermoregulation (Falk, 1998).

During exercise in a hot environment, evaporative cooling of sweat off the skin is the main mechanism of thermoregulation in adults (Bar-Or, 1989; Falk, 1998). Young people do not sweat as much nor as quickly as adults do for a given relative exercise intensity. For instance Bar-Or (1989), reported that children's sweat rate is only between 60 and 70% of that of adults. Young

people also have smaller sweat gland size compared to adults (Sato & Sato, 1983). It appears that sweat gland size is directly related to sweating rate and also sensitivity to sweating activation in laboratory experiments. Therefore, young people not only have a higher sweating threshold compared to adults, the time to the onset of sweating is also longer and they also have a lower rate of sweating, even when corrected for body size or calculated per gland (Falk, 1998). The higher threshold of sweating which translates to a delayed onset to sweating and lower rate of sweating means that the young people has to tolerate a 'higher thermal load' (i.e. bear with a higher core temperature) before thermoregulation is activated. This places the young person at a distinct disadvantage to the older person when it comes to sports performance in the heat.

<sup>2</sup> *Thermoneutral environment is defined as one where the ambient temperature is between 21 and 25°C and where there is negligible heat exchange between the subject and the environment.*

## Adaptation to Thermal Stress

Adaptation to heat stress is achieved mainly through the process of natural acclimatization or acclimation (i.e. repeated exposures to heat). On the other hand it appears that limited adaptation occurs with repeated exposure to cold (Falk, 1998).

The process of acclimation in young people and adults is apparently similar but the rate of acclimation to exercise in the heat is slower in young people than in adults. For instance, research demonstrated that 10-year-old boys reach an acclimation level that is similar to young adult men following a two-week, three-times-per-week acclimation protocol that involved exercising in the heat (43°C and 21% relative humidity), albeit the rate of acclimation is slower in the boys. Interestingly, it appears that young people, unlike adults, can acclimatize to the heat by merely being passively exposed (e.g. sitting or standing) to the hot environment without the need for exercise in the hot environment to harvest the fruits of acclimatization (e.g. reduced exercise heart rate, increased sweating rate, and lower core temperature) (Inbar, Bar-Or & Dotan, 1985).

## Implications for the Physical Education Teachers, Sports Trainers and Activity Organisers

The physical and physiological differences that exist between young people and adults in thermoregulation suggest an increased vulnerability to heat illness such as heat strain, heat exhaustion and in extreme cases, heat stroke, even though the extent of the risk compared with adults remains worthy of research attention. Prudence is advised especially when dealing with young people

who are engaged in exercise or physical activity in hot environments. Young people are also at risk of cold exposure (hypothermia) if they spend a long time in water activities or if they are exposed to wind chill. Table 2 provides a summary of prudent practices that the PE teacher, sports trainer or activity organizer may find useful when working with young people in our hot and sometimes 'unforgiving' climate.

An informed understanding of how young people thermoregulate can help PE teachers, activity organizers and sports trainers of young people plan and organize their activities appropriately without exposing them to dire and adverse environmental situations, especially during exercise and physical activity. Importantly, they can practice precautionary procedures such as making available adequate sources of hydration before, during and after exercise.

**Table 2. Guidelines for Young People Exercising or Training in the Heat and the Cold.**

- ❖ Allow longer time for acclimation e.g. at least four or five sessions of exposure to the heat
- ❖ Ensure full hydration before, during and after exercise (e.g. 300-400 mL fluid 20-30 min prior to activity for a 12-year-old child)
- ❖ Drink periodically throughout prolonged activities (e.g. 100mL every 15 min)
- ❖ Fluids should be chilled, flavored and not too concentrated (e.g. 0.3 g/L sodium chloride and 25g/L glucose)
- ❖ Discourage keeping to a certain weight category by dehydration
- ❖ Make sure that activities suit the prevailing climate: take into account the special needs of young people
- ❖ Make sure that the clothing is appropriate for the climate (light colored clothing and porous to sweat)
- ❖ Young people should be educated to drink beyond thirst or their subjective needs. Weigh young people before and after the exercise session to gauge the extent of sweat loss so that adequate compensatory drinking can be encouraged
- ❖ When exercising in water or when wet out of the water, avoid exposing young people inappropriately to the cold or the wind to avoid any wind chill. Make hot beverages and snacks available to young people so as to compensate for the 'extra' energy expended
- ❖ Caution is advised when young people of different age groups compete with one another or when young people compete with adults. Special consideration should be made with regards to the disparate thermoregulatory abilities of the different groups of people

## Conclusion

Research informs us that young people and adults handle exercise in the heat and cold rather differently and young people are disadvantaged especially when exercising in the heat. Activity organizers, sports trainers and PE teachers must therefore be mindful of the differences and take appropriate precautionary measures to avoid exposing young people to the deleterious effects of the heat or cold.

In Singapore, where the climate can be described as "hot and hotter", the Ministry of Education "strongly advises" that physical education classes be held in the mornings before 10.30 am and in the afternoons, from 3.30 p.m. onwards (Handbook for Heads of Department [PE], p 9, 1997). The Co-Curricular Activities Center (CCAC) also furnishes guidelines to schools on how outdoor activities including annual cross-country races, swimming events and sports days should be organized to avoid any inappropriate exposure of young people to the elements. Paying attention and adherence to the guidelines in practice will help safeguard the well being of young people.

## References

- Armstrong, N., & Welshman, J. (1997). *Young people and physical activity*, pp. 224-225. UK: Oxford University Press.
- Bar-Or, O. (1989). Temperature regulation during exercise in children and adolescents. In C.V. Gisolfi, and D.R. Lamb (Eds). *Perspectives in Exercise Science and Sports Medicine, Vol 2, Youth, Exercise and Sport*. pp. 335-367. Indianapolis, IN, Benchmark Press.
- Falk, B. (1998). Effects of thermal stress during rest and exercise in the paediatric population. *Sports Medicine*, 25 (4), 221-240.
- Falk, B., Bar-Or, O., & MacDougall, J. (1992). The thermoregulatory response of pre, mid- and late pubertal boys to exercise in dry heat. *Medicine and Sports in Sports and Exercise*, 24, 688-694.
- Docherty, D., Eckerson, J., & Hayward, J. (1986). Physique and thermoregulation in prepubertal males during exercise in a warm and humid environment. *American Journal of Physical Anthropology*, 70, 19-23.

- Drinkwater, B., Kupprat, I., & Denton, J. (1977). Response of pre-pubertal girls and college women to work in the heat. *Journal of Applied Physiology*, 43, 1046-1053.
- Inbar, O., Bar-Or, O., & Dotan, R. (1985). Conditioning versus exercise in heat as methods for acclimatizing 8-10 year-old boys to dry heat. *Journal of Applied Physiology*, 50, 406-411.
- Ministry of Education. (1997). *Handbook for Heads of Department [PE], PE Unit*. Singapore. p.9.
- Sato, K., & Sato, F. (1983). Individual variations in structure and function of human eccrine sweat glands. *American Journal of Physiology*, 245, R203-208.
- Smolander, J., Bar-Or, O., & Korhnen, O. (1992). Thermoregulation during rest and exercise in the cold in pre- and early pubescent boys and in young men. *Journal of Applied Physiology*, 72, 1589-1594.

### Correspondence:

Dr. Michael Chia  
Physical Education & Sports Science Group,  
National Institute of Education,  
Nanyang Technological University, SINGAPORE  
Email: yhmchia@nie.edu.sg