Effect of hydration on performance

Hydration and Performance

Humans are endothermic homeotherms, which means that our body temperature is maintained within a narrow range (~37°C) despite thermal fluctuations in the internal or external environment (Labocha & Hayes, 2008). This function is crucial for survival as the essential processes for sustaining life are temperature dependant (Nilsson, Kogure & Busto, 1975; Lepock, 2003). Upon exposure to external heat stress the thermoregulatory mechanisms which promote heat loss are activated, however, under circumstances in which these thermoeffector responses are impaired drastic deviations from resting values are inevitable (McArdle, Katch & Katch, 2010; Maughan, Watson & Shirreffs, 2007). Changes ±3. 5°C can lead to thermoregulatory disorders (e. g. hyperthermia), permanent disability and in extreme cases death (Moran & Mendal, 2002; Gomez, 2014).

Vigorous physical activity undertaken in hot ambient conditions presents a considerable challenge to thermal equilibrium the imbalance is exacerbated when fluid intake is disproportionate to fluid loss (Reilly & Waterhouse, 2005; Young, 1990). This state of hypohydration is associated with several physiological ramifications many of which negatively affect performance (Cheuvront et al., 2005). Numerous studies have demonstrated that water consumption alone following training or competition in the heat is an inefficient rehydration strategy (Nielsen et al., 1986; González-Alonso, Heaps & Coyle, 1992). Recent evidence has suggested that the nutrient composition of a fluid replacement beverage can facilitate a more complete rehydration (Baker & Jeukendrup, 2014). Considering the consequences of prolonged physical exertion in hot environmental conditions, an understanding of the physiological responses to dehydration, its limiting effects on performance and effective rehydration strategies are essential for those concerned with athletic endeavors.

The purpose of this essay is to threefold; to describe the physiological responses to dehydration during prolonged exercise in the heat, discuss the evidence that dehydration impairs endurance exercise performance and to review the literature concerning the role that drink volume and nutrient composition has in optimizing fluid replacement following a lengthy bout of exercise in hot ambient conditions.

Exposure to excessive heat stress during prolonged exercise can have tremendous physiological consequences (Moran, 2001; Armstrong, 2003). Thermogenetic reflexes (cutaneous vasodilation and sweating) are the primary defense against overheating, however, due to the narrowing of the heat gradient between the epidermis and the environment skin temperature approaches or exceeds ambient temperature nullifying convective and evaporative heat transfer (Crandall & González-Alonso, 2010; Johnson, 2010; Cheung, McLellan & Tenaglia, 2000). The inability to exchange heat with the environment results in an increase in core body temperature (Sawka et al., 1992). The combination of environmental and metabolic heat stress provokes a substantial reduction in total body water (Cheuvront & Kenefick, 2014). The amount of fluid lost through perspiration under such conditions can reach up to 2-3 L/hour (Wenger, 1988). If the fluid lost is not adequately replenished the resultant increase in physiological strain can lead to dehydration (Cheuvront & Kenefick, 2014).

Sweat induced hypohydration leads to hypovolemia (decreased plasma volume) as plasma provides fluid for sweat and hyperosmolality (increased plasma osmolality) as sweat is hypertonic in comparison to plasma (Sawka et al., 2011). The combinations of these alterations modify thermoregulatory responses (Cheuvront et al., 2013). A reduction in plasma volume causes an increase in core temperature thresholds for perspiration and cutaneous vasodilation (Takatama et al., 1998), consequently, as heat cannot be effectively liberated through evaporation more of it is retained (Fortney et al., 1984; Nadel et al., 1980). In addition, hypovolemia impairs the hearts capacity to maintain central blood volume as it reduces cardiac filing which results maldistribution of blood flow as a consequence of decreased stroke volume (González-Alonso et al., 1995). Furthermore, the physiological strain is worsened by the competition between the central and peripheral circulatory systems for the limited blood volume (Rowell, 1986). This has a profound effect on performance as perceived exertion due to the limited oxygen delivery to exercising skeletal muscle and increased cardiovascular strain (Wingo et al., 2012; Nybo et al., 2001; Ganio et al., 2006).

The deleterious physiological effects of the resultant heat stress derived from metabolism and the environment has led to considerable research attention being devoted to studying the effects of hydration status on sports performance yet the notion that dehydration impairs endurance exercise capacity remain a point of contention among exercise physiologists (Goulet, 2011; Judelson et al., 2007a; Judelson et al., 2007b). Ample evidence exists in support the view that dehydration has a limiting effect on endurance capacity in thermoneutral and hot ambient conditions (Montain et al., 1998; Pichan et al., 1988; Walsh et al., 1994).

Montain and Coyle (1992) investigated the effects of various grades of dehydration on performance and found a progressive decline in cardiovascular and thermoregulatory function with greater rates of dehydration. Below et al (1995) aimed to determine the effects of fluid and carbohydrate ingestion on performance, core temperature, and cardiovascular responses during intense exercise lasting 60 minutes. The participants entered a hypohydrated state by cycling for 50 minutes at ~80% VO2max then performed an endurance test whilst being exposed to external heat stress. Under such conditions 7% reduction in exercise capacity was observed. Supporting evidence is provided by the research of Walsh et al (1994). In which the subjects rode at 70% of their VO2max for 60 minutes on a cycle ergometer then undertook a performance test to exhaustion at 90% VO2max in an environmental heat chamber which maintained a temperature of 30 °C. Their findings were that participants either replaced or under replaced the fluid lost during these exercise sessions. The participants that didn’t rehydrate reached exhaustion faster.

Those who disagree with the notion object on the basis of the presence of methodological flaws in the research which calls their validity into question. Numerous studies in this research area are conducted when the participant is already dehydrated (Gigou et al., 2010). This is an irrational approach as such a precondition would be disadvantageous in a competitive context rendering the findings ecologically invalid.

A contrasting view shows that a decline in performance capacity could be a result of a range of factors. Three main factors being either, a long period of exercise before performing in heated conditions and a lack of access to fluid intake (Dougherty, Baker, Chow & Kenney, 2006), a disruption in fluid balance because of extended exposure to heat (Craig & Cummings, 1966), or after consuming a diuretic encouraging diuresis (urination) (Armstrong, Costill & Fink, 1985).

Research looking into the evidence of dehydration being an impairment to exercise has been conducted by Noakes (2007). He suggested that growing thirst can impair aerobic exercise performance. This is supported by evidence provided by Sharwood et al (2004) and Zouhal et al (2011) who found that athletes who experienced higher levels of dehydration meant greater endurance and greater exercise performance. Gibson and Noakes (2004) suggested that thirst is the main deficiency which impairs exercise performance. It regulates in order to increase the feeling of thirst and reduce the exercise intensity, by doing this the athlete can prevent homeostasis (Noakes & Gibson 2005). Noakes' theory is plausible, however it does not fall consistent with the exercise being done. Hyperosmolality and hypovolemia signal the thirst sensation once the sensation of dehydration is identified (Mack, 2005). Noakes' research could be considered as minimalistic as it lacks the required evidence supporting the physiological logic.

Replenishing the fluid lost following prolonged exercise in the heat is essential for the recovery process due to significant disruption in fluid balance (Sutton, 1990). Many researchers still struggle to come to a common conclusion on how to achieve effective rehydration in the hypohydrated state. It is agreed that replenishing the water lost via sweat with purely water is insufficient. The debate, however, on the most effective form of fluid replacement being retained for longer whether it be with sodium, carbohydrates or protein has been an ongoing one. Recent literature concerning the optimisation of fluid replacement suggests the nutrient composition of a beverage can have a substantial impact on fluid ingestion, absorption, distribution and retention (Baker & Jeukendrup, 2014). Fluid-replacement beverages are often formulated with other ingredients, especially those intended to improve physical performance. This suggests that although the means in which replenishing the lost water through retention is done can be left to debate, each of them have proven to be both effective and ineffective in different ways.

Carbohydrate can be considered for fluid-replacement beverages, partially because of its impact on the rate of water absorption. It is also vital in the maintenance of blood glucose concentrations and high rates of carbohydrate oxidation, especially when endogenous carbohydrate stores are being depleted, for example, during physical activity (Jeukendrup, 2008; Jeukendrup, 2004). Evans et al. (2009) found that a larger amount of fluid was retained for a recovery period of six hours after the ingestion of a drink containing 10% glucose as opposed to a drink containing 0%. Osterberg et al (2010) also reported that the greatest level of fluid retention was at 4 hours post sustained physical activity, they found higher amounts of carbohydrate (between six and ten percent) in rehydration drinks consumed in a volume equal to 100% of body mass loss during exercise. Collectively, these studies show that the addition of carbohydrate, glucose especially enhances post exercise rehydration. There have also been proven side effects of this, for example, feeling excessively bloated when drinks are consumed above 150% of the body mass lost during exercise (Evans et al, 2009). This poses the question on whether or not athletes should consume the required volume in situations of ad libitum. Clayton et al (2014) reported a reduced urine output and resultant maintenance of euhydration during recovery following ingestion of high-carbohydrate drinks after exercise was due to a reduction in overall fluid absorption. This suggests that the addition of carbohydrate to rehydration drinks could potentially enhance fluid retention depending on the carbohydrate concentration on ad libitum fluid consumption.

Research into the effect of sodium concentration of rehydration drinks on the restoration of fluid balance have demonstrated a decrease in urine output with an increase in sodium concentration in a drink (Merson, Maughan & Shirreffs, 2008). Effective rehydration was achieved when there was a greater volume of fluid against the volume of fluid lost and when the sodium drink concentration was greater than the sweat level. This suggests that sodium can be effective in water retention but the possibility remains that high sodium intakes might have other adverse effects. Many endurance athletes consume salt supplements while exercising, despite the possibility that it may impair thermoregulation during prolonged endurance exercise (Earhart et al 2015). Overall, research shows that the addition of sodium at a concentration equal or more than the sweat lost is what maintains a positive fluid balance. The presence of sodium in a fluid-replacement beverage enhances palatability and stimulates the physiological drive to drink. Contrastingly, consumption of plain water will reduce plasma osmolality and sodium concentration, minimising the drive to drink, usually before body water volume has been restored completely (Takamata et al 1994). very high sodium concentrations (≥50 mmol/L) decrease drink palatability (Wemple, Morocco & Mack, 1997), which could restrict ad libitum fluid intake.

Milk not only contains sodium and carbohydrate in concentrations, it also contains protein, which is not usually found in commercial rehydration drinks. Seery & Jakeman (2016) and Sherriffs et al (2007) have investigated the efficiency of protein regarding metered intake of milk following exercise and thermal dehydration. They identified how effectively it restores whole-body net fluid balance better than a carbohydrate-electrolyte solution or water. Many milk based drinks have proven to enable rehydration post exercise, compared to carbohydrate-electrolyte drinks (Seery & Jakeman, 2016, James et al, 2012) found enhanced rehydration with combined carbohydrates and milk protein drinks compared to carbohydrate-only drinks. Contrastingly, Hobson & James (2015) investigation into adding whey protein to rehydration drinks reported no benefit when energy is either matched or not, with al libitum in a volume equal to 150% of the body mass loss during exercise. Collectively, these studies suggest in instances where it appears as if protein-containing drinks enhance rehydration after exercise may be related to a slowing of the overall rate of fluid uptake and or an increase in oncotic pressure. More research needs to be done to understand what in combination with protein would make for effective post exercise rehydration, but it is clear that protein alone, cannot do this. In addition to a recovery drink, depending on the type of protein, it could enhance rehydration.

In conclusion, a volume of fluid must be greater than that lost during exercise in order to achieve complete recovery of fluid balance in order to allow dialysis. Although plain water is not considered to be an effective rehydration drink when consumed on its own, there is a higher chance of effectiveness if consumed with a meal that contains the appropriate electrolytes. The addition of carbohydrate and milk protein appears to be beneficial to the rehydration process due to a reduced rate of fluid uptake. Future research in this field should further explain and identify the conclusions made in the research described here and also consider the rehydration strategies for different forms of exercise. It should also focus on the optimal rate of fluid ingestion and how effective these strategies with different forms of exercise for varying periods.

References

- Armstrong, L. (2003). Exertional Heat Illnesses (pp. 17–28). Champaign, IL: Human Kinetics.
- Baker, L. B. & Jeukendrup, A. E. (2014). Optimal Composition of Fluid-Replacement Beverages. *Comprehensive Physiology* .
- Baker, L. B. & Jeukendrup, A. E. (2014). Optimal Composition of Fluid-Replacement Beverages. *Comprehensive Physiology* .
- Bergeron, M. (2014). Heat Stress and Thermal Strain Challenges in Running. Journal Of Orthopaedic & Sports Physical Therapy, 44(10), 831-838.

- Cheung, S., McLellan, T., & Tenaglia, S. (2000). The Thermophysiology of Uncompensable Heat Stress. Sports Medicine, 29(5), 329-359.
- Cheuvront, S. N., & Kenefick, R. W. (2014). Dehydration: physiology, assessment, and performance effects. *Comprehensive Physiology* .
- Cheuvront, S., Carter, R., Castellani, J., & Sawka, M. (2005). Hypohydration Impairs Endurance Exercise Performance in Temperate but not Cold Air. Journal Of Applied Physiology, 99(5), 1972-1976.
- Cheuvront, S., Kenefick, R., Charkoudian, N., & Sawka, M. (2013). Physiologic basis for understanding quantitative dehydration assessment. The American Journal Of Clinical Nutrition, 97(3), 455-462.
- Clayton, D., Evans, G., & James, L. (2014). Effect of Drink Carbohydrate Content on Postexercise Gastric Emptying, Rehydration, and the Calculation of Net Fluid Balance. International Journal Of Sport Nutrition And Exercise Metabolism, 24(1), 79-89.
- Crandall, C., & González-Alonso, J. (2010). Cardiovascular function in the heat-stressed human. Acta Physiologica, 199(4), 407-423.
- Criswell, D., Renshler, K., Powers, S., Tulley, R., & Cicale, M. (1992). Fluid Replacement Beverages and Maintenance of Plasma Volume During Exercise: Role of Aldosterone and Vasopressin. European Journal Of Applied Physiology And Occupational Physiology, 65(5), 445-451.
- Earhart, E. L., Weiss, E. P., Rahman, R., & Kelly, P. V. (2015). Effects of oral sodium supplementation on indices of thermoregulation in trained, endurance athletes. *Journal of Sports Science & Medicine* , *14* (1), 172–178.

- Evans, G., James, L., Shirreffs, S., & Maughan, R. (2017). Optimizing the restoration and maintenance of fluid balance after exercise-induced dehydration. Journal Of Applied Physiology, 122(4), 945-951.
- Fortney, S., Wenger, C., Bove, J., & Nadel, E. (1984). Effect of Hyperosmolality on Control of Blood Flow and Sweating. Journal Of Applied Physiology, 57(6), 1688-1695.
- GANIO, M., WINGO, J., CARROLLL, C., THOMAS, M., & CURETON, K. (2006). Fluid Ingestion Attenuates the Decline in &OV0312; O2peak Associated with Cardiovascular Drift. Medicine & Science In Sports & Exercise, 38(5), 901-909.
- Gibson, A. S. C., & Noakes, T. D. (2004). Evidence for complex system integration and dynamic neural regulation of skeletal muscle recruitment during exercise in humans. *British Journal of Sports Medicine* , *38* (6), 797-806.
- Gibson, A. S. C., & Noakes, T. D. (2004). Evidence for complex system integration and dynamic neural regulation of skeletal muscle recruitment during exercise in humans. *British Journal of Sports Medicine* , *38* (6), 797-806.
- Gomez, C. (2014). Disorders of body temperature. Handbook Of Clinical Neurology, 120, 947-957.
- González-Alonso, J., Heaps, C., & Coyle, E. (1992). Rehydration after Exercise with Common Beverages and Water. *International Journal Of Sports Medicine* , *13* (05), 399-406
- González-Alonso, J., Heaps, C., & Coyle, E. (1992). Rehydration after Exercise with Common Beverages and Water. International Journal Of Sports Medicine, 13(05), 399-406.

- González-Alonso, J., Heaps, C., & Coyle, E. (1992). Rehydration after Exercise with Common Beverages and Water. *International Journal Of Sports Medicine* , *13* (05), 399-406
- Goto, M., Okazaki, K., Kamijo, Y., Ikegawa, S., Masuki, S., Miyagawa, K., & Nose, H. (2010). Protein and Carbohydrate Supplementation During 5-day Aerobic Training Enhanced Plasma Volume Expansion and Thermoregulatory Adaptation in Young Men. Journal Of Applied Physiology, 109(4), 1247-1255.
- Heiderscheit, B. (2014). Always on the Run. Journal Of Orthopaedic & Sports Physical Therapy, 44(10), 724-726.
- James, L. (2012). Milk ingestion in athletes and physically active individuals. Nutrition Bulletin, 37(3), 257-261.
- James, L., Stevenson, E., Rumbold, P., & Hulston, C. (2018). Cow's milk as a post-exercise recovery drink: implications for performance and health. European Journal Of Sport Science, 19(1), 40-48.
- Jeukendrup, A. (2004). Carbohydrate Intake During Exercise and Performance. Nutrition, 20(7-8), 669-677.
- Johnson, J. (2010). Exercise in a hot environment: the skin circulation. Scandinavian Journal Of Medicine & Science In Sports, 20, 29-39.
- Judelson, D., Maresh, C., Anderson, J., Armstrong, L., Casa, D., Kraemer, W., & Volek, J. (2007). Hydration and muscular performance – Does fluid balance affect strength, power and high-intensity endurance?. Sports Medicine, 37(10), 907-921.
- Judelson, D., Maresh, C., Farrell, M., Yamamoto, L., Arstrong, L., & Kraemer, W. et al. (2007). Effect of Hydration State on Strength, Power,

and Resistance Exercise Performance. Medicine & Science In Sports & Exercise, 39(10), 1817-1824.

- Labocha, M., & Hayes, J. (2019). Encyclopedia of Ecology (2nd ed., pp. 368-374). New York: Elsevier Science.
- Lepock, J. (2003). Cellular effects of hyperthermia: relevance to the minimum dose for thermal damage. International Journal Of Hyperthermia, 19(3), 252-266.
- LESHEM, M., ABUTBUL, A., & EILON, R. (1999). Exercise Increases the Preference for Salt in Humans. Appetite, 32(2), 251-260.
- Maughan, R., Watson, P., & Shirreffs, S. (2007). Heat and Cold: What does the Environment do to the Marathon Runner?. Sports Medicine, 37(4), 396-399.
- McArdle, W., Katch, F., & Katch, V. (1991). Exercise Physiology. Medicine & Science In Sports & Exercise, 23(12), 1403.
- McArdle, W., Katch, F., & Katch, V. (2010). *Exercise Physiology: Nutrition, Energy and Human Performance* (pp. 614-615). Philadelphia, Pa: Wolters Kluwer Lippincott Williams & Wilkins.
- McArdle, W., Katch, F., & Katch, V. (2010). *Exercise Physiology: Nutrition, Energy and Human Performance* (pp. 614-615). Philadelphia, Pa: Wolters Kluwer Lippincott Williams & Wilkins.
- Montain, S., & Coyle, E. (1992). Influence of graded dehydration on hyperthermia and cardiovascular drift during exercise. Journal Of Applied Physiology, 73(4), 1340-1350.
- Montain, S., Smith, S., Mattot, R., Zientara, G., Jolesz, F., & Sawka, M. (1998). Hypohydration Effects on Skeletal Muscle Performance and

Metabolism: a 31P-MRS study. Journal Of Applied Physiology, 84(6), 1889-1894.

- Moran, D. (2001). Potential Applications of Heat and Cold Stress Indices to Sporting Events. Sports Medicine, 31(13), 909-917.
- Moran, D., & Mendal, L. (2002). Core Temperature Measurement. Sports Medicine, 32(14), 879-885.
- Nadel, E., Fortney, S., & Wenger, C. (1980). Effect of Hydration State of Circulatory and Thermal Regulations. Journal Of Applied Physiology, 49(4), 715-721.
- Nielsen, B., Kubica., Bonnesen, A., Rasmussen, I., Stoklosa, J., & Wilk, B. (1981). Physical work capacity after dehydration and hyperthermia. *Scandinavian Journal Of Sports Science* , *3* , 2–10.
- Nielsen, B., Kubica., Bonnesen, A., Rasmussen, I., Stoklosa, J., & Wilk, B. (1981). Physical work capacity after dehydration and hyperthermia. *Scandinavian Journal Of Sports Science* , *3* , 2–10.
- Nilsson, L., Kogure, K., & Busto, R. (1975). Effects of Hypothermia and Hyperthermia on Brain Energy Metabolism. Acta Anaesthesiologica Scandinavica, 19(3), 199-205.
- Nose, H., Mack, G., Shi, X., & Nadel, E. (1988). Role of Osmolality and Plasma Volume During Rehydration in Humans. Journal Of Applied Physiology, 65(1), 325-331.
- Nybo, L., Jensen, T., Nielsen, B., & González-Alonso, J. (2001). Effects of Marked Hyperthermia With and Without Dehydration onV˙o 2 Kinetics During Intense Exercise. Journal Of Applied Physiology, 90(3), 1057-1064.

- Osterberg, K., Pallardy, S., Johnson, R., & Horswill, C. (2010). Carbohydrate Exerts a Mild Influence on Fluid Retention Following Exercise-Induced Dehydration. Journal Of Applied Physiology, 108(2), 245-250.
- Pichan, G., Gauttam, R., Tomar, O., & Bajaj, A. (1988). Effect of Primary Hypohydration on Physical Work Capacity. International Journal Of Biometeorology, 32(3), 176-180.
- Pichan, G., Gauttam, R., Tomar, O., & Bajaj, A. (1988). Effect of Primary Hypohydration on Physical Work Capacity. International Journal Of Biometeorology, 32(3), 176-180.
- Popkin, B., D’Anci, K., & Rosenberg, I. (2010). Water, Hydration and Health. Nutrition Reviews, 68(8), 439-458.
- Reilly, T., & Waterhouse, J. (2005). Sport, Exercise and Environmental Physiology (pp. 13-15). Edinburgh: Churchill Livingstone.
- Rowell, L. (1986). Human Circulation: Regulation during Physical Stress (pp. 363-406). New York: Oxford University Press.
- SAWKA, M. (1992). Physiological Consequences of Hypohydration. Medicine & Science In Sports & Exercise, 24(6), 657??? 670.
- Sawka, M. N., Leon, L. R., Montain, S. J., & Sonna, L. A. (2011). Integrated physiological mechanisms of exercise performance, adaptation, and maladaptation to heat stress. *Comprehensive Physiology* .
- Sawka, M., Cheuvront, S., & Carter, R. (2005). Human Water Needs. Nutrition Reviews, 63, S30-S39.

- Sawka, M., Young, A., Latzka, W., Neufer, P., Quigley, M., & Pandolf, K. (1992). Human Tolerance to Heat Strain During Exercise: Influence of Hydration. Journal Of Applied Physiology, 73(1), 368-375.
- Seery, S., & Jakeman, P. (2016). A metered intake of milk following exercise and thermal dehydration restores whole-body net fluid balance better than a carbohydrate–electrolyte solution or water in healthy young men. British Journal Of Nutrition, 116(6), 1013-1021.
- Shirreffs, S., Watson, P., & Maughan, R. (2007). Milk As An Effective Post-Exercise Rehydration Drink. British Journal Of Nutrition, 98(1), 173-180.
- Takamata, A., Mack, G., Gillen, C., & Nadel, E. (1994). Sodium Appetite, Thirst, and Body Fluid Regulation in Humans During Rehydration Without Sodium replacement. American Journal Of Physiology-Regulatory, Integrative And Comparative Physiology, 266(5), R1493-R1502.
- Takamata, A., Nagashima, K., Nose, H., & Morimoto, T. (1998). Role of Plasma Osmolality in the Delayed Onset of Thermal Cutaneous Vasodilation During Exercise in Humans. American Journal Of Physiology-Regulatory, Integrative And Comparative Physiology, 275(1), R286-R290.
- Walsh, R., Noakes, T., Hawley, J., & Dennis, S. (1994). Impaired High-Intensity Cycling Performance Time at Low Levels of Dehydration. International Journal Of Sports Medicine, 15(07), 392-398.

- Walsh, R., Noakes, T., Hawley, J., & Dennis, S. (1994). Impaired High-Intensity Cycling Performance Time at Low Levels of Dehydration. International Journal Of Sports Medicine, 15(07), 392-398.

- Wemple, R., Morocco, T., & Mack, G. (1997). Influence of Sodium Replacement on Fluid Ingestion Following Exercise-Induced Dehydration. International Journal Of Sport Nutrition, 7(2), 104-116.

- Wemple, R., Morocco, T., & Mack, G. (1997). Influence of Sodium Replacement on Fluid Ingestion Following Exercise-Induced Dehydration. International Journal Of Sport Nutrition, 7(2), 104-116.

- Wenger, C. B. (1988) Human heat acclimatization. In Human Performance Physiology and Environmental Medicine at Terrestrial Extreme (pp. 153–197). Indianapolis, Ind: Benchmark Press.

- Wenger, C. B. (1988) Human heat acclimatization. In Human Performance Physiology and Environmental Medicine at Terrestrial Extreme (pp. 153–197). Indianapolis, Ind: Benchmark Press.

- Wingo, J., Ganio, M., & Cureton, K. (2012). Cardiovascular Drift During Heat Stress. Exercise And Sport Sciences Reviews, 40(2), 88-94.
- Young, A. (1990). Energy Substrate Utilization during Exercise in Extreme Environments. Exercise And Sport Sciences Reviews, 18(1), 65-117.
- Young, A. (1994). Perspectives in Exercise Science and Sports Medicine. Medicine & Science In Sports & Exercise, 26(2), 265-266.