Journal of Science and Medicine in Sport 23 (2020) 322–328

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

journal homepage: www.elsevier.com/locate/jsams

Review

Intravenous fluids and their use in sport: A position statement from the Australian Institute of Sport

Samantha Pomroy*, Greg Lovell, David Hughes, Nicole Vlahovich

Australian Institute of Sport, Sports Medicine Department, Australia

ARTICLE INFO

Article history:
Received 22 July 2019
Received in revised form 22 October 2019
Accepted 26 October 2019
Available online 5 November 2019

Keywords:
IV fluid
WADC
Sport

ABSTRACT

Objective: The use of intravenous fluids in out-of-hospital settings has evolved from the practices used by military and emergency response teams. When used in the elite sporting environment, IV fluid use must comply with the World Anti-Doping Code. Uncertainty can arise as clinicians seek to balance the appropriate use of IV fluids in delivering athlete care against the need for World Anti-Doping Code compliance.

Design and method: This position statement reviews the current literature and incorporates clinical experiences to present best-practice recommendations on the clinical use of Intravenous fluids in the elite sport environment, framing recommendations in the context of the World Anti-Doping Code.

Results and conclusion: The World Anti-Doping Code restricts the use of Intravenous fluids in athletes under certain conditions. This report takes into account the World Anti-Doping Code and the risks of Intravenous fluid administration to provide guidelines around the judicious use of IV fluids for:

1. Treatment of severe dehydration in an athlete,
2. Management of exertional heat illness in an athlete,
3. Hypovolaemia because of trauma in sport,
4. Administering medications.

1. Introduction

Intravenous (IV) fluid prescription in medicine mainly occurs within a hospital setting. The use, timing, type and volume of IV fluids, outside of a hospital setting has, however, evolved over recent decades. Changes have occurred because of the lessons learnt in operational requirements of military and emergency response teams. Medical practitioners working within the elite sporting environment are required to give consideration to the World Anti-Doping Code (WADC) which places limitations on the location, indications and rate of delivery of IV fluids and infusions.[1] Therapeutic Use Exemptions (TUE) can be granted for use of IV fluids with appropriate clinical justification.[1,2] There is little information in the medical literature to inform clinicians in the elite sport environment about the appropriate indications for IV fluid use in balancing the medical care of the athlete against the restrictions stipulated in the WADC. This position statement seeks to assist clinicians by providing evidence-based and ethically justified guidelines for the use of IV fluids in elite sport.

2. WADA regulations

The World Anti-Doping Agency (WADA) is the international, independent organisation created in 1999 to promote, coordinate and monitor the fight against doping in sport. WADA coordinated the development, and subsequent evolution, of the WADC.[1] The WADC provides the framework for anti-doping policies, rules and regulations within sports organisations and among public authorities around the world. The WADC informs a broad range of activities including testing, laboratory analysis, Therapeutic Use Exemption (TUE) processes, maintenance of the List of Prohibited Substances and Methods,[3] the protection of privacy and personal information, and Code Compliance by Signatories.

WADA defines doping as the occurrence of one or more of the anti-doping rule violations (ADRV).[4] One of these ADRVs is the

Abbreviations: IV, intravenous; WADC, world anti-doping code; WADA, World Anti-Doping Agency; TUE, therapeutic use exemption; ADRV, anti-doping rule violations; ABP, Athlete Biological Passport; ICD-10, International Classification of Diseases; NICE, National Institute of Care Excellence; ORT, oral rehydration therapy; EHI, exertional heat illness; EHS, exertional heat stroke; CNS, central nervous system; TBI, traumatic brain injury.

* Corresponding author.
E-mail address: sampomroy@hotmail.com (S. Pomroy).

https://doi.org/10.1016/j.jsams.2019.10.020

use or attempted use of a prohibited substance or method. IV infusions were included on the WADA List of Prohibited substances and methods, under section M2 (Prohibited Methods, chemical and Physical Manipulation) from 2005.[5] The current wording in the 2019 Prohibited List states that "Intravenous infusions and/or injections of more than a total of 100 mL per 12 h period except for those legitimately received in the course of hospital admissions, surgical procedures or clinical diagnostic investigations" is prohibited.[3] However, a TUE may be necessary for a prohibited substance delivered by IV infusion, even if the infusion itself is delivered in the setting of one of the three exceptions.

The method (i.e. IV infusion) is prohibited to mitigate the risk that some athletes may try to manipulate their plasma volume to mask a prohibited substance. Secondly, inappropriate use of IV fluids is a risk in weight categorised sports, where athletes may be tempted to undergo significant weight loss prior to weigh-in, followed by rapid rehydration post weigh-in. Thirdly, there are examples in the past where professional team sports used IV fluid hydration pre-game and at half time to rehydrate athletes in preparation for the second half of the match,[6] and most recently IV infusions claiming to assist in recovery. Lastly, athletes may try to manipulate their Athlete Biological Passport (ABP) test results by using IV fluids. The aim of the ABP is to monitor selected biological variables over time that indirectly reveal the effects of doping rather than attempting to detect the doping substance or method itself.[7] These practices pose a threat to the health of the athlete but also compromise the spirit of sport to enhance performance.

The WADC requires application for a TUE "if an intravenous infusion of more than 100 mL in 12 h is administered (apart from hospital admissions, surgical procedures or clinical investigations) or when a prohibited substance is administered via IV (no matter what the volume, rate or setting)".[5] In situations of a medical emergency or under clinical time constraints, a retroactive TUE application is acceptable.[8]

The settings outside of a hospital setting, where application for a TUE would need to be considered, include[5]:

1. A medical practitioner's office, suite, home, tent or vehicle,
2. IV clinics or any clinic/treatment room or centre outside of a hospital facility unless a clinical diagnostic investigation or surgical procedure has been performed,
3. Event organisers' medical facility, tent, first aid station, or start-finish line facility.

The documentation for a TUE for IV Infusion administered to an athlete has to meet the following criteria[1]:

1. Diagnosis of a medical condition, in accordance with the International Classification of Diseases standards of the World Health Organisation (ICD-10),
2. A precise description of the clinical situation and specific medical indication, including supportive evidence that no permitted alternative treatment can be used,[9]
3. Clear documentation that a qualified medical practitioner diagnosed, ordered and administered the treatment,
4. Conducted in an appropriate medical setting. If conducted in a non-medical setting, documentation is required to support the reasons as to why this occurred,
5. Adequate medical records of the treatment including medical history of the presenting complaint, past medical history and medications, examination findings including vital signs and signs of fluid loss, name of prohibited method and recommended duration of the TUE.[9]

Table 1
Common forms of IV crystalloid fluids used for adults in 'out-of-hospital' settings.

Name	Content	Osmolality	Tonicity
Normal saline (0.9% NaCl)	Sodium 154 mmol/L Chloride 154 mmol/L	308 mOsmol/L	Isotonic
5% dextrose	Dextrose hydrous (D-glucose) 5 g/100 mL of water	252 mOsmol/L	Hypotonic after absorption
Ringers lactate/ hartmann's solution	Sodium 131 mmol/L Chloride 111 mmol/L Potassium 5 mmol/L Lactate 29 mmol/L Calcium 2 mmol/L	278 mOsmol/L	Isotonic

References 11,14.

Box 1: Potential adverse effects caused by IV fluid administration.

- Complications at the injection site (infection, phlebitis and venous thrombosis)
- Fluid and solute overload resulting in electrolyte abnormalities
- Over-hydration
- Congestive conditions (central and peripheral)
- Acid base imbalances
- Financial cost to administer IV fluids, which includes appropriate staffing and monitoring
- References[16,17]

3. Types of IV fluids

There are three main types of IV fluids: crystalloids (isotonic, hypertonic, hypotonic), colloids (starch and gelatine solutions) and blood and blood substitutes.[10] Crystalloids are usually the IV fluids of choice in the pre-hospital setting due to low cost and low risk of adverse events.[11]

The National Institute for Health and Care Excellence (NICE) guidelines published in 2004 reviewed ten systematic reviews of randomised controlled trials comparing different IV fluid types in different settings and populations, and concluded that there was insufficient evidence of benefit of a particular IV fluid because of the clinical heterogeneity between the studies.[11] Cotton et al. (2009) concluded that Lactated Ringers Solution and 0.9% Normal Saline are "equivalent in efficacy in trauma patient outcomes".[12] Alam and Santry (2016) concluded the "L-isomer of Lactated Ringers Solution is the most reasonable choice as it induces relatively less inflammation and immune dysfunction, causes fewer electrolyte abnormalities, is cost effective and is widely available for clinical use".[13] The medical literature is inconsistent in supporting a standard prescription applying to all populations. The physician will therefore make the choice of IV fluids based on risk, availability and cost (Table 1).

3.1. Risks of IV fluids

Physicians must be aware that IV fluid administration is not without risk or harm. Potential adverse effects of IV fluid administration are listed in Box 1.

Within the sporting arena studies done thus far show there is no clear evidence to support the use of IV fluids in non-emergency situations.[5,15]

3.2. When should physicians consider the use of IV fluids?

There are four main indications for which physicians may consider use of IV fluids:

Table 2
Clinical signs of dehydration.

Symptom	Mild	Moderate	Severe
% wt. loss	3–5%	6–9%	>10%
Pulse	Full, normal rate	Rapid, thready	Very rapid and weak or absent
Respiration	Normal	Deep, may be increased	Deep, rapid or decreased
Systolic blood pressure	Normal	Normal to low	Low
Buccal mucosa	Normal	Dry	Parched
Eyes	Normal	Sunken	Markedly sunken
Skin turgor	Normal	Reduced	Tenting
Skin	Normal	Cool	Cool, mottled
Urine output	Decreased	Oliguria	Oliguria to anuria
Systemic signs	Increased thirst, alert	Listless, irritable	Lethargic, coma
Capillary refill	2 s	2–4 s	>4 s, cool limbs

Reference 16.

1. Treatment of severe dehydration in an athlete,
2. Management of exertional heat illness in an athlete,
3. Hypovolaemia because of trauma in sport,
4. Administering medications.

The first three are emergency situations so the initial pre-hospital assessment must include standard life support protocols of which IV volume resuscitation may be a part. These four main considerations for use of IV fluids are examined in the context of the limitations stipulated by the World Anti-Doping Agency with reference to scientific and clinical literature for evidence of their use.

4. Severe dehydration

4.1. Diagnosing dehydration

The term 'dehydration' describes a state of negative fluid balance. The causes are; reduced intake, increased losses or fluid shifts into third spaces.[16] The most common causes of dehydration in athletes include inadequate hydration (particularly in endurance events or in the heat), weight loss strategies used in events requiring 'weighing in' prior to competition and gastrointestinal illness.

Hydration status is a dynamic and complex concept involving multiple body systems (skin, lungs, kidneys and gastrointestinal tract) involved in the regulation of water balance. A single gold standard of measuring hydration status remains elusive so a combination of clinical signs and symptoms and investigations is recommended.[17]

4.1.1. Clinical signs and symptoms

Dehydration can range from mild, moderate and severe based on clinical signs (Table 2). Much of the literature on clinical signs of dehydration investigates patients within a hospital setting, paediatric or elderly population, making inferences to healthy elite athletes difficult.[18–21] The precision and accuracy of any one of these physical signs of dehydration is also poor when used in isolation. Using a combination or cluster of multiple signs is recommended.[15–19,22] Percentage weight loss requires pre-competition weights and scales to measure patients in the field, which may not be feasible with a severely dehydrated patient. Urine output progressively decreases with worsening dehydration, therefore commonly used measures of hydration status such as urine osmolality, specific gravity and colour may not be applicable in more severe cases. Clinical signs and symptoms are useful to suspect water and electrolyte disturbances and prompt investigations for confirmation.

4.1.2. Blood indices

Blood tests are generally not required in mild to moderate dehydration.[23–25] Severe dehydration will often necessitate use of IV fluids. The cause of the loss of fluids will dictate the tonicity and therefore treatment.[26] In an out-of-hospital setting, this assessment is challenging. The use of a portable blood analyser (if available) can provide information on electrolyte concentration (sodium, potassium) as well as blood glucose level (a glucometer can also be used). These results can then guide treatment options.

4.2. Treatment of severe dehydration

Mild to moderate dehydration is more effectively treated with oral rehydration rather than IV Fluid Infusion.[13,15,27] Adults with signs of severe dehydration who cannot tolerate oral fluids, have a reduced mental status, and are haemodynamically unstable may require IV rehydration.[22,28] A caveat here is the physician also needs to consider other causes of the athlete's signs and symptoms such as exercise-associated hyponatremia (EAH) or hypoglycaemia as this will dictate IV fluid use and type.[29] EAH is often the result of overhydration in endurance events. Severe EAH, manifesting in neurological impairment and inability to tolerate oral hypertonic salt broth, is treated with IV hypertonic saline bolus of 100 mL 3% Normal Saline once low serum sodium levels are confirmed.[30]

When there is haemodynamic compromise a bolus of 10–20 mL/kg of isotonic saline is recommended, and this should be repeated until haemodynamics are restored.[31] Ongoing therapy is guided by response, serum electrolyte concentrations, fluid deficit, ongoing losses and co-morbidities.[31]

As the patient stabilises Oral Rehydration Therapy (ORT) can then be initiated at a volume of 100 mL every 5 min. In addition, losses from the gastrointestinal tract should be calculated. ORT is based on the preserved co-transport of glucose and sodium assisting in water absorption across the gastrointestinal villi.[32]

Physicians providing medical care in high performance sport settings must plan appropriately. This includes consideration of appropriate examination and investigations to inform the decision to administer IV fluids in cases of severe dehydration. This needs to occur as part of normal best medical practice and for use in the TUE application process (Box 2).

5. Exertional heat illness

Exertional heat illness (EHI) is among the leading causes of death in young athletes each year despite the educational efforts focussing on prevention.[33,34] The National Centre for Catastrophic Sport Injury Research reported a total of 153 deaths from 1931 to 2018 as a result of heat stroke.[35] Prevention of EHI requires understanding of risk factors, recognition of symptoms, thorough clinical assessment and prompt evidence-based intervention.

Risk factors for EHI include strenuous activity in high ambient temperature and humidity, direct sun exposure, absence of breeze, lack of acclimatisation, poor physical fitness, dehydration, acute or recent illness, certain medications and external loads (cloth-

Box 2: Evidence based recommendations for the treatment of severe dehydration

- When assessing for severe dehydration monitor clinical signs and symptoms (see Table 2) and consider measurement of plasma sodium and blood glucose
- In a severely dehydrated patient, IV rehydration is used. 10–20 mL/kg bolus of 0.9% sodium chloride initially and consider repeating these boluses until adequate haemodynamics are restored
- Severe EAH, manifesting in neurological impairment and inability to tolerate oral hypertonic salt broth, is treated with IV hypertonic saline bolus of 100 mL 3% Normal Saline once low serum sodium levels are confirmed.
- A TUE is required if IV fluids are used >100 mL/12 h or outside of approved settings

Table 3
Simple strategies for the treatment of heat syncope.

Move to shaded, cool area
Lay supine with feet elevated above head
Oral fluids once mentally alert
Fanning the athlete
Wet ice towels
Water spray
Remove excess clothing and equipment

ing, equipment and protective gear).[28] These risk factors increase thermoregulatory stress by disrupting the cooling mechanisms of conduction, convection, evaporation or radiation.

Diagnosis of EHI requires a careful history and clinical examination. Significant heat illness presentations in an isolated sporting environment should trigger a call for emergency medical support followed by a primary survey utilising the SABCDE approach (Safe to Approach, Airways, Breathing, Circulation, Disability and Environment).[36–38]

The international classification of diseases (ICD) outlines a method for categorising the various forms of exertional heat illness.[39] Three significant subtypes of EHI include heat syncope and exercise associated collapse, heat exhaustion and exertional heat stroke.

5.1. Heat syncope and exercise associated collapse

Heat syncope with exercise is commonly observed at the completion of endurance events and postulated to result from an abrupt decrease in venous return because of the cessation of muscular work.[40] Heat may be an indirect contributor as the body is dually tasked to provide blood to the exercising muscle and the periphery to assist in thermoregulation.[28,41] This can impact upon the baroreflex-mediated regulation of blood pressure during exercise.[42] Dehydration and/or hypovolaemia is a risk factor in some individuals.[43–45]

The athlete should recover in 15–20 min with simple strategies (Table 3). Failure to respond to these should prompt further evaluation (e.g. heart rate, blood pressure, rectal temperature and mental status) and transfer to an emergency facility for syncope work up (Box 3).[28,45]

5.2. Heat exhaustion

Heat exhaustion is the "inability to maintain adequate cardiac output due to strenuous activity and environmental heat stress".[41] Acute dehydration may be present but is not required for the diagnosis. The core body temperature is 38.3–40 °C. Other

Box 3: Evidence based recommendations for the treatment of heat syncope

- Oral fluids are encouraged if mentally alert
- No IV fluids are indicated for the initial management of heat syncope and therefore no TUE is required
- If there is a failure to improve after 15–20 min, then transfer to a medical facility for further investigation is recommended

Box 4: Evidence based recommendations for the treatment of heat exhaustion

- Heat exhaustion occurs when the core body temperature is elevated to 38.3–40 °C
- IV fluids should be considered in the setting of deteriorating mental status or persistent nausea or vomiting
- If there is no rapid improvement following cooling strategies transfer immediately to hospital to exclude heat stroke
- A TUE application must be submitted after the immediate emergency is resolved if IV fluids are used

signs and symptoms include tachycardia and hypotension, extreme weakness, ataxia, light-headedness, syncope, headache, profuse sweating pallor, abdominal cramps, nausea, vomiting, diarrhoea and persistent muscle cramps.[41]

Management includes those mentioned in Table 3 as well as methods such as cold water immersion to cool the patient until their rectal temperature is approximately 38.3 °C.[28] If signs of dehydration are evident rehydrate the patient with chilled water or ORT if not nauseated or vomiting. IV fluids can be considered if the patient is unable to drink due to nausea or vomiting. However IV fluids are rarely required for heat exhaustion.[47] Monitoring of the patient's vital signs, rectal temperature and mental status should continue during treatment interventions.[28] Necessity for IV fluids, failure to improve, or deterioration of haemodynamic and/or mental status requires transfer to an emergency medical facility. In such circumstances, a diagnosis of heat stroke must be considered (Box 4).[28]

5.3. Exertional heat stroke

Exertional heat stroke (EHS) is a multi-system illness characterised by central nervous system (CNS) dysfunction and organ and tissue damage in association with high core temperatures (>40–40.5 °C).[41] CNS dysfunction includes disorientation, headache, irrational behaviour, irritability, altered consciousness, coma and seizure. Other features of EHS include tachycardia, hypotension, hyperventilation, profuse sweating, dehydration, thirst, muscle cramps, ataxia, loss of muscle function, nausea and vomiting. The initial pre-hospital assessment must include SABCDE in accordance with standard life support protocols of which IV volume resuscitation may be a part.[37,38,47,48]

Initiating cooling immediately and ensuring that the core temperature does not remain elevated is vital in improving prognosis. If appropriate equipment is available, measure blood glucose level and serum sodium to exclude hypoglycaemia and/or exercise associated hyponatremia.[28] If appropriate medical staff and materials for rapid cooling are present and no other medical emergencies exist, "cool first and transport second" until the temperature is approximately 39 °C then transport to an emergency department.[28,49] Treatment should include removal of all equipment and excess clothing, and ice water immersion.[50–52] The provision of IV fluids in EHS can be considered for circulatory sup-

Box 5: Evidence based recommendations for the treatment of exertional heat stroke

- EHS affects multiple body systems in association with high core temperatures (>40–40.5 °C)
- Aim to cool the patient first and transport second if appropriate medical staff and cooling strategies are present
- IV hydration can be considered for circulatory support in EHS, however small boluses should be given
- A TUE application should be submitted once appropriate clinical management interventions have been completed if IV fluids are used

port as heat stroke patients will likely be volume depleted. External cooling may redistribute blood flow centrally so aggressive fluid resuscitation is generally not recommended.[52] Cold IV hydration, can be a useful adjunct to evaporative or conductive cooling in reducing the core temperature.[48] Cardiac monitoring should take place with cold IV cooling as HR can rise in response due to its interaction with the autonomic nervous system. This may have implications in cardiac function and recovery.[58] Avoid treatment induced shivering as this will elevate the core temperature.[47]

Rhabdomyolysis can occur in association with EHS. This can lead to acute kidney injury. Renal function, serum creatine kinase levels and serum potassium levels should be closely monitored in patients with rhabdomyolysis.[54] Treatment of exertional rhabdomyolysis involves large volumes of IV fluids. In-hospital IV therapy should be guided by invasive haemodynamic monitoring in a hospital facility (Box 5).[55]

6. Trauma in sport

Trauma in the sporting environment is more prevalent in contact and high velocity sports. A single study collecting statistics on all sport and active recreation-related major trauma cases and deaths in Victoria Australia, found that the five sports with the highest frequency of major trauma were cycling, motor sports, equestrian, Australian Football and all other football codes combined.[56] Trauma in an athlete resulting in haemorrhagic hypovolaemia may require IV fluids for haemodynamic support. This can be a result of blunt or penetrating injury, fracture of long bones or pelvis, intra-abdominal or retro-peritoneal bleeds and chest trauma.[38] Early recognition of the signs of haemorrhagic hypovolaemia is vital to prevent shock. Haemodynamic instability is one if the major causes of death in trauma patients.[11]

Management of sport-related trauma resulting in haemorrhagic hypovolaemia requires a systematic assessment following advanced life support procedures.[37,38] Calls for ambulance support should be made early. The area surrounding the patient must be made safe. First aid principles of airway, breathing and circulation should be applied. Measurement of blood pressure, heart rate, respiratory rate, colour and conscious level should occur.[38,57] Interpreting the vital sign values in the context of elite athletic fitness is essential.

Once known or suspected uncontrolled bleeding is identified in the assessment, prompt interventions to stop the bleeding with pressure and/or tourniquet should be made.[38,58] If there is no external haemorrhage, consideration should be given to the possibility of internal bleeding into the chest or abdomen, and/or fractures of the long bones and pelvis. Fractures should be stabilised with a splint or pelvic binder.[38,57]

Experimental data strongly supports the limitation of fluid resuscitation in uncontrolled post-traumatic haemorrhage.[59,60] This restrictive fluid approach of permissive hypotension is recommended until control of active bleeding to minimise disruption of blood clots and dilution of clotting factors.[10,58,61]

Box 6: Evidence based recommendations for the treatment of trauma in sport

- When there is loss of the radial pulse (or central pulse in penetrating torso trauma) IV crystalloid boluses of 250 mL are recommended
- Boluses are titrated to maintenance of a pulse
- If a significant head injury exists, consider larger volumes to maintain cerebral perfusion pressure
- Most importantly transport the patient to a trauma centre as soon as possible
- If IV fluids are provided, a retrospective TUE will need to be completed

Indications for IV fluids include haemodynamic support once there is control of active bleeding, loss of the radial pulse in uncontrolled bleeding (correlating with a systolic blood pressure <90 mmHg), absence of central pulse in uncontrolled bleeding in penetrating torso injuries and significant traumatic brain injury (TBI).[11,38] Patients with a significant TBI are thought to be more sensitive to hypotension so when traumatic brain injury is the dominant condition a less restrictive approach to fluid resuscitation to maintain cerebral perfusion pressure can be considered.[11,60]

The recommendations, once clinical indications for IV fluids exist, are to obtain emergency vascular access intravenously or via interosseous access and administer a 250 mL bolus of crystalloid titrated to maintenance of the radial pulse in uncontrolled bleeding and central pulse in penetrating torso trauma.[11,60] Crystalloids are recommended for fluid volume replacement, particularly in pre-hospital settings where blood components are not available.[11] The most important aspect of management of trauma is to get the patient to a trauma centre as soon as possible for definitive management and no intervention should delay this (Box 6).[10–12,61–63]

7. Administration of medications

IV medications prescribed to an athlete in an out of hospital setting may include iron, antibiotics, and less commonly hydrocortisone and bisphosphonates. These parenteral medications often require IV fluids as a vehicle for administration. When administering IV medications, the Prohibited List must be taken into consideration. Where IV medications involve administration of IV fluids exceeding 100 mL in 12 h, and the setting is not a hospital environment, a TUE application must be submitted. Medications that are on the Prohibited List, and which are delivered by IV infusion, require a TUE for the prohibited substance, even if the IV infusion is given during a hospital admission, surgical procedure or clinical diagnostic evaluation. Blood transfusions always require a TUE, regardless of the setting.[2]

IV iron for example can be administered as an injection, or an infusion according to the product information. This should be consulted for IV fluid requirements in administration. This would then dictate the fluid volumes and therefore TUE requirements (Box 7).

8. Conclusion

This AIS position statement provides recommendations for physicians working in the elite sporting environment when prescribing intravenous fluids in adherence with the WADC guidelines. The current literature supports judicious use of intravenous fluids to protect the health of athletes in specific clinical situations. Prioritising athlete health aligns with the WADC. Clinical scenarios

Box 7: Evidence based recommendations for administration of medication by IV

- Administration of IV medications may be required in athletes and must be considered on a case by case basis
- The IV medication should be checked against the WADA Prohibited List as it may require a TUE
- If not prohibited but the volume of fluid required to deliver the medication is >100 mL in 12 h, then a TUE is required

within elite sport that warrant use of intravenous fluids includes severe dehydration, exertional heat illness, trauma and administration of medications. This position statement provides guidance for medical practitioners when using IV fluids in sport.

9. Practical implications

- This manuscript provides recommendations for physicians working in the elite sporting environment when prescribing intravenous fluids in adherence with the WADC guidelines
- Severe dehydration, exertional heat illness, trauma and administration of medications may warrant the use of IV fluids in elite athletes

Acknowledgements

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors would like to acknowledge the contributions towards the preparation of this manuscript from Dr. Susan White and Dr. Nicolin Tee.

References

1. *World Anti-Doping Code 2015 with 2019 amendments*, 2019. Available at: https://www.wada-ama.org/sites/default/files/resources/files/wada_anti-doping_code_2019_english_final_revised_v1_linked.pdf. Accessed June 2019.
2. *International standard for therapeutic use exemptions*, 2019. Available at: https://www.wada-ama.org/sites/default/files/resources/files/istue_2019_en_new.pdf. Accessed June 2019.
3. , Available at: https://www.wada-ama.org/sites/default/files/wada_2019_english_prohibited_list.pdf. Accessed June 2019 *Prohibited List*, 2019.
4. *Anti-Doping Important Facts and Highlights from WADA's Athlete Guide*, 2015. Available at: https://www.wada-ama.org/sites/default/files/wada_anti-doping_aag_eng_web.pdf. Accessed June 2019.
5. *TUE Physician Guidelines Medical Information to Support the Decisions of TUECs Intravenous Infusions*, 2018. Available at: https://www.wada-ama.org/sites/default/files/resources/files/intravenous_infusions_v5.0_jan2018_en.pdf. Accessed June 2019.
6. Coombes JS, van Rosendal SP. *Use of intravenous rehydration in the National Football League*, LWW, 2011.
7. *Athlete Biological Passport*, 2018. Available at: https://www.wada-ama.org/en/athlete-biological-passport. Accessed November 2018.
8. *Therapeutic Use Exemption (TUE)*, 2019. Available at: https://www.wada-ama.org/en/questions-answers/therapeutic-use-exemption-tue#item-730. Accessed January 2019.
9. *TUEC Guidelines Medical Information to Support the Decisions of TUE Committees Intravenous Infusions*, 2018. Available at: https://www.wada-ama.org/sites/default/files/resources/files/tue_intravenousinfusions_version5.1_july2018.pdf. Accessed November 2018.
10. Revell M, Porter K, Greaves I. Fluid resuscitation in prehospital trauma care: a consensus view. *Emerg Med J* 2002; 19:494–498.
11. National Institute for Clinical Excellence. *Prehospital initiation of fluid replacement therapy in trauma: technology appraisal guidance 74*, London, NHS Publishers, 2004.
12. Cotton BA, Jerome R, Collier BR et al. Guidelines for prehospital fluid resuscitation in the injured patient. *J Trauma Acute Care Surg* 2009; 67:389–402.
13. Casa DJ, Ganio MS, Lopez RM et al. Intravenous versus oral rehydration: physiological, performance, and legal considerations. *Curr Sports Med Rep* 2008; 7:S41–S49.
14. *Summary of IV fluids composition (mmol/L)*, 2018. Available at: http://www.frca.co.uk/article.aspx?articleid=295#. Accessed January 2019.
15. Casa DJ, Maresh CM, Armstrong LE et al. Intravenous versus oral rehydration during a brief period: responses to subsequent exercise in the heat. *Med Sci Sports Exerc* 2000; 32:124–133.
16. Huang LH, Lennox H. Dehydration, In: *Medscape Reference.*, 2009.
17. Cheuvront SN, Sawka MN. Hydration assessment of athletes. *Sports Sci Exch* 2005; 18:1–6.
18. Steiner MJ, DeWalt DA, Byerley JS. Is this child dehydrated? *JAMA* 2004; 291:2746–2754.
19. Gorelick MH, Shaw KN, Murphy KO. Validity and reliability of clinical signs in the diagnosis of dehydration in children. *Pediatrics* 1997; 99, e6-e.
20. McGee S, Abernethy III WB, Simel DL. Is this patient hypovolemic? *JAMA* 1999; 281:1022–1029.
21. Thomas DR, Tariq SH, Makhdomm S et al. Physician misdiagnosis of dehydration in older adults. *J Am Med Dir Assoc* 2003; 4:251–254.
22. Noakes T. Fluid and electrolyte disturbances in heat illness. *Int J Sports Med* 1998; 19:S146–S149.
23. Vesikari T, Isolauri E, Baer M. A comparative trial of rapid oral and intravenous rehydration in acute diarrhoea. *Acta Pædiatr* 1987; 76:300–305.
24. Freedman SB, Ali S, Oleszczuk M et al. Treatment of acute gastroenteritis in children: an overview of systematic reviews of interventions commonly used in developed countries. *Evid-Based Child Health: Cochr Rev J* 2013; 8:1123–1137.
25. Stanton BF, Rowland M, Clemens J. Oral rehydration solution – too little or too much? *Lancet (London, England)* 1987; 1:33–34.
26. Spital A. Dehydration versus volume depletion—and the importance of getting it right. *Am J Kid Dis* 2007; 49:721–722.
27. Maresh CM, Herrera-Soto JA, Armstrong LE et al. Perceptual responses in the heat after brief intravenous versus oral rehydration. *Med Sci Sports Exerc* 2001; 33:1039–1045.
28. O'Connor FG, Casa D. *Exertional heat illness in adolescents and adults: management and prevention*, UpToDate, 2015.
29. Hew-Butler T, Ayus JC, Kipps C et al. Statement of the second international exercise-associated hyponatremia consensus development conference, New Zealand, 2007. *Clin J Sport Med* 2008; 18:111–121.
30. *Supportive management of acute gastroenteritis*, 2018. Available at: https://tgldcdp.tg.org.au/viewTopic?topicfile=supportive-management-gastrointestinal&guidelineName=Gastrointestinal#toc_d1e453. Accessed January 2019.
31. Hew-Butler T, Rosner MH, Fowkes-Godek S et al. Statement of the third international exercise-associated hyponatremia consensus development conference, Carlsbad, California, 2015. *Clin J Sport Med* 2015:303–320.
32. Freedman S. *Oral rehydration therapy*, UpToDate, 2017.
33. Maron BJ, Doerer JJ, Haas TS et al. Sudden deaths in young competitive athletes: analysis of 1866 deaths in the United States, 1980–2006. *Circulation* 2009; 119:1085–1092.
34. Kucera K, Yau R, Cox Thomas L et al. *Catastrophic sports injury research—thirty second annual report*, 2015.
35. Kucera K, Klossner D, Colgate B et al. *Annual survey of football injury research: 1931–2018*, Chapel Hill, NC, National Center for Catastrophic Sport Injury Research at the University of North Carolina at Chapel Hill for the American Footbal Coaches Association, National Collegiate Athletic Association, & National Federal of State High School Associations: National Center for Catastrophic Sport Injury Research at the University of North Carolina at Chapel Hill, 2019.
36. Australian Resuscitation Council. *The ARC guidelines*, 2016.
37. Monsieurs KG, Nolan JP, Bossaert LL et al. European resuscitation council guidelines for resuscitation 2015 section 1. Executive summary. *Resuscitation* 2015; 95:1–80. http://dx.doi.org/10.1016/j.resuscitation.2015.07.038. Epub 2015 Oct 15.
38. *Medical Protocols for Match Day Medical Staff*, 2018. Available at: http://playerwelfare.worldrugby.org/?documentid=module&module=23. Accessed October 2018.
39. Centers for Disease Control Prevention, National Center for Health Statistics. *International classification of diseases, clinical modification (ICD-9-CM)*, Hyattsville, National Center for Health Statistics, 2008.
40. Murrell C, Wilson L, Cotter JD et al. Alterations in autonomic function and cerebral hemodynamics to orthostatic challenge following a mountain marathon. *J Appl Physiol* 2007; 103:88–96.
41. O'Connor FG, Casa D. *Exertional heat illness in adolescents and adults: epidemiology, thermoregulation, risk factors, and diagnosis*, Waltham, MA, UpToDate, 2018. Accessed October 2018.
42. Crandall CG. Heat stress and baroreflex regulation of blood pressure. *Med Sci Sports Exerc* 2008; 40:1–14, 2063.
43. Charkoudian N, Halliwill JR, Morgan BJ et al. Influences of hydration on post-exercise cardiovascular control in humans. *J Physiol* 2003; 552:635–644.
44. Cheuvront SN, Kenefick RW, Montain SJ et al. Mechanisms of aerobic performance impairment with heat stress and dehydration. *J Appl Physiol* 2010; 109:1989–1995.
45. Wilson TE, Cui J, Zhang R et al. Heat stress reduces cerebral blood velocity and markedly impairs orthostatic tolerance in humans. *Am J Physiol Regul Integr Comp Physiol* 2006; 291:R1443–R1448.
47. Therapeutic Guidelines Ltd. *Heat-related illness*, 2018. Available at: https://tgldcdp.tg.org.au/viewTopic?topicfile=heat-related-illness. Accessed June 2019.
48. Moore TM, Callaway CW, Hostler D. Core temperature cooling in healthy volunteers after rapid intravenous infusion of cold and room temperature saline solution. *Ann Emerg Med* 2008; 51:153–159.
49. Casa DJ, DeMartini JK, Bergeron MF et al. National Athletic Trainers' Association position statement: exertional heat illnesses. *J Athlet Train* 2015; 50:986–1000.

50. Gaudio FG, Grissom CK. Cooling methods in heat stroke. *J Emerg Med* 2016; 50:607–616.
51. Smith J. Cooling methods used in the treatment of exertional heat illness. *Br J Sports Med* 2005; 39:503–507.
52. Lipman GS, Eifling KP, Ellis MA et al. Wilderness Medical Society practice guidelines for the prevention and treatment of heat-related illness: 2014 update. *Wildern Environ Med* 2014; 25:S55–S65.
54. Miller ML. *Clinical manifestations and diagnosis of rhabdomyolysis*, UpToDate, Version, 2014. p. 11.
55. Helman R. *Medscape reference: heatstroke [online]*, 2017. Updated May 2017.
56. Ekegren C, Gabbe B. Ten-year incidence of sport and recreation injuries resulting in major trauma or death in Victoria. *J Sci Med Sport* 2017; 20:e107–e108.
57. Australasian College of Sport and Exercise Physicians. *Advanced Course in the Management of Sporting Trauma (MOST)*, 2018.
58. Roppolo LP, Wigginton JG, Pepe PE. Intravenous fluid resuscitation for the trauma patient. *Curr Opin Crit Care* 2010; 16:283–288.
59. Mapstone J, Roberts I, Evans P. Fluid resuscitation strategies: a systematic review of animal trials. *J Trauma Acute Care Surg* 2003; 55:571–589.
60. National, Clinical Guideline Centre UK. *Major Trauma: Assessment and Initial Management*, 2016.
61. Levett D, Vercueil A, Grocott M. Resuscitation fluids in trauma 1: why give fluid and how to give it. *Trauma* 2006; 8:47–53.
62. De Crescenzo C, Gorouhi F, Salcedo ES et al. Prehospital hypertonic fluid resuscitation for trauma patients: a systematic review and meta-analysis. *J Trauma Acute Care Surg* 2017; 82:956–962.
63. Dretzke J, Burls A, Bayliss S et al. The clinical effectiveness of pre-hospital intravenous fluid replacement in trauma patients without head injury: a systematic review. *Trauma* 2006; 8:131–141.