The taste of salt in the athlete's soup: a short update with practical recommendations

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Abstract

The general recommendation for daily sodium consumption is about 6 g/d, as a higher intake was associated with an increased risk for cardiovascular mortality in individuals already suffering from hypertension. However, this recommendation is not necessarily valid for athletes as they often experience high sweat and sodium losses during exercise. While it is well-known that a balanced hydration status and fluid replacement are important factors to maintain an adequate exercise performance, the importance of salt losses during exercise seems to be often underestimated. This short update will focus on the role and impact of salt or sodium ingestion before, during and after exercise and its implication on performance.

Pre-exercise ingestion of highly concentrated sodium solutions (164 mmol/l) induces a plasma volume expansion leading to a performance enhancing effect. Sodium intake during exercise of more than 60 min helps to prevent from or compensate dehydration. Sports drinks ingested during exercise commonly contain a sodium concentration of 30-50 mmol/l, whereas a higher concentration might be advantageous for so called salty sweaters or athletes prone to heat cramps. For a fast rehydration after exercise, drinks with a sodium concentration of around 100 mmol/l were found to be most effective. In any case, taste preference and gastrointestinal discomfort have to be considered individually and the amount of salt or sodium to be ingested in the different exercise settings depends highly on the desired goal. Finally, the timing of salt or sodium intake as well as the right dosage are of high importance to successfully influence exercise performance.

Keywords: sports nutrition, dehydration, performance, sodium chloride

Zusammenfassung

Allgemein wird für den täglichen Natriumkonsum eine Menge von rund 6 g empfohlen, da ein höherer Konsum bei Hypertonikern mit einem gesteigerten Risiko für kardiovaskuläre Mortalität einhergeht. Solche Empfehlungen haben allerdings für Athleten kaum Gültigkeit, weil diese während körperlicher Belastung häufig grosse Mengen an Schweiss und somit auch Salz verlieren. Auch wenn allgemein bekannt ist, dass ein ausgeglichener Flüssigkeitshaushalt sowie der Ersatz der schweissbedingten Flüssigkeitsverluste eine wichtige Rolle bei der Aufrechterhaltung der sportlichen Leistungsfähigkeit spielt, wird die Bedeutung einer entsprechenden Salzzufuhr oftmals unterschätzt oder ganz vernachlässigt. Dieser kurze Übersichtsartikel befasst sich mit den Auswirkungen einer gezielten Natrium- bzw. Salzeinnahme vor, während und nach körperlicher Belastung.

Die Einnahme einer hoch konzentrierten Natrium-Lösung (164 mmol/l) vor einer körperlichen Belastung bewirkt eine Expansion des Plasmavolumens, welche sich positiv auf die nachfolgende Ausdauerleistung auswirkt. Bei Belastungen von über 60 min Dauer hilft die Natriumzufuhr einer Dehydrierung vorzubeugen oder diese entsprechend zu kompensieren. In der Regel enthalten Sportgetränke, die während Belastung eingenommen werden, eine Natriumkonzentration von 30 bis 50 mmol/l. Bei Athleten, die sehr stark schwitzen oder zu Krämpfen neigen, scheint es sinnvoll, den Natriumgehalt entsprechend zu erhöhen. Zur raschen Rehydratation haben sich Getränke mit einem Natriumgehalt von bis zu 100 mmol/l bewährt. Beim Einsatz von Natrium oder Salz müssen Geschmack und gastrointestinale Verträglichkeit unbedingt individuell berücksichtigt werden. Zudem hängt die eingenommene Menge stark vom Anwendungsziel sowie von der Art und der Dauer der Belastung ab. Schliesslich entscheiden die richtige Dosierung und der richtige Einnahmezeitpunkt darüber, inwiefern die Leistungsfähigkeit durch eine gezielte Natriumsupplementation positiv beeinflusst werden kann.

Introduction

At the first glance, salt is an unimpressive, white, crystalline substance with a molecular weight of 58 g/mol. It consists of about 40% sodium and 60% chloride, with sodium playing an important role in the regulation of the human fluid balance and blood pressure regulation [1]. A very high dietary salt intake was found to be associated with an increased risk for hypertension and cardiovascular mortality in individuals already suffering from hypertension [2]. For this reason, a daily sodium intake of no more than 6 g was recommended for these individuals [2]. However, such a general recommendation is not necessarily valid for athletes, who sometimes experience high sweat losses of over 3 l/h (corresponding to a salt loss of more than 5 g/h) during exercise [3,4]. In this context, it seems obvious that an individual's exercise performance is not only highly dependent on hydration status but also on an adequate supply with salt (for review see [5]).

Although numerous studies (for review see [6]) discussed the importance of hydration status and fluid replacement for exercise performance, the simultaneously occurring salt loss during exercise seems to be often underestimated or even neglected [1]. However, an adequate replacement of sodium losses seems to be necessary to maintain athletes well hydrated in order to keep exercise performance at a high level [1]. The following short overview will focus on practical aspects and recommendations of salt or sodium ingestion before, during and after exercise.

Sodium ingestion before exercise

Several studies [7–10] were able to show a pre-exercise plasma volume expansion between 3 and 8% following the ingestion of 10 ml/kg body mass of a 164 mmol/l sodium enriched solution, which corresponds to about 7 g sodium for a person of 75 kg. In these studies, a significant increase in exercise performance compared to control trials was reported *(Tab. 1)*. Additionally, it was shown that the extent of the pre-exercise plasma volume expansion did not only depend on the sodium concentration of the beverage, but also on the individual's training status [11].

Regular endurance training per se leads to a higher plasma volume [12]. Thus, it is not surprising that endurance-trained athletes seem to benefit less from a pre-exercise sodium ingestion compared to untrained individuals [11]. It was concluded that the ergogenic benefit of pre-exercise salt consumption is possibly moderate in a thermo-neutral environment and somewhat higher for endurance exercise in the heat [11]. However, as the performance difference between winning and losing a medal at international championships is very small, it seems worthwhile to think about pre-exercise plasma volume expansion by means of sodium ingestion, especially for competitions in a hot environment.

However, instead of the plasma volume expansion there might be also another reason for the reported positive effects on exercise performance in the above mentioned studies [8–11] as a sodium citrate solution was used. Sodium citrate was found to have ergogenic effects concerning anaerobic exercise [13] by indirectly increasing blood buffer capacity.

Sodium ingestion during exercise

There seems to be no need to ingest sodium during short-term exercise up to a duration of 60 min. However, with an ongoing exercise duration, there might be several reasons for sodium ingestion. During prolonged exercise of several hours (e.g. marathon, ironman triathlon), an exercise-associated hyponatremia can occur if only water is ingested in the absence of sodium. However, the most pronounced reason to experience a hyponatremia is not a deficit of sodium but an inadequately high fluid ingestion. Noakes and colleagues [14] reported a hyponatremia incidence of 9% during ultra-endurance events, a condition that can lead to severe health problems or even to death [15].

Sodium ingestion during exercise helps also to preserve plasma volume, which seems to have some thermoregulatory (e.g. lower core temperature) and cardiovascular (e.g. lower heart rate) benefits [16]. It is widely accepted that hydration during exercise plays an important role in preventing from heat-related health problems and performance declines [8,17,18]. Although a sodium intake during prolonged exercise is thus warranted, it is difficult to set up a general recommendation concerning the amount of sodium to be ingested during exercise. The main reason is that sweat-related sodium losses vary widely between individuals and depend on different factors including environmental conditions, exercise intensity and duration, hydration status as well as clothing [19]. Individual sweat losses ranged between 1.0 and 3.6 l/h with sweat sodium concentrations varying from 16 to 83 mmol/l [3,4,20]. Average sodium losses were reported with 30.2 mmol/l [20] and 44.5 mmol/l [3]. These findings are in line with the recommendation of De Oliveira and Burini [21], who postulated to ingest a 30–50 mmol/l sodium solution for hyponatremia prevention. However, because of the high inter-individual differences, it seems worthwhile to determine individual sweat and sodium losses during train-

Author, Year	Participants and average VO_{2peak}	Time point of ingestion	Exercise performance	Results
Greenleaf et al., 1997 [7]	5 untrained men 38.7 ml/min/kg	105–45 min before exercise	Cycling time to exhaustion at 87–91% VO_{2peak}	+23.6% increase in time to exhaustion
Coles and Luetkemeier, 2005 [8]	14 male cyclists 50.2 ml/min/kg	50–20 min before exercise	45 min cycling at 70% VO_{2peak} followed by a 15 min time trial (21–23° C)	+7.8% in time trial performance
Sims et al., 2007a [9]	13 female cyclists 52 ml/min/kg	80–20 min before exercise	Cycling time to exhaustion at 70% VO_{2peak} (32° C and 50 % rel. humidity)	+20.9% in time to exhaustion
Sims et al., 2007b [10]	8 male runners 58 ml/min/kg	105–45 min before exercise	Running time to exhaustion at 70% VO_{2peak} (32° C and 50% rel. humidity)	+19.7% in time to exhaustion

Table 1: Effects of a pre-exercise ingested 164 mmo/l sodium solution (10 ml/kg body mass) on performance

ing sessions at different ambient temperatures, especially in elite athletes.

Heat cramps are often associated with extensive sweating and a concomitant sodium loss as primary contributing factors [3, 22, 23]. Athletes prone to develop heat cramps had significantly higher average sweat sodium concentrations compared to a reference group (53 mmol/L versus 38 mmol/L) [23]. It seems worthwhile to identify such athletes (in practice this can be done by checking their clothing for white salt spots after exercise) and to enrich their sports drinks with an adequate amount of salt.

Sodium ingestion after exercise

The purpose of fluid and sodium replacement after exercise is to optimize the rehydration process. This is very important – especially for those athletes who train more than once per day – in order to enhance recovery. To start a new training session in a dehydrated state will decrease the training quality and impair exercise performance. According to Valentine [1], an adequate rehydration is only possible if sweat-related sodium losses were replaced together with fluid ingestion. The ingestion of sodium prevents from a decrease of the vasopressin level, which avoids a diuretic effect [1]. Shirreffs and Maughan [24] compared rehydration beverages with different sodium concentrations of 0, 25, 50 and 100 mmol/l and concluded that euhydration was reached after 6 h only with the 100 mmol/l sodium solution. However, euhydration might also be reached with beverages with lower sodium contents when a repetitive drinking strategy will be applied. Finally, it has to be taken into account that after exercise, sodium must not necessarily be replaced only with beverages, but that also common foods can contribute to salt delivery *(Tab. 2)*.

In sport disciplines with weight classes such as lightweight rowing, judo or boxing a fast rehydration is very important and crucial for an optimal exercise performance. In these sports, athletes often make weight by severe sweating interventions before the weighing process in order to reach the postulated body weight. Once the weighing control is passed, there remain only 1 to 2 h in certain sports to replace the fluid and electrolyte losses in order to avoid a decrease in the subsequent exercise performance. It was found that a massive weight loss induced by sweating can significantly reduce subsequent exercise performance [25]. Given that in elite sports very small performance differences of less than 0.5% can decide between winners and losers [26], a fast rehydration strategy is needed with athletes undergoing rapid weight loss. For this purpose, the authors recommend to use beverages with high sodium contents of up to 164 mmol/l.

Serving	Food	Amount of salt per serving
60 g	Whole-grain bread	0.6 g
60 g	White bread	0.7 g
30 g	Emmental cheese	0.2 g
30 g	Gouda cheese	0.6 g
30 g	Feta cheese	0.7 g
30 g	Salami	1.2 g
40 g	Jerky beef	1.7 g
30 g	Crackers	0.6 g
25 g	Potato chips	0.3 g
30 g	Peanuts (salted and roasted)	0.4 g
30 g	Pretzel sticks	1.3 g

Table 2: Examples for salt-rich foods

Further practical aspects

The amount of salt or sodium needed in the different exercise settings depends highly on the goal that should be achieved *(Fig. 1)*.

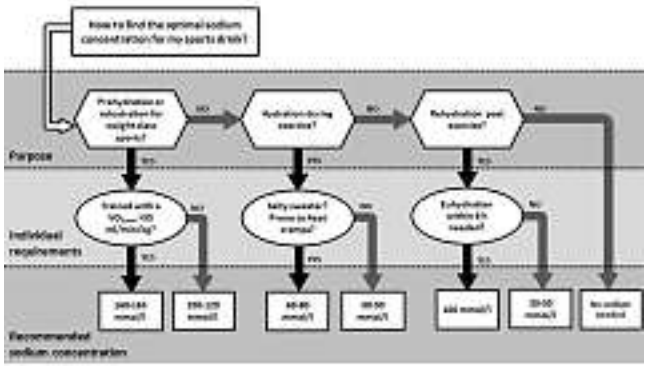

Figure 1: Simplified flowchart to estimate the optimal sodium concentration of a sports drink needed for different exercise situations in order to positively influence exercise performance.

The best sodium mixture is worthless if it has a bad taste and a poor gastrointestinal tolerance. Acute sodium loading through sodium bicarbonate ingestion was associated with a high prevalence of gastrointestinal distress [27]. Thus, it is of utmost importance to test sodium-rich beverages during training sessions before applying them during competitions. Additionally, the timing of the ingestion seems to be crucial as well. The ingestion of a sodium-rich solution 180 min before an exercise resulted in significantly less gastrointestinal discomfort compared to its intake 60 or 120 min before the same exercise, although performance was not affected by the different timing strategies [28].

Athletes often ask about the ideal method of ingesting salt. In general, salt can be provided by means of infusions, tablets or as an oral solution in form of a sports drink. The use of infusions with a volume of more than 50 ml is prohibited and banned as a violation of the current antidoping rules [29]. Thus, this possibility will not be discussed further here. Casa et al. [30] reported that time to exhaustion at 74% of VO_{2peak} in trained athletes after rehydration was not significantly different when the same amount of a sodium chloride solution was administered orally (34.9 min) or intravenously (29.5 min). A recently published article by Savoie and colleagues [31] found that fluid retention with an oral sodium chloride solution was significantly higher compared to the

same amount of fluid and sodium chloride ingested as tablets. Nevertheless, both approaches induced an effective pre-exercise hyperhydration. However, there might be some practical reasons in certain situations to prefer the one or the other method. One argument to use tablets might be the salty taste of the solution, which can be avoided by the ingestion of tablets. On the other hand, the salt delivery can be better dosed by using solutions.

Conclusion

Dosage and timing of salt ingestions have to be adapted individually according to different factors such as sweat rate, environmental conditions, training status and gastrointestinal tolerance. In general, the use of sodium solutions can be helpful before, during and after exercise in order to positively influence exercise performance by direct or indirect means. The targeted sodium concentration varies between 30 and 165 mmol/l depending on the purpose. In any case, sodium should definitely be a component of each sports drink.

Conflict of interest

The authors have no conflicts of interest relevant to this article.

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