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Supplementation and Performance in Spinal Cord-Injured Elite Athletes: a Systematic Review

Supplemente und körperliche Leistungsfähigkeit querschnittgelähmter Athleten: ein systematisches Review

REVIEW

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Summary

› **Purpose:** Supplement use has gained increasing interest in the past decade including in Paralympic sports. However, several physiological differences (e.g. prolonged gastrointestinal transition time, reduced resting energy expenditure) exist between able-bodied and athletes with a spinal cord-injury due to the impairment of the autonomic nervous system, which might influence supplement effects. The aim of this review was to investigate the impact of supplement use on exercise performance in spinal cord-injured athletes.

› **Methods:** A comprehensive review was performed using Pubmed as search engine to detect studies investigating supplement use in spinal cord-injured athletes.

› **Results:** Only five studies were identified. These studies dealt with the use of carbohydrates, creatine, caffeine, sodium citrate or the combination of the latter two supplements. One study using an 11% carbohydrate solution found an endurance performance enhancing effect. Caffeine seemed to have ergogenic effects on sprint and short-term but not on endurance performance in athletes with a para- or tetraplegia. Sodium citrate and creatine showed no performance enhancing effects.

› **Conclusions:** The results showed that results from studies performed with able-bodied individuals cannot be transferred into a wheelchair sport context. Evidence-based recommendations on supplement use are not feasible due to the lack of data from spinal cord-injured athletes. This means that individually tailored solutions for each wheelchair athlete are necessary for supplement use at present and further studies are needed to gain more evidence-based information.

KEY WORDS:
Sports Nutrition, Paraplegia, Elite Sport, Caffeine, Creatine

Zusammenfassung

› **Problemstellung:** Der Einsatz potenziell leistungssteigernder Supplemente rückt zunehmend ins Sportinteresse. Diese Entwicklung wird auch im paralympischen Sport beobachtet. Allerdings muss bedacht werden, dass zwischen nichtbehinderten und querschnittgelähmten Athleten mit beeinträchtigtem autonomen Nervensystem massive physiologische Unterschiede (verlängerte Darmpassagezeit, verminderter Grundumsatz) bestehen, die die Wirkung von Supplementen beeinflussen können. Resultate aus Fußgängerstudien können daher nicht direkt in den Rollstuhlsport transferiert werden. Ziel des vorliegenden Übersichtsartikels war es, den Einfluss von Supplementen auf die Leistungsfähigkeit querschnittgelähmter Athleten zu erfassen.

› **Methode:** Eine umfassende Literatursuche wurde mit Pubmed als Suchmaschine durchgeführt, um den Einfluss potenziell leistungssteigernder Substanzen auf die körperliche Leistungsfähigkeit querschnittgelähmter Athleten zu analysieren.

› **Ergebnisse:** Insgesamt konnten fünf Studien identifiziert werden. Sie untersuchten Kohlenhydrate, Kreatin, Koffein, Natriumcitrat sowie die Kombination von Koffein und Natriumcitrat. Eine Studie zeigte eine signifikante Verbesserung der Ausdauerleistung bei Rollstuhlleichtathleten nach Einnahme einer 11%-igen Kohlenhydrat-Lösung. Bei para- und tetraplegischen Athleten wurde ein leistungssteigernder Effekt unter Koffeinsupplementation im Bereich kurzer Einsatzzeiten, aber nicht bei Ausdauerleistungen gefunden. Natriumcitrat und Kreatin zeigten keine leistungssteigernden Effekte.

› **Diskussion:** Diese Resultate stehen teilweise in einem deutlichen Widerspruch zu Daten von nichtbehinderten Sportlern. Diese Unterschiede sind vermutlich auf erwähnte physiologische Unterschiede zurückzuführen. Dies unterstreicht die Notwendigkeit spezifischer Studien für Rollstuhl-Athleten. Die aktuelle Datenlage lässt keine evidenzbasierten Empfehlungen für den Supplement-Gebrauch bei Rollstuhl-Athleten zu. Für die tägliche Praxis müssen aktuell individuelle Lösungen erarbeitet werden. Dabei sollen unerwünschte Nebenwirkungen und Supplement-Medikament-Interaktionen beachtet sowie ineffektive oder verbotene Supplemente vermieden werden.

SCHLÜSSELWÖRTER:
Sporternährung, Paraplegie, Leistungssport, Koffein, Kreatin

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Introduction

Exercise performance in Paralympic wheelchair races depends on a number of different factors. The chance to win a medal at Paralympic Games lies within a time span of 0.5% (13). In other words: marginal details can decide between winners and losers. In this context, sports nutrition in general and especially the use of supplements complementing the individual nutrition to optimize exercise performance, gained increasing interest in the past decade in Paralympic sports. This is underlined by two studies on the ›

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Table 1

Identified studies dealing with supplement use and performance in athletes with a spinal cord injury.

REFERENCE	SPORT/PARTICIPANTS	SUPPLEMENT	SUPPLEMENT DOSAGE	EXERCISE PROTOCOL	PERFORMANCE OUTCOME
Spendiff & Campbell (2005)	Wheelchair athletics 8 male paraplegic athletes	Carbohydrates	600ml of a low (4%) and high (11%) carbohydrate drink 20min before start of exercise	Wheelchair exercise at 65% of VO_{2peak} for 1h followed by a 20min time trial performance test	Tendency for greater performance distance and power output, higher blood glucose concentrations, respiratory exchange ratios and significantly lower free fatty acid concentrations during the high carbohydrate trial compared to low carbohydrate trial
Perret et al. (2006)	Wheelchair athletics 6 (4 male, 2 female) competitive athletes	Creatine monohydrate	4x5g/day for 6 days	800m time trial	No significant differences between creatine and placebo supplementation in 800m performance, rate of perceived exertion, lactate concentrations, heart rate and body mass
Graham-Paulson et al. (2015)	Wheelchair rugby 12 male wheelchair rugby players	Caffeine	4mg/kg body mass 70min before exercise	Four sets of 4min upper body push exercise and 3 sets of 3x20m sprints	Average sprint times were significantly faster compared to placebo and participants pushed significantly further during the first set of 4min push exercise
Flueck et al. (2015)	Arm crank exercise in trained paraplegic (P, n=10), tetraplegic (T; n=7) and able-bodied (AB; n=17) participants	Caffeine	6mg/kg body mass 1h prior test	3min all out arm cranking	Significantly increased average power over first 30s and 60s in P but not in T nor in AB compared to placebo. Tendency for increased peak power in AB (+46W; p=0.10) and P (+21W; p=0.17) but not in T (+2W; p=0.49). Plasma caffeine significantly increased in all groups whereas epinephrine significantly increased only in AB and P. Norepinephrine significantly increased only in AB
Flueck et al. (2014)	Wheelchair athletics 9 (6 male, 3 female) elite athletes	Caffeine	6mg/kg body mass 1h prior test	1500m time trial	Significantly higher maximal lactate concentrations compared to placebo. No significant difference in 1500m performance
	Wheelchair athletics 9 (6 male, 3 female) elite athletes	Caffeine & sodium citrate	6mg/kg body mass caffeine 1h prior exercise; 0.5g/kg body mass sodium citrate 120-90min prior exercise	1500m time trial	Significantly higher maximal lactate concentrations compared to placebo. No significant difference in 1500m performance
	Wheelchair athletics 9 (6 male, 3 female) elite athletes	Sodium citrate	0.5g/kg body mass 120-90min before exercise	1500m time trial	Significantly increased blood pH and bicarbonate concentrations compared to placebo. No significant difference in 1500m performance. 5 out of 9 athletes complained about side effects under supplementation

prevalence of supplement use in Paralympic athletes (7, 23), where 64% and 58% of included athletes declared the use of supplements or medication. Paralympic athletes mostly ingested multivitamins, sports drinks, protein and carbohydrate supplements, which is comparable to the supplements used by able-bodied athletes .

However, one has to keep in mind that substantial physiological differences exist between able-bodied and spinal cord-injured athletes due to the impairment of the autonomic nervous system. This implies that nutrient recommendations from studies with able-bodied athletes can't be transferred automatically one-to-one into a wheelchair sport context. From a nutritional point of view, the most important differences after a spinal cord-injury include a prolonged gastrointestinal transition time (6, 10), a reduced resting energy expenditure (16), changes in body composition (20) and muscle fiber type distribution (18) as well as less active muscle mass compared to whole or lower body exercise in able-bodied athletes. Energy expenditure during strenuous exercise is limited as well, although remarkable values up to 700 kcal per hour were measured in trained handcyclists (1).

Additionally, stress or medication (drugs were prescribed quite often to individuals with a spinal cord-injury) in combination with the autonomic disruption of the gastrointestinal system may decline digestion, resorption, absorption and excretion of nutrients (21). Of course, the extent of such negative influences on bladder and bowel function depends on level and severity of the lesion (2, 3) and has to be taken into account when supplements were used in athletes with a spinal cord-injury. Under these circumstances, it seems desirable to provide evidence-based individual information in case of supplement use in this special group of athletes, in order to prevent athletes from ineffective (no beneficial effect) or forbidden (violating the current anti-doping regulations) supplement ingestion. Thus, the following systematic review aimed to focus on the effects of supplement use on exercise performance in wheelchair athletes with a spinal cord-injury.

Methods

To perform this review, a comprehensive literature search was undertaken using Pubmed as search engine. The analysis included only peer-reviewed articles until the end of November 2015, which were published in English, performed as double-blind placebo-controlled trials, related to performance in trained wheelchair users. Review articles, animal studies, studies not related to upper-body exercise (e.g. functional electrical stimulated leg cycling) and studies performed with able-bodied or untrained participants (e.g. patients during their rehabilitation process) were excluded. A first selection of articles was done by the first author. All relevant articles were then read and judged independently by all authors. Only articles meeting all inclusion criteria were considered for the final analysis of the review process, whereas a first selection was undertaken based on a review of abstract contents. The literature search was performed using the keywords outlined below combined as follows: ("paraplegia OR tetraplegia OR spinal cord-injury") AND ("nutrition OR supplement OR supplementation"). The flow diagram of this comprehensive literature search can be found in Figure 1.

Results

Five studies met all inclusion criteria for the final analysis. These studies investigated the effects of carbohydrates, creatine, caffeine, sodium citrate or the combination of the latter two supplements on performance. The relevant information on dosage and application of the supplements as well as on study outcomes are illustrated in more detail in Table 1.

In summary, a study dealing with the use of carbohydrates pointed toward a performance enhancing effect of a high percentage (11%) carbohydrate solution (19). The use of caffeine seemed to have some ergogenic effects on sprint and short-term performance in athletes with a para- (4) and tetraplegia (8) but not on 1500m wheelchair racing performance (5). Under sodium citrate (5) and creatine (14) supplementation no performance enhancing effects were found.

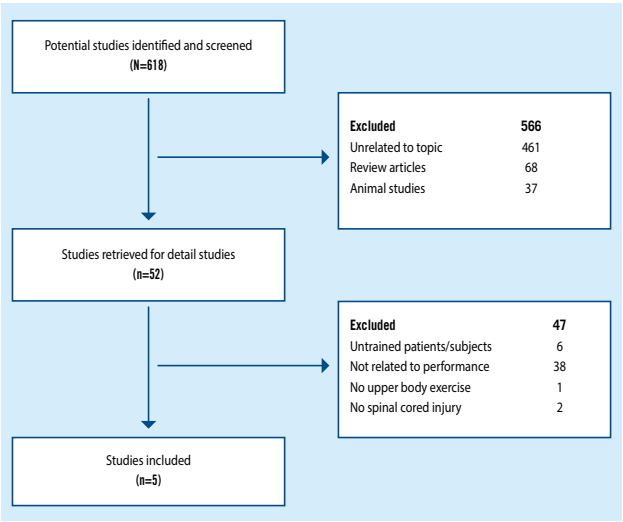

Figure 1
Study selection process.

Discussion

Although supplement use in Paralympic athletes is very common (7, 23) this comprehensive review revealed, that studies dealing with the effects of supplement use on exercise performance in athletes with a spinal cord-injury are scarce. Additionally, the findings were often controversial to study results obtained from able-bodied athletes, where carbohydrates, creatine (11), sodium citrate (17) and caffeine (22) were shown to provoke ergogenic effects on exercise performance under certain conditions. These results might be explained by the physiological differences between able-bodied individuals and athletes with a spinal cord-injury.

One of the most important difference after the incidence of a spinal cord-injury is a prolonged gastrointestinal transition time (6, 10) due to the impairment of the autonomic nervous system. In theory, this would mean that athletes with a spinal cord-injury should ingest supplements earlier compared to able-bodied athletes. However, having a closer look at recent findings on the effects of caffeine (4, 8) and sodium citrate ingestion (5) in wheelchair athletes, it seems to be needless to change the timing of ingestion. Blood bicarbonate as well as plasma and saliva caffeine concentrations found in these studies after supplement ingestion, were comparable to able-bodied athletes, which supports the assumption, that the supplement reached its destination within the given time frame. Moreover, even higher caffeine concentrations were reached in athletes with a tetraplegia compared to paraplegic or able-bodied athletes (4).

The reason for this finding might be a reduced plasma volume in individuals with a tetraplegia and thus a smaller volume of distribution leading to higher plasma concentrations, which favors a dose reduction from 6mg/kg to e.g. 4mg/kg body mass for this group. In general, dose reductions might also help to avoid or diminish potential side effects. In fact, in the study of Flueck et al. 5 out of 9 athletes complained about side effects (mainly from gastro-intestinal origin) after sodium citrate supplementation (5), whereas Graham-Paulson et al. found side effects (e.g. increased spasticity and nausea) in 5 out of 12 wheelchair rugby players after caffeine ingestion (8).

Although the latter study reported no link between changes in performance and the experience of side-effects/no side-effects, one has to keep in mind that such effects might have a direct or indirect impact on performance during competition and should be avoided. However, an increase in transition time might also lead to concentration-dependent faster or slower absorption characteristics of supplements. This might help to explain, why the study of Spendiff and Campbell (19) found an ergogenic effect on endurance performance after the ingestion of a high percentage carbohydrate solution (11%), whereas the low percentage solution (4%) did not show any benefits.

Another reason for different findings comparing supplement use in able-bodied and spinal cord-injured athletes might be the amount of muscle mass actively involved during exercise. Compared to whole or lower body exercise, performance of the upper body seems to be limited more peripherally and thus less influenced by any kind of supplementation. Moreover, muscle fiber type distribution might also play an important role, as arm muscles considerably differ from leg muscles in this respect. This argument possibly explains, why creatine monohydrate supplementation revealed no performance enhancing effect in wheelchair athletes compared to placebo (14), whereas able-bodied individuals clearly showed to benefit from creatine supplementation during lower-body exercise (for review see ref. 11). Further, the ergogenic effects of caffeine on short-term, high-intensity upper body exercise in paraplegic athletes (4) might be caused as well by differences in muscle fiber type distribution. Arm muscles of individuals with a paraplegia seem to contain more type I fibers compared to their able-bodied counterparts (18). As type I fibers are more sensitive to caffeine (12), a potential ergogenic effect might be more pronounced in athletes with a paraplegia compared to able-bodied controls, which was the case in the above mentioned study.

Additionally, training status might also play an important role when talking about performance enhancing effects of supplements. It seems reasonable to speculate that highly trained elite athletes experience only marginal or no benefits due to supplementation compared to moderately or untrained individuals. This hypothesis is supported by two studies on creatine supplementation. The study with elite wheelchair racing athletes (14) found no benefit on performance following creatine ingestion, whereas the investigation by Jacobs and colleagues (9), detected a significantly increased performance in untrained patients with tetraplegia.

It is known that wheelchair athletes often use medication due to the impairment itself or due to secondary complications related to the impairment (24). Thus, food- or supplement-drug interactions can't be excluded and might influence digestion, resorption, absorption and excretion of nutrients (21). Hereby, the impact of potential negative influences and side effects seems to depend on severity and level of lesion, which determines ›

the extent of the autonomic disruption of the gastrointestinal system in persons with a spinal cord-injury. Thus, in case of supplement use, individually adapted solutions are required for daily clinical practice due to the lack of evidence-based recommendations for this population (15).

Conclusion

Based on distinct physiological differences, supplementation strategies from studies with able-bodied athletes can't be directly transferred into a wheelchair sport context. However, evidence-based data on supplementation in wheelchair athletes are scarce, which makes it impossible to establish general guidelines for the use of ergogenic aids in this special population. Interestingly, differences in gastrointestinal transition times between able-bodied and spinal cord-injured athletes seem to play no important role when supplements were ingested. At present, the practical consequences of these findings lead to individually tailored solutions for each athlete who decides to ingest supplements. Hereby, potential side effects, supplement-drug interactions and the potential risk for a positive doping test have to be taken into account. Ineffective or forbidden supplements should be avoided and athletes and coaches should be aware of the fact, that supplement use neither replaces a well-balanced diet nor that this review must be mistaken for a recommendation to use supplements in order to reach sporting excellence.

Conflict of Interest
The authors have no conflict of interest.

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