Akademia Wychowania Fizycznego

im. Jerzego Kukuczki w Katowicach

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Wpływ przyjmowania wody alkalicznej na stan nawodnienia oraz beztlenowe możliwości wysiłkowe zawodników gier zespołowych i sportów walki

Rozprawa na stopień doktora nauk o kulturze fizycznej

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Katowice 2019

Spis treści

Wstęp

Organizm ludzki w przeważającej mierze składa się z wody. Stwierdzenie to, często powtarzane przez autorów, zdaje się być już banalne i trywialne. Być może fakt ten jest powszechnie znany, ale na pewno wśród sportowców na każdym poziomie wyszkolenia często pomijany i lekceważony. Wodą odpowiada za szereg funkcji ustroju człowieka [1] i stanowi 50-55% masy ciała kobiet, 60-65% masy ciała mężczyzn, a u dzieci jej wartość sięga nawet 75%. Prawidłowe nawodnienie warunkuje harmonijne funkcjonowanie organizmu zarówno w czasie wysiłku jak i w spoczynku. Podczas wysiłku fizycznego dochodzi do wzrostu temperatury ciała, a nadmiar ciepła uwalniany jest w znacznej mierze przez skórę. Proces termoregulacji prowadzi do utraty wraz z potem wody i elektrolitów. Obniżenie zawartości wody w organizmie o 2% masy ciała, ma znaczący wpływ na wydolność zawodnika, może prowadzić do podwyższenia ciśnienia tętniczego krwi, powstawania skurczów mięśni, bólów głowy, obniżenia koncentracji oraz szybszego męczenia się. Utrata 5% zasobów wody powoduje szereg zaburzeń w układzie krążeniowo-oddechowym i mięśniowym, obniżając wydolność organizmu o 20-30%. 15% deficyt wody jest niebezpieczny dla zdrowia i życia, w najpoważniejszym wypadku może skutkować nawet śmiercią. Odpowiednie nawodnienie przed, w trakcie oraz po wysiłku jest bardzo ważnym czynnikiem zarówno w procesie treningowym, restytucyjnym oraz podczas startów w zawodach [2]. Zapotrzebowanie sportowców na wodę jest uwarunkowane wieloma czynnikami tj.: intensywnością i czasem trwania wysiłku, temperaturą i wilgotnością otoczenia, stanem nawodnienia przed treningiem, dietą oraz predyspozycjami osobniczymi. Trening w warunkach podwyższonej temperatury (powyżej 25°C) powoduje zaburzenie hemodynamiki krwi. Przewodnictwo cieplne skóry wzrasta nawet 7-krotnie, co powoduje zwiększone wydzielanie potu, które u wytrenowanych sportowców kształtuje się na poziomie 2-3l/h, a w ekstremalnych warunkach temperatury przy intensywnym wysiłku może dochodzić nawet do 5-7l/h. Dobowa utrata wody przez skórę w temperaturze otoczenia 40-50°C może sięgać nawet 10l, co skutkuje dużym ubytkiem elektrolitów i enzymów oraz determinuje hiponatremię. Zawodnicy dyscyplin wytrzymałościowych są zdolni do ćwiczeń przy temperaturze wewnętrznej oscylującej w granicach 40°C, jednak przy braku odpowiedniego nawodnienia długotrwały wysiłek w wysokiej temperaturze może być mniej efektywny i prowadzić do nieodwracalnych zmian, a w skrajnych przypadkach może być nawet przyczyną zgonu. Problem ten dotyczy szczególnie maratończyków, chodziarzy, kolarzy i piłkarzy nożnych [3]. Również nie bez znaczenia pozostaje ciśnienie pary wodnej, które znacząco wpływa na proces termoregulacji skórnej, obniżając go. Wzrasta wówczas utrata wody z wydychanym powietrzem, która w zimnym i suchym powietrzu górskim może sięgać 1500ml/dobę [4].

Na rynku dostępnych jest coraz więcej preparatów nawadniających, które mają na celu przyspieszyć proces restytucji powysiłkowej. Powinny zapewnić one odpowiednią podaż energii (węglowodanów), składników mineralnych i witamin. Do napojów sportowych stosowanych około-treningowo lub podczas zawodów można zaliczyć suplementy hipotoniczne, izotoniczne, hipertoniczne, z dodatkiem substancji pobudzających oraz wodę [5]. Ponieważ w czasie wysiłku dochodzi do zaburzenia równowagi kwasowo-zasadowej organizmu, trwają badania nad zasadnością wykorzystania wody o regulowanym pH. W praktyce klinicznej w celu oceny stanu nawodnienia stosuje się różne metody badawcze, do których należy badanie całkowitej zawartości wody w organizmie (za pomocą impedancji elektrycznej), pomiar wskaźników krwi (osmolalność, objętość i zawartość sodu) i moczu (objętość, ciężar właściwy, osmolalność), ocena zabarwienia moczu oraz krótkoterminowe zmiany masy ciała [6]. Jak pokazują badania zdecydowana większość zawodników uprawiających różne dyscypliny sportu nie realizuje dobowych norm zapotrzebowania na wodę. Szczególnie narażeni na odwodnienie są zawodnicy sportów wytrzymałościowych o długim czasie trwania, jednak jak wynika z badań w grupie ryzyka znaleźli się mężczyźni trenujący dyscypliny siłowe i sporty walki [7].

Zyskującym popularność alternatywnym rozwiązaniem dla dotychczas wykorzystywanych napojów sportowych staje się woda o regulowanej zawartości makroskładników i zwiększonym pH (woda alkaliczna). Dotychczas była ona wykorzystywana głównie w profilaktyce chorób, którym towarzyszy kwasica metaboliczna. Udowodniono jej pozytywny wpływ na stan tkanki łącznej. Randomizowane badania prowadzone na kobietach w wieku przed menopauzalnym wykazały, iż spożycie wody alkalizowanej w ilości 1,5 l na dobę miało znaczący wpływ na poprawę gęstości mineralnej kości, wzrost pH moczu oraz spadek stężenia parathormonu i C-telopeptydu kolagenu typu I w surowicy [8, 9]. Liczne badania naukowe dowodzą, że woda o regulowanej alkalizacji wykazuje działanie przeciwcukrzycowe i przeciwmiażdżycowe poprzez obniżenie stężenia glukozy we krwi i HbA1c oraz spadek stężenia triglicerydów, lipoprotein o małej gęstości (LDL) i całkowitego stężenia cholesterolu we krwi. Ponadto hamuje angiogenezę guzów nowotworowych i ma działanie przeciw neurodegeneracyjne [10].

Obecnie coraz częściej porusza się temat wody alkalicznej w kontekście poprawy zdolności wysiłkowych i regeneracyjnych u sportowców. Istnieją badania eksperymentalne traktujące o jej pozytywnym wpływie na gospodarkę kwasowo-zasadową organizmu, zarówno w spoczynku jak i po wysiłku o charakterze beztlenowym [11]. Woda alkalizowana hamuje powstawanie wolnych rodników i reaktywnych form tlenu tworzących się w komórkach w trakcie wysiłku o dużej intensywności [12]. Randomizowane badania z podwójnie ślepą próbą wykazały, że woda o pH 9,3 wpłynęła pozytywnie na obniżenie kwasicy powysiłkowej, co stwierdzono poprzez wzrost spoczynkowego i powysiłkowego pH krwi oraz stężenia dwutlenku węgla grupy testowej w stosunku do grupy spożywającej placebo [13].

Reasumując najnowsze i niezależne prace badawcze wskazują, że woda alkalizowana ma pozytywny wpływ na organizm człowieka. Fakt ten w przyszłości może zostać wykorzystany do wspomagania restytucji powysiłkowej i zmniejszenia kwasicy metabolicznej u wyczynowych sportowców. W świetle przytoczonych argumentów, wydaje się zasadne przeprowadzenie badań na sportowcach w celu bardziej szczegółowego przeanalizowania wpływu wody alkalicznej na organizm poddany reżimowi treningowemu.

Analiza dostępnej literatury opisującej badania z wykorzystaniem wody o wysokiej alkalizacji potwierdza uzyskane w niniejszym opracowaniu wyniki. Próżno szukać licznych badań o podobnej tematyce, natomiast dostępne pozycje wskazują podobną do zaprezentowanej tendencję. Heil [14] przeprowadził eksperyment na grupie 38 nietrenujących ochotników z wykorzystaniem wody o pH 10,0. Dzienna podaż testowanej wody wyniosła 2,2-2,4 litra na dobę. Po 4-tygodniowej interwencji zaobserwowano istotny wzrost pH krwi i moczu w grupie spożywającej wodę alkalizowaną w porównaniu do grupy kontrolnej [14]. Zadowalające wyniki uzyskali również Ostojic i Stojanovic, którzy testowali wodę o pH 9,3 na grupie 52 aktywnych fizycznie mężczyzn. Ochotnicy pili wodę o podwyższonym pH przez okres dwóch tygodni w ilości 2 litrów na dobę, co było znacząco niższe w porównaniu z wykorzystaną w moich pracach metodologią. W konsekwencji nastąpił istotny wzrost pH krwi oraz stężenia dwuwęglanów po spożyciu wody alkalicznej [13]. Porównując własne wyniki z przytoczoną literaturą można zaobserwować pozytywne skutki stosowania wody o wyższym pH na niektóre parametry określające równowagę kwasowo-zasadową organizmu. Wyniki te nie są jednak jednoznaczne, co może być związane z czasem trwania eksperymentu, poziomem wytrenowania badanych, oraz ilością spożywanej wody alkalicznej.

Przedmiot Rozprawy

Przedmiotem rozprawy doktorskiej jest osiągniecie naukowe w postaci 5 prac traktujących o wpływie wody o zwiększonej alkalizacji na stan równowagi kwasowo-zasadowej organizmu zawodników uprawiających różne dyscypliny sportu. Cztery z poniższych prac mają charakter empiryczny, a jedna jest pracą poglądową na poruszany temat. Łączna wartość punktowa opublikowanych prac wynosi: IF = 4,495; MNSiW = 75 pkt. KBN.

Prace zostały przedstawione pod wspólnym tematem: ***Wpływ przyjmowania wody alkalicznej na stan nawodnienia oraz tlenowe i beztlenowe możliwości wysiłkowe zawodników gier zespołowych i sportów walki.***

Wykaz prac opublikowanych:

Anna Kurylas, Tomasz Zajac, Grzegorz Zydek, Adam Zajac. *The Effectiveness of Alkaline Water in Hydrating Athletes*. Journal of Nutritional Health & Food Science. 2017 5(2): 1-4.

Jakub Chycki, Tomasz Zając, Adam Maszczyk, **Anna Kurylas**. *The effect of mineral-based alkaline water on hydration status and the metabolic response to short-term anaerobic exercise*. Biology of Sport. 2017;34:255-261. IF 1,729; 15 p. MNiSW

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Anna Kurylas, Jakub Chycki, Tomasz Zając. *Anaerobic power and hydration status in combat sport athletes during body mass reduction.* Baltic Journal of Health and Physical Activity. 2019; 11(4). 20 p. MNiSW

Praca nr 1. - *The Effectiveness of Alkaline Water in Hydrating Athletes*

Praca poglądowa traktująca o funkcjach wody w ustroju człowieka, istocie prawidłowego nawodnienia organizmu oraz skutkach obniżenia jej zawartości w organizmie. Ponadto w artykule zaprezentowano wpływ różnych czynników środowiskowych na stan nawodnienia min. temperatury, wilgotności i ciśnienia. Sedno natomiast stanowi przegląd prac naukowych związanych z tematyką nawodnienia wśród sportowców oraz nowatorskie zastosowanie wody o regulowanej wartości pH (wody alkalizowanej). Najnowsze i niezależne prace badawcze wskazują, że woda alkalizowana ma pozytywny wpływ na organizm człowieka. Fakt ten w przyszłości może zostać wykorzystany do wspomagania restytucji powysiłkowej i zmniejszenia kwasicy metabolicznej u sportowców.

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Review article Journal of Nutritional Health & Food Science Open Access

The Effectiveness of Alkaline Water in Hydrating Athletes

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Received: February 22,2017; Accepted: March 24,2017; Published: April 07, 2017

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The most important ingredient of the human body includes water. Water consists 60-65% of an adult's body mass, 55% or less for women, while it reaches values of close to 75% in infants. A proper hydration state is a must for general health, yet it is even more important for individuals that exercise on a regular basis, and especially for competitive athletes submitted to extreme loads, often under extreme environmental conditions [1]. Intra and extra cellular water is responsible for numerous functions in our bodies. Water allows for homeostasis, it facilitates most biochemical reactions, it allows numerous particles and compounds to dilute; it helps in the transport of metabolites and speeds up the utilization of by–products. Water plays a major role in thermoregulation; it nourishes and moisturizes tissues and organs. Effective hydration determines proper functioning of the whole body, at rest and especially during and after exercise. During exercise heat is produced by the muscles and other organs and it must be eliminated, not to cause hyperthermia. Excess heat produced during exercise has to be removed, and it is mostly accomplished through sweating, what causes significant water loss. Reducing water volume by 2% or more doing exercise has significant consequences on functions of particular organs and the whole body. Dehydration can decrease aerobic capacity, it can increase blood pressure, cause headaches, decrease concentration and speed of reaction, and may also influence cognitive abilities in sport disciplines that require tactical thinking and decision making [2]. Some studies indicate that even a minor hypohydration of 2% influences a variety of cognitive functions such as vigilance, alertness, perceptual discrimination, arithmetic ability, visuomotor tracking and psychomotor skills significant in many sport disciplines and everyday life activities [3, 2].

There are sport disciplines for which fluid intake before, during and after competition is a key factor determining performance, and those that are not much affected by hydration status. Explosive track and field events such as the shot put or high jump are not influenced to a great degree by hydration status, while performance in aerobic endurance events, especially those lasting several hours, performed under extreme environmental conditions (temperature, humidity, altitude), are very much dependent on the volume, quality and timing of fluid intake. Road cycling is an excellent example, where races last for 4-6 hours and can be performed under very hot or cold conditions, with significant radiation and at low or high altitudes.

There is significant evidence to indicate that hypohydartion impairs aerobic endurance performance, and these effects are significantly related to the degree of body water deficit [4]. Fatigue in prolonged aerobic exercise do to hypohydration is explained by thermoregulatory, cardiovascular and metabolic factors. Dehydration in such circumstances increases core temperature and causes elevation of heart rate parallel to the decrease in blood flow, stroke volume, cardiac output and skin blood flow [5]. Since evaporation is the most effective manner of heat loss during exercise, core body temperature rises at a greater extent as hypohydration levels increase. Dehydration during exercise may also affect muscle metabolism by accelerating the rate of glycogen depletion [6].

Hypohydration and its consequences may also occur in sport disciplines that require high intensity and intermittent bouts of effort over several hours of competition or training. This is especially true in soccer tournaments played in high temperature, with insufficient rest and hydration between games. Some authors [7] reported decreased performance when hypohydration acceded 2.4% in soccer, while no impairments were observed in shooting, passing or spiking in basketball and volleyball when hypohydration reached 2% [8]. Tennis and especially long 4-5 set matches played in severe heat have shown to cause significant hypohydration and negatively affect shot precision and speed of reaction [2].

It is unclear how much hypohydration impairs muscular strength, and inconsistent results may be due to the use of different protocols to achieve hypohydration and measurements of strength and power abilities. Some authors have observed significant reductions in isometric and isokinetic force after 2% hypohydration [5], while others did not register significant changes in muscular activity even after a 4% hypohydration [9]. It seems that strength and power as well as aerobic capacity may be significantly affected by a state of hypohydration in combat sports, where athletes usually dehydrate before competition to reduce body mass for a certain weight category, and then sweat immensely during competition. This has been observed in tournaments which last for several hours during a day in judo, wrestling and boxing [10]. The applied power diminishes significantly in the later stages of these bouts. This has been explained by an increase in core temperature which affects the sequence of muscle strength production by reducing motor cortex activation, peripheral stimulus and power output [9]. A dehydration of 5% causes serious consequences in the cardio respiratory and muscular systems, decreasing aerobic capacity by 20-30%. Hypohydration in excess of 10% may be dangerous to the athlete's health and a threat to life. An appropriate hydration of the body is crucial during exercise for adaptive changes to occur at all levels of the organism and also very significant after training and competition for recovery.

Athletes engaged in high intensity exercise for 2 hours a day should consume at least 3-4 l of water or other fluids. Thirst should not be the main factor determining hydration, since it always appears with a certain delay, while fluids should be replaced on the spot, if possible every 10-15 minutes of activity, with an increased intake during recovery [11].

The demand for water in athletes is conditioned by numerous factors, which include volume, intensity and frequency of training sessions, temperature, humidity, environment, pre-exercise hydration status, diet, supplementation and clothing. Individual metabolic characteristics also must be considered, as some athletes have much higher BMRs with greater thermogenesis. As a consequence they produce more heat and sweat to a greater extent, losing significant amounts of water [12].

Exercising in a hot environment (above 25C) causes significant disturbances in blood hemodynamics. The skin conductivity increases 7 – fold, what stimulates sweating and evaporation. Well trained athletes undergoing intensive exercise sweat in excess of 2-3l/h, while in extreme conditions even up to 5-7l/h. A daily loss of 10l of water under conditions of extreme heat and humidity causes a significant loss of electrolytes, enzymes and stimulates hyponatremia. Endurance athletes can continue to exercise with the inner temperature close to or even above 40C, yet without sufficient hydration, fatigue settles in, hindering coordination and sports performance. Prolonged exercise under such conditions can cause irreversible changes in the body and can even be fatal.

This phenomenon has been observed in marathon runners, cyclists, triathletes and soccer players. Water vapor pressure seems an important factor in exercise tolerance, because of its thermoregulatory effect. In such cases water is lost while exhaling, which can increase up to 1500ml/d in a cold dry climate.

Currently there are numerous products available on the market used for hydrating athletes before, during and after exercise. The main objective is to increase exercise tolerance and speed up the recovery process. Most sport drinks are fortified with carbohydrates, minerals and vitamins, or chosen amino acids. The most popular drinks are isotonic in nature, while hypotonic and hypertonic drinks are also used depending on the type of activity, its length and environment in which the exercise is performed [12].

Despite the abundance of sports drinks on the market, water is still one of the most often used forms of replacing fluids during and after exercise, especially in individuals who are watching their body mass closely. Because exercise especially that of high intensity causes significant disturbances in acid-base balance, it has been hypothesized that drinking alkaline water could increase the buffering capacity of blood and muscle tissues and improve the hydration status of athletes. Since most biochemical reactions are very sensitive to pH, drinking alkaline water could facilitate most of these reactions and speed up post-exercise recovery.

Water, the most widely used fluid during exercise comes in different forms, with specific properties depending on the mineral content. The mineral content, and especially the proportions between SO42- and HCO3- as well as the pH determine hydration status and other therapeutic properties. This has been documented in numerous experiments and clinical trials [13]. Mineral water has a significant impact on acid-base balance which determines anaerobic exercise capacity [14]. Many researchers have suggested that water rich in Ca is characterized by this specific quality [15]. Even subtle changes in blood and tissue pH have significant metabolic consequences, including the response to oxidative stress [16]. During supramaximal exercise, there is a significant increase in Reactive Oxygen Species (ROS) and reactive nitrogen species (RNS). In trained individuals the antioxidant system is more efficient due to the adaptation to exercise [11]. The neutralization of ROS may promote the use of water rich in hydrogen ions. This action is explained by the stimulation of numerous antioxidant proteins [1]. The results of long-term research show that the use of hydrogen-rich water is helpful in preventing metabolic diseases, including diabetes [17]. Alkaline mineral water with a high pH, through the effect on acid-base balance can also increase the rate of lactate utilization following anaerobic exercise [18].

Acid-base equilibrium within the body is tightly maintained through the interaction of three complementary mechanisms: Blood and tissue buffering systems (e.g., bicarbonate), the diffusion of carbon dioxide from the blood to the lungs via respiration, and the excretion of hydrogen ions from the blood to urine by the kidneys [19].

Many studies have shown that the consumption of alkalizing supplements can have a significant effect on the body's acid-base balance using surrogate markers of urine and blood pH [16]. It seems possible that the regular consumption of alkaline water could have a similar effect on markers of acid-base balance, yet the available data is conflicting, thus further research is necessary with different populations, different exercise protocols and varied environmental conditions.

For practical purposes, different methods of evaluating hydration status are used. They include total body water content (electrical impedance), blood variables (osmolality, volume and sodium concentration), as well as urine variables (osmolality, volume, specific urine gravity. Research indicates that most athletes do not meet the daily norms of water intake, considering their training loads, energy demands and sweating rate [11]. Athletes practicing and competing in long distance endurance events are most prone to dehydration, yet hypohydration has also been observed in team sport games and combat sports. An experiment conducted in extreme heat (31°C) and high humidity (60-65%) on youth athletes subjected to a continuous run (65% VO_{2max}) until volitional exhaustion showed no difference in hydration status when different types of fluid were ingested during the exercise protocol. Unrestricted intake of tap water, grape-flavored water and grape-flavored water with 6% carbohydrate and 18.0 mmol/L NaCl showed no differences in performance and hydration status after the exercise protocol [4]. Alkaline water with a specific mineral content and increased pH has recently been proposed as an alternative sports drink. There are reports indicating a positive effect of alkaline water on resting and post-exercise acid-base balance [18]. The results of this study indicates, that the use of water with alkalizing properties exhibits a significant potential for hydration, it reduces fluid-electrolyte disturbances and accelerates the rate of lactate utilization following intensive anaerobic interval exercises. Skeletal muscles fatigue by numerous mechanisms, including accumulation of metabolites, such as potassium, or H+ [11]. To a large extent, the structural damage to the myocytes and inflammation depend on the exercise ROS production [20]. Several authors have indicated that consumption of alkaline water inhibits the production of ROS during exercise of high intensity [20]. A randomized double blind study showed that the consumption of highly alkaline water with a pH of 9,3 allowed for increased resting and post-exercise blood pH and a lower level of metabolic acidosis after an intensive physical effort [21].

In another randomized study conducted on pre-menopause women, regular consumption of 1,5l/d of highly alkaline water caused a significant increase in bone density, increased urine pH and a decrease of parathyroid hormone and serum C-telopeptide [22]. Other studies indicate that regular consumption of alkaline water prevents diabetes and atherosclerosis by lowering blood concentration of glucose and HbA1c, as well as Triglycerides (TG), Low Density Lipoproteins (LDL) and Total Cholesterol (TCH). Some authors also indicate that drinking alkaline water may slow down neurodegenerative processes [23].

In competitive sports urine osmolality, specific urine gravity and color are often used as indicators of the state of hydration [24]. Consumption of alkaline water following a dehydrating bout of cycling exercise has previously been shown to rehydrate cyclists faster and more completely than the consumption of placebo water. Following the consumption of alkaline water, the cyclists demonstrated less total urine output, their urine was more concentrated (higher specific gravity), and total blood protein concentration was lower [25]. In another well controlled experiment Heil [26] reported that water retention at the end of a 3-hour recovery period was 79.2 ± 3.9% when subjects drank alkaline water versus 62.5 ± 5.4% when consuming a placebo.

It can be concluded that the habitual consumption of highly alkaline mineralized water can significantly improve hydration status. Alkaline water with a pH as high as 9.3 can improve resting and exercise acid-base balance and thus improve both, aerobic and anaerobic performance. Daily recommendations for alkaline water intake should be strictly individualized, and in case of competitive athletes depend on their age, sex, body mass, BMR, training volume and intensity, diet, type of sport discipline and the environment in which the training or competition takes place. Thus, children and youth athletes with a body mass of 25-35 kg and low energy expenditure can consume as little as 1l of water a day, while male adult road cyclists (70-75kg) performing a continuous effort of 4-5h in a hot and humid environment may need up to 7-8l of alkaline water to fully hydrate the body, and utilize its full potential for exercise and recovery.

Citation: Anna Kurylas, Tomasz Zajac, Grzegorz Zydek, Adam Zajac. (2017) The Effectiveness of Alkaline Water in Hydrating Athletes. J Nutrition Health Food Sci 5(1):1-4

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Prac nr 2. - *The effect of mineral-based alkaline water on hydration status and the metabolic response to short-term anaerobic exercise*

Celem badania było określenie efektów przyjmowania wody o różnej mineralizacji na stopień nawodnienia i równowagę kwasowo-zasadową mężczyzn uprawiających wyczynowo piłkę nożną. Do badania zakwalifikowano 36 piłkarzy nożnych w wieku 21 ± 4 lat. Zawodnicy stanowili homogenną grupę pod względem stopnia wytrenowania, wieku i stażu treningowego oraz większości parametrów somatycznych. Badani posiadali aktualne badania lekarskie, które pozwoliły im na wzięcie udziału w eksperymencie. W trakcie badania zawodnicy zostali podzieleni na trzy grupy, liczące po 12 – stu uczestników. Każda z grup poddana została innemu protokołowi nawodnienia, który trwał siedem dni. Grupa pierwsza przyjmowała wodę o wysokim stopniu mineralizacji, grupa druga przyjmowała wodę o niskim stopniu mineralizacji ale o wysokiej alkalizacji, a grupa trzecia, kontrolna przyjmowała wodę stołową. Ilość spożywanej przez zawodników wody była dostosowana indywidualnie na podstawie zaleceń National Athletic Trainers Association i wynosiła średnio 4,2 litra na dobę. Podczas eksperymentu wszyscy uczestnicy badań spożywali izokaloryczną mieszana dietę, realizując treningi o niskiej intensywności. W tym czasie badani nie stosowali leków, suplementów diety oraz alkoholu i innych używek. Każdy uczestnik eksperymentu został szczegółowo zapoznany z protokołem badania oraz z możliwością wycofania się z niego na każdym etapie badań. Eksperyment trwał 7 dni. Wyróżniono trzy fazy: diagnostyczną, terapeutyczną i kontrolną. Etap diagnostyczny i kontrolny obejmował następujące testy i pomiary:

Badania składu ciała za pomocą impedancji elektrycznej,

Pomiar pH i ciężaru właściwego moczu,

Pomiar temperatury ciała,

Testy fizyczne z oznaczeniem równowagi kwasowo-zasadowej organizmu oraz spoczynkowego i wysiłkowego stężenia mleczanu w osoczu krwi.

Oceniono następujące zmienne:

W spoczynku przed testem wysiłkowym (t0): TBW, ECW, ICW, temperaturę ciała, ciężar właściwy i pH moczu,

Bezpośrednio po teście wysiłkowym (t1): temperaturę ciała, W 5 minucie restytucji (t2): TBW, ECW, ICW,

W 30 minucie restytucji (t3): ciężar właściwy i pH moczu.

Test wysiłkowy na ergometrze rowerowym został przeprowadzony przed i po okresie nawodnienia. Składał się z 5 powtórzeń po 60 s przy obciążeniu 120% VO_{2max} (którego oceny dokonano na podstawie progresywnego wysiłku do odmowy tydzień przed badaniem właściwym) i kadencji w granicach 75-80 obrotów na minutę. Przerwa wypoczynkowa pomiędzy kolejnymi seriami wysiłku wynosiła 60 s. Przed testem wytrzymałościowym każdy z zawodników wykonywał 5-minutową rozgrzewkę z oporem 100 W i kadencją w granicach 70-80 obr. / min. Po rozgrzewce zawodnicy rozciągali kończyny dolne i przystępowali do testu wysiłkowego. W celu określenia natężenia glikolizy określono stężenie mleczanu (LA) i zmienne równowagi kwasowo-zasadowej. Próbki krwi z opuszki palca pobierano w spoczynku, bezpośrednio po ostatnim powtórzeniu testu wysiłkowego oraz w 3, 6, 9 i 12 minucie restytucji. Uzyskane wartości wykorzystano do określenia stopnia utylizacji mleczanu po wysiłku.

Wyniki przeprowadzonego eksperymentu wykazały zwiększone pH moczu w grupie stosującej wodę zasadową. Ciężar właściwy moczu po wysiłku uległ zmniejszeniu we wszystkich trzech grupach, najistotniejszą różnicę zaobserwowano jednak w grupie stosującej wodę alkaliczną. Również w tej grupie odnotowano najskuteczniejsze wykorzystanie mleczanu powstającego po teście obciążeniowym po okresie hydratacji.

Original Paper DOI: 10.5114/biolsport.2017.66003 Biol. Sport 2017;34:255-261

The effect of mineral-based alkaline water on hydration status and the metabolic response to short-term anaerobic exercise

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ABSTRACT: Previously it was demonstrated that mineralization and alkalization properties of mineral water are important factors influencing acid-base balance and hydration in athletes. The purpose of this study was to investigate the effects of drinking different types of water on urine pH, specific urine gravity, and post-exercise lactate utilization in response to strenuous exercise. Thirty-six male soccer players were divided into three intervention groups, consuming around 4.0 l/day of different types of water for 7 days: HM (n=12; highly mineralized water), LM (n=12; low mineralized water), and CON (n=12; table water). The athletes performed an exercise protocol on two occasions (before and after intervention). The exercise protocol consisted of 5 bouts of intensive 60-s (120% VO_{2max}) cycling separated by 60 s of passive rest. Body composition, urinalysis and lactate concentration were evaluated – before (t0), immediately after (t1), 5' (t2), and 30' (t3) after exercise. Total body water and its active transport (TBW – total body water / ICW – intracellular water / ECW – extracellular water) showed no significant differences in all groups, at both occasions. In the post-hydration state we found a significant decrease of specific urine gravity in HM (1021±4.2 vs 1015±3.8 g/L) and LM (1022±3.1 vs 1008±4.2 g/L). We also found a significant increase of pH and lactate utilization rate in LM. In conclusion, the athletes hydrated with alkaline, low mineralized water demonstrated favourable changes in hydration status in response to high-intensity interval exercise with a significant decrease of specific urine gravity, increased urine pH and more efficient utilization of lactate after supramaximal exercise.

CITATION: Chycki J, Zając T, Maszczyk A, Kurylas A. The effect of mineral-based alkaline water on hydration status and the metabolic response to short-term anaerobic exercise. Biol Sport. 2017;34(3):255–261.

Received: 2016-11-09; Reviewed: 2017-01-22; Re-submitted: 2017-01-24; Accepted: 2017-02-04; Published: 2017-02-19.

Key words:
Hydration
Mineral water
Alkaline water
Urine specific gravity
Urine pH
Lactate
Anaerobic exercise

INTRODUCTION

A good hydration state, regardless of the sport discipline and training intensity, provides the opportunity to achieve an optimal physical and mental state [1]. Hydration protocols during training and competition are a basic part of athletic training [2]. The hydration strategy should consider in detail the type and properties of administered fluids, and their volume in relation to the type of physical activity, its intensity and duration [3]. The American College of Sports Medicine, The National Athletic Trainer's Association and other institutions of sport and science present their recommendations to optimize performance, and to reduce the probability of injuries and overtraining due to dehydration [4]. The optimal hydration state is determined by monitoring urine specific gravity [5].

Acid-base equilibrium within the body is tightly maintained through the interaction of three complementary mechanisms: blood and tissue buffering systems (e.g., bicarbonate), the diffusion of carbon dioxide from the blood to the lungs via respiration, and the excretion of hydrogen ions from the blood to the urine by the kidneys [6].

The most widely used fluid during exercise includes water. Different properties and especially the mineral content, the proportions between SO_4^{2-} and HCO_3^- as well as the pH determine hydration status and other therapeutic properties. This has been documented in numerous experiments and clinical trials [7, 8]. Mineral water has a significant impact on acid-base balance, which determines anaerobic exercise capacity [9]. Many researchers have suggested that water rich in Ca is characterized by this specific quality [10]. Even subtle changes in blood and tissue pH have significant metabolic consequences, including the response to oxidative stress [11, 12]. During supramaximal exercise, there is a significant increase in reactive oxygen species (ROS) and reactive nitrogen species (RNS). In trained individuals the antioxidant system is more efficient due to the adaptation to exercise [13, 14, 15, 16]. The neutralization of ROS may promote the use of water rich in hydrogen ions. This action is explained by the stimulation of numerous antioxidant proteins [17, 18]. The results of long-term research show that the use of hydrogen-rich water is helpful in preventing metabolic diseases [19], including diabetes [20]. Alkaline mineral water with a high pH, through the effect on acid-base balance can increase the rate of lactate utilization following anaerobic exercise [10].

Many studies have shown that the consumption of alkalizing supplements can have a significant effect on the body's acid-base balance using surrogate markers of urine and blood pH [21]. It is possible that the regular consumption of alkaline water could have an effect similar to nutritional supplements on markers of acid-base balance, yet this has not been evaluated in a controlled manner.

The aim of this study was to investigate the effects of water intake with different mineralization and alkalization properties on the state of hydration and the rate of lactate utilization in athletes following high-intensity interval exercise.

MATERIALS AND METHODS

Study participants

The study included 36 male, well-trained soccer players with an average age of 21.3± 1.8 years (Table 1). The selected group of athletes was homogeneous with strictly defined criteria for research – age (19-23 years), anthropometric indices (BM, %TBW, ECW, BF), and chosen variables of aerobic and anaerobic capacity (VO_{2max}, P_{max}). All players had valid medical examinations and showed no contraindications to participate in the experiment.

The athletes (n = 36) were randomly assigned to 3 groups – two experimental groups (HM; n = 12), (LM; n = 12) and a control group (CON; n = 12). All participants were submitted to different hydration protocols, ingesting water with specific biochemical properties for 7 days. Group I ingested highly mineralized water (Table 2), group II drank low mineralized high alkaline water, while the control group hydrated with table water. The volume of water intake was individualized based on the recommendation of the National Athletic Trainers Association and averaged 4.2 litres per day. All study

TABLE 1. Basic anthropometric characteristics of the experimental and control groups.

Variables	High mineral (n=12)	Low mineral (n=12)	Control (n=12)
AGE	21.0 ± 3.0	20.0 ± 3.0	21.0 ± 2.0
BM (kg)	69.9 ± 8.6	76.1 ± 6.8	71.5 ± 4.8
FFM (kg)	62.1 ± 7.2	67.8 ± 6.5	64.3 ± 4.6
FM (kg)	7.2 ± 2.3	8.4 ± 0.9	7.2 ± 2.7
FM (%)	10.2 ± 2.9	11.0 ± 1.3	9.8 ± 3.3
TBW (l)	45.6 ± 5.5	49.6 ± 4.3	47.1 ± 2.1
ICW (l)	28.8 ± 3.5	31.4 ± 2.8	29.9 ± 1.4
ECW (l)	16.8 ± 2.0	18.1 ± 1.6	17.2 ± 0.7

Note: Data are expressed as mean ± SD, n=12; BM (kg) - total body mass, FFM (kg) - fat free mass, FM (kg/%) - fat mass, TBW (l) - total body water, ICW (l) - intracellular water, ECW (l) - extracellular water

TABLE 2. Chemical properties of mineral water used in the study.

Variable	Measurement unit	High mineral	Low mineral	Control
pH	pH	6.1 ± 0.04	8.0	5.00 ± 0.08
CO_2	mg/L	92.2 ± 6.2	11.23 ± 2.3	14.98 ± 0.66
HCO^{3-}	mg/l	1326 ± 11.3	260 ± 6.14	3.62 ± 0.12
Cl^-	mg/l	8.4 ± 0.3	7.9 ± 1.3	0.41 ± 0.03
SO_4^{2-}	mg/l	28.7 ± 2.0	68.0 ± 3.6	1.60 ± 0.09
Na^+	mg/l	82.7 ± 6.2	8.24 ± 1.1	1.21 ± 0.05
K^+	mg/l	7.41 ± 0.05	1.83 ± 0.5	0.30 ± 0.03
Ca^{++}	mg/l	177 ± 5.2	89.6 ± 4.6	1.21 ± 0.05
Mg^{++}	mg/l	151 ± 4.1	11.4 ± 2.7	0.40 ± 0.04

Note: Data show the mean ± SD of three analyses for each water; pH - potential of hydrogen, CO_2 - carbon dioxide, HCO^{3-} - bicarbonate, Cl^- - chlorine, SO_4^{2-} - sulphates, Na^+ - sodium, K^+ - potassium, Ca^{++} - calcium, Mg^{++} - magnesium participants abstained from intensive exercise 3 days prior to initial evaluations and testing.

The study participants consumed an isocaloric, mixed diet, both before and during the experiment (55% carbohydrates, 20% protein, 25% fat). The players participating in the experiment did not take any medications or ergogenic substances, 2 weeks before and during the study. In addition, all athletes taking part in the experiment adhered to the requirement of 8 hours of sleep daily, and refrained from consuming alcohol and supplements during the experiment.

The athletes were informed about the purpose and the procedure of the research and signed an informed consent form before participating in the study. They were also informed about the potential risks and benefits associated with participating in the research project. The study received the approval of the Bioethics Committee at the Academy of Physical Education in Katowice, Poland. The test protocol was presented in detail to each player during the interview. Each participant was informed about the possibility to withdraw from the research at any stage of the experiment.

Procedures

The experiment lasted 7 days. Three phases were distinguished – diagnostic, therapeutic and control. Subjects involved in the diagnostic stage were qualified based on previously described criteria.

The diagnostic and control stage involved the following tests and assays (Fig. 1):

- Determination of body mass and body composition based on the method of electrical impedance (BM, TBW, ECW, ICW).
- Determination of urine pH and its specific gravity.
- The measurement of body temperature.
- Interval test protocol with evaluation of acid-base balance and lactate concentration.

The following variables were assessed:

- At rest, before the stress test (t0) – TBW, ECW, ICW, body temperature, urine specific gravity, urine pH.
- Immediately after the stress test (t1) – body temperature.
- 5 minutes after the stress test (t2) – TBW, ECW, ICW.
- 30 minutes after the stress test (t3) – specific gravity of urine, urine pH.

The therapeutic hydration phase involved the daily intake of 4-4.5 l of a particular type of water. The athletes drank either alkaline water, highly mineralized water or base mineral water as a control. The duration of the hydration procedure was 7 days.

Laboratory tests

Two sets of laboratory analysis were performed in this study. Stress tests were carried out at the beginning and at the end of the experiment. All biochemical variables were determined within 24 h, in both the diagnostic and control phases. The research was carried out at the Human Performance Laboratory of the Academy of Physical Education in Katowice.

Body mass and body composition

The measurements of body mass and body composition were conducted in the morning between 8.00 and 9.00. The day before the measurements, the participants had the last meal at 20.00 and hydrated with 1.5 litres of water between 20.00 and 22.00. The subjects were informed about the need to standardize measurement conditions. They reported to the laboratory after an overnight fast, refraining from exercise for 24 h and not consuming alcohol or liquids containing caffeine and carbohydrates before the diagnostic measurements. Body mass and body composition were determined based on

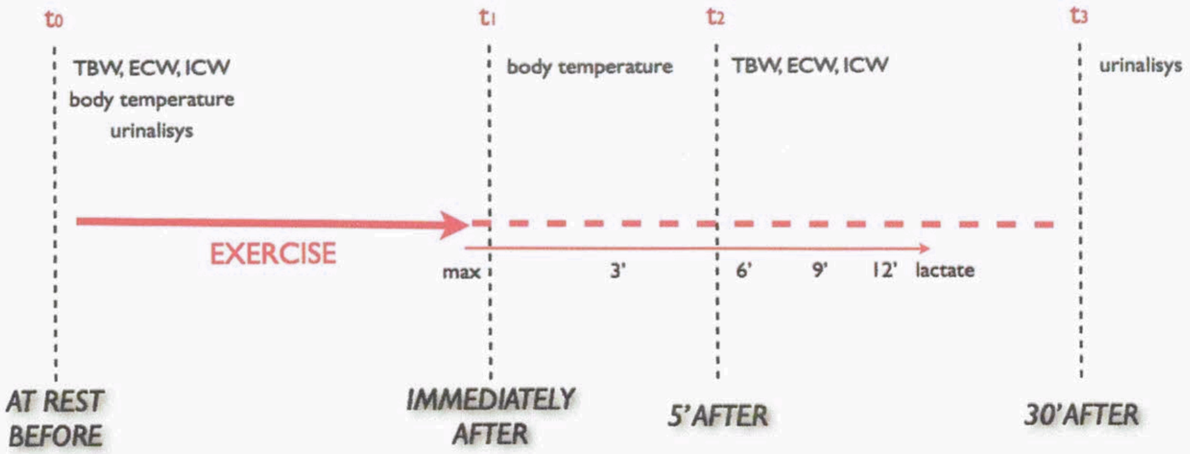

FIG. 1. Temporal structure od examinations.

the method of electrical impedance using the 370 InBody apparatus (InBody 370, USA). Body mass (BM), body fat (FAT), fat-free mass (FFM) and the compartmental and total body water (TBW, ICW, ECW) were determined, while BMI was calculated from BM and height. The t0 test was conducted with the above standards, while the t2 test was conducted following supervised hydration.

Body temperature

Body temperature was measured with a Braun thermometer (Thermo Scan Pro 6000, Germany) according to the timetable of the experiment.

Urine test

Urine samples were placed in a plastic container and mixed with 5 ml/L of a 5% solution of isopropyl alcohol and thymol to secure the properties. Material was stored at 5°C. Urine samples were assayed for the presence of blood and proteins. Specific gravity of urine was determined using the Atago Digital refractometer (Atago Digital, USA). Urine pH was determined based on the standardized Mettler Toledo potentiometer (Mettler Toledo, Germany).

Biochemical assays

To determine lactate concentration (LA) and acid-base equilibrium variables: pH, pCO_2, pO_2, serum bicarbonate (SB), base excess (BE), oxygen saturation (O_2SAT) and total bicarbonate ($ctCO_2$), capillary blood samples were collected. Blood was taken from the fingertip in a volume of 1 ml. Determination of lactate was based on an enzymatic method using a commercial test from Boehringer Mannheim using the Shimadzu UV1201 spectrophotometer (Shimadzu UV 1201, Japan).

Stress tests

The exercise stress test included an interval test protocol, performed under control conditions (CT) and after hydration (HT). The exercise protocol consisted of 5 sets of 60 s exercise at an individualized load of 120% VO2max and a cadence within 75-80 rpm. The rest interval between bouts of exercise equalled 60 s. Before the stress test, each athlete performed a 5-min warm-up with a resistance of 100 W and cadence within 70-80 rpm. After the general warm-up on the ergo-cycle, the athletes stretched the lower limbs, and proceeded with the stress test. To avoid the orthostatic effect, the participants were advised to rest for 3 min in the supine position. In order to determine the intensity of glycolysis, the concentration of lactate (LA) and acid-base equilibrium variables were determined. Finger-tip blood samples were drawn at rest, immediately after the last set of the stress test and in the 3rd, 6th, 9th and 12th minute of recovery. The obtained values were used to determine the rate of post-exercise lactate utilization.

The test was performed on an Excalibur Sport bicycle ergometer (Lode, Netherlands) with electromagnetic adjustable resistance of

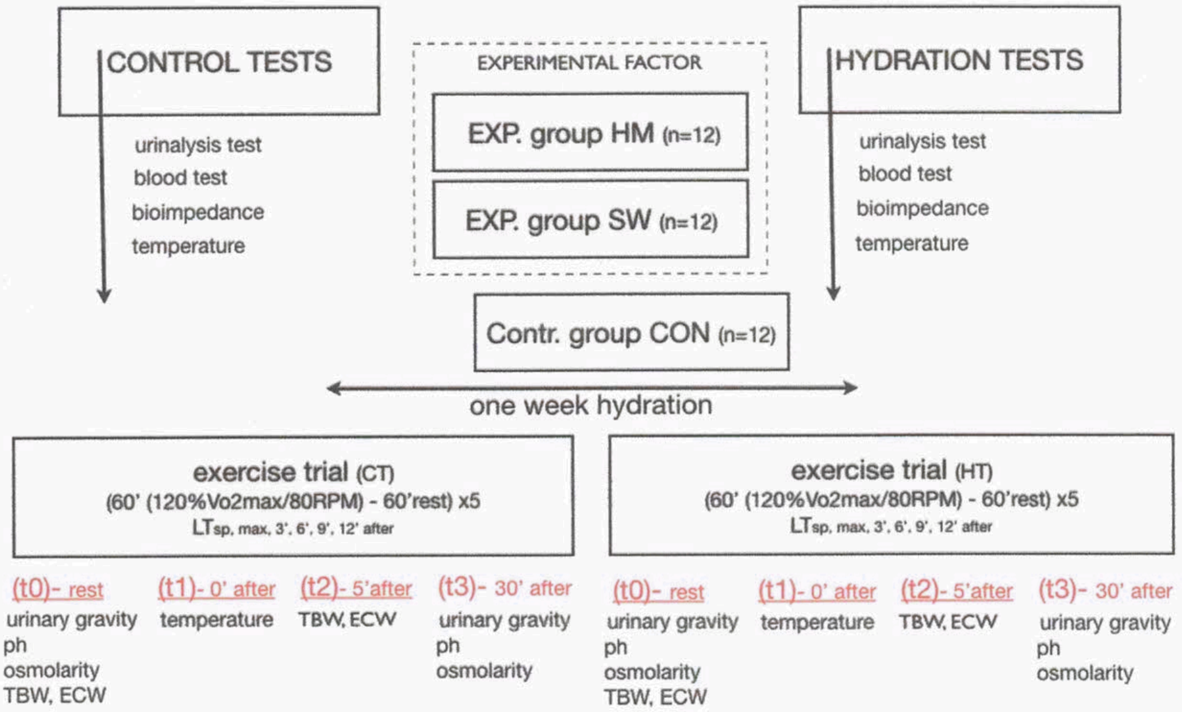

FIG. 2. Experimental procedure.

the flywheel. The generated power (W), cadence (RPM) and total work performed (J) were recorded with the Lode ergometer manager software.

The progressive test during which the 120% VO_{2max} load was determined was conducted a week before the start of the experiment. Each participant performed a ramp ergo-cycle test (T20x1) (20 W/1 min) with the work load increasing linearly (0.33 W per 1 s). The test evaluating VO_{2max} started with a resistance of 40 W and lasted until volitional exhaustion. The cadence was maintained with 60-65 RPM. Heart rate (HR), minute ventilation (VE), oxygen uptake (VO_2), expired carbon dioxide (CO_2), respiratory ratio (RER) and breath frequency (BF) were constantly monitored (Meta Lyzer 3B-2R, Cortex, Germany). Maximal oxygen uptake (VO_{2max}) and maximal work rate (Wr_{max} – W) were registered using the Lode Ergometry Manager (LEM Software, Germany).

Statistical analysis

Normality of distribution was verified using the Shapiro-Wilk test. All data are presented as mean ± SD. Verifications of the differences between analyzed variables and groups were carried out using ANOVA with repeated measures. Statistical significance was set at $p<0.05$. All statistical analyses were performed using Statistica 9.1 with the neural network module, and Microsoft Office Excel 2010.

TABLE 3. Changes in urine pH in the initial and hydration state before and after exercise.

TEST $_{pre}$HYDRATION	T_0	T_3
HM	6.8 ± 0.3	6.3 ± 0.7
LM	6.0 ± 0.8	5.7 ± 0.5
CON	6.4 ± 0.4	5.3 ± 0.4
TEST $_{post}$HYDRATION	**T_0**	**T_3**
HM	6.1 ± 1.0	6.3 ± 0.8
LM	6.0 ± 1.0	6.5 ± 0.5
CON	6.4 ± 1.1	6.3 ± 1.3

Note: Data are expressed as mean ± SD, n=12. HM - high mineral water, LM - low mineral water, CON - control group (table water).

RESULTS

All participants completed the described testing protocol. The procedure was carried out in identical environmental conditions with the air temperature of 19.20 ± 0.34°C and humidity of 57.92 ± 0.46%.

The analysis of urine in the pre-hydration state, in accordance with the anticipated acute adaptation to anaerobic exercise, showed a decrease in pH and a reduction in specific gravity. Intergroup comparative analysis with respect to pH and the specific gravity of urine, carried out before and after exercise, showed no significant difference (HM vs. LM vs. Con.).

After the hydration procedure the athletes consuming alkaline water with specific mineralization (LM) showed significantly increased urine pH. In all groups of athletes, after exercise, the specific gravity of urine decreased (HM, LM, Con.). Intergroup analysis showed that the gradation of urine specific gravity was lowest in the LM group, consuming low mineralized water.

The total body water and its active transport (TBW / ICW / ECW) showed no significant differences in all investigated groups, at both the pre- and post-hydration state.

There were no changes in the value of LT_{max} in all groups (HM, LM and Con). The largest statistically significant differences related to the rate of lactate utilization ΔrestLT were observed after the stage of hydration. Lactate utilization was most efficient in the group of athletes using low mineralized water (LM).

DISCUSSION

Many studies have focused on the maintenance of proper hydration during prolonged aerobic exercise [1], whereas inadequate data have been presented regarding rehydration procedures and benefits during short-term anaerobic exercise. During high-intensity exercise water loss is minimal and other aspects of recovery should be taken into account.

TABLE 4. Exercise-induced changes in the concentration of lactate in the pre-hydration and post-hydration state

$_{pre}$HYDRATION	rest	max	3'	6'	9'	12'	Δ	Δ res
HM	1.20±0.33	10.10±1.96	8.60±2.01	7.52±2.27	6.52±2.34	5.75±2.47	8.90±2.02	4.35±0.32
LM	1.38 ±0.36	8.94 ±0.95	7.90 ±1.18	7.17 ±0.91	5.59 ±0.94	4.83 ±0.80	7.56 ±1.08	4.11 ±0.12
Con.	1.19 ±0.13	10.80 ±1.08	9.31 ±1.29	7.90 ±1.38	7.14 ±1.01	6.28 ±1.24	9.60 ±1.18	4.52 ± 1.12
$_{post}$HYDRATION	**rest**	**max**	**3'**	**6'**	**9'**	**12'**	**Δ**	**Δ res**
HM	1.25 ±0.31	10.09 ±1.52	9.00 ±1.89	7.76 ±1.63	6.49 ±2.06	5.69 ±2.10	8.85 ±1.45	4.40 ±0.34
LM	1.12±0.41	9.34±0.93	6.43±1.01	5.57±1.04	4.23±1.06	3.51±0.90	8.22±0.81	5.83±0.25
Con.	1.34±0.45	9.74±1.18	9.07±1.43	8.26±1.40	7.01±1.33	6.33±1.26	8.40±1.17	3.41±0.18

Note: Data are expressed as mean ± SD, n=12. HM - high mineral water, LM - low mineral water, CON - control group (table water).

Fluid-electrolyte balance and hydration affect the mental and physical state of athletes. Hydration can have a significant influence on both aerobic and anaerobic performance [1]. The results of our study indicate that the use of water with alkalizing properties exhibits a significant potential for hydration. It reduces fluid-electrolyte disturbances and accelerates the rate of lactate utilization following intensive anaerobic interval exercises.

Skeletal muscle fatigue is caused by numerous mechanisms, including accumulation of metabolites, such as potassium, or H^+ [20]. To a large extent, the structural damage to the myocytes and inflammation depend on the exercise ROS production [22].

Analysis of urine osmolality, specific urine gravity and colour may suggest the state of hydration [23]. Consumption of alkaline water following a dehydrating bout of cycling exercise has previously been shown to rehydrate cyclists faster and more completely than the consumption of placebo water. Following the consumption of alkaline water, the cyclists demonstrated lower total urine output, their urine was more concentrated (higher specific gravity), and total blood protein concentration was lower, all of which are expected observations for improved hydration status [24]. Heil [6] reported that water retention at the end of a 3-hour recovery period was 79.2 ± 3.9% when subjects drank alkaline water versus 62.5 ± 5.4% when drinking a placebo ($p < 0.05$). Thus, the present study has shown that the habitual consumption of mineralized bottled water can actually improve indicators of hydration status. The test procedures included in the study determined urine specific gravity and urine pH before and after exercise, in the pre- and post-hydration state. In both pre-hydration and the post-hydration states, the urine specific gravity decreased. However, in the LM group after hydration the changes were more significant (HM 1015 ± 3.8 g/L vs LM 1008± 4.2 g/L, LM 1008± 4.2 g/L vs Con. 1014± 4.1; $p< 0.001$).

The specific gravity of urine is dependent on the amount and weight of the solutes, including electrolytes. Improved water absorption causes a lower concentration of soluble particles and suggests stronger water retention, as observed in the LM group.

Simultaneously, we recorded an exercise-induced increase in urinary pH. This change could be the result of drinking large amounts of alkaline water with aforementioned mineralization properties. Consumption of alkaline water in the present study was associated with an increase in urine pH, while the dietary composition remained stable. Previous research by Welch et al. [25] demonstrated that urinary pH from 24-hour collection samples could function as an effective surrogate marker for changes in acid-base balance when evaluating differences in dietary intake.

A study conducted by Konig et al. [11] suggested that drinking water rich in minerals causes an increase in urine pH (5.94 to 6.57). Numerous experiments confirm the benefits of alkalizing additives in water. Heil [26] described the effects of highly alkalized water on the state of hydration and improved acid-base balance. Similarly, Berardi et al. [27] reported that urinary pH increased from 6.07 to 6.21 and 6.27 following one and two weeks of ingestion, respectively, of a plant-based supplement. The observations from these studies [6, 11] are consistent with the changes in urine pH (6.00 to 6.51) observed by the present study for group 2. Our study confirms the possible effect on hydration and accelerated recovery. Group 2 hydrating with alkaline water had much more efficient lactate utilization following the high-intensity interval training protocol (5.83±0.25 $p<0.05$). This result can be attributed to the specific properties of the alkaline water used for hydration in this group of athletes.

There are a few well-recognized activating factors at the cellular level: ATP, inorganic phosphate and H^+ ions. Skeletal muscle has a large capacity for ammonia production, which is usually revealed by its high blood accumulation during exercise above 60 VO_{2max}. It is clear that an increase in lactate production mirrors recruitment and activity of type II muscle fibres, and this process starts at exercise intensity reaching the anaerobic threshold. Rapid adenosine triphosphate hydrolysis during high-intensity exercise builds up adenosine di-phosphate and adenosine monophosphate (AMP). In the further metabolic degeneration cascade known as the purine nucleotide cycle, AMP is deaminated into inosinomono-phosphate, with the parallel formation of ammonia (NH^3). Because ammonia is correlated with the number of fast switch muscle fibres, an increase in lactate and efficacy of oxidative metabolism, this may suggest that ammonia might be an important player in modulation of central fatigue [28].

Dehydration in athletes may also lead to fatigue, poor performance, decreased coordination, and muscle cramping. Although further studies are absolutely warranted, drinking highly alkaline water seems an effective fluid hydration strategy for high-intensity interval training.

CONCLUSIONS

Drinking alkaline water in amounts of 4.0 l per day shows a positive effect on hydration status after anaerobic exercise with a significant decrease of specific urine gravity.
Intake of alkaline water also shows a positive effect on urine pH during the anaerobic test protocol, and much more efficient lactate utilization after the high-intensity interval exercise.

The consumption of alkaline water was associated with improved acid-base balance and hydration status. In contrast, subjects who consumed table water showed no changes over the same period of time. These results indicate that the habitual consumption of alkaline water may be a valuable nutritional vector influencing both acid-base balance and hydration status in active healthy adults.

These preliminary data demonstrated that consumption of alkaline water can improve anaerobic performance and post-exercise recovery.

Acknowledgement

This study was supported by research grants from Ministry of Science and Higher Education of Poland (NRSA3 03953 and NRSA4 040 54).

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Praca nr 3. - ***Anaerobic Performance and Acid-Base Balance in Basketball Players after the Consumption of Highly Alkaline Water***

Do badania zakwalifikowano 15 mężczyzn uprawiających wyczynowo koszykówkę w drużynie AZS AWF Katowice. Zawodnicy stanowili jednorodną grupę pod względem wieku, stażu treningowego i poziomu sportowego. Wszyscy badani posiadali aktualne badania lekarskie, które pozwalały na udział w zaplanowanych próbach wysiłkowych i analizach biochemicznych. W eksperymencie zadbano o minimalne zróżnicowanie diety, czasu snu, intensywności oraz liczby jednostek treningowych. W okresie trwania eksperymentu badani nie stosowali żadnych suplementów diety, leków i używek.

Badania rozpoczęto od analizy spoczynkowej moczu porannego. Następnie w godzinach popołudniowych tego samego dnia został przeprowadzony anaerobowy test sprawności specjalnej dla koszykówki w postaci biegu wahadłowego 6 x 28 m. Przed i po wysiłku pobierano krew kapilarną w celu oznaczenia równowagi kwasowo-zasadowej oraz stężenia mleczanu. Kilka minut po wysiłku dokonano ponownej analizy próbek moczu. Następnie zawodnicy przez okres 6 tygodni spożywali wodę alkaliczną (pH 9,13) w ilości 2,5-3 litrów na dobę. Woda przyjmowana była rano, po przebudzeniu, oraz przed, w trakcie i po zajęciach treningowych (1,5 litra) oraz przed snem. Po okresie próby uczestnicy zostali ponownie poddani badaniom wysiłkowym i laboratoryjnym. Zawodnicy zostali szczegółowo zapoznani z procedurą badania i wyrazili pisemną zgodę na udział w eksperymencie.

W eksperymencie wykorzystano następujące pomiary laboratoryjne i testy sprawnościowe :

Badania krwi - określono: pH, pCO_2, pO_2, HCO_3^-act, HCO_3^-std, BE(ecf), BE(B), O_2SAT, $ctCO_2$. Na ich podstawie dokonano oceny równowagi kwasowo-zasadowej przed i po wysiłku oraz przed i po hydratacji.

Badania moczu – określono: pH, ciężar właściwy (CW) i osad. Na ich podstawie dokonano oceny równowagi kwasowo-zasadowej przed i po wysiłku oraz przed i po hydratacji.

Testy sprawnościowe - zawodnicy wykonali specyficzny test wytrzymałości beztlenowej dla koszykówki, który polegał na biegu wahadłowym 6 x 28m. Każdy odcinek 28m został zakończony przecięciem fotokomórki dowolną częścią ciała.

Wyniki badań krwi wykazały, iż po hydratacji wodą alkalizowaną, nastąpił istotny wzrost pH krwi w spoczynku i bezpośrednio po wysiłku (test 6 x 28 m). Wyniki badań moczu przed hydratacją nie różniły się znacząco przed i po wysiłku. Znaczące zmiany odnotowano również w porównaniu wyników ciężaru właściwego moczu (CW) w spoczynku. Po suplementacji wodą o regulowanym pH nastąpił istotny spadek CW moczu. Również analiza porównawcza czasów uzyskanych w pierwszym i w drugim teście biegowym (po hydratacji) wykazała znaczącą poprawę wyników w próbie wytrzymałości beztlenowej. Wykazano istotne statystycznie różnice biegu wahadłowego 6 x 28m przed i po suplementacji wodą alkaiczną. Średnia wartość poprawy wyniku w biegu wahadłowym wynosiła 0.71s., przy p=0.03.

International Journal of Food and Nutritional Science
OMMEGA Publishers
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Research Article
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Anaerobic Performance and Acid-Base Balance in Basketball Players after the Consumption of Highly Alkaline Water

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Abstract

Many researchers have unequivocally demonstrated that water of higher pH has a positive effect on the human body. In terms of undertaken research, the adjustment of acid-base balance during anaerobic effort, a decrease in the concentration of free radicals as well as the improvement of connective tissue condition is of primary importance. The aim of this study was to evaluate an influence of high alkaline water consumption on anaerobic performance and acid-base balance in professional basketball players. There was evaluating changes in parameters of blood and urine in laboratory tests (pH, pCO_2, pO_2, HCO_3 act, HCO_3 std, BE (ecf), BE(B), O_2 std, and $ctCO_2$). The group of fourteen adults male underwent in two experimental trials, before and after six weeks hydration tested water. Statistical analysis of blood tests showed that after ingestion of alkaline water there was a significant increase of blood pH at rest and after anaerobic exercise. The same results were obtained in urine tests, respectively 1.30 in rest and 0.93 after physical examination. The results of the specific anaerobic endurance test revealed a significant difference in performance between the tests performed after hydrating with highly alkaline water in comparison to table water. The average improvement of results equaled 0.71s. ($p = 0.03$). In conclusion the athletes hydrated with alkaline water showed a positive impact on acid-base balance with a significant increase of blood and urine pH. The daily intake of 2.5 - 3.0 l of highly alkalized water delay in muscular acidosis during anaerobic exercise, as well as prevention of dehydration, and faster recovery.

Received Date: December 04, 2017
Accepted Date: January 17, 2018
Published Date: January 25, 2018

Citation: Zając, A., et al. Anaerobic Performance and Acid-Base Balance in Basketball Players after the Consumption of Highly Alkaline Water. (2018) Int J Food Nutr Sci 5(1): 134- 139.

DOI: 10.15436/2377-0619.18.1754

Introduction

Basketball is a team sport that involves speed, acceleration, changes of direction as well as numerous technical and tactical activities that require concentration and precision[1,2]. Actions are executed and repeated at high intensity, causing significant disturbances in acid-base equilibrium and gradual fatigue. A basketball game played at the elite level can elicit up to 90% of maximal heart rate, while blood lactate concentrations can reach 6 - 7 m mol/l at half time and close to 8 - 10 m mol/l after the game[3,4]. In addition, new game rules initiated in 2000 such as the reduction of offensive possession time from 30 to 24 s and a limit of 8 s to cross the midcourt line significantly increased the pace of the game, and the physical demand on players. The physical ability to perform repeated sprints at high intensity until the end of the game plays a central role in competition and can determine the final outcome[5,6]. A crucial aspect of competitive sports includes the appropriate supply of fluids. The hydration status in professional athletes should be maintained at an optimal level, as both the lack and excess of fluid intake adversely affect exercise tolerance. The systematic maintenance of fluid balance is crucial in providing the appropriate volume of blood in vessels, and, consequently, an efficient transport of oxygen, nutrients, by-products of metabolism and heat. A frequent issue of competitive sports, including team sport games is the inadequate supply of water or other fluids. A dehydration of 1-2% may result in the lack of concentration, weakened cognitive functions, reduced efficiency and lower exercise tolerance[7].

Athletes can control hydration through thirst, changes in body mass or by observing the colour of urine. However, changes in the above-named variables can be observed once dehydration has already taken place, making it impossible to prevent reduced efficiency during training or competition. Because of that fact, athletes should anticipate and prevent oncoming changes in the body. Controlling fluid intake before, during and after physical effort is of great importance to competitive athletes. Only a complex approach can ensure that an athlete will be fully hydrated for training or competition[8-11]. The issue of adequate hydration becomes even more significant when exercises at altitude[12]. An increasingly popular alternative to various sports drinks and supplements includes water with adjusted contents of minerals and pH. The wide application spectrum of such water results from its buffering and therapeutic properties. Experimental research with alkaline water revealed its positive effect on acid-base balance, both during rest and after anaerobic effort[13]. Weidman et al revealed that water with higher pH ensured better rehydration after intense physical effort-induced dehydration than that provided by standard water. The foregoing conclusion was based on research involving blood viscosity tests in a randomised group of 100 adults. Alkaline water decreased blood viscosity by 6.30%, which was significantly more than the result obtained with standard water (3.36%)[14]. Alkaline water may also inhibit the effect of oxidative stress generated in cells during high-intensity exercise. The above mentioned favourable influence was identified using a marker enabling the determination of oxidative damage to DNA in lymphocytes, i.e. 8-oxy-2′-deoxyguanosine (8-oxo-2dG). In contrast to water with a higher pH, water having high contents of electrolytes did not trigger any significant changes[15]. In addition, advantages related to alkaline water intake, include its positive effect on connective tissue. Randomised tests involving females at a pre-menopausal age revealed that the consumption of 1.5 l of alkaline water per day significantly improved the mineral density of bones, increased urine pH, and decreased the concentration of parathyroid hormone as well as that of serum C-telopeptide[16,17]. Numerous research has confirmed that water of adjustable alkalisation has antidiabetic and antiatherogenic effect by reducing the concentration of glucose in blood and HbA1c, as well as by lowering the concentration of triglycerides, Low-Density Lipoproteins (LDL) and the concentration of total cholesterol in the blood[18,19]. In addition, alkaline water inhibits the angiogenesis of neoplasm's and has an anti-neurodegenerative effect[20]. To sum up, many research-related tests have unequivocally demonstrated that water ofhigher pH has a positive effect on the human body. In terms of undertaken research, the adjustment of acid-base balance during anaerobic effort, a decrease in the concentration of free radicals as well as the improvement of connective tissue condition are of primary importance[21].

Material and Methods

Study participants

Fourteen male competitive basketball players with an average age of 25, 7 ± 3, 4 years were qualified for the research. Trainings took place 5 times a week, and each session lasted 2 hours, with official games played during the weekend. The players constituted a homogenous group in regards to age, physical fitness and training experience. The average body height and body mass of the participants equaled 190.6 ± 4.8 cm, at 88.5 ± 5.7 kg respectively, with 9.8 ± 2.3 years of training experience. All participants had valid medical examination which allowed them to take part in the experiment. The study participants consumed an caloric, mixed diet both before and during the experiment (55% carbohydrates, 20% protein, 25% fat). The players taking part in the experiment did not take any medications or cryogenic substances, 6 weeks before and during the study. In addition, all athletes taking part in the experiment adhered to the requirement of 8 hours of sleep daily, and refrained from consuming alcohol and supplements during the experiment. Moreover, for the purpose of the study there has been an appropriate training monocycle planned which was repeated twice- before the study and during hydration.

Procedure

The research was performer in a basketball gym and in the Human Performance Laboratory of the Academy of Physical Education in Katowice, Poland. The research started with the analysis of morning urine. Then in the afternoon the same day there was a specific test of anaerobic endurance performed which was about shuttle running 6 x 28m. At rest and after the physical effort the analysis of capillary blood and urine was carried out. The study participants have consumed 2, 5 - 3 liters of alkaline water per 24 hours for 6 weeks. In the morning after awakening, before, during and after the training (1. 5 liter) and before going to sleep. After the interference period the contestants have been put through an exercise stress tests and laboratory tests again. Figure 1 depicts the procedure of the study in detail.

Figure 1: Procedure of the study in detail.

The players were familiarized with the procedure, possible benefits and side effects of the research, signing the consent for participation before the commencement of the study. The study received the approval of the Bioethics Committee at the Academy of Physical Education in Katowice, Poland nr 5/2015.

Alkaline water characteristics: The water used in the study was captured from a well in Humniska with a pH of 9, 13 which is highly alkaline compared to other commercial products. The amount of Pt was 9, 4 mg/dm^3 and carbonates 26, 5 mg/dm^3. The chemical composition is presented in detail in Table 1.

The alkaline water contained 840 mg/dm^3 of permanent ingredients what classified it as middle mineral content. The bicarbonate ion HCO_3- (357, 8 mg/dm^3) and carbonate ion

CO_3^{2-} (163, 5 mg/dm^3) consisted the dominant anions. Sodium Na^+ (254, 55 mg/dm^3 dominated among cations. The water's characteristic was bicarbonate-carbonate-sodium [HCO_3-, CO_3-, and Na^+].

Table 1: Mineral content of alkaline water used in the study.

Cations	**mg/dm^3**	**Cr^{3+}**	**0,005**
Na+	254,55	Mo^{6+}	0,0011
K^+	0,91	V^{5+}	0,001
Li^+	0,079	Zr^{4+}	0,010
NH^{4+}	0,793	Ti^{4+}	0,02
Be^{2+}	0,0005	As^{3+}	0,005
Ca^{2+}	10,00	Tl^{4+}	0,0001
Mg^{2+}	0,371	W^{6+}	0,0013
Ba^{2+}	0,0099	TOTAL K^+	266,9
Sr^{2+}	0,0344		
Fe^{2+}	0,09	Anions	mg/dm^3
Mn^{2+}	0,009	F	1,28
Ag^+	0,001	Cl	26,4
Zn^{2+}	0,016	Br	0,1
Cu^{2+}	0,017	J	0,24
Ni^{2+}	0,001	SO_4^{2-}	7,81
Co^{2+}	0,0002	HCO_3-	357,8
Pb^{2+}	0,0009	CO_3^{2-}	163,5
Hg^{2+}	0,0001	NO_2	3,0
Cd^{2+}	0,0003	NCV	0,24
Se^{2+}	0,01	CN	0,002
Sb^{3+}	0,0011	PO_4^{3-}	0,7647
Al^{3+}	0,010	TOTAL A^-	558,1

Laboratory tests: The contestants have been put through capillary blood and urine test in order to evaluate the acid-base balance of the body. The analysis has been performed at rest and after the physical effort (6 x 28 m shuttle run).

Blood tests: The research was carried out at the Human Performance Laboratory of the Academy of Physical Education in Katowice. Capillary blood sample was taken from contestants' index finger tips in the amount of 1 ml. pH, pCO_2, pO_2, HCO_3act, HCO_3std, BE (ecf), BE(B), O_2SAT, $ctCO_2$ parameters were measured. On their basis the acid-base balance of the body was evaluated before and after the physical effort as well as before and after hydration.

Urine tests: The tests were carried out at a Diagnostics Laboratory. Urine pH, specific gravity and residue variables were evaluated. On the base of the above mentioned variables, the acid-base balance was evaluated before and after the anaerobic physical effort as well as before and after hydration.

Physical fitness test: The players performed a specific basketball anaerobic endurance test, which consisted of a 6 x 28 m shuttle run (length of a basketball court) timed with photocells (Microgate, Italy). The test was preceded by a 20 min warm-up which included dribbling, shooting and the 3 man weave followed by 5 min of dynamic stretching.

Statistical analysis

Normality of distribution was verified using the Shapiro-Wilk test. All data are presented as mean ± SD. Verifications of the differences between analyzed variables and groups were carried out using the ANOVA analysis of variance with repeated measures. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using Statistica 9.1 with neural network module, and Microsoft Office - Excel 2010 packets.

Results

All the measurements were carried out with greatest care, according to established procedures and methodology. The players performed both tests under similar external conditions (air temperature 25 C°, relative humidity 65%).The study participants rested the day before testing to minimize the effects of fatigue. In order to minimalize the influence of dependent variables on the tested variables, a specific 6-week training mesocycle was programmed and repeated twice during the experiment. During the experiment the participants did not take any supplements, medications, did not smoke and refrained from alcohol. Throughout the study the basketball players used a mixed, isocaloric (3255 ± 676 kcal/d) diet (55% CHO, 20% Pro and 25% Fat), which was similar to the one adopted before the study. One player was eliminated from the study due to injury which prevented him from training and performing the anaerobic exercise protocol.

Statistical analysis of blood tests showed that after ingestion of alkaline water there was a significant increase of blood pH at rest (0.192), pCO_2 (7.459), HCO_3act (12.977), HCO_3std (11.615), BE(ecf) (-9.390), BE(B) (-8.701) and $ctCO_2$ (13.191) (Table 1). A comparison of other blood variables, such as pO_2 and O_2 SAT did not show any statistically significant differences. After the 6 x 28 m anaerobic exercise test blood evaluations revealed a significant increase in blood pH (0.15 with $F = 4.459$ and $p = 0.002$), what did not occur when the players drank table water. No significant changes were observed in other blood variables (pO_2, pCO_2, HCO_3 act, HCO_3 std, BE (ecf), BE (B), $ctCO_2$ and O_2 SAT) in the group of basketball players drinking table water during the 6 week intervention period.

Table 2: Results of statistical analysis (ANOVA) of blood after hydration with alkaline water at rest.

Variables	**F**	**P**
pH	280,271	0,001*
pCO_2 [mmHg]	37,874	0,001*
pO_2 [mmHg]	3,996	0,055
HCO_3 act [mmol/L]	384,810	0,001*
HCO_3 std [mmol/L]	547,292	0,001*
BE(ecf) [mmol/L]	476,883	0,001*
BE(B) [mmol/L]	503,360	0,001*
O_2 SAT[%]	0,063	0,803
$stCO_2$ [mmol/L]	366,184	0,001*

* statistically significant differences

The initial urine test results, before hydration with alkaline water did not reveal significant differences before and after the intense physical effort. However, the intergroup analysis indicated a significant increase of urine pH at rest (1,301 with F = 39,942 and p = 0.0001) and directly after the physical effort, after the 6-week hydration with alkaline water (0.933 with F = 19,601 and p = 0.0001). Significant changes were also noticed during the comparison of urinary specific gravity at rest (F = 5,446 and p = 0.0270). After hydration with alkaline water there was a significant decrease in urinary specific gravity (-0.006) (Table 2).

The results of the specific anaerobic endurance test (6 x 28 m shuttle) revealed a significant difference in performance between the tests performed after hydrating with highly alkaline water in comparison to table water. The average improvement of results equaled 0.71s. With F = 5.256 and p = 0.03.

Discussion

The conducted experiment concerning the effect of alkalised water on acid-base, and water-electrolyte balance of basketball players revealed positive changes confirmed by blood and urine pH-related tests). The values obtained prior to and following the exercise protocol were significantly improved after the period of alkalised water-based hydration. The specific exercise protocol was characterised by a predominance of anaerobic processes activating metabolic acidosis. Results of the specific basketball endurance test (6 x 28 m) improved by 0.71 s in comparison to those obtained in the pre-hydration period.

Players participating in the tests constituted a homogenous group. They were characterised by similar age, training experience, and the level of physical fitness. The anthropometric variables of tested individuals differed accordingly which corresponded to the specific nature of basketball where, e.g. playmakers are characterised by lower height and lower body mass (180 - 190 cm and 80 - 85 kg respectively), whereas pivot players are significantly taller and heavier (200 - 210 cm and 95 - 115 kg respectively). Before the study commenced, the players participating in the experiment completed a 6-week conditioning period. During the experiment the players completed 5 training units a week, each lasting 90 - 120 min, where 2 training sessions were characterised by high intensity, specific basketball drills, during which exercise metabolism was dominated by anaerobic glycolysis, with a significant disturbance of acid-base balance. Besides the 5 training units the study participants played an official league game on Saturdays.

One of the novel aspects of this research included the use of highly alkalized water (pH 9.13). Another novel element of the experiment was the time of intervention amounting to 6 weeks, and the amount of consumed water (2.5 - 3 litres/d). This facilitated the course of adaptive changes, and increased the accuracy and reliability of the evaluations. The study protocol also involved the monitoring of the players' diet to minimise its impact on experimental results. During the 6-week intervention period the basketball players were on a mixed diet (55% CHO, 20% Pro and 25% Fat), where the average caloric value amounted to 3285 ± 688 kcal/d and was similar to the food intake preceding the experiment. The caloric diversity resulted primarily from significantly different body mass of the players and not from energy expenditure (similar in terms of all study participants).

The results obtained in our study are mostly confirmed in the available literature regarding the use of alkalized water, although few studies have been conducted on competitive athletes involved in intense anaerobic exercise[13,14,23].

Heil[17] performed an experiment involving a group of 38 untrained volunteers and water having a pH of 10.0. The daily intake of the alkalised water was individualized and, in the experimental group, amounted to 2.2 - 2.4 litres per day. After a 4-week intervention it was possible to observe a significant increase in blood and urine pH of participants ingesting alkalised water in comparison with values registered for the control group. An average increase in blood pH after the physical effort amounted to 0.15, whereas that of urine amounted to 0.93. The tests also revealed an increase in blood osmolality and a decrease in urine osmolality. Interesting results were also obtained by Ostojic and Stojanovic[22], who tested water having a pH of 9.3 in a group of 52 physically active men. The volunteers consumed 2 litres of water per 24 hours for a period of 2 weeks. The amount of water was smaller and the intervention period was shorter than those used in the tests described in this work. As a consequence of drinking Hydrogen Rich Water (HRW), significant increases in blood pH and bicarbonates were registered. After 2 weeks of administration, the HRW group had higher levels of fasting pH than the placebo group (7.44 ± 0.10 vs. 7.38 ± 0.09, p = 0.03), and a higher concentration of bicarbonates (30.5 ± 1.9 vs. 27.1 ± 1.3 m Eq/L, p < 0.001). The intake of HRW significantly increased post exercise pH from 7.39 ± 0.15 to 7.46 ± 0.11 (p = 0.03) after intervention. Results confirming the advantageous effect of water having higher pH values were obtained by[13], who observed a group of 36 soccer players consuming 4 litres of variously mineralised water (highly mineralized water pH 6.1, low mineralized water pH 8 and table water pH 5). In spite of a relatively short intervention time the results obtained in the above-named experiment were similar to those reached in our study. The group consuming the water characterised by the highest alkalisation revealed a significant increase in urine pH (by 0.5) after anaerobic effort following the period of hydration, and a decrease in the specific weight of urine. The groups consuming highly mineralised and table water did not reveal significant changes. When comparing the results obtained within this study and those referred to in reference publications it was possible to observe positive effects resulting from the consumption of water having higher pH on variables characterizing the acid-base balance of the body. Studies involving both, untrained individuals and competitive athletes revealed an increase in blood and urine pH after the hydration with alkalised water, as well as a decrease in specific weight of urine. The authors found it interesting that positive changes were obtained regardless of the duration of the intervention.

Numerous researches demonstrate that a common issue concerning basketball players is connected with the fact that they play games in a state of dehydration. Seventy five percent of young elite basketball players at the FIBA Europe U20 Championship started the tournament with a dehydration of 883 m Osmol/bm. In turn, tests involving adult NBA players during the summer basketball league revealed that 52% of tested individuals started games in the state of dehydration (USG > 1,020) [24]. During official competition in basketball the loss of fluids is significant, and can reach 2 litres per 20 minutes of the game. Tests performed by Osterberg et al.,[25] revealed that players lost on the average 2.2 litres during a game lasting 21-40 minutes. Specific individual recommendations concerning the intake of fluids should be calculated based on sweat rates, sport dynamics, and individual tolerance. Some authors suggest a general rehydration protocol for basketball players: 200 mL at quarter breaks, 400 mL at half time and 100 mL at one timeout/half[24]. However, certain tests indicate the lack of appropriate supply of fluids during the game in spite of players having unlimited access to them. There are reports indicating that the fluid demand in competitive basketball is only replaced in 50 to 70% of the need needs[26]. The most sensitive method enabling the determination of hydration is the measurement of plasma osmolality, the proper value of which amounts to 280 - 290 m Osmol/kgbm. The body dehydration increases along with plasma osmolality values. An increase in osmolality by a mere 1% impedes the activation of compensation mechanisms, i.e. the secretion of ADH and the intensification of thirst aimed to prevent dehydration[27,28]. Metabolism during anaerobic exercises is significantly affected by the acid-base balance of the organism. Variables enabling the assessment of fluctuation include the level of lactate and bicarbonate in the blood, blood and urine pH as well as the saturation of blood with oxygen and carbon dioxide[29]. The reduction of acidification during and after anaerobic effort increases the efficiency of exercises through the intensification of lactate utilisation and an increase in the production of ATP[30]. The effect of metabolic alkalosis can be obtained by the use of sodium bicarbonate and ß-alanine supplements, which was demonstrated in numerous researches[31,32]. Recent reports, as well as the results of our study indicate that drinking alkalised water may have a positive effect on acid-base balance and in consequence improve high intensity exercise performance. However, this problem requires further observation to optimise the recommended doses and hydration time.

The results of this experiment confirm that ingesting water with a higher pH favourably influences acid-base balance and hydration of competitive athletes, in this case semi-professional basketball players. The daily intake of 2.5 - 3.0 l of highly alkalized water brings about several advantages including, a delay in muscular acidosis during anaerobic exercise, as well as prevention of dehydration, and faster recovery. Importantly, favourable properties of alkalised water are not limited to athletes and exercise. Regular consumption of alkalised water has several clinical advantageous, such as the treatment of gout, decreased oxidative stress, slowing down of osteoporosis, regulating blood glucose levels in diabetes, as well as anti-atherogenic and antineoplastic effects[19,33-35].

Conflict of Interest: Authors have no conflict of interest to declare.

Acknowledgements: This work was supported by the Ministry of Science and Higher Education of Poland under Grant NRSA3 03953 and NRSA4 040 54.

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Praca nr 4. - *Alkaline water improves exercise-induced metabolic acidosis and enhances anaerobic exercise performance in combat sport athletes*

Celem pracy było określenie wpływu wody mineralnej o wysokim stopniu alkalizacji na równowagę kwasowo-zasadową i stan nawodnienia organizmu oraz na wydolność beztlenową zawodników uprawiających wyczynowo sporty walki. Grupę badaną stanowiło 16 zawodników sportów walki, w podobnym wieku i o zbliżonym stopniu wydolności tlenowej i beztlenowej. Zostali oni w sposób losowy podzieleni na dwie grupy: grupę eksperymentalną (n=8), która przez okres trzech tygodni przyjmowała wodę o wysokiej alkalizacji i grupę kontrolną (n=8), która w tym samym czasie otrzymywała wodę stołową. Podczas eksperymentu uczestnicy stosowali izokaloryczną, mieszaną dietę (55% węglowodanów, 20% białka, 25% tłuszczu). Badanie przeprowadzono podczas okresu przygotowawczego rocznego cyklu szkoleniowego, a na dwa dni przed próbą zawodnicy zaprzestali treningów, tak by zminimalizować efekty zmęczenia. W trakcie eksperymentu i 3 tygodnie przed rozpoczęciem badania uczestnicy nie przyjmowali żadnych leków ani suplementów. Podczas eksperymentu spożycie wody było zindywidualizowane w oparciu o zalecenie National Athletic Trainers Association i wynosiło średnio 2,6-3,2 l na dobę. Do badania została wykorzystana woda o pH 9,13 i zawartości składników stałych na poziomie 840 mg / dm3 (średnia zawartość minerałów). Oceny wydolności beztlenowej dokonano za pomocą dwóch podwójnych testów Wingate dla kończyn dolnych i górnych z 3 minutowymi przerwami wypoczynkowymi. Test wysiłkowy poprzedzono 5-minutową rozgrzewką z oporem 100 W i rytmem w zakresie 70-80 obrotów na minutę dla kończyn dolnych oraz 40 W i 50-60 obrotów na minutę dla kończyn górnych. Po rozgrzewce rozpoczęto próbę, w której celem było osiągnięcie najwyższej kadencji w jak najkrótszym czasie i utrzymanie jej przez czas trwania testu. W celu określenia stężenia mleczanu (LA), równowagi kwasowo-zasadowej i poziomu elektrolitów, oceniono następujące zmienne: LA (mmol / L), pH krwi, pCO_2 (mmHg), pO_2 (mmHg), akt HCO_3^- (mmol / L), HCO_3^- std, (mmol / L), BE (mmol / L), O_2SAT (mmol / L), $ctCO_2$ (mmol / L), Na^+ (mmol / L) i K^+ (mmol / L). Oznaczenia wykonano z próbek krwi kapilarnej w spoczynku i po 3 minutach restytucji. Próbki moczu pobierano w spoczynku, po całonocnym poście, w punkcie wyjściowym i po zakończeniu badania.

Testy ujawniły statystycznie istotny wzrost średniej mocy dla kończyn górnych i dolnych w grupie stosującej wodę alkalizowaną. Zmian tych nie zaobserwowano w grupie kontrolnej. Wykazano również statystycznie istotne zmniejszenie stężenia LA w spoczynku (z 1,99 mmol / L do 1,30 mmol / L przy p = 0,008), oraz istotny wzrost stężenia LA po wysiłku (z 19.09 mmol / L do 21,20 mmol / L przy p = 0,003) w grupie eksperymentalnej spożywającej wodę alkaliczną. Dodatkowo, znaczny wzrost pH krwi w spoczynku (z 7,36 do 7,44 z p = 0,001), HCO_3^- w spoczynku (z 23,87 do 26,76 przy p = 0,001) i HCO_3^- po wysiłku (od 12,90 do 13,88 przy p = 0,002) zaobserwowano w grupie eksperymentalnej. Pozostałe znaczące zmiany adaptacyjne wystąpiły w stężeniu po wysiłku K^+ (z 4,15 do 4,41 przy p = 0,039), w pH moczu (z 5,75 do 6,62 przy p = 0,017) i obniżeniu wartości SG (od 1,02 do 1,00) przy p = 0,001), wszystkie w grupie eksperymentalnej stosującej wodę alkaliczną.

RESEARCH ARTICLE

Alkaline water improves exercise-induced metabolic acidosis and enhances anaerobic exercise performance in combat sport athletes

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Abstract

Hydration is one of the most significant issues for combat sports as athletes often use water restriction for quick weight loss before competition. It appears that alkaline water can be an effective alternative to sodium bicarbonate in preventing the effects of exercise-induced metabolic acidosis. Therefore, the main aim of the present study was to investigate, in a double blind, placebo controlled randomized study, the impact of mineral-based highly alkaline water on acid-base balance, hydration status, and anaerobic capacity. Sixteen well trained combat sport athletes (n = 16), were randomly divided into two groups; the experimental group (EG; n = 8), which ingested highly alkaline water for three weeks, and the control group (CG; n = 8), which received regular table water. Anaerobic performance was evaluated by two double 30 s Wingate tests for lower and upper limbs, respectively, with a passive rest interval of 3 minutes between the bouts of exercise. Fingertip capillary blood samples for the assessment of lactate concentration were drawn at rest and during the 3rd min of recovery. In addition, acid-base equilibrium and electrolyte status were evaluated. Urine samples were evaluated for specific gravity and pH. The results indicate that drinking alkalized water enhances hydration, improves acid-base balance and anaerobic exercise performance.

OPEN ACCESS

Citation: Chycki J, Kurylas A, Maszczyk A, Golas A, Zajac A (2018) Alkaline water improves exercise-induced metabolic acidosis and enhances anaerobic exercise performance in combat sport athletes. PLoS ONE 13(11): e0205708. https://doi.org/10.1371/journal.pone.0205708

Editor: Michal Toborek, University of Kentucky Medical Center, UNITED STATES

Received: July 4, 2018

Accepted: September 28, 2018

Published: November 19, 2018

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Funding: This work was supported by the Ministry of Science and Higher Education of Poland under Grant NRSA3 03953 and NRSA4 040 54.

Competing interests: The authors have declared that no competing interests exist.

Introduction

Despite numerous scientific data, there is still no conclusive answer regarding what and how much we should drink to optimize sports performance. Until the middle of the 20th century, the recommendation was to avoid drinking to optimize performance. The first drinking guidelines were introduced by the ACSM to avoid heat stress in 1975, while hydration and performance were first addressed only in 1996 [1]. At that time, athletes were encouraged to drink the maximum amount of fluids during exercise that could be tolerated without gastrointestinal discomfort and up to the rate lost through sweating. Depending on the type of exercise and the environment, volumes from 0.6 to 1.2 L per hour were recommended. These drinking guidelines have been questioned recently, and other issues such as over hydration and hyponatremia have been addressed [2].

The inconsistency of the results regarding hydration and sports performance arise from differences in experimental protocols. In studies in which dehydration develops during exercise, fluid loss of up to 4% body mass does not compromise performance, while in studies that induced dehydration prior to exercise, performance impairments have been observed after dehydration as low as 1–2% body mass [3]. Several comprehensive reviews on the influence of dehydration on muscle endurance, strength, anaerobic capacity, jumping performance and skill performance in team sport games have revealed negative effects of dehydration $\geq$ 2% body mass [4, 5, 6]. Hydration is one of the most significant issues for combat sports, as athletes often use water restriction for quick weight loss before competition. During tournaments lasting several hours, combat sport athletes sweat immensely and increase their core temperature affecting muscle strength, reducing motor cortex activation, peripheral stimulus as well as the speed of reaction and power output [7].

Considering the vast amounts of fluids used during exercise, water seems to be the most often form of hydration. Water comes in different forms, with specific properties depending on its mineral content. The pH of water, as well as the proportions between SO_4^{2-} and HCO_3^- determines hydration status and other therapeutic properties [7]. Drinking hydrogen rich water in human nutrition is a rather new concept, and it is recently suggested for medical purposes and hydration during exercise [8–10]. Alkaline water is being marketed as a nutritional aid for the general public for acidity-lowering, antioxidant, and antiaging properties. Some of the animal and human research has confirmed its effectiveness as an alkalizing agent in the treatment of metabolic acidosis [11, 12]. However, metabolic acidosis that occurs during high intensity exercise is a distinct form of metabolic alteration, when cells are forced to rely on anaerobic ATP turnover that leads to proton release and a decrease in blood pH that can impair performance [8, 13].

Anaerobic exercise metabolism leads to the production of lactic acid in the working muscles. Part of the produced lactic acid is released to the blood, reducing blood pH, and disturbing acid—base balance. Several studies have provided evidence that hydrogen ions are released from the muscles in excess of lactate after intense exercise [14]. Two mechanisms have been proposed to explain this phenomenon. It seems that hydrogen ions are released both by a sodium-hydrogen ion exchanger and by a lactic acid transporter [15]. Since red blood cells have a higher buffering capacity than blood plasma, the lactate generated during exercise largely remains in the plasma while hydrogen ions are transferred to the red blood cells and buffered by hemoglobin [16]. One of the objectives of training and supplementation in high intensity anaerobic sports disciplines is to increase the buffering capacity of the blood and tissues [17]. The use of sodium bicarbonate has proven effective in speed endurance and strength endurance sports, yet its use has been limited due to the possibility of gastrointestinal distress, metabolic alkalosis, and even edema due to sodium overload [8, 18]. It appears that alkaline water can be an effective alternative to sodium bicarbonate in preventing exercise-induced metabolic acidosis [8, 19]. Contrary to bicarbonate, alkaline water can be used on an everyday basis and has no known side effects. However, there are only few cross-sectional or longitudinal studies on the impact of alkaline water ingestion in combat sport athletes. Therefore, the main objective of the current study was to investigate in a double blind, placebo controlled randomized study, the impact of mineral-based highly alkaline water on acid-base balance, hydration status, and anaerobic capacity in experienced combat sport athletes subjected to a very intense exercise protocol.

Materials and methods

Subjects

Sixteen very well-trained males, who trained and competed in combat sports for at least 7.6 years, participated in the study. The athletes constituted a homogenous group in regard to age (average age of 22.3 ± 0.5 years), somatic characteristics, as well as aerobic and anaerobic performance (Table 1). The subjects ($n = 16$) were randomly divided into two groups, the experimental group (EG; $n = 8$), which received highly alkaline water, and the control group (CG; $n = 8$), which was hydrated with table water. All subjects had valid medical examinations and showed no contraindications to participate in the study. The athletes were informed verbally and in writing of the experimental protocol, the possibility to withdraw at any stage of the experiment, and gave their written consent for participation. The study was approved by the Research Ethics Committee of the Academy of Physical Education in Katowice, Poland.

Diet and hydration protocol

Energy intake, as well as macro and micronutrient an intake of all subjects was determined by the 24 h nutrition recall 3 weeks before the study was initiated. The participants were placed on an isocaloric (3455 ± 436 kcal/d) mixed diet (55% carbohydrates, 20% protein, 25% fat) prior and during the investigation. The pre-trial meals were standardized for energy intake (600 kcal) and consisted of carbohydrate (70%), fat (20%) and protein (10%). During the experiment, and 3 weeks before the commencement of the study, the participants did not take any medications or supplements. Throughout the experiment water intake was individualized based on the recommendation of the National Athletic Trainers Association and averaged 2.6–3.2 L per day. In our study we used water which had a pH of 9.13 which is highly alkaline compared to other commercially available products. The water ingested during the experiment contained 840 mg/dm^3 of permanent ingredients, and was classified as medium mineral content. The bicarbonate ion HCO_3^- (357.8 mg/dm^3) and carbonate ion CO_3^{2-} (163.5 mg/dm^3) consisted the dominant anions. Sodium (Na^+ 254.55 mg/dm^3) dominated among cations. The water contained bicarbonate, carbonate-sodium (HCO_3^-, CO_3^- Na^+). The chemical properties of both types of water used in the experiment (alkaline and table water) are presented in Table 2.

Study protocol

The experiment lasted 3 weeks, during which two series of laboratory analyses were performed. The tests were carried out at baseline and after three weeks of hydration with alkaline

Table 1. Characteristics of the study participants.

Variables	Experimental Group (n = 8)	Control Group (n = 8)
Age (yrs.)	22.7±3.2	22.4 ± 2.8
Height (cm)	181.2±2.1	178.3±4.9
Body mass (kg)	81.8±3.2	79.2 ±2.6
FM (%)	10.2±2.1	10.8±2.4
$W_{t\text{—upper limbs}}$ (J/kg)	138±14	136±19
$W_{t\text{—lower limbs}}$ (J/kg)	276±04	283±26
$P_{\text{max–lower limbs}}$ (W/kg) $P_{\text{max–upper limbs}}$ (W/kg)	19.8±0.9 8.9±1.1	20.2±1.6 8.7±0.4
VO_{2max} (ml/kg/min)	64.7±2.8	62.6±3.2

https://doi.org/10.1371/journal.pone.0205708.t001

Table 2. Chemical properties of water used in the study.

Variable	Measurement Unit	Alkaline Water	Table Water
pH	pH	9.13 ± 0.04	5.00 ± 0.08
CO_3^{2-}	mg/dm^3	163.5 ± 6.3	14.98 ± 0.66
HCO_3^-	mg/dm^3	357.8 ± 6.14	3.62 ± 0.12
Cl^-	mg/dm^3	26.4 ± 2.3	0.41 ± 0.03
SO_4^{2-}	mg/dm^3	7.81± 1.2	1.60 ± 0.09
Na^+	mg/dm^3	254.55 ± 7.1	1.21 ± 0.05
K^+	mg/dm^3	0.91 ± 0.04	0.30 ± 0.03
Ca^{2+}	mg/dm^3	10.00 ± 1.6	1.21 ± 0.05
Mg^{2+}	mg/dm^3	0.37 ± 0.03	0.40 ± 0.04

Note: Data shows mean values ± SD of three analysis of each type of water

https://doi.org/10.1371/journal.pone.0205708.t002

or table water. The study was conducted during the preparatory period of the annual training cycle, when a high volume of work dominated the daily training loads. The participants refrained from exercise for 2 days before testing to minimize the effect of fatigue.

The subjects underwent medical examinations and somatic measurements. Body composition was evaluated in the morning, between 8.00 and 8.30 am. The day before, the participants had the last meal at 20.00. They reported to the laboratory after an overnight fast, refraining from exercise for 48h. The measurements of body mass were performed on a medical scale with a precision of 0.1 Kg. Body composition was evaluated using the electrical impedance technique (Inbody 720, Biospace Co., Japan). Anaerobic performance was evaluated by a two double 30-second Wingate test protocol for lower and upper limbs respectively, with a passive rest interval of 3 minutes between the bouts of exercise. The test was preceded by a 5 min warm-up with a resistance of 100 W and cadence within 70–80 rpm for lower limbs and 40 W and 50–60 rpm for the upper limbs. Following the warm-up, the test trial started, in which the objective was to reach the highest cadence in the shortest possible time, and to maintain it throughout the test. The lower limb Wingate protocol was performed on an Excalibur Sport ergocycle with a resistance of 0.8 Nm·Kg-1 (Lode BV, Groningen, Netherland). The upper body Wingate test was carried out on a rotator with a flying start with a load of 0.45 Nm·Kg-1 (Brachumera Sport, Lode, Netherland). Each subject completed 4 test trials with incomplete rest intervals. The variables of peak power–P_{max} (W/Kg) and total work performed–W_t (J/Kg), were registered and calculated by the Lode Ergometer Manager (LEM, software package, Netherland).

Biochemical assays

To determine lactate concentration (LA), acid-base equilibrium and electrolyte status the following variables were evaluated: LA (mmol/L), blood pH, pCO_2 (mmHg), pO_2 (mmHg), $HCO_{3-\ act}$ (mmol/L), $HCO_{3\text{-std}}$, (mmol/L), BE (mmol/L), O_{2SAT} (mmol/L), $ctCO_2$ (mmol/L), Na^+ (mmol/L), and K^+ (mmol/L). The measurements were performed on fingertip capillary blood samples at rest and after 3 minutes of recovery. Determination of LA was based on an enzymatic method (Biosen C-line Clinic, EKF-diagnostic GmbH, Barleben, Germany). The remaining variables were measured using a Blood Gas Analyzer GEM 3500 (GEM Premier 3500, Germany).

Urine samples were taken at rest, after an overnight fast, at baseline and at the conclusion of the investigation. They were placed in a plastic container and mixed with 5 ml/L of 5% solution of isopropyl alcohol and thymol for preservation. Urine samples were assayed for the presence of blood and proteins. Specific gravity was determined using the Atago Digital refractometer (Atago Digital, USA). Urine pH was determined based on the standardized Mettler Toledo potentiometer (Mettler Toledo, Germany).

Statistical analysis

The Shapiro-Wilk, Levene and Mauchly´s tests were used to verify the normality, homogeneity and sphericity of the sample's data variances, respectively. Verifications of the differences between analyzed variables before and after water supplementation and between the EG and CG were performed using ANOVA with repeated measures. Effect sizes (Cohen's d) were reported where appropriate. Parametric effect sizes were defined as large for $d > 0.8$, as moderate between 0.8 and 0.5, and as small for < 0.5 (Cohen 1988; Maszczyk et al., 2014, 2016). Statistical significance was set at $p<0.05$. All statistical analyses were performed using Statistica 9.1 and Microsoft Office, and were presented as means with standard deviations.

Results

All participants completed the described testing protocol. All procedures were carried out in identical environmental conditions with an air temperature of 19.2˚C and humidity of 58% (Carl Roth hydrometer, Germany).

The repeated measures ANOVA between the experimental and control group and between the baseline and post-intervention period (3 weeks of alkaline and table water ingestion) revealed statistically significant differences for thirteen variables (Table 3).

Post-hoc tests revealed a statistically significant increase in mean power when comparing the values (7.98 J/kg to 9.38 J/kg with $p = 0.001$) at baseline vs. at the conclusion of the study in the experimental group supplemented with alkaline water. In contrast, the control group which received table water did not reveal any statistically significant results. Similar changes were observed for Upper Limb Average Power (from 4.32 J/kg to 5.11 J/kg with $p = 0.011$) and Upper Limb Peak Power (from 7.90 J/kg to 8.91 J/kg with $p = 0.025$) in the experimental group. The post-hoc tests also showed statistically significant increases in values for Lower

Table 3. Statistically significant differences between the experimental and control groups at baseline and after 3 weeks of intervention (alkaline vs table water).

Variables	d	p	F
Wingate Lower Limbs Average Power Exp.	0.884	0.001	21.161
Wingate Upper Limbs Average Power Exp.	0.587	0.011	8.528
Wingate UL Peak Power Exp.	0.501	0.026	6.228
Wingate LL Total Work Exp.	0.567	0.045	4.822
Wingate UL Total Work Exp.	0.522	0.011	8.459
LA_{rest}	0.534	0.008	9.429
$LA_{post\ exr}$	0.618	0.003	13.382
pH_{rest}	0.834	0.001	120.159
$HCO_3^-{}_{rest}$	0.844	0.001	109.250
$HCO_3^-{}_{post\ exr}$	0.632	0.002	14.724
$K^+{}_{post\ exr}$	0.501	0.040	5.154
Urine pH	0.589	0.017	7.298
SG	0.884	0.001	19.707

Note: d—effect size; p—statistical significance
F–value of analysis of variance function

https://doi.org/10.1371/journal.pone.0205708.t003

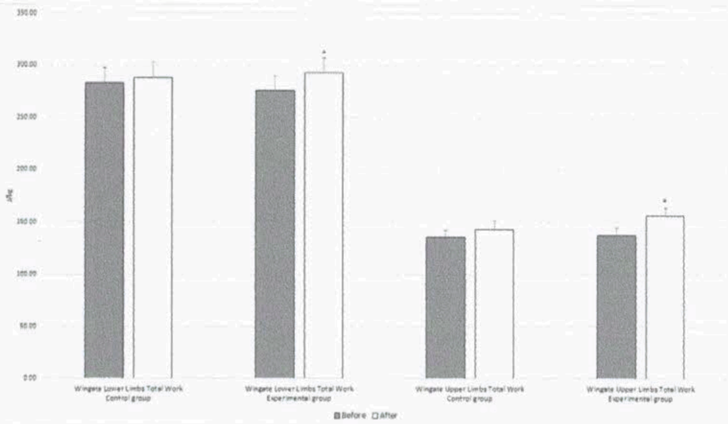

Fig 1. Differences between the control and experimental groups in total work of the lower and upper limbs (30s Wingate test) at baseline and after 3 weeks of alkaline or table water ingestion. Note: * statistically significant values.

https://doi.org/10.1371/journal.pone.0205708.g001

Limb Total Work (from 276.04 J/kg to 292.96 J/kg with $p = 0.012$) and Upper Limb Total Work (from 138.15 J/kg to 156.37 J/kg with $p = 0.012$) when baseline and post intervention values were compared. The changes in the control group were not statistically significant. These results are presented in Fig 1.

Post-hoc tests also revealed statistically significant decreases in LA concentration at rest (from 1.99 mmol/L to 1.30 mmol/L with $p = 0.008$), and a significant increase in post exercise LA concentration (from 19.09 mmol/L to 21.20 mmol/L with $p = 0.003$) in the experimental group ingesting alkaline water.

Additionally, a significant increase in blood pH at rest (from 7.36 to 7.44 with $p = 0.001$), HCO_3^- at rest (from 23.87 to 26.76 with $p = 0.001$), and HCO_3^- post exercise (from 12.90 to 13.88 with $p = 0.002$) were observed in the experimental group. The other significant changes occurred in the post exercise concentration of K^+ (from 4.15 to 4.41 with $p = 0.039$), in urine pH (from 5.75 to 6.62 with $p = 0.017$), and a decrease in the value of SG (from 1.02 to 1.00 with $p = 0.001$), all in the experimental group supplemented with alkaline water.

Discussion

Acid-base equilibrium within the human body is tightly maintained through the blood and tissue buffering systems, the diffusion of carbon dioxide from the blood to the lungs via respiration, and the excretion of hydrogen ions from the blood to urine by the kidneys. These mechanisms also regulate acid-base balance following high intensity exercise. Metabolic acidosis is a consequence of exercise induced ionic changes in contracting muscles. Increased intramuscular acidity impairs muscle contractibility, significantly limiting high intensity exercise performance [20]. Importantly, acid-base equilibrium can be influenced by dietary supplementation.

In the present study, we investigated the effect of mineral-based alkaline water on acid-base balance, hydration status and anaerobic performance of competitive combat sport athletes. The study participants were experienced athletes (Table 1), capable of performing extreme anaerobic efforts. We have chosen such an approach for two reasons. First, it is well-documented that consumption of alkalizing water can have a significant effect on the hydration status, acid-base balance, urine and blood pH [8, 10], as well as Ca metabolism and bone resorption markers [21]. However, the majority of these research reports have been performed on sedentary individuals [22] or on subjects with self-reported physical activity [10]. Second, alkalization by alkaline water has been mostly discussed in the context of dehydration and aerobic performance [10]. Therefore, our study is novel by including both well trained combat sport athletes and the use of an extremely intensive anaerobic exercise protocol.

Acid-base balance and hydration status

The exchange of ions, CO_2, and water between the intracellular and extracellular compartments helps to restore acid-base balance following intensive exercise. There is sufficient data indicating that, supplements that modify the blood buffering system affect high-intensity exercise performance [23]. In humans, especially well trained athletes muscle pH may decrease from 7.0 at rest to values as low as 6.4–6.5 during exercise [24]. Ergogenic aids that help buffer protons attenuate changes in pH and enhance the muscle's buffering capacity. This in turn allows for a greater amount of lactate to accumulate in the muscle during exercise.

The results of our study are in line with the available literature regarding the impact of alkaline water on blood and urine pH at rest [9, 19, 25]. However, novel results of the present research are related to the changes in HCO_{3-} after exercise in athletes ingesting alkaline water. Bicarbonate-CO_2 accounts for more than 90% of the plasma buffering capacity. Supplementation can increase bicarbonate concentration in the blood and its pH. Since bicarbonate concentration is much lower in the muscles (10 mmol/L) than in the blood (25 mmol/L), the low permeability of charged bicarbonate ions precludes any immediate effects on muscle acid-base status [24]. These results confirm the view that an appropriate hydration status is necessary for active bicarbonate ion transport.

Several lines of evidence support the negative impact of dehydration (>2% body mass) on muscle endurance, strength, and anaerobic performance [6]. On the other hand, literature data indicates that consumption of alkaline water following a dehydrating bout of cycling exercise was shown to rehydrate cyclists faster and more completely compared to table water. Following consumption of alkaline water, the cyclists demonstrated lower total urine output, their urine was more concentrated (i.e., with higher specific gravity), and the total blood protein concentration was lower, indicating improved hydration status [26]. Our previous study revealed that the use of water with alkalizing properties exhibits a significant potential for hydration during anaerobic exercise [9]. The results of the present study confirm a decrease in urine specific gravity (from 1.02 to 1.00, with $p = 0.001$) and an increase in urine pH as the result of consumption of alkaline water. These results illustrate that the habitual consumption of highly alkaline water can markedly improve hydration status.

Anaerobic performance

The current investigation demonstrated a significant increase in anaerobic capacity (W_t–J/Kg) of athletes in the experimental group supplemented with alkaline water. The improvements in W_t following alkaline water consumption were influenced by positive changes in blood pH and bicarbonate. This phenomenon could be explained by the ergogenic effects of high alkalization and mineral ingredients.

High intensity exercise in which anaerobic glycolysis provides ATP for muscle contraction leads to an equal production of lactate and hydrogen ions. Most of the released hydrogen ions are buffered; however, a small portion (~0.001%) that remains in the cytosol causes a decrease in muscle pH and an impairment of exercise. Lactate efflux [15] and its oxidation are accompanied by a similar removal of hydrogen ions. The results of the current study demonstrated a statistically significant decrease in lactate concentration at rest (from 1.99 mmol/L to 1.30

mmol/L, $p = 0.008$), and a significant increase post exercise (from 19.09 mmol/L to 21.20 mmol/L, $p = 0.003$) when compared to the baseline levels with the values recorded at the end of alkaline water supplementation. The extremely intense 4 x 30s upper/lower limb Wingate test protocol employed in our study, with only short rest intervals between each bout of exercise, was a likely reason that less of the total lactate produced in the muscles was transported to the blood [27].

Muscle blood flow determines lactate efflux from the muscle [28], and is dependent on the activity of lactate transport proteins [29], the extracellular buffering capacity [30], and the extracellular lactate concentration [28]. Thus, our results on lactate concentration are in agreement with the view that anaerobic performance (i.e., W_t–J/Kg, W_{Avr}–J/Kg) depends on counter-regulatory variables. Indeed, we demonstrated that changes in resting blood pH and HCO_3^- significantly improved anaerobic performance. Another variable that can affect anaerobic performance includes blood viscosity. Weidmann et al. (2016) showed that the intake of highly alkaline water decreased blood viscosity by 6.30%, compared to table water (3.36%) in 100 recreationally active female and male subjects. Therefore, it may be possible that the excess of metabolic end-products (namely, H^+ and Pi), which disturb cellular homeostasis and muscle contraction, are more effectively transported. The available literature data does not specify clearly which components of buffering capacity are altered by the above changes. It must be indicated, that there are several methods available to determine muscle buffering capacity. Due to the methodological complexity, none of these methods are free from criticism. In most studies buffering capacity has been determined in vitro by titration, which does not include trans-membrane transport of acid-base substances or dynamic buffering by biochemical processes occurring in vivo [31].

Most studies show a documented ergogenic effect of bicarbonate loading during exhaustive exercise lasting 1–7 min, when anaerobic glycolysis plays a major role in energy provision [32]. The rationale for the ergogenic effect of bicarbonate is that the increase in extracellular pH and bicarbonate will enhance the efflux of lactate and H^+ from muscle. There is also evidence that the ergogenic effect of bicarbonate is more pronounced during repeated sprints than during sustained exercise [30].

Different strategies used for improving buffering capacity of tissues and blood do not allow for a direct comparison. Despite this, there appears to exist an ergogenic effect in response to $NaHCO_3^-$, what may explain the large effect size noted by Tobias et al. [33]. In our research we obtained large effect sizes with regards to 4 variables (Average power of the lower limbs, resting HCO_3^-, resting blood pH and urine SG).

Conclusions

The results of the present study indicate that drinking alkalized water improves hydration status, acid-base balance, and high intensity anaerobic exercise performance. It appears that both greater muscle buffering capacity and enhanced removal of protons, resulting in increased glycolytic ATP production, may be responsible for these effects. Considering the energy demands and the intense sweat rate of combat sport athletes, the authors recommend the daily intake of 3–4 L of highly alkaline mineralized water to improve hydration and anaerobic performance during training and competition.

Supporting information

S1 Table. Data for Fig 1.
(XLSX)

S2 Table. Stress test data.
(XLSX)

S3 Table. Water data.
(XLSX)

Acknowledgments

This work was supported by the Ministry of Science and Higher Education of Poland under Grant NRSA3 03953 and NRSA4 040 54.

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Praca nr 5. - *Anaerobic power and hydration status in combat sport athletes during body mass reduction*

W związku z poważnymi konsekwencjami jakie niesie za sobą potrzeba redukcji masy ciała w sportach walki, począwszy od spadku wydolności i mocy, poprzez zaburzenia równowagi wodno-elektrolitowej, po poważne konsekwencje zdrowotne włącznie, wydaje się być zasadne prowadzenie dalszych badań nad rzeczywistą skalą tego zjawiska. Choć problem redukcji masy ciała jest powszechnie znany i coraz częściej opisywany w literaturze, zarówno zawodnicy jak i trenerzy nie korygują swoich metod osiągania pożądanej kategorii wagowej.

W prezentowanym artykule podjęto próbę oceny zmian wydolności beztlenowej, masy ciała, składu ciała oraz stanu nawodnienia u elitarnych sportowców, w ciągu czterech tygodni redukcji masy ciała w okresie przed zawodami. Do badania włączono sześciu, dobrze wyszkolonych zawodników sportów walki. Wszyscy uczestnicy badania mieli co najmniej 8 letni staż treningowy, oraz kilkuletnie doświadczenie w rywalizacji na poziomie międzynarodowym. Stanowili oni jednorodną grupę pod względem wieku (średni wiek 27,3 ± 0,5 lat), cech somatycznych oraz wydolności beztlenowej (średnia masa ciała (BM) 79,4 ± 1,1; zawartość tłuszczu (FAT%) 10,8 ± 1,7%).

Eksperyment trwał 29 dni, w tym czasie badani cztery razy zostali poddani testom laboratoryjnym. Masę ciała, stan nawodnienia i wydolność beztlenową oceniano w czterech punktach czasowych (t1 - cztery tygodnie przed walką, t2 - dwa tygodnie przed walką, t3 - jeden dzień przed walką, t4 - dzień walki). Badanie zostało przeprowadzone w okresie przygotowawczym rocznego cyklu szkoleniowego. Eksperyment imitował okres przygotowania do zawodów i obejmował duże obciążenia treningowe. Uczestnicy powstrzymywali się od ćwiczeń przez 2 dni przed badaniem, aby zminimalizować efekt zmęczenia. Wydolność beztlenowa została oceniona za pomocą 30-sekundowego testu Wingate dla kończyn górnych. Test został poprzedzony 5-minutową rozgrzewką z oporem 40 W i kadencją w zakresie 50-60 obrotów na minutę. Po rozgrzewce rozpoczęła się próba testowa, w której celem było osiągnięcie najwyższej kadencji w najkrótszym możliwym czasie i utrzymanie jej przez cały test. Oceniono zmienne: moc szczytową - Pp (W), moc średnią - Pm (W) i pracę całkowitą - Wt (J).

Analiza wariancji wykazała najbardziej istotne statystycznie różnice w wartości Pp między 1 dniem przed walką a dniem walki (z p = 0,021), po nawodnieniu. Jak również między 1 dniem przed walką a dniem walki w wartościach Pm i Wt (p = 0,039 i p = 0,036).

Podczas gdy wartości LA (p = 0,04) wykazały najbardziej istotne statystycznie różnice między 1 dniem, a czterema tygodniami przed walką. Istotne statystycznie wyniki uzyskano również w wartościach pomiarów masy ciała i stanu nawodnienia (U_{SG}, U_{OSM}) dzień przed walką i w dniu walki.

Przeprowadzone badanie wydaje się potwierdzać, że stan hypohydratacji spowodowany koniecznością przedstartowej drastycznej redukcji masy ciała w celu osiągnięcia pożądanej kategorii wagowej, w znacznym stopniu obniża poziom mocy anaerobowej w czasie walki. Wysoce prawdopodobne, że pełne nawodnienie zawodnika w okresie startu, niosło by korzyści w postaci wzrostu wydolności beztlenowej i sprawności nerwowo-mięśniowej.

Baltic Journal of Health and Physical Activity 2019; 11 (4): 1-8
Journal of Gdansk University of Physical Education and Sport
e-ISSN 2080-9999

ORIGINAL

doi: 10.29359/BJHPA.11.4.01

Anaerobic power and hydration status in combat sport athletes during body mass reduction

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
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abstract

Background: Hydration is one of the most significant issues for combat sports as athletes often use water restriction for quick weight loss before competition. There is significant evidence to indicate that the hypohydration status impairs anaerobic performance. The aim of this study was to investigate if hypohydration, to reach a weight category, affects anaerobic performance.

Material and methods: Six well trained combat sport athletes, classified in the middleweight division, took part in the experiment. The hydration status and anaerobic performance parameters were evaluated at four points in time (t_1 – four weeks before fight, t_2 – two weeks before fight, t_3 – one day before fight, t_4 – the fight day). The hydration status was determined using urine osmolality (U_{OSM}) and urine specific gravity (U_{SG}) techniques. Anaerobic performance was evaluated by 30s Wingate tests for upper limbs.

Results: The current investigation demonstrated a significant impairment of anaerobic performance parameters, such as peak power – P_p (W), mean power – P_m (W) and total work performed – W_t (J), as a consequence of dehydration in the weight cutting process.

Conclusions: The overall results indicate that hypohydration in combat sports athletes is not fully compensated in the 24 h from weigh-in to competition.

Key words: hydration, rehydration protocol, anaerobic performance.

article details

Article statistics: **Word count:** 2,920; **Tables:** 0; **Figures:** 2; **References:** 19
Received: September 2019; **Accepted:** October 2019; **Published:** December 2019

Full-text PDF: http://www.balticsportscience.com

Indexation: Celdes, Clarivate Analytics Emerging Sources Citation Index (ESCI), CNKI Scholar (China National Knowledge Infrastructure), CNPIEC, De Gruyter - IBR (International Bibliography of Reviews of Scholarly Literature in the Humanities and Social Sciences), De Gruyter - IBZ (International Bibliography of Periodical Literature in the Humanities and Social Sciences), DOAJ, EBSCO - Central & Eastern European Academic Source, EBSCO - SPORTDiscus, EBSCO Discovery Service, Google Scholar, Index Copernicus, J-Gate, Naviga (Softweco, Primo Central (ExLibris), ProQuest - Family Health, ProQuest - Health & Medical Complete, ProQuest - Illustrata: Health Sciences, ProQuest - Nursing & Allied Health Source, Summon (Serials Solutions/ProQuest, TDOne (TDNet), Ulrich's Periodicals Directory/ulrichsweb, WorldCat (OCLC)

Funding: This research was supported by the Ministry of Science and Higher Education of Poland under Grant NRSA3 03953 and NRSA4 040 54.

Conflict of interests: Authors have declared that no competing interest exists.

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INTRODUCTION

Combat sports are among the sport disciplines which have weight categories to make competition fair for athletes of different anthropometric characteristics. This phenomenon relates to the drastic reduction of body mass before competition in order to meet particular weight standards [1]. As research shows, most athletes do not incorporate long term dietary and training procedures to reach the optimal body mass for competition. On the contrary, the majority of combat sports athletes reduce their weight drastically before the competition to reach appropriate weight categories. This may mean a reduction of up to 5% body mass within 2-3 weeks or even a shorter time period. The analysis of dietary procedures of elite female judo athletes in the precompetitive period has revealed that 80% of them use very low calorie diets, which do not cover the basic energy needs, and in some cases reached values as low as 470 kcal/d [2]. The results of studies considering the effects of body mass reduction on physical and mental performance are quite controversial. There is research indicating that drastic weight reduction negatively influences repeated-effort performance, while other studies show no impact on aerobic and anaerobic single or repeated physical tasks [3]. It seems that large magnitudes of weight loss (> 3% BM) over a short period of time (24-48h) are detrimental to strength speed performance, while weight loss over multiple days (5-12) using food restriction and fluid manipulation have not shown negative effects on performance [4]. Studies that show a negative impact of weight reduction usually relate to high intensity repeat effort performance up to 24h following the weight loss [5, 6]. Combat sports with longer competition duration are likely to be at a greater risk of impaired performance resulting from rapid weight reduction. There are many methods of body mass reduction which have different consequences on sport performance. Acute reduction in energy intake influences performance through reduced glycogen concertation [4, 6]. Lower levels of muscle glycogen induce fatigue and lower the strength-endurance by reducing glycolytic potation. When using acute dehydration as a weight loss strategy, different physiological changes will influence exercise performance. Dehydration by sweat loss is associated with a reduction in blood plasma, and total blood volume which impairs the cardiovascular function, muscle blood flow and thermoregulation [5, 7]. The recovery period between weight control and competition is usually 24h or less, which seems insufficient to recover the hydration status [6, 7]. Some authors indicate that acute dehydration significantly alters electrolyte concentration which may influence cells fluid balance, and as a result impair the neuromuscular function [6, 8]. There is little research investigating the acute effects of dehydration and rehydration on the neuromuscular function and anaerobic performance in combat sports.

Considering the significant consequences of rapid weight reduction on physical performance in combat sports, we have attempted to evaluate changes in anaerobic power, body mass and body composition as well as the hydration status in elite athletes over four weeks' body mass reduction before competition

MATERIAL AND METHODS

PARTICIPANTS

Six, apparently well-trained combat sport athletes were enrolled in the study. All study participants had at least eight years of training experience and competed at the international level. Subjects were classified in the middleweight division (154-160 lbs, 69.85-72.56 kg). The athletes constituted a homogenous group with regard to age (average age of 27.3 ±0.5 years), somatic and anthropometric characteristics as well as anaerobic performance (mean body mass (BM) 79.4 ±1.1 kg; fat content (FAT%) 10.8 ±1.7%). All subjects had valid medical examinations and showed no contraindications to participate in the study. The athletes were informed verbally and in writing of the experimental protocol, the possibility to withdraw at any stage of the experiment, and they gave their written consent for participation. The experimental protocol was approved by the Ethics Committee of the Jerzy Kukuczka Academy of Physical Education in Katowice, Poland, and conformed to the principles presented in the Declaration of Helsinki.

EXPERIMENTAL DESIGN

The experiment lasted 29 days. The study consisted of four visits to the laboratory. The body mass, hydration status and anaerobic performance were evaluated at four points in time (t_1 – four weeks before fight, t_2 – two weeks before fight, t_3 – one day before fight, t_4 – the fight day) (Fig. 1). The study was conducted during the preparatory period of the annual training cycle, when a high volume of work dominated the daily training loads. The experiment reliably imitated the preparations for competition. In fact, the preparations are not crowned with a real fight. The exercise protocol would not be applicable on the day of competition. The participants refrained from exercise for 2 days before testing to minimise the effect of fatigue.

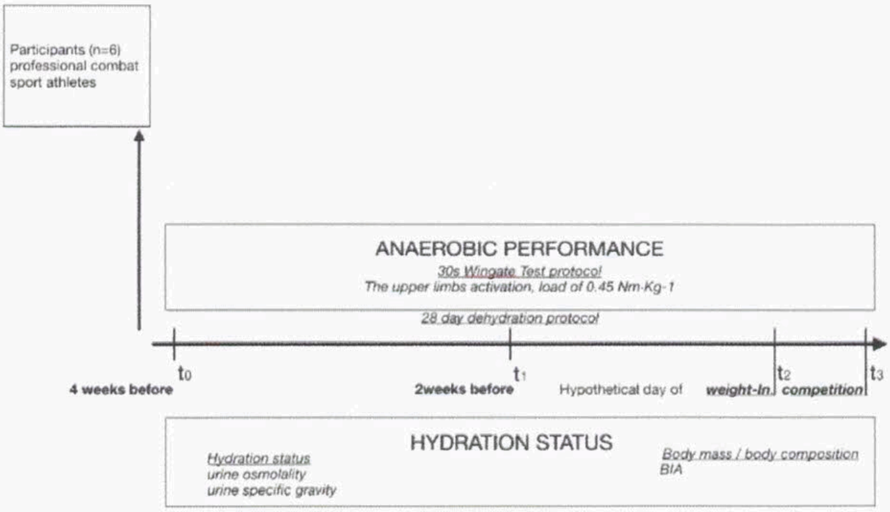

Fig. 1. Experimental design flowchart

BIOCHEMICAL ASSAYS

Urine samples were taken at each of the four time points (t_1, t_2, t_3, t_4). They were placed in a plastic container and mixed with 5 ml/L of 5% solution of isopropyl alcohol and thymol for preservation. Urine samples were assayed for the presence of blood and proteins. Specific gravity was determined using the Atago Digital refractometer (Atago Digital, USA). Urine osmolality (U_{OSM}) was analysed in duplicate by freezing point depression osmometry (Model 3250, Advanced Instruments, USA).

BODY MASS COMPOSITION

The measurements of body mass were performed on medical scales with a precision of 0.1 kg. Body composition was evaluated using the electrical impedance technique (Inbody 720, Bioscpace Co., Japan).

STRESS TEST

Anaerobic performance was evaluated by the 30-second Wingate test protocol for upper limbs. The test was preceded by a 5 min warm-up with resistance of 40 W and cadence within 50–60 rpm. Following the warm-up, the test trial started, in which the objective was to reach the highest cadence in the shortest possible time and to maintain it throughout the test. The lower limb Wingate protocol was performed on an Excalibur Sport ergocycle with a resistance of 0.8 $Nm{\cdot}Kg^{-1}$ (Lode BV, Groningen, Netherlands). The upper body Wingate test was carried out on a rotator with a flying start with a load of 0.45 $Nm{\cdot}Kg^{-1}$ (Brachumera Sport, Lode, Netherlands). Each subject completed test trials. The variables of peak power – P_p (W), mean power – P_m (W) and total work performed – W_t (J), were registered and calculated by the Lode Ergometry Manager (LEM, software package, Netherlands).

STATISTICAL ANALYSIS

The data were processed using the Statistica software and presented as means with standard deviations. The Shapiro-Wilk, Levene and Mauchly's tests were used in order to verify the normality, homogeneity and sphericity of the sample's data variances, respectively. The repeated measure ANOVA was performed to determine differences between four weeks before, two weeks before, one day before and the fight day for PP, MP, TW, LA, U_{OSM} and U_{SG}. The one way ANOVA was used to determine differences between values of body mass changes, after the hydration. Statistical significance was set at $p < 0.05$.

All statistical analyses were performed using Statistica 9.1 and Microsoft Office and were presented as means with standard deviations.

RESULTS

Changes in P_p, P_m, W_t, LA, U_{OSM} and U_{SG} values, after hydration four weeks before the fight day, two weeks before the fight day, one day before the fight day and on the fight day were presented in Tables 1 and 2. Similarly, the changes in body mass values after the hydration were presented in Figure 2.

The ANOVA analysis of variance with repeated measures showed the most significant statistical differences in value of Pp between 1 day before the fight and on the fight day (with $p = 0.021$), after the hydration, as well as between 1 day before the fight and on the fight day in the values of P_m and W_t ($p = 0.039$ and $p = 0.036$). On the other hand, ANOVA showed the most significant statistical differences between 1 day before the fight and four weeks before the fight in the value of LA with $p = 0.040$ (Table 3).

The same ANOVA analysis of variance with repeated measures revealed the most significant statistical differences in values of U_{OSM} and U_{SG} between 1 day before the fight and on the fight day (with $p = 0.031$ and $p = 0.009$) after the hydration (Table 4).

Table 1. Changes in PP, MP, TW and LA values in the hydration status four weeks before the fight day, two weeks before the fight day, one day before the fight day and on the fight day

Variables	4 weeks before		2 weeks before		1 day before		Fight day	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
P_{p1}(W)	976.00	147.70	982.38	140.20	672.43	107.70	923.24	126.90
P_{m1}(W)	464.70	56.90	467.70	39.55	397.00	42.00	460.70	36.55
W_{t1} (J)	13412.60	1695.50	13971.60	1163.90	10393.60	1314.10	13271.60	1147.90
Δ LA mmol/l)	10.42	1.69	10.55	1.45	9.70	2.11	10.56	1.45

Table 2. Changes in U_{OSM} and U_{SG} values after hydration four weeks before the fight day, two weeks before the fight day, one day before the fight day and on the fight day

Variables	4 weeks before	2 weeks before	1 day before	Fight day
U_{OSM} (mOsmkg H_2O^{-1})	340.000	380.000	1121.300	780.800
U_{SG}	1.012	1.010	1.045	1.011

Table 3. Results of differences between four weeks before, two weeks before, one day before and on the fight day for PP, MP, TW and LA with ANOVA repeated measures

Variables	Measures	4 weeks before	2 weeks before	1 day before	Fight day
P_{p1} (W)	4 weeks before		0.231	0.034	0.167
	2 weeks before	0.231		0.032	0.189
	1 day before	0.034	0.032		0.021
	fight day	0.167	0.189	0.021	
P_{m1} (W)	4 weeks before		0.451	0.041	0.387
	2 weeks before	0.451		0.039	0.401
	1 day before	0.041	0.039		0.043
	fight day	0.387	0.401	0.043	
W_{t1} (J)	4 weeks before		0.397	0.040	0.333
	2 weeks before	0.397		0.038	0.405
	1 day before	0.040	0.038		0.039
	fight day	0.333	0.405	0.039	
Δ LA (mmol/l)	4 weeks before		0.114	0.040	0.314
	2 weeks before	0.114		0.043	0.714
	1 day before	0.040	0.043		0.043
	fight day	0.314	0.714	0.043	

Table 4. Results of differences between four weeks before, two weeks before, one day before and on the fight day for U_{OSM} and U_{SG} with ANOVA repeated measures

Variables	Measures	4 weeks before	2 weeks before	1 day before	Fight day
U_{OSM}	4 weeks before		0.124	0.021	0.041
	2 weeks before	0.124		0.012	0.034
	1 day before	0.021	0.012		0.031
	Fight day	0.041	0.034	0.031	
U_{SG}	4 weeks before		0.114	0.009	0.111
	2 weeks before	0.114		0.010	0.115
	1 day before	0.009	0.010		0.009
	Fight day	0.111	0.115	0.009	

One way ANOVA revealed significant statistical differences in the changes of body mass values after the hydration for one day before the fight with p = 0.021 and with reference to values for four weeks before, two weeks before and for the fight day (Fig. 2).

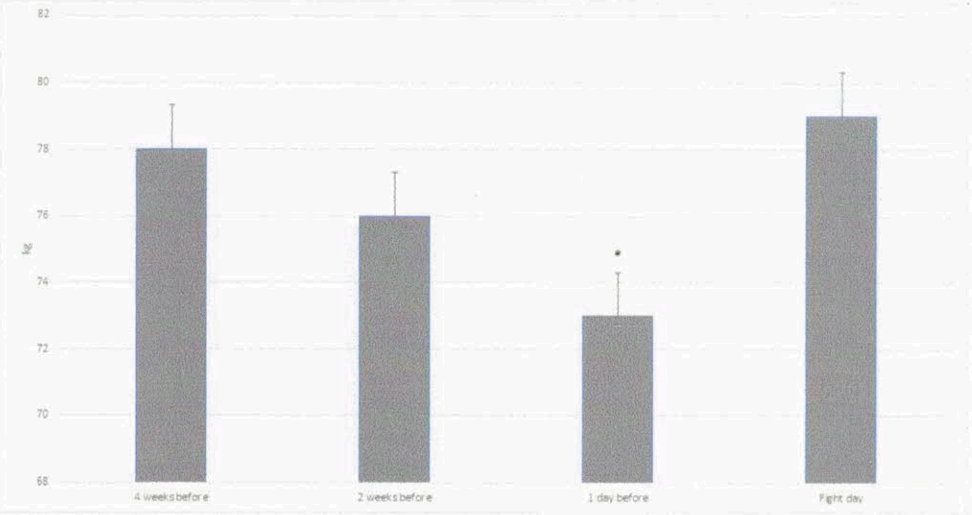

Fig. 2. Changes of body mass in the hypohydration protocol

DISCUSSION

There are such sport disciplines as combat sports for which fluid intake before, during and after competition is a key factor determining performance, as well as being part of the strategy for reaching the weight category limit [9]. Effective hydration determines proper functioning of the human body at rest and especially during and after exercise. Water allows for homeostasis; it facilitates most biochemical reactions; it allows numerous particles and compounds to dilute. It helps in the transport of metabolites and utilization of by-products [10, 11]. Exercise induces ionic changes within contracting muscles that contribute to the development of metabolic acidosis. The increased intramuscular acidity can then limit the capacity to perform exercise of high intensity [12].

In the present study, we investigated the effect of the hypohydration status on anaerobic performance of competitive combat sport athletes. The study participants were experienced athletes, capable of performing extreme anaerobic efforts and with the body mass reduction practice using energy and fluid restriction. We have chosen such an approach for two reasons. Firstly, it is well documented that hypohydration impairs aerobic and anaerobic performance. However, the majority of these research reports have been carried out in specific hydration statues, not presenting performance changes in increasing dehydration and after rapidly 24-hours hydration. Secondly, impairment of metabolism has been mostly discussed in the context of sedentary and recreationally active individuals [12]. Therefore, our study is novel by including both well-trained combat sport athletes and the use of protocol correlating an increasing hypohydration status with selected anaerobic performance parameters.

It is unclear how much hypohydration impairs anaerobic performance, and inconsistent results may be due to the use of different protocols to achieve hypohydration and measurements of strength and power abilities. Some authors have observed significant reductions in isometric and isokinetic force after 2% hypohydration [13], while others did not register significant changes in muscular activity even after 4% hypohydration [13, 14]. The current investigation demonstrated a significant decrease in anaerobic capacity (W_t - J) during a 29-day hypohydration protocol (from 13412.6 (J) - 4 weeks before to 10393.6 J - one day before the fight, $p = 0.0008$). This has been explained by an increase in core temperature which affects the sequence of muscle strength production by reducing motor cortex activation, peripheral stimulus and power output [10, 12].

The impairments in W_t were influenced by changes in U_{OSM} and U_{SG}. The results of the current study demonstrated a statistically significant increase U_{OSM} (from 340 (mOsmkg H_2O^{-1}) to 1131.3 (mOsmkg H_2O^{-1}), $p = 0.031$) and U_{SG} (1.012 to 1.045, $p = 0.009$) in the weight cutting process. For practical purposes, different methods of evaluating the hydration status are used. They include total body water content (bio-electrical impedance), blood variables (osmolality, volume, isotope tracers and sodium concentration), as well as urine variables (osmolality, volume, specific urine gravity). In our study, we used monitoring of U_{OSM} and U_{SG}. This choice is consistent with the suggestion of Popowski et al. [15], who compared the validity of U_{OSM} and U_{SG} to plasma osmolality and concluded that both are greatly correlated and are good measurements of hydration status.

The results of our study are in line with the available literature regarding the impact of hypohydration on P_p (W) and P_m (W). This phenomenon could be explained by the influence of the suppressed neuromuscular function, although membrane excitability is not reduced by dehydration [16]. It is well accepted that water is bound to the glycogen molecule in the cellular environment. Each gram of glycogen is stored in human muscle with at least three grams of water [17]. Olsson et al. assessed body water by tritium trace in dilution before and after glycogen loading, suggesting that each gram of glycogen was stored with 3-4g of water. Some authors sustain that different ratios of muscle glycogen to water following post-exercise glycogen repletion under different fluid intakes. A ratio of 1:3 was found when only 400 ml of water was consumed, while a ratio of 1:17 was determined when participants replaced the fluid lost during exercise [15, 18]. Despite numerous scientific data , there is still no conclusive answer regarding how much time is needed to recover fluid and energy substrates after a weight cutting protocol. Tarnopolsky et al. observed that the weight loss using energy and fluid restriction before weigh-in results in a marked decrease in muscle glycogen concentration which could affect high intensity anaerobic actions common in combat sports. However, those reductions in muscle glycogen concentrations are largely reversed during the 17-hour period allowed between weigh-in and the start of the competition [19]. The results of our study indicate that, despite 24h hydration, selected Wingate test parameters (P_p and P_m) were impaired if compared to the baseline value.

CONCLUSIONS

It seems that strength and power is significantly affected by a state of hypohydration in combat sports, where athletes usually dehydrate before competition to reduce body mass for a certain weight category. It is possible that full rehydration would have resulted in larger gains in neuromuscular performance.

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Cite this article as:

Kurylas A, Chycki J, Zajac T.
Anaerobic power and hydration status in combat sport athletes during body mass reduction
Balt J Health Phys Act. 2019;11(4):1-8
doi: 10.29359/BJHPA.11.4.01

Podsumowanie

Istota prawidłowego nawodnienia jest zagadnieniem poruszanym od dłuższego czasu. Szczególnie ważne jest to w kontekście sportu wyczynowego i wpływu na wynik sportowy. Jak pokazują liczne prace naukowe odpowiednia podaż płynów przed, w trakcie, po wysiłku oraz w okresie między treningowym prawie nigdy nie jest pokrywana w sposób odpowiedni i wystarczający. Mimo powszechnej wiedzy w tym temacie i znajomości korzyści oraz powikłań mogących wynikać z optymalnej hydratacji jest to temat bagatelizowany i często pomijany przez zawodników i trenerów. Odpowiednio nawodniony organizm jest w stanie wykonać cięższą, dłuższą i bardziej efektywną pracę, co będzie niosło za sobą lepsze skutki treningowe, a co za tym idzie poprawę wyników w czasie rywalizacji sportowej. Natomiast odwodnienie znacząco pogarsza zdolność do wysiłku, obniża wydolność układu sercowo-naczyniowego w skutek hipowoliemii, ogranicza mechanizmy termoregulacyjne oraz zaburza prawidłowy przebieg procesów metabolicznych. Odwodnienie jest jedną z przyczyn pojawienia się zmęczenia. Zyskującym popularność alternatywnym rozwiązaniem dla dotychczas wykorzystywanych napojów stosowanych u sportowców staje się woda o regulowanej zawartości makroskładników i zwiększonym pH (woda alkaliczna). Jak dotąd była ona wykorzystywana głównie w profilaktyce chorób, którym towarzyszy kwasica metaboliczna. Obecnie coraz częściej porusza się temat wody alkalicznej w kontekście poprawy zdolności wysiłkowych i regeneracyjnych u sportowców. Najnowsze i niezależne prace badawcze wskazują, że woda alkalizowana ma pozytywny wpływ na organizm człowieka. W przeprowadzonych eksperymentach uzyskano progresję wyników w testach wydolności beztlenowej, poprawę właściwości buforujących krwi, spadek ciężaru właściwego moczu, wzrost pH krwi i moczu oraz skuteczniejsze wykorzystanie mleczanu. Fakt ten w przyszłości może zostać wykorzystany do wspomagania restytucji powysiłkowej i zmniejszenia kwasicy metabolicznej u zawodników uprawiających dyscypliny sportu z przewagą metabolizmu beztlenowego.

Streszczenie

Istota prawidłowego nawodnienia jest zagadnieniem poruszanym od dłuższego czasu. Szczególnie ważne jest to w kontekście sportu wyczynowego i wpływu na wynik sportowy. Jak pokazują liczne prace naukowe odpowiednia podaż płynów przed, w trakcie, po wysiłku oraz w okresie między treningowym prawie nigdy nie jest pokrywana w sposób odpowiedni i wystarczający. Mimo powszechnej wiedzy w tym temacie i znajomości korzyści oraz powikłań mogących wynikać z optymalnej hydratacji jest to temat bagatelizowany i często pomijany przez zawodników i trenerów. Odpowiednio nawodniony organizm jest w stanie wykonać cięższą, dłuższą i bardziej efektywną pracę, co będzie niosło za sobą lepsze skutki treningowe, a co za tym idzie poprawę wyników w czasie rywalizacji sportowej. Zyskującym popularność alternatywnym rozwiązaniem dla dotychczas wykorzystywanych napojów stosowanych u sportowców staje się woda o regulowanej zawartości makroskładników i zwiększonym pH (woda alkaliczna). Dotychczas była ona wykorzystywana głównie w profilaktyce chorób, którym towarzyszy kwasica metaboliczna. Obecnie coraz częściej porusza się temat wody alkalicznej w kontekście poprawy zdolności wysiłkowych i regeneracyjnych u sportowców. Istnieją badania eksperymentalne traktujące o jej pozytywnym wpływie na gospodarkę kwasowo-zasadową organizmu, zarówno w spoczynku jak i po wysiłku o charakterze beztlenowym. Celem pracy była szczegółowa analiza wpływu wody alkalicznej na organizm poddany reżimowi treningowemu. Przedmiotem rozprawy doktorskiej jest osiągniecie naukowe w postaci 5 prac traktujących o wpływie wody o zwiększonej alkalizacji na stan nawodnienia i beztlenowe możliwości wysiłkowe zawodników uprawiających gry zespołowe i sporty walki. W zaprezentowanych pracach przedstawiono wyniki eksperymentów przeprowadzonych na wysokiej klasy zawodnikach czynnie trenujących koszykówkę, piłkę nożną i sporty walki (judo, MMA). Badania obejmowały pomiary antropometryczne (BIA), wywiad żywieniowy, okres hydratacji wodą o różnym stopniu alkalizacji i w różnej ilości, testy fizyczne (test Wingate, testy na cykloergometrze rowerowym, testy biegowe) i testy laboratoryjne (pH, osad i ciężar właściwy moczu, pH krwi, stężenie LA, pCO2, pO2, HCO3-act, HCO3-std, BE(ecf), BE(B), O2SAT, ctCO2, K+, Na+). Uzyskane wyniki wykazały, że woda alkalizowana ma pozytywny wpływ na organizm człowieka. W przeprowadzonych eksperymentach uzyskano progresję wyników w testach wydolności beztlenowej, poprawę właściwości buforujących krwi, spadek ciężaru właściwego moczu, wzrost pH krwi i moczu oraz skuteczniejsze wykorzystanie mleczanu. Fakt ten w przyszłości może zostać wykorzystany do wspomagania restytucji powysiłkowej

i zmniejszenia kwasicy metabolicznej u zawodników uprawiających dyscypliny sportu z przewagą metabolizmu beztlenowego.

Summary

The essence of proper hydration has been brought up since a long time. It is especially important in the context of competitive sport and peak performance. As has been shown in several studies, proper fluid supply before, during and after exercise, as well as between training sessions is hardly ever met sufficient. In spite of the common knowledge on this topic, understanding both benefits and complications that may result from optimal hydration, this topic is often underestimated by combat sport athletes and coaches. A properly hydrated body is able to perform harder, longer and more efficient physical work, what is followed by better training effects and consequently improved sports performance. Alkaline water has become an alternative solution for drinks that have so far been used by athletes. It has mainly been used to prevent diseases with metabolic acidosis. Currently, the topic of alkaline water is often tackled in the meaning of improving athletes post exercise recovery. There are experimental studies about its positive influence on acid-base balance both at rest and after anaerobic exercise. The objective of the thesis was a detailed analysis of the influence of alkaline water on hydration and physical work capacity. The topic of the doctoral dissertation includes 5 papers related to the influence of alkaline water on hydration and anaerobic exercise capacity of team sport and combat sport athletes. The presented studies include results of experiments conducted on competitive basketball, soccer players as well as combat sport athletes (judo, MMA). The study consisted of anthropometric measurements, eating habits interview, hydration with water of different alkalization, fitness tests (Wingate test, cycle ergometer test, running test) and laboratory tests (pH, urine sediment and specific gravity, blood pH, LA concentration, pCO2, pO2, HCO3-act, HCO3-std, BE(ecf), BE(B), O2SAT, ctCO2, K+, Na+). The results indicated a positive influence of alkaline water on the human body. The experiments showed improved results in anaerobic capacity tests, improvement of blood buffering capacity, decreased urine specific gravity, blood and increased urine pH and more efficient use of lactate. In the future, this knowledge can be used to support post workout recovery and decrease metabolic acidosis in athletes subjected to intense exercise with a predominance of anaerobic metabolism.

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