Alternatives to Rapid Weight Loss in US Wrestling

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Key words
- rapid weight loss
- anaerobic metabolism
- high-intensity exercise

Abstract

Amateur wrestling at the high school and collegiate level in the United States often involves exercise and thermal dehydration as well as food and fluid restriction to "make weight". Available evidence suggests this is the opposite of what is optimal for high-intensity exercise performance. A high-intensity taper will substantially improve performance when conducted after a period of high-volume high intensity training. Additionally, dehydration of ~3–4% of body weight will most definitely impair muscular endurance during high-intensity exercise although it likely will not impair maximal muscular strength or power. Even more gradual weight loss practices over a few days, which result in a reduction of body weight by ~3.3 to 6% will result in impaired performance as assessed by wrestling specific tests. It would seem of paramount importance for wrestlers to maintain a high-carbohydrate diet of ~8–10 g carbohydrate/kg body weight/day to maintain training intensity and optimize performance during individual matches and tournaments. Thus, the evidence would suggest that, prior to competition, collegiate wrestlers should be: 1) tapered, 2) in the euhydrated state, and 3) have ingested a high carbohydrate diet, rather than undergo rapid weight loss prior to competition.

Introduction

It is common knowledge that rapid weight reduction (weight cutting) is a wide spread practice among US wrestlers in high-school [2] and college [25, 28, 30]. This weight reduction involves primarily active (exercise and heat exposure) and passive dehydration (heat exposure) and fluid and food restriction. This is despite the fact that there is limited time to replace fluid and carbohydrate stores prior to competition (1 h between weigh-ins and the match during dual meets and 2 h between weigh-ins and tournaments). In this review, we will make the case that tapering, or reduced training volume, improves physiologic performance in athletes, that dehydration impairs the ability to maintain high-intensity power output, and that carbohydrate availability is extremely important for maximal high-intensity exercise capacity during practices, where improvements in wrestling performance are made, and during matches and when multiple matches are to be wrestled on the same day. We have chosen to address US Wrestling and omit discussion of international wrestling as prior to major events in international wrestling there are ~24 h between weigh-ins and competition. This duration between weigh-ins and competitions is much greater than in US wrestling and therefore lends itself to significant dehydration and carbohydrate restriction, which in almost all circumstances, can be reversed prior to competition. Data supporting this contention comes from Tarnopolsky et al. [34] who reported 17 h of ad libitum food and fluid intake was sufficient to restore muscle glycogen concentrations to levels (83% of the pre-weight cutting concentration) to those attained prior to food and fluid restriction, and exercise which was utilized to "make weight".

Effects of Tapering on Performance

Optimal recovery prior to a major competition involves tapering or a reduced volume of training. The highly beneficial effects of tapering on human physical performance become apparent when one examines the available data on this topic. Shepley et al. [31] found that a *high-intensity, low volume*, 7-day taper improved time to

accepted after revision
April 28, 2010

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DOI http://dx.doi.org/10.1055/s-0030-1254177
Published online: June 11, 2010
Int J Sports Med 2010; 31: 523–528 © Georg Thieme Verlag KG Stuttgart · New York
ISSN 0172-4622

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fatigue at 1 500 m race pace significantly by 22 %, whereas a *low intensity moderate volume* taper or a rest only taper was ineffective at improving time to fatigue. Subjects in this investigation were highly trained (VO_{2max} 67.2 ± 1.7 mL/kg/min) middle distance and cross-country runners. The physiologic positive changes that accompany the improvement in performance were a significant increase in citrate synthase activity as well as significant increases in total blood volume and red cell volume. Houmard et al. [17] examined the effects of a taper comprised of replacing high volume training with low volume high-intensity interval training, which was comprised of cycle exercise or running exercise on 5 km run time and running economy. These investigators found a statistically significant 3 % decrease in 5 km run time and a 7 % improvement in running economy as measured by a decrease in energy expenditure during standardized submaximal exercise. In the only study to our knowledge to examine the effects of a taper on strength training performance, Gibala et al. [10] found that reduced volume, high-intensity training was effective in improving strength training performance over an 8 day period when compared to rest only tapering. Thus, the results from this strength training study parallel the results obtained during studies utilizing aerobic swimming, running, and cycling regarding the beneficial effects of *low volume high-intensity* taper. Trappe et al. [35] examined the effects of a swimming taper (21 days of tapering after 5 months of *high-intensity high-volume training*) on the function of muscle fibers and the whole muscle. These investigators found that indicators of swimming power as indicated by whole muscle function increased ~15 % as a result of the taper and swim performance was improved by 4 %. The fast twitch oxidative glycolytic fibers (type IIa fibers) increased in size by 11 % and the type I fibers shortened 32 % faster while the type IIa fibers shortened 67 % faster. The power of the type IIa fibers increased by 2.5 fold. These are the first direct data supporting a role for changes intrinsic to the active musculature being responsive to tapering. Swimming is a very complex activity requiring a large amount of technique for optimal performance. The very large increase in the power of type IIa fibers could be of great advantage for sports which are more directly dependent on power such as US wrestling where successfully executed explosive movements such as single leg and double leg takedowns as well and a high degree of anaerobic power (as measured by peak and average power over a 30 s maximal exercise period) are highly rewarded.

Effects of Dehydration on High-Intensity Exercise Performance

Watson et al. [36] reported that diuretic induced dehydration (a reduction of body mass by 2.2 %) did not result in a statistically significant reduction in vertical jump height or 50, 200, or 400 m running velocity in former sprint athletes. Hoffman et al. [15] reported that dehydration by ~2 % had no statistically significant effect on squat-jump performance, countermovement jump performance, or anaerobic power. Bigard et al. [4] reported that sauna induced dehydration by 2.95 % resulted in no effect on maximal isometric strength but time to fatigue at 25 % of maximal voluntary contraction was reduced by 23 % (195 to 150 s) whereas time to fatigue at 70 % of maximal voluntary contraction was not significantly affected (~45 s). Guitierrez et al. [12] reported that rapid weight loss of 1.8 % in men and 1.4 % in women resulted in no effect on the standing jump in men but a significant reduction in this measure for women. Additionally, neither rowing strength nor handgrip strength were affected in either gender by this level of dehydration.

Armstrong et al. [3] reported that 1 500 m run performance was unaffected but that 5 000 m and 10 000 m run performance were substantially impaired by a reduction of body mass equivalent to a ~2 % body mass loss. Cheuvront et al. [7] reported that moderate dehydration (2.7 % loss of body mass) through passive heating had no significant effect on the ability to perform the Wingate Anaerobic Power test in 8 recreationally active men. Maxwell et al. [22] reported a 3.9 % reduction in the ability to perform intermittent anaerobic running after a body weight reduction of ~2.0 % induced by exercise and heat induced dehydration. The duration of the test used in that investigation typically was ~150 s. Webster et al. [37] examined the effects of a weight loss of 4.9 % over 36 h on exercise performance parameters in collegiate wrestlers. These investigators found that all of the wrestlers chose to lose the weight in the last 12 h prior to weigh-ins using exercise in rubberized suits. Little effect of this rapid weight loss was seen on muscle strength but there was a 21.5 % reduction in anaerobic power and a 9.7 % reduction in anaerobic capacity during a 40 s Wingate test (both $p < 0.05$). Additionally, there was a significant 6.6 % reduction in VO_2 peak with weight loss. From this study, however, it is unclear whether the reduction in performance was due to the magnitude of the weight loss and/or to the rapid nature of the weight loss.

In a very well controlled study Montain et al. [23] isolated the effects of hypohydration from the additional effects of the exercise used to induce the hypohydration. These investigators found that exercise induced dehydration (4 % weight loss) resulted in a 15 % reduction in quadriceps endurance relative to exercise with fluid replacement. These investigators found no effect of the hypohydration on muscle strength or on hydrogen ion concentrations or inorganic phosphate and suggested a central mechanism for the reduced muscle endurance. The time taken to fatigue during this performance test was ~3.9 min for the mean of both conditions. Saltin [29] reported that time to fatigue at 100 % of VO_{2max} was reduced by ~16 % following thermal dehydration by 2.78 % while a similar level of dehydration via exercise resulted in a ~9.4 % reduction in exercise time and exercise with thermal dehydration to a similar level resulted in a ~5.9 % reduction in work time. Clearly, from this investigation hypohydration will reduce maximal exercise capacity as measured by time to fatigue at 100 % of VO_{2max}. Time taken to fatigue at this intensity approximated 6 min. Caldwell et al. [5] reported that a 4.1 % reduction in body weight through physical activity resulted in a 6.9 % reduction in the power output corresponding to VO_{2max} whereas sauna induced hypohydration resulted in a ~23 % reduction in power output corresponding to VO_{2max}, and a similar level of dehydration induced by a diuretic resulted in a ~21 % reduction in the power output corresponding to VO_{2max}. The difference in the effects of dehydration on exercise power output due to different modes of dehydration are likely due to the rate at which the water was lost. The diuretic and sauna induced water loss occurred over 24 h while the exercise induced water loss occurred over 48 h. In a study designed to directly study the effects of thermal dehydration on muscular endurance in individuals with differing training backgrounds, Caterisano et al. [6] reported that a 3 % reduction in body weight resulted in a 19.5 % reduction in muscular endurance in anaerobically trained individuals, a non-significant 2.9 % reduction in individuals who were aerobically trained and a 19.3 % reduction in individuals who were untrained. The duration of the task was between 30 s and 1 min and therefore was heavily reliant on the ATP-PC system and even more so on anaerobic glycolysis.

In summary, dehydration on the magnitude of 2–3 % has little effect on muscle strength and anaerobic power [4, 12, 15, 36]. One study reported that 4.9 % dehydration resulted in a reduction in anaerobic power but this may have been due to the rapidity of the weight loss. Therefore, the level of dehydration that will result in reduced absolute muscle power/strength is unknown. In contrast, taken collectively, 2–3 % dehydration has profound effects on the ability to maintain a high power-output as measured by muscular endurance in tasks that derive energy from anaerobic and aerobic sources [5, 6, 22, 23, 29]. Wrestling success, in matches that do not end in a rapid fall, are dependent on both a high absolute power output and the ability to maintain intermittent and repeated efforts of high power for the duration of the match.

Effects of More Gradual Weight Loss on High-Intensity Exercise Performance

Horswill et al. [16] reported that 4 days of weight loss (6 % of body weight) resulted in a significant reduction in 6 min wrestling specific sprint performance test when subjects were on a high or low carbohydrate diet. Energy intake during the 4 days was relatively high (2 485 kcal, day 1; 2 485 kcal, day 2; 1 956 kcal, day 3; 1 343 kcal day 4). However, there was a positive effect of a high-carbohydrate diet with those ingesting 66 % of their energy in the form of carbohydrate maintaining performance to a greater extent than those ingesting 42 % of their diet as carbohydrate.

Rankin et al. [27] reported that a reduction of body weight by 3.3 % over 3 days while utilizing energy restriction (18 kcal/kg/day; 1 260 kcal/day for the 70 kg individual), without dehydration resulted in a 7.6 % reduction in the average work produced during a wrestling specific sprint performance test similar to that used by Horswill et al. [16] in collegiate wrestlers. Based on these 2 excellent studies it appears even more gradual weight loss over a few days will impair high-intensity exercise performance. The wrestling specific test used in these 2 investigations (8, 15 s sprints separated by 30 s of active recovery) is reliant on a high absolute power output and maintenance of a high power output for the duration of the 6 min test [14, 16, 27].

Importance of a High-Carbohydrate Diet to Performance During a Single Match, Multiple Matches on a Given Day and During a Multiple Day Tournament

A time to exhaustion test at 100 % of VO_{2max} in recreationally active individuals typically takes between 3–5 min and therefore may be applicable to amateur wrestling as high-school matches last 6 min whereas collegiate matches last 7 min. Gleeson et al. [11] reported that a 24 h fast reduced time to exhaustion at 100 % VO_{2max} by 12.8 % compared to the condition in which individuals ingested a standard meal 4 h prior to exercise. Maughan and Poole [21] reported that 3 days of a very low carbohydrate diet, resulted in reduced time to exhaustion by 31.8 % compared to a normal carbohydrate diet when exercise was undertaken at 104 % of VO_{2max}. Time to exhaustion under conditions of high carbohydrate availability was enhanced by 36.6 % compared to a normal carbohydrate diet. Similar results were obtained by Pizza et al. [26] who found a statistically significant 8.4 % improvement in time to exhaustion at a treadmill speed approximating 100 % VO_{2max} in endurance-trained men as a result of a glycogen loading regimen. It has been consistently observed that there is an impaired ability to perform high-intensity exercise (time to fatigue at 100 % of VO_{2max}) with a low CHO diet but a high-CHO diet does not always enhance high-intensity exercise capacity compared to a moderate CHO diet. A potential mechanism for the improvements in performance with a moderate or high CHO intake compared with a low or moderate CHO intake, is increased muscle glycogen availability for substrate provision when muscle glycogen becomes limiting.

Houston et al. [18] examined the blood lactate response to a 6 min wrestling match and found that the venous blood lactate concentration was 10.5 mmol/L, 3 min after the match. This venous lactate concentration is very similar to the lactate observed by Spencer and Katz [33] after cycle exercise to fatigue at 95 % of VO_{2max} (duration 5.5 min) of 9.76 mmol/L in a low glycogen condition and 10.74 mmol/L in a high glycogen condition. Additionally, the arterialized-venous lactates in the study of Gleeson et al. [11] in which subjects cycled to exhaustion at 100 % of VO_{2max} reached ~11 mmol/L, ~2 min after exercise to fatigue which lasted ~4 min. From these lactate values and exercise durations, it would appear that the exercise intensity during a wrestling match approximates 95–100 % of VO_{2max}. The rate of glycogen depletion *in a prime mover muscle group* at 95 % of VO_{2max} is 20 mmol glucosyl units/kg dry wt/min and this rate does not appear to depend on the initial starting level of muscle glycogen [33]. If the glycogen concentration of the prime mover is reduced to 60 mmol glucosyl units/kg dry wt a reduction in the rate of muscle glycogen breakdown is observed and therefore a reduction in ATP provision is also observed [19]. Assuming a starting concentration of 200 mmol glucosyl units/kg dry wt when carbohydrate intake was very low and a rate of glycogen depletion of 20 mmol glucosyl units/kg dry wt/min it would take approximately 7 min (the equivalent of 1 collegiate match) for the muscle glycogen concentration to become limiting to performance in a muscle group that is under continuous contraction. For a high glycogen condition (580 mmol glucosyl units/kg dry wt) it would take ~26 min of wrestling (equivalent of 3.7 collegiate matches) for glycogen to become limiting. Clearly, for tournament wrestling, weight cutting (which typically results in a reduced carbohydrate intake) in the 2–3 days preceding the tournament results in inadequate carbohydrate intake to maintain optimal performance for even 1 day of wrestling during the tournament. Additionally, even a high carbohydrate diet in the days preceding the tournament may be only adequate on the first day of tournament wrestling and a high rate of carbohydrate intake is required during the first day of the tournament and during subsequent days of the tournament to maximize recovery and performance over the course of the tournament, as there appears to only be enough carbohydrate available for a muscle group that is continuously contracting to maintain optimal performance for a total of 3.5–4 matches. Indeed, when Tarnopolsky et al. [34] allowed wrestlers to ingest food and fluid *ad libitum* over the course of 6 h in which a simulated tournament was wrestled (4, 5 min matches), muscle glycogen declined slightly but was not statistically significantly different from the glycogen concentration prior to the wrestling match. Additionally, glycogen was at 195 mmol glucosyl units/kg dry weight muscle after the simulated tournament which is well above the 60 mmol glucosyl units/kg thought to be the level below which there would be a performance limitation. It is clear that the 1 or 2 h between weigh-ins and the individual or tournament matches is inadequate to adequately replace muscle glycogen stores anywhere near an optimal level for the first match if the wrestler has been cutting even a moderate amount of weight through caloric restriction. Additionally, during practice wrestlers perform well over 26 min of wrestling type activity and the ability to practice for 1 day or multiple days will clearly suffer if the wrestler is not on a high-carbohydrate diet.

Based on these considerations it appears that carbohydrate ingestion should be high (at least 8–10 g CHO/kg body weight/day) in the days prior to the event. This rate of carbohydrate ingestion is similar to that suggested for individuals involved in intense endurance training such as runners, cyclists and swimmers. Additionally, carbohydrate ingestion should be high (8–10 g of CHO/kg body weight/day) over the course of the day during a tournament so that muscle glycogen stores do not get critically low on that day or during subsequent days of the tournament.

Importance of a High-Carbohydrate Diet for Optimal High-Intensity Exercise Training

As previously discussed, a high carbohydrate diet would be important for maintaining performance during training and potentially for augmenting the effects of training on performance over the course of weeks and months of training. Costill et al. [8] reported that a doubling of training for 10 days in trained swimmers (from 1.5 h/day to 3 h/day) resulted in 4 of the 12 men having a significant reduction in swimming speed. Shoulder muscle glycogen concentrations were also significantly reduced in the individuals who had a decreased swimming speed. Concomitantly, those individuals who tolerated the doubling of swimming load took in 8 g of carbohydrate per kilogram of body weight/day whereas those who were non-tolerant took in only 5 g/kg/day. Using a slightly different design utilizing runners rather than swimmers Kirwan et al. [20] found similar results regarding the importance of a high carbohydrate diet (8 g of carbohydrate/kg bodyweight/day) on the ability to tolerate high training loads. In a different study, Costill et al. [9] found that for the restoration of calf muscle (gastrocnemius) glycogen concentrations to return back to normal within 24 h after a strenuous running workout, between 525 and 648 g of carbohydrate needed to be consumed (6.9–8.6 g CHO/kg body weight/day). More recently, Achten [1] examined the effects of intensified training under conditions of a high-carbohydrate diet (8.5 g CHO/kg body weight/day) relative to a control condition in which 5.4 g CHO/kg body weight/day was ingested in trained runners. Prior to and after intensified training, performance was assessed by 8 km and 16 km all out runs. In both groups, performance was negatively affected by the intensified training but the higher carbohydrate intake resulted in better maintenance of physical performance and mood state than the control condition. In a similar study from the same research group, utilizing cyclists rather than runners, Halson et al. [13] reported both a high-carbohydrate supplemented group (9.4 g CHO/kg body weight/day) and a low carbohydrate supplemented group (6.4 g CHO/kg body weight/day had symptoms of overreaching and a reduction in performance, however, the reduction in performance was significantly less under conditions of high carbohydrate supplementation than under conditions of low carbohydrate supplementation. This was the case during the intensified training and during recovery from the intensified training.

Simonsen et al. [32] compared the effects of a high carbohydrate diet (10 g CHO/kg body weight/day) compared to a low-moderate carbohydrate diet (5 g/kg/day) during 1 month of training, on a rowing performance test. These investigators found a significant 3.6 % increase in rowing power output after 1 month of training on a high-carbohydrate diet relative to a low-moderate carbohydrate diet.

The implications of the studies cited in this section suggest that during intensified training a high-carbohydrate intake of ~8–10 g CHO/kg body weight/day is ergogenic relative to a carbohydrate intake of ~5 g CHO/kg body weight/day. The daily training duration during the intensified period was 3–4 h in the investigations of Costill et al. [8] and Halson et al. [13]. However, the training duration in the investigation of Achten et al. [1] and Kirwan et al. [20] were 60–70 min and 80 min, respectively. 60–80 min would be similar to the duration of a typical US high-school or collegiate wrestling practice. It is likely that the glycogen degradation during high-intensity, intermittent training such as wrestling would be similar to that of high-intensity running in the studies of Achten et al. [1] and Kirwan et al. [20]. Thus, based on these studies, it would appear to be important for individuals involved in high-intensity, high-volume training, such as US wrestlers, to eat a diet that is composed of at least 8–10 g of CHO/kg body weight/day. Clearly, in the days preceding the match or tournament, individuals involved in typical weight-cutting practices are not ingesting this large quantity of carbohydrate and therefore recovery between training sessions will suffer as will performance in match or tournament situations.

Effects of Tapering, a High-Carbohydrate Diet and Adequate Hydration on Weight Class: To Cut or not to Cut

Tapering, a high-carbohydrate diet, and adequate hydration will increase weight. Olsson and Saltin [24] reported that a carbohydrate loading regimen and 5 days of limited activity resulted in a 3.3 % increase in body weight. Clearly, if these practices are undertaken, the wrestler will have to compete at a weight class which is one higher than the one in which he would compete with fluid and food restriction and dehydration. The decision to reduce body weight via dehydration and energy restriction or increase body weight via carbohydrate loading, tapering and being adequately hydrated, is based on the perceived benefit to capacities related to wrestling success. It appears from the literature that dehydration has little effect on maximal strength or anaerobic power [4, 7, 12, 15, 36]. Therefore, assuming no change in maximal power output or maximal strength by weight cutting from the top of one weight class down to the top of a lower weight class via dehydration and energy restriction, the increase in strength or power relative to body weight is 5.1–7.1 % depending on weight class (this is based on the differences in weight for the present collegiate weight classes). However, dehydration does have profound effects on the ability to maintain high-intensity power output/muscular endurance [5, 6, 22, 23, 29]. Time to fatigue at 100 % of VO_{2max} is negatively impacted by dehydration [29] and the duration of this task closely approximates the duration/intensity of a US high-school or collegiate match. With this in mind, absolute power output or maximal strength is not the only consideration for US wrestling success. The other major consideration is the ability to maintain intermittent and repeated efforts of high power.

Based on the time to fatigue at 95–100% of VO_{2max} in exercise studies [11,21], and the blood lactates attained during this type of exercise in comparison to the blood lactates attained after a wrestling match [18], it appears that over the course of a 7 min match wrestlers are exercising at an average of 95–100% of VO_{2max}. Having a high absolute instantaneous power-output without being able to maintain a high power-output is only an advantage in a rapid pinning situation. In contrast, obtaining a 15 point advantage and thus a technical fall requires generating a high but sustainable power output to accumulate points i.e. muscular endurance. Furthermore, in a more competitive situation where 2 opponents are closely matched which is likely the case during the semifinals and/or finals of state/national tournaments, being exceptionally strong/powerful is important but so is being able to maintain a high power output for the full 6–7 min.

Practical Implications

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Clearly, a high-intensity, low volume taper will substantially improve physical performance when conducted after a period of high-volume, high intensity training [10,17,31]. Thus, it would appear that before major competitions, a US wrestler should be adequately rested by way of a taper. Additionally, dehydration of ~3–4% of body weight will clearly impair muscular endurance/maintenance of high-power outputs [5,6,22,23,29], but likely will not impair absolute power or absolute strength [4,7,12,15,36]. Matches that do not end in a fall are dependent on both muscular endurance and absolute power. Clearly the wrestling specific test that has been employed by Horswill et al. [16] and Hickner et al. [14] is dependent on absolute muscle power and the maintenance of a high power output as discussed above. When utilizing this test, even a more gradual weight loss of ~3.3 to 6% resulted in impaired performance. Therefore, it would seem of paramount importance for wrestlers to maintain a high-carbohydrate diet of ~8–10 g CHO/kg body weight/day to maintain training intensity and optimize performance during individuals' matches and tournaments. Dehydration will likely have the effect of allowing the wrestler to have greater maximal strength and power relative to body weight but the demands of a US wrestling match that does not end in a fall is dependent on *both* maintenance of a high power output during the course of a match and the ability to generate a high-instantaneous absolute force/power output. Thus, the scientific evidence would suggest that prior to competition, US wrestlers should decrease their training volume, increase their training intensity, maintain adequate hydration, and ingest large amounts of carbohydrate to optimize their training, optimize performance during individuals matches, multiple matches in 1 day, and multiple day tournaments.

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