Effects of Dehydration and Rehydration on the One-Repetition Maximum Bench Press of Weight-Trained Males

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ABSTRACT

Dehydration, a common practice among competitive athletes in sports including weight classes, has uncertain effects on strength. This study examined the effects of passive dehydration (D, ~2 hours in a sauna) followed by rehydration (R, ~2 hours of rest with water ad libitum) on bench press one-repetition maximum (1RM). Ten weight-trained males (x ± SE; age = 25 ± 1 years; mass = 85.5 ± 5.2 kg; height = 173.5 ± 1.7 cm; body fat = 17.8 ± 2.2%; 1RM = 118 ± 8 kg) completed 2 testing sessions (E1/E2 and D/R) consisting of, respectively, 2 euhydration 1RM measurements separated by 2 hours of rest; and D 1RM followed by R 1RM. Testing sessions were administered in counterbalanced order and separated by 1 week. D resulted in increases (p < 0.005) in body temperature, urine specific gravity, hematocrit, and hemoglobin (calculated 8% decrease in plasma volume) as well as decreased body mass (p < 0.005). 1RM was decreased following D (111.4 ± 7.2 kg) compared to both E1 (118 ± 7.6 kg, p = 0.0015) and R (117.3 ± 7.8 kg, p = 0.0023), with no significant difference between E1 and R. A significant association (r = -0.67, p < 0.05) was observed between percent lean body mass (%LBM) and the change in 1RM following D. In conclusion, passive dehydration resulting in ~1.5% loss of body mass adversely affects bench press 1RM performance. The adverse affects of dehydration seem to be overcome by a 2-hour rest period and water consumption.

Key Words: resistance exercise, thermoregulation, anaerobic, total body water, hypohydration, hyperhydration


Introduction

Water is the organic solvent for most biochemical processes; therefore adequate hydration is important for peak performance. Optimal extracellular and intracellular fluid volumes affect such physiologic processes as transport of respiratory gases and energy substrate, as well as energy metabolism. Over the past 40 years, investigators have examined the effects of hypohydration (i.e., dehydration) and hyperhydration on running and cycling tasks (3, 6–9, 28, 32). As a result, it is well established that adequate water volume is essential for optimal thermoregulatory, cardiovascular, and metabolic function (16).

There has also been interest in the effects of dehydration on various anaerobic and neuromuscular performance tasks (13, 17, 18, 20, 22, 26, 27, 29, 30), primarily in wrestlers. A common practice in sports that divide competitors into weight classes (e.g., wrestling) is for athletes to dehydrate close to the competition in order to make a particular weight class and then attempt to rehydrate in the hours immediately preceding competition. The objective of this practice is to enter the competition as a larger and stronger competitor than others in the athlete’s weight class (12). Available methods to induce dehydration are (a) use of a sauna (passive dehydration), (b) vigorous exercise (active dehydration), and/or (c) use of diuretic pharmacologic agents. Because diuretics are banned by most organizations governing sports, use of these agents to make weight could result in disqualification and possible suspension from the sport. Active dehydration is often avoided because the exercise that is used to promote the water loss may also lead to fatigue, depletion of energy substrate (i.e., ATP, phosphocreatine, glycogen, etc.), and impaired performance. Adverse effects of passive dehydration have been reported for such tasks as cycle ergometry (8), vertical jumping and isometric strength/endurance (27), and isometric/dynamic endurance (26).

The effects of dehydration on strength are conflicting (4), with reports of no change (13, 20, 22) and decreased strength (27, 29). Little is known about the effects of dehydration on power lifters, who also com-
Table 1. Experimental design.*

<table>
<thead>
<tr>
<th></th>
<th>E1</th>
<th>E2</th>
<th>E3</th>
<th>D</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1RM</td>
<td>2-h break</td>
<td>1RM</td>
<td>1 week between</td>
<td>Dehydration by</td>
<td>2-h break</td>
</tr>
<tr>
<td>Hct</td>
<td></td>
<td>Hct</td>
<td>trials; subjects</td>
<td>1.5% body mass</td>
<td>coupled with</td>
</tr>
<tr>
<td>[Hb]</td>
<td></td>
<td>[Hb]</td>
<td>trained normally</td>
<td>in the sauna</td>
<td>the intake of</td>
</tr>
<tr>
<td>Body mass</td>
<td>Trec</td>
<td>Body mass</td>
<td>for 5 d, with no</td>
<td>Body mass</td>
<td>water</td>
</tr>
<tr>
<td>Trec</td>
<td></td>
<td>Trec</td>
<td>exercise 2 d</td>
<td>Trec</td>
<td>Trec</td>
</tr>
<tr>
<td>SG_urine</td>
<td></td>
<td>SG_urine</td>
<td>prior to trial</td>
<td>SG_urine</td>
<td>SG_urine</td>
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<tr>
<td>SBP</td>
<td></td>
<td>SBP</td>
<td>2</td>
<td>SBP</td>
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<tr>
<td>DBP</td>
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<td>DBP</td>
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<td>DBP</td>
<td>DBP</td>
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<tr>
<td>HR</td>
<td></td>
<td>HR</td>
<td></td>
<td>HR</td>
<td>HR</td>
</tr>
</tbody>
</table>

* Order of E1/E2 and D/R trials was counterbalanced.

pete by weight class. To our knowledge, the effect of passive dehydration on dynamic strength remains to be investigated. Therefore, the purpose of this study was to examine the effects of dehydration on upper body dynamic strength. Specifically, the current study examined the effects of passive dehydration induced by sauna exposure on one-repetition maximum (1RM) bench press performance in competitive power lifters.

Methods

Subjects
Potential subjects were recruited by advertisements and word-of-mouth. Ten experienced male competitive power lifters with at least 2 years of experience volunteered to participate in the study. Subjects were risk stratified as young and apparently healthy according to American College of Sports Medicine guidelines (2). Procedures for the study were explained and informed consent was obtained from each subject. This study was reviewed and approved by the institutional review board for human subjects research.

Experimental Design
A single-group repeated measures cross-over design with counterbalanced trial order was employed (Table 1). Following familiarization with the testing environment (i.e., laboratory, type of bench used to measure 1RM, sauna), body composition was determined by hydrostatic weighing, and bench press 1RM bench was estimated in order to obtain an accurate prediction of 1RM prior to actual measurement. During the study, bench press 1RM was measured 4 times, twice in each of 2 test sessions. The euhydration session consisted of two 1RM measurements in an euhydrated state (E1/E2). The dehyrdration/rehydration session consisted of a 1RM measurement in a dehydrated state (D) followed by a second 1RM measurement after rehydration (R). Subjects were matched on baseline estimated 1RM and randomly assigned to 1 of 2 groups. One group completed the E1/E2 session first, followed by the D/R session, while the other group completed the D/R session first, followed by the E1/E2 session. Sessions were separated by 1 week, during which the subjects maintained normal training for the first 5 days. Subjects were instructed to refrain from exercise, any activity that might affect hydration state, or any change in fluid intake 2 days prior to testing. Subjects completed both sessions at the same time of day in order to avoid diurnal variation in any of the measured variables.

E1/E2 Session Protocol
Measurement of body mass, rectal temperature (Trec), heart rate (HR), systolic (SBP), and diastolic (DBP) blood pressures, and collection of venous blood and urine samples immediately preceded both E1 and E2 1RM measurements that were separated by a 2-hour rest period.

D/R Session Protocol
Euhydrated measurements (E3) of body mass, Trec, HR, SBP, DBP, and collection of blood and urine samples preceded passive dehydration in a sauna (McCoy Sauna, Novi, MI) that was heated to 60°C. Subjects were seated in a comfortable position during D. Subjects were observed through a window in the sauna door by one of the investigators for symptoms of heat-related illness. Every 20 minutes during D, subjects were given a 5-minute rest period during which they exited the sauna to dry off with a towel and have body mass measured. This process continued until subjects had attained the goal of losing 1.5% of euhydrated (E3) body mass. Upon attainment of the criterion body mass, Trec was recorded. Subjects then took a cool shower and Trec was monitored until core temperature was within 0.5°C of Trec at E3. At that point, measurement of HR, SBP, and DBP, and collection of blood and urine samples preceded measurement of D 1RM. Following measurement of D 1RM, all subjects were given a standard time of 2 hours to rehydrate during which they consumed water ad libitum in order to in-
crease body mass to predehydration (E₃) values. The 2-hour time was in accordance with International Powerlifting Federation (IPF) technical rules that state that weigh-in must take place no earlier than 2 hours before the start of competition (19). Volumes of water consumed and urine excreted by each subject were measured in separate 1,000-ml graduated cylinders. Finally, measurement of mass, Tₑ, HR, SBP, and DBP, and collection of urine and blood samples preceded measurement of R 1RM.

**Body Composition**

Nude body mass and height were measured to the nearest 0.1 kg and 0.5 cm, respectively, using a Continental 159.0-kg capacity scale/stadiometer (Continental Scale Corporation, Chicago, IL). Body density was measured by a computerized hydrostatic weighing system equipped with a load cell (Hydrowt model AD-4321, Vaccumetrics, Ventura, CA), with estimation of residual volume (31) from measurement of forced vital capacity (SensorMedics 2900c, Anaheim, CA). Body fat percentage (%fat) was subsequently estimated from body density using the equation of Siri (24). Percent lean body mass (%LBM) was calculated as follows: %LBM = 100 - %fat.

**Bench Press Protocol**

A Brutus Triad weight lifting bench (Excel Products, Pico Rivera, CA) and standard Olympic-style weight lifting set were used to determine 1RM. During the initial familiarization visit, estimated 1RM (1RMₑ) was determined from a self-selected mass (M) that could be pressed from 2 to 20 times (Reps). Estimated 1RM was calculated as follows: 1RMₑ = M ÷ [(100 - (Reps-2)) ÷ 100] (1). Prior to measurement of 1RM, subjects completed a standardized warmup consisting of 10 repetitions at 25% of 1RMₑ, 5 repetitions at 50% of 1RMₑ, 1 repetition at 75% of 1RMₑ, and 1 repetition at 90% of 1RMₑ. Mass was then added to the bar in 2.5% increments until 1RM was attained. Proper form was enforced, with feet flat on the floor and head, shoulders, and buttocks in contact with the bench at all times. After receiving the bar from the spotter, the subject lowered the bar to his chest in a controlled manner. Once the bar was stationary on the subject’s chest, he was instructed by the spotter to press the bar. After achieving full arm extension, the bar was racked with the assistance of the spotter. Failure to lift the mass successfully or maintain proper body position constituted a failed attempt. Subjects were given one opportunity to repeat a failed attempt. The lifters were given at least 5 but no more than 10 minutes between attempts. The 1RM was recorded as the greatest mass successfully lifted. Five to 7 attempts were typically necessary to determine 1RM.

**HR, SBP, and DBP**

Prior to measurements, subjects were seated in a relaxed state for 5 minutes with the left arm supported at the level of the heart. HR (beats·min⁻¹) was measured based on a 30-second pulse count by palpation of the radial artery. SBP (Korotkoff phase 1, mm Hg) and DBP (Korotkoff phase 5, mm Hg) were measured indirectly by auscultation of the left brachial artery using an Hg column sphygmomanometer (Majestic, Graham-Field, Smithtown, NY) and a Sprague-Rappaport stethoscope (Dav-Mar Medical Products, Yonkers, NY).

**Tₑ**

Core temperature (Tₑ, °C) was measured using an Hg thermometer (Sanitherm System II, Applied Technology, Franklin Park, NY). Subjects were instructed to insert the thermometer while standing to a depth of 5 cm past the anal sphincter.

**Specific Gravity of Urine (SGₑ)**

SGₑ was determined using Urinary Multisixt 10SG containing 2.8% (w/w) bromthymol blue, 68.8% (w/w) poly (methyl vinyl ether/maleic anhydride), and 28.4% (w/w) sodium hydroxide (Miles Medical Diagnostics, Elkart, IN). Briefly, a drop from a well-mixed aliquot of urine was placed on the reagent strip. The resulting change in color after 45 seconds indicated SGₑ and ranged from deep blue-green (low urinary [ion] and low SGₑ) to yellow-green (high urinary [ion] and high SGₑ).

**Hemoglobin ([Hb]), Hematocrit (Hct), and Calculated Change in Plasma Volume (%ΔPV)**

Using minimum hemostasis, venous blood was collected from an antecubital vein in a 5-ml K₃EDTA Vacutainer (Becton Dickinson, Rutherford, NJ). The blood was well mixed by gently inverting the vacutainer 10 times. Duplicate aliquots were then drawn into Sahli pipettes and placed into Drabkin’s solution (20 μl in 5 ml) for determination of [Hb] (g·100 ml⁻¹) by the cyanmethemoglobin method (11). The mean intra-assay coefficient of variation on duplicate measures of [Hb] was 0.4%. Hct was also measured in duplicate by microcentrifugation (Adams Micro-Hematocrit, Clay Adams, Parsippany, NJ) and calculated as percent packed cell volume to total volume using a millimeter ruler. [Hb] and Hct were used to calculate changes in plasma volume as a marker of dehydration according to the equation of Dill and Costill (10).

**Statistical Analysis**

Significant differences between mean values for 1RM, Hct, [Hb], calculated %ΔPV, body mass, core temperature, SGₑ, SBP, DBP, and HR were determined by repeated measures ANOVA (23). The association between the change in 1RM bench press (Δ1RM) from E₁ to D and percent lean body mass (%LBM) was de-
Table 2. Effect of euhydration (E₁, E₂, E₃), dehydration (D), and rehydration (R) on body mass, bench press 1RM, rectal temperature, specific gravity of urine, [Hb], Hct, calculated change in plasma volume, heart rate, and blood pressure (±SE).

<table>
<thead>
<tr>
<th>Variable</th>
<th>E₁</th>
<th>E₂</th>
<th>E₃</th>
<th>D</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (kg)</td>
<td>85.5 ± 5.2</td>
<td>85.4 ± 5.2</td>
<td>85.1 ± 5.0</td>
<td>83.9 ± 5.0*</td>
<td>85.0 ± 4.9</td>
</tr>
<tr>
<td>1RM (kg)</td>
<td>118 ± 7.6</td>
<td>115 ± 7.2</td>
<td>—</td>
<td>111.4 ± 7.2†</td>
<td>117 ± 7.8</td>
</tr>
<tr>
<td>T₆₅°C (ºC)</td>
<td>37.4 ± 0.1</td>
<td>37.4 ± 0.2</td>
<td>37.5 ± 0.2</td>
<td>37.8 ± 0.1‡</td>
<td>37.4 ± 0.1</td>
</tr>
<tr>
<td>SGurine (g·ml⁻¹)</td>
<td>1.02 ± 0.002</td>
<td>1.02 ± 0.002</td>
<td>1.02 ± 0.002</td>
<td>1.03 ± 0.002‡</td>
<td>1.02 ± 0.002</td>
</tr>
<tr>
<td>[Hb] (g·100 ml⁻¹)</td>
<td>15.7 ± 0.3</td>
<td>16.0 ± 0.2</td>
<td>15.5 ± 0.3</td>
<td>16.4 ± 0.2†</td>
<td>15.7 ± 0.3</td>
</tr>
<tr>
<td>Hct (%)</td>
<td>43.9 ± 1.2</td>
<td>44.0 ± 0.9</td>
<td>43.7 ± 0.9</td>
<td>45.5 ± 0.9†</td>
<td>44.4 ± 0.9</td>
</tr>
<tr>
<td>%ΔPV from E₃</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>−8.5 ± 0.6*</td>
<td>−2.6 ± 0.4</td>
</tr>
<tr>
<td>HR (beats·min⁻¹)</td>
<td>69 ± 3</td>
<td>70 ± 3</td>
<td>71 ± 3</td>
<td>76.4‡</td>
<td>64.2</td>
</tr>
<tr>
<td>SBP (mm Hg)</td>
<td>119 ± 3</td>
<td>121 ± 2</td>
<td>122 ± 2</td>
<td>115 ± 2*</td>
<td>121 ± 2</td>
</tr>
<tr>
<td>DBP (mm Hg)</td>
<td>77 ± 3</td>
<td>78 ± 2</td>
<td>77 ± 2</td>
<td>76 ± 2</td>
<td>76 ± 2</td>
</tr>
</tbody>
</table>

*D < E₁, E₂, E₃; R (p < 0.005).
† D < E₁, E₂ (p < 0.002).
‡ D > E₁, E₂, E₃; R (p < 0.005).

Results

Baseline Characteristics of the Subjects

Subjects (n = 10) were 25 ± 1 (±SE) years of age, with 85.5 ± 5.2 kg of body mass, 173.5 ± 1.7 cm in stature, 17.8 ± 2.2 %fat, and a euhydrated (E₁) bench press 1RM of 118 ± 8 kg.

Effects of D and R on Selected Physiologic Variables

The mean body mass for E₁, E₂, and E₃ was 85.3 kg. As illustrated in Table 2, D resulted in a 1.7% decrease in body mass (p < 0.005). Compared to euhydration (E₁), a calculated 8% decrease in plasma volume (based on increases [p < 0.005] in [Hb] and Hct), as well as increased HR (p < 0.005) and decreased SBP (p < 0.005), indicated that the subjects were in a hypovolemic state. Increased T₆₅°C (p < 0.005) and SGurine (p < 0.005) provided additional corroboration for the attainment of a dehydrated state. Rehydration and 2 hours of rest returned body mass, [Hb], Hct, SGurine, and T₆₅°C to baseline, confirming effective rehydration by this protocol. During R, subjects ingested 1,360 ± 152 ml of water and excreted 70 ± 47 ml of urine.

Effects of D and R on 1RM

As shown in Figure 1, 1RM was significantly decreased following D compared to both euhydration (E₁, p = 0.0015) and R (p = 0.0023), with no difference between E₁ and R (p = 0.58). There was no difference (p = 0.28) between the number of attempts necessary to obtain 1RM for E₁ (± SD; 5 ± 2), E₂ (4 ± 2), D (4 ± 2), and R (4 ± 2). A difference was observed between the 2 euhydration 1RM measurements, with E₂ being significantly less than E₁ (p = 0.0019). The Bonferroni adjustment of the α-level for all pairwise comparisons resulted in no difference between E₂ and dehydration 1RM (p = 0.023).

Association of Body Composition Status and Decrement in 1RM Performance

As illustrated in Figure 2, a moderate, significant correlation was observed between the decrement in 1RM from E₁ to D (Δ1RM) and %LBM (r = −0.67, p = 0.04), with body composition status accounting for 45% of the variance in Δ1RM.
Discussion

The key findings of this study were that acute passive dehydration decreased bench press 1RM of experienced male competitive powerlifters by 5.6% and that this reduction was eliminated by 2 hours of rest and rehydration. Several studies have also reported decrements in strength following acute dehydration. In a study of college wrestlers, Webster et al. (29) studied the effects of active dehydration (4.9% loss of body mass by exercise in a rubberized suit over 12 hours) on isokinetic torque and work. Dehydration decreased isokinetic performance of upper body musculature by 7.6 and 6.6% for peak torque of latissimus dorsi pull-down and chest push exercises, respectively, as well as 12% decrease in mean work per shoulder press repetition. Mean work for lower body musculature was not adversely affected by dehydration. Viitasalo et al. (27) reported decreased maximal isometric leg strength (7.8%) and rate of force production (16.2%) in 2 groups of volleyball players and track and field athletes assigned to either sauna exposure (3.8% reduction in body mass) or hypocaloric diet combined with diuretic ingestion (5.8% reduction in body mass). The decrements in dynamic strength observed in this study following dehydration are of similar magnitude as those reported for isokinetic (29) and isometric (27) strength measures.

The literature is equivocal regarding the effects of dehydration on strength (4). In contrast to the above-discussed findings (27, 29), 2 recent studies report no effect of dehydration on isometric (13) or dynamic (22) strength. Greiwe et al. (13) reported a 3.8% loss of body mass in 7 males following passive dehydration in a sauna. However, isometric knee extension and elbow flexion peak torque and time to fatigue were unaffected despite a 7.5% decrease in plasma volume 60 minutes following sauna exposure, a similar loss as that observed in the present study. Montain et al. (22) used magnetic resonance spectroscopy ($^{31}$P-MRS) to examine the effects of hypohydration on muscle metabolites and performance. Ten physically active male subjects were actively dehydrated (4% loss of body mass), then performed supine single-leg knee extension exercise. Although muscle endurance was impaired, strength was unaffected by dehydration. Reasons for these discordant findings are unclear but may be related to differences in types of strength measurement, subject populations, and body composition status.

We also investigated the extent to which detrimental effects of dehydration on 1RM performance could be attenuated by rest and rehydration. Rehydration 1RM was significantly (5%) greater than dehydration 1RM. Furthermore, rehydration 1RM was similar to the initial 1RM measured in the euhydrated state. In a similar study, Torrain et al. (26) demonstrated that acute thermal dehydration adversely affected isometric and dynamic muscular endurance by 31 and 29%, respectively, in 20 male subjects who lost 4% of body mass by sauna exposure. Following rehydration, however, performance remained impaired for isometric muscular endurance (−13%) and dynamic muscular endurance (−21%). One reason for these conflicting results may be the difference in severity of dehydration. The decrement in performance following a 4% loss of body mass by dehydration may not be as easily overcome in a short period of rehydration as the 1.5% loss of body mass used in the current study.

The purpose of the E2 1RM measurement was to ascertain the role of fatigue on successive measurements of dynamic upper body strength. We are unaware of any other study reporting the effects of successive measures of bench press 1RM within ~2 hours. The decrease in 1RM between E1 and E2 (2.5%) was similar to reported decreases of 2.9 and 9% in maximal leg extensor isometric strength during 2 strength training sessions separated by 6 hours (14). In that study, Hakkinen reported the change in maximal neural activation in the second session, as measured by integrated muscle electromyogram (EMG), to be correlated significantly with the changes in maximal isometric strength (14). Decreased voluntary neural activation of leg extensor muscles has also been reported following fatiguing heavy-resistance squat exercise consisting of 10 sets of 10 repetitions at 70% of 1RM (15). Although the present study did not include EMG measurement, α-motor neuron recruitment patterns are known to differ between isometric and dynamic muscle contractions (25), it is possible that E2 1RM was lower due to decreased motor unit activation and/or afferent feedback from the exercising muscle.
(21). It is important to note that rehydration 1RM that followed dehydration 1RM in this study was both greater than the dehydration 1RM and similar to the E1 1RM. This observation suggests that rehydration following moderate dehydration may partially ameliorate the adverse effects of neuromuscular fatigue on successive measures of strength, as well as offset the adverse effects of the dehydration itself. Alternatively, the lack of a fatigue effect on the R 1RM may be due to lesser fatigue having occurred during the D attempt relative to the E1 attempt, given that the D 1RM was lower.

The significant inverse association between %lean body mass and the decrement in 1RM indicates that body composition status is a factor that determines the athlete’s ability not only to overcome the detrimental effects of dehydration, but also to compete at their optimal level. Teleologic support for this association comes from the fact that muscle mass, which is related to strength, is part of lean body mass. In addition, the vast majority of total body water is sequestered in the lean body mass compartment. In comparing 2 athletes of the same mass but different body compositions, the individual with a greater %LBM has a greater water reservoir and a 1RM that is less affected by dehydration.

While the current study has demonstrated that dehydration resulted in a reduction in maximal strength, it did not evaluate the mechanisms by which this effect was produced. Previous authors (3) have speculated that dehydration may impair anaerobic metabolism and impair lactate efflux from muscle to blood. While these changes could conceivably affect force development, further research should also consider the possible effects of dehydration on action potential propagation along the α-motorneuron and muscle fibers and membrane polarity (5), as well as calcium release from the sarcoplasmic reticulum.

In conclusion, moderate passive dehydration produced significant decrements in strength compared to those of euhydration; however, following a rehydration period of ~2 hours, strength values were similar to those of euhydration. Athletes who are no more than 2 kg above a desired weight class on the same day of a competitive event may be able to apply these findings with a reasonable confidence in unimpaired performance. The efficacy of this practice for athletes who are attempting to rehydrate following more severe passive dehydration is uncertain and requires further study. The ethics of this practice is a separate, but equally important issue that is beyond the scope of this discussion. Although dynamic upper body strength as measured by bench press 1RM was not significantly affected by moderate dehydration that is followed by rehydration, this practice is not recommended for making weight prior to a competition.

### Practical Application

Moderate dehydration (loss of ≤2% of body mass) can adversely affect the maximum muscular strength of male athletes. The effects of dehydration can be eliminated by a 2-hour period of rest coupled with the ingestion of fluids. The information gained from this study can assist athletes and coaches to make more informed decisions regarding level of hydration. This information is important to all athletes but particularly to those involved in sports with weight categories such as wrestling, boxing, weight lifting, and power lifting. These sports often involve the athletes altering their level of hydration in order to make weight on the day of competition.

### References


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