Effects of rapid weight loss on sports performance

- A systematic review

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Effekter av snabb viktminskning på idrottsprestation

- En systematisk granskning

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GYMNASTIK- OCH IDROTTSHÖGSKOLAN

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Abstract

Aim and research questions: The aim of this study was to investigate the effects of rapid weight loss (RLW) in relation to physiological aspects, psychological aspects, and sport specific performance through a systematic review. This study further aimed to investigate what methods are being used when studying the effects of RWL. To examine the above the following research questions have been used: what physiological and psychological effects can be found in concurrence with RWL, how does the effects of RWL impact sports performance, and what methods are recurrently being used when studying the effects of RWL?

Method: For this purpose a systematic review was conducted using three databases; PubMed, Cochrane Library, and SPORTDiscus. Out of 1163 screened articles 20 of them were included in the review. Further analysis was conducted using Forsberg & Wengströms *quality evaluation for quantitative studies* screening form and the Swedish agency for health technology assessment and assessment of social services *Risk of systematic bia*s screening form. Results were later summarized and compiled.

Result: The most evident finding was that the athletes suffer from dehydration with significantly elevated levels of Urine Specific Gravity, USG. In addition the utilization of RWL also have a negative impact on both cognitive functions and mood, it affects important central factors such as reaction time. However many of the negative physiological effects have been show to subside after 4-12 hours if adequate recovery measures are implemented. The foremost evident sport specific finding was a maintained or increased relative anaerobic peak power. Furthermore positive results in maintaining performance for factors such as; Counter Movement-Jump, clean, snatch, judo specific test, and balance test.

Conclusion: Although athletes were found dehydrated performance was still maintained in sport specific factors. However, this systematic review also found an overall lack of quality within the studies conducted. Sufficient scientific evidence was not found to draw reliable conclusions, additional studies of higher quality are needed for future reviews.

Sammanfattning

Syfte och frågeställningar: Studiens syfte var att göra en systematisk granskning kring effekterna av snabb viktreducering (RWL) kopplat till fysiologiska aspekter, psykologiska aspekter, och idrottsspecifik prestation. Studien strävar sedermera efter att undersöka vilka metoder som vanligtvis används för att studera RWL. För detta användes följande frågeställningar: Vilka fysiologiska och psykologiska effekter kan påträffas i samband med RWL, samt hur påverkar effekter av RWL idrottsprestation, vilka metoder används återkommande för att studera effekterna av RWL?

Metod: En systematisk granskning har utförts i tre databaser: PubMed, Cochrane Librairy, och SPORTDiscus. Utav 1163 screenade artiklar inkluderades 20 stycken i granskningen. Vidare analys bedrevs med Forsberg & Wengströms *kvalitetsgranskning för kvantitativa studier*-formulär samt Statens beredning för medicinsk och social utvärderings *Risk för systematisk bias*-formulär. Resultaten summerades sedan och sammanställdes.

Resultat: Det tydligaste resultatet var att idrottarna lider av uttorkning och signifikant förhöjda nivåer av Urine Specific Gravity, USG. Dessutom har nyttjandet av RWL negativ inverkan på både kognitiva funktioner och humör, det påverkar viktiga centrala faktorer som reaktionstid. Däremot har många av de negativa fysiologiska faktorerna avtagit efter 4-12 timmar om adekvata återhämtningsmetoder implementerats. Det främsta idrottsspecifika fyndet var en bibehållen relativ anaerob peak power. Därutöver syntes fler positiva resultat bibehållen prestation hos faktorer såsom; counter movement-jump, frivändningar, ryck, judospecifika tester, och balanstester.

Slutsats: Trots att utövarna var dehydrerade bibehölls prestation i sportspecifika faktorer. Denna systematiska granskning fann emellertid också en övergripande bristande kvalitet inom de genomförda studierna. Tillräckliga vetenskaplig evidens har inte visat för att konkludera tillförlitliga slutsatser, ytterligare studier av högre kvalitet behövs för framtida granskningar.

Content

Figures and tables

1. Introduction

1.1 Background

In many sports it is common that the athletes have an advantage from a relatively low bodyweight, usually out of efficiency reasons, but sometimes out of biomechanical reasons. Other sports have a weight category where there is a weight restriction for the athlete’s maximal weight. Amongst the athletes who compete within weight categories it is common that the athletes ordinarily prefer to be within the top tier regarding their weight, which is quite understandable. This however results in that many athletes chose to use rapid weight loss (RWL) strategies, because it is perceived that it is advantageous to weight the most possible in relation to one’s specific weight category. Thus the athlete will be able to compete in a lower weight category in the hope of encountering weaker opponents (Brito, Roas, Brito, Marins, Cordova & Franchini 2012; Steen & Brownell 1990; Kordi, Ziaee, Rostami & Wallace 2011; Artioli, Franchini & Nicastro 2010). However, RWL can entail negative physiological, psychological, as well as sport specific effects when RWL occurs frequently (Kordi et al. 2011). This can result in effects such as stress, tiredness, dehydration, and even a few deaths have occurred when using RWL strategies (Davis, Dwyer, Reed, Bopp, Stosic & Shepanski 2002; Aldeman, Landers, Carlson & Scott 2004; Brito et al. 2012).

Sports where RWL is commonly implemented within are sports such as martial arts, weight lifting, some rowing forms, and jockeys, and the weight reduction tradition seem to be widely spread amongst both a large age span and amongst both men and women. What strategy is used can vary vastly and seems to be differing somewhat between different sports but also depending on club culture. Consensus amongst many elite athlete trainers however seem to lean towards that a weight reduction closely before competition now has reduced effect as consequence of increased competition, to lose too much weight-in other words is supposedly counterproductive regarding performance (Sungot-Borgen & Garthe 2011). This is also underlined by researchers saying that findings suggest that dehydration impairs non-body-weight-dependent performance (Reale, Slater & Burke 2017; Savoi, Kenefick, Ely, Cheuvront, & Goulet 2015)

1.2 Prevalence and strategies

Many athletes who compete in weight sensitive sports does see an advantage in competing in a lower weight, they do so with the expectation to encounter smaller and potentially weaker opponents. Based on sports, level, age, sex, and body composition the athletes apply different strategies to reduce weight, some are considered passive – such as low calorie diet or expose oneself to hot environments, while other are considered active – such as increased exercise load. It is common for an athlete to reduce somewhere between 5% to 10% of total body weight using RWL strategies (Reale, Slater & Burke 2017; Cullen, Dolan, McGoldrick, Brien, Carson, & Warrington 2015, Franchini, Brito & Artioli 2012). It is reported that within American collegiate wrestlers who has been competing in the Olympic Games, 41% have weight cycled around 5kg to 9,1kg in body weight during each week throughout the season (Steen & Brownell 1990). In addition it was found that using RWL strategies were common within several groups of North American wrestlers; high-school wrestlers, collegiate wrestlers, and international wrestlers, where a prevalence have been seen from 40% to 90% (Kiningham & Gorenflo 2001; Oppliger, Steen & Scott 2003; Viveiros, Moreira & Zourdos 2015). Regardless of any specific martial arts it has been found that around 60% of all athletes have used methods for RWL (Brito et al. 2012).

Main strategies for RWL usually falls within the following topics; reduce food intake and/or fluid intake, increase body secretion, increase the body's metabolic rate and reduce adipose tissue (Reale, Slater & Burke 2017; Wilson, Drust & Morton 2014; Turocy DePalma & Horswill 2011; Artioli, Franchini & Nicastro 2010; Oppliger et al. 2003 Kiningham & Gorenflo 2001). The central RWL strategy usually involves reduction of calorie- and liquid intake, though it is usually a combination of several approaches. Usually the RWL starts within one weeks' notice of the weight-in and competition, as the competition closes in – the restrictions increase (Artioli et al. 2010). Further methods for RWL is to ingest diet pills to block hunger feelings and thus burn adipose tissue (Kiningham et al. 2001). Generally speaking the athlete is interested in maximizing fat loss and at the same time maintains muscle mass as well as glycogen storage to enhance their relationship between strength and weight, and at the same time try to retain their anaerobic energy source (Trexler, Smith-Ryan & Norton 2014). However there are situations where the athlete choses to sacrifice both muscle mass and glycogen storages through restricted protein- and carbohydrate intake, which usually results in what is called "post-starvation obesity" and instead creates a weight gain over time (Weyer, Walford & Harper 2000). It has been shown that repeated cycles of RWL results in long-term weight gain (Saarni, Rissanen & Sarna 2006).

As previously mentioned increasing body secretion, sweating, and dehydration are common strategies which usually initiates close to the weight-in. Since the body consists of a large portion of water this is one of the most common ways to reduce weight fast, which is also called “drying out” (Morton, Robertson & Sutton 2010). Methods involving severe dehydration commonly involves utilizing a sauna, heated exercising rooms, exercise wearing a “sweat-suit” (usually rubber or plastic) together with a restricted fluid intake. The severe dehydration process often starts a couple of hours before the weight-in (Aghaei, Rohani & Golestani 2011; Oppliger, Case & Sutton 1996; Oppliger et al. 2003). It has been shown that RWL over 5% of body weight can result in severe health complications, in worst case scenario it will result in death. Laxatives and voluntarily induced vomiting are amongst the most extreme methods used closely to the weight-in (Bauditz, Norman & Biering 2008; Filaire, Rouveix & Pannafieux 2007). Despite the fact that diuretics are doping classed by the World Anti-Doping Agency is the usage frequently occurring close to the weight-in (Brito et al. 2012), and it is also one of the most common doping violations amongst martial arts (Halbachi 2009). To the more unusual courses of action found belongs methods such as using laxatives, together with shaving of hair, and chew on chewing gum to increase saliva production to later spit the saliva out (Bauditz et al. 2008; Kiningham et al. 2001).

1.3 Clinical relevance

Since RWL is frequently used by athletes and the techniques vary widely, as seen above, it is important to know how it stresses the body, to what extent, and what the implications are regarding sports performance. This study strive to systematically summarize and compile the evidence that is available as it is paramount to have an in-depth knowledge of the effects of RWL to draw valid conclusions regarding athletes health, sports performance, and choice of weight class.

1.2 Aim and research questions

The aim of this study was to summarize the available knowledge on how RWL affects physiological aspects, psychological aspects, and sport specific performance through a systematic review. This study further aimed to investigate what methods are being used when studying the effects of RWL. To examine the above the following research questions have been used:

- What physiological and psychological effects can be found in concurrence with rapid weight loss?
- How does the effects of rapid weight loss impact sports performance?
- What methods are recurrently being used when studying the effects of rapid weight loss?

2. Method

2.1 Search strategies and article selection

Searches have been made through PubMed, Cochrane Library, and SPORTDiscus. Search terms being used in combination: "Rapid weight loss", "Dehydration", "Hypohydration", "Athletes", "Sports", "Athletic performance" (see appendix 1 for searches). These search terms were chosen since they were related to rapid weight loss strategies within sports. From the conducted database search the reviews that were found have been excluded from this study – however their reference list were further screened for additional material. See screening procedure below (figure 1).

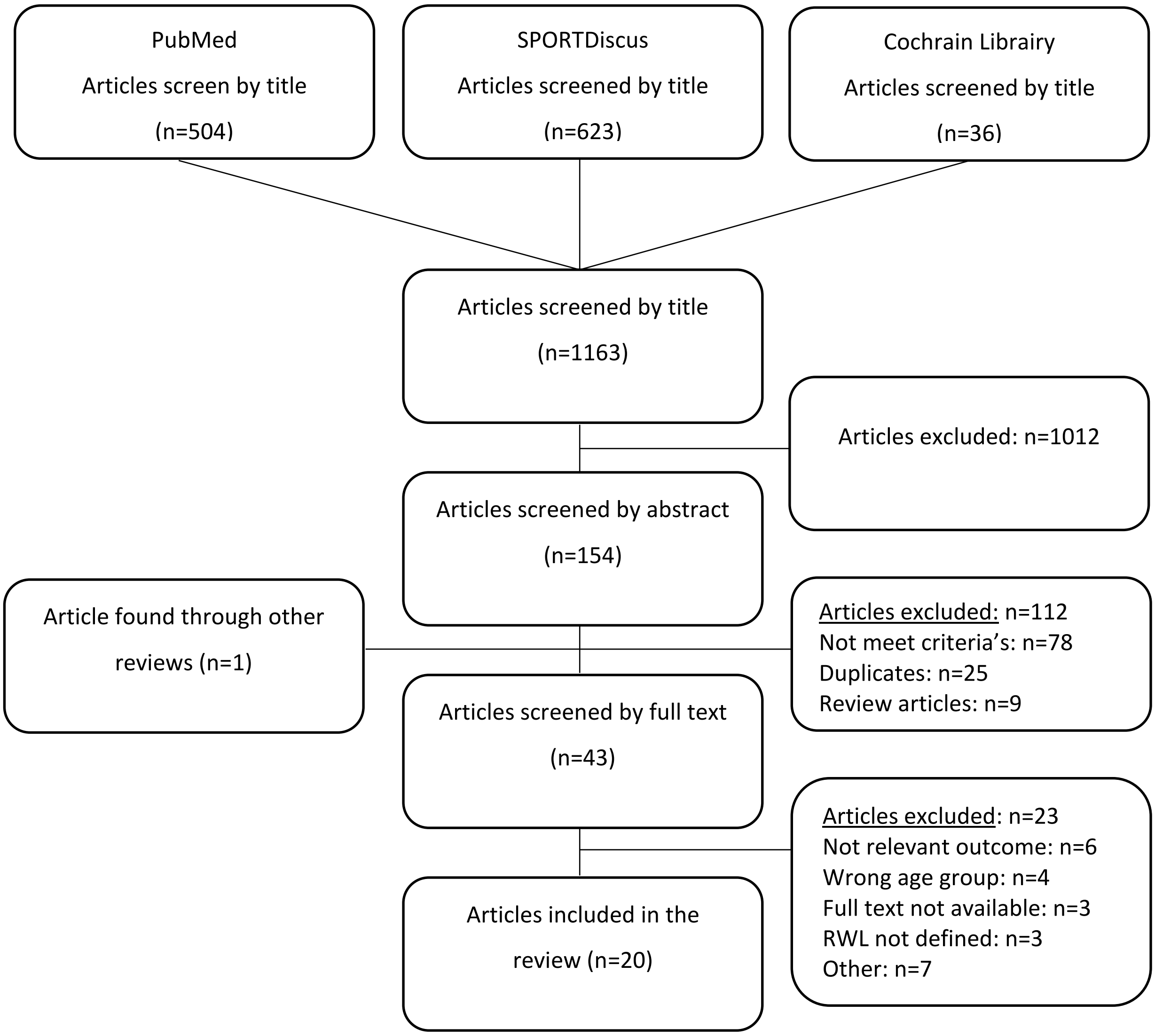

Figure 1- Flowchart of the search

2.2 Criteria's

2.2.1 Type of studies

Only original articles with a true experimental or quasi-experimental design have been included; no longitudinal studies, systematic reviews, or meta-analyses have been included.

2.2.2 Subjects

This systematic review chose to only include studies that included healthy, uninjured, trained individuals and athletes, both male and female above 18 years of age. Because of the suspected variety along with sparse quantity of studies it did not seem realistic to define the included subjects any further.

2.2.3 Type of interventions

This systematic review aimed to investigate experimental studies which examined effects of rapid weight-loss in relation to sports performance. This involves studies where the subject was asked to induce a rapid weight-loss regime where they lose a significant amount of weight after baseline testing, somewhere between 4%-10% of the total body weight (TBW). The RWL should then follow by a weigh-in where the subjects are asked to make weight. Weight-in should further be followed by performance testing, game simulation, or other tests to investigate the physiological or psychological state of the athletes. Testing needs to be performed within 24 hours after weigh-in.

2.2.4 Inclusion criteria's

For the purpose of this study this review was solely focusing on studies where the subject was asked to lose 4% body weight or more within seven days followed by a weight-in and post RWL, performance, physiological, and/or psychological, test within 24 hours. This assortment was most coherent with the behavior around rapid weight-loss this review aim to examine. The search interval was set to find studies between January 1997 and December 2017.

2.2.5 Exclusion criteria's

Studies who did not ask their subjects to lose at least 4% of their body weight within seven days before a weigh-in. Studies who did examine unhealthy and/or injured individuals. Lastly, studies that did not include an ethics approval section were excluded.

2.3 Screening methodology

The article search was conducted in alignment with the recommendations of the Swedish agency for health technology assessment and assessment of social services (SBU) together with other research methodological guidelines found in appropriate literature (SBU 2014, pp. 13-39; Forsberg & Wengström 2013, pp. 17-35, 69-83; Johansen & Pors 2013, pp. 41-48, 59-71; Hassmén & Hassmén 2008, pp. 32-121, 171-295).

For quality evaluation the *quality screening template for experimental studies* by Forsberg & Wengström (2013) was used (see appendix 2). The articles were graded on a scale from 1-16, where 0-7 points was considered low quality, 8-12 was considered average quality, 13-16 was considered high quality. Additionally the screening template from SBU (2014) were employed to determine the risk of systematic bias (see appendix 3).

2.4 Ethical considerations

To establish that ethical considerations were taken, this systematic review only accepted articles which were approved by an ethics committee. Furthermore an unbiased and objective approach was utilized when processing and presenting the data so that no researcher would be specifically portrayed in a negative manner.

2.5 Validity and reliability

To ensure the validity of this systematic review a thorough preliminary investigation was made to acquire relevant information within the field and applied keywords – information which later on was used to conduct the search. Also the choosing of a well-rounded set of screening templates was an important factor (Forsberg &Wengström 2013, pp. 85-121, 165-174; Johansen & Pors 2013; Krippendorff 2013, pp. 329-354; Hassmén & Hassmén 2008, pp. 136-160).

To further ensure the quality of the systematic review a well-documented, systematic, and reproducible procedure was applied as described throughout the method section (Forsberg &Wengström 2013, pp. 85-121; Krippendorff 2013, pp. 267-276; Johansen & Pors 2013, pp. 73-98; Hassmén & Hassmén 2008, pp. 122-136).

3. Results

The 20 included articles were screened and presented below; two true experimental studies, and 18 quasi-experimental studies, of which five had a non-equivalent control, two matched control, and one counter balanced control. For a clear depiction the result was presented in two ways – tables containing quality evaluation according to Forsberg & Wengström (2008), and risk of systematic bias according to SBU (2014) (see table 1), and a summary of the articles (see table 2). Following will be a synopsis of the results merged into four categories in accordance to the research questions; methods used, physiological effects, psychological effects, and sport specific effects.

3.1 Quality evaluation and risk evaluation of systematic bias

Both scales are graded with low – average (AVG) – high, for the quality evaluation *high* was the optimum answer, whilst the risk of bias has an ideal answer as *low*. Out of the 20 articles screened seven articles were found to be of high quality, and 13 of average quality according to Forsgren & Wengströms (2008) screening tool (full screening see appendix 4). When screening for risk of systematic bias with the screening tool from SBU (2014) four articles were found to be of low risk, and 16 to be of average risk. Within the subcategories of the risk of systematic bias screening, two articles showed a low risk of selection bias, two showed an average risk, and 16 showed a high risk. In addition; all of the articles were found to have an average risk of treatment bias (full screening see appendix 5).

Table 1 - Quality evaluation and risk of systematic bias evaluation

Article	Quality evaluation	Risk of bias
A. Durguerian et al. 2015, *"Weight Loss, Performance and Psychological Related States in High-level Weightlifters"*	High	Low
G. Artioli et al. 2010, *"Rapid weight loss followed by recovery time does not affect judo-related performance"*	High	AVG
S. Cullen et al. 2015(a), *"Lack of Effect of Typical Rapid-Weight-Loss Practices on Balance and Anaerobic Performance in Apprentice Jockeys"*	High	AVG
S. Cullen et al. 2015(b), *"The impact of making-weight on cognitive performance in apprentice jockeys"*	High	Low
H. Sagyama et al. 2014, *"Effects of rapid weight loss and regain on body composition and energy expenditure"*	High	AVG
R. Marttinen et al. 2011, *"Effects of self-selected mass loss on performance and mood in collegiate wrestlers"*	High	AVG
S. Timpmann et al. 2008, *“Acute effects of self-selected regimen of rapid body mass loss in combat sports athletes”*	High	AVG
S. Mendes et al. 2013, *" Effect of rapid weight loss on performance in combat sport male athletes: does adaptation to chronic weight cycling play a role?"*	AVG	AVG
V. Coswig et al 2015, *"Rapid Weight Loss Elicits Harmful Biochemical and Hormonal Responses in Mixed Martial Arts Athletes"*	AVG	Low
A. Cengiz 2015, *"Effects of self-selected dehydration and meaningful rehydration on anaerobic power and heart rate recovery of elite wrestlers"*	AVG	AVG
C. Hall et al. 2001, *"Effects of rapid weight loss on mood and performance among amateur boxers"*	AVG	AVG
D. Rejic et al. 2013, *"Rapid Weight Loss and the Body Fluid Balance and Hemoglobin Mass of Elite Amateur Boxers"*	AVG	AVG
M. Jlid et al. 2013, *"Rapid weight loss alters muscular performance percieved extertion as well as postural control in elite wrestlers"*	AVG	AVG
M. Talaei et al. 2017, *"The impact of rapid weight loss (4%) on leptin, adiponectin, and insulin resistance in elite adult free style wrestlers"*	AVG	AVG
L. Armstrong et al. 2006, *"No Effect of 5% Hypohydration on Running Economy of Competitive Runners at 23-C"*	AVG	AVG
J. Finaud et al. 2006, *"Competition and Food Restriction Effects on Oxidative Stress in judo"*	AVG	Low
D. Rejic et al. 2016, *"Rapid body mass loss affects erythropoiesis and hemolysis but does not impair aerobic performance in combat athletes"*	AVG	AVG

I. Ozkan et al 2016, *"Dehydration, skeletal muscle damage and inflammation before competitions among the elite wrestlers"*	AVG	AVG
B. Matulevičiūtė et al. 2013, *"Effects of two different methods reducing body mass (rapid and medium rapid) on proffesional wrestlers' changes in body composition and force"*	AVG	AVG
W. Yang et al. 2015, *"Rapid Rather than Gradual Weight Reduction Impairs Hemorheological Parameters of Taekwondo Athletes through Reduction in RBC-NOS Activation"*	AVG	AVG

3.2 Article presentation

Table 2- Article presentation

Author and year	Study design	Aim	Population	Intervention	Methods	Result
A. Durguerian et al. 2015, *"Weight Loss, Performance and Psychological Related States in High-level Weightlifters"*	Experimental, counter-balanced control	Simulate a competition to examine the effects of different nutritional strategies on psychological and physiological effects.	11 male weightlifters on international junior elite level. Control group (CG) n = 5 Diet group (DG) n = 6	Baseline- and after tests. Group was split into two after baseline, control- and diet group. After 6 days of RWL with >5% total body weight (TBW) among the diet group, after tests were conducted. Simulated competition, urine sample, and questionnaire.	Skinfold, Countermovement jump (CMJ), simulated competition, diet journal with pictures. Questionnaires: POMS & RESTQ-52, ”Urine specific gravity” USG-refractometer.	USG-values significantly elevated during after tests ($p<0.01$) for the DG. No significant difference in CMJ, clean, and snatch. Relative performance increased significantly however ($p<.0.05$) within the DG. “Fatigue” significant elevation according to POMS ($p<0.05$). Elevated Emotional stress according to RESTQ-52 ($p<0.05$).
G. Artioli et al. 2010, *"Rapid weight loss followed by recovery time does not affect judo-related performance"*	Quasi-experimental, non-equivalent control group	Examine whether RWL achieved through common diet strategies followed by a 4 hour recovery time would affect the high intensity judo specific performance among weight cyclers.	14 male experienced judo competitors, split into two groups depending on RWL-experience. Weight loss group (WLG) n= 7 Non weight cyclers (NWG) n = 7	Baseline- and after tests. Weight loss intervention for WLG, >5% TBW. 5-7 days later after baseline the after tests were performed. Judo specific test, wingate, hydrostatic weighing, judo specific test, and plasma glucose status and blood lactate.	Judo specific test, upper-body wingate, hydrostatic weighing, blood samples.	WLG decreased TBW significantly, 4.8%±1.1% ($p<0.001$). No significant difference in the judo specific test. RWL did not affect upper-body wingate significantly. Plasma glucose significantly lower among the WLG after the intervention. No significant difference in blood lactate between groups or test occasion.

S. Cullen et al. 2015(a), *"Lack of Effect of Typical Rapid-Weight-Loss Practices on Balance and Anaerobic Performance in Apprentice Jockeys"*	Quasi-experimental, matched control	Examine the effects of RWL on balance and anaerobic performance among apprentice jockeys.	24 male apprentice jockeys on national elite level. Jockeys (J) n = 12 Control (CG) n = 12	Baseline- and after tests. Baseline were performed hydrated. Before after tests J were asked to reduce >4% of TBW within 48h. Thereafter, balance tests, anaerobic performance tests, .anthropometry, and hydration status were examined.	Y balance test, lower-body wingate, digital scale, USG-refractometry.	TWB significantly reduced 4.2%±0.3% ($p<0.001$). USG-values significantly elevated ($p<0.001$). No difference between groups on the balance test. No significant difference in anaerobic performance or lower body wingate.
S. Cullen et al. 2015(b), *"The impact of making-weight on cognitive performance in apprentice jockeys"*	Quasi-experimental, matched control	Examine the effects of RWL on cognitive functions amongst jockeys in a simulated competition environment.	34 male apprentice jockeys on national elite level. Jockeys T1(J1) n = 12 Control (CG) n = 12 Jockeys T2(J2) n = 10	Baseline- and after tests. Baseline were performed hydrated, A simulated competition for J1. Before after tests J1 was asked to reduced >4% of TBW within 48 hours. Cognitive functions, anthropometry, and hydration status were examined. J2 were recruited at a competition and were asked to perform the test protocol.	CogSport computerized test battery, digital scale, USG-refractometry.	TWB significantly reduced 4.2%±0.3% ($p<0.001$). USG-values significantly elevated ($p<0.001$). J1 significantly worse than KG on the reaction test ($p<0.05$) visual learning, and memory ($p<0.01$). However no significant difference in baseline tests and after tests between the groups When J2 were tested no significant difference between baseline and after tests.
H. Sagyama et al. 2014, *"Effects of rapid weight loss and regain on*	Quasi-experimental	Evaluate the changes in fat mass (FM) and fat free mass (FFM during RWL and following weight gain through examination of	10 male weight class athletes. Test subjects (TS) n = 10	Three measurement points. Baseline, 1 week before RWL, 1 week after RWL, and after recovery from RWL. TS were asked to reduce >5% of TBW. Body	Hydrostatic weighing, calculated FFM, accelerometer, self-reported diet journal with pictures, metabolic chamber.	Bodyweight significantly lower after RWL, 6%±0.9% ($p<0.05$).No significant difference in BMR or SMR. No difference in physical activity, however did the

body composition and energy expenditure"		hydrostatic weighing and isotope dilution. And examine the effects of RWL on BMR and SMR.		composition, physical activity, and metabolic rate were examined.		energy intake decrease significantly during RWL ($p<0.05$).
R.Marttinen et al. 2011, *"Effects of self-selected mass loss on performance and mood in collegiate wrestlers"*	Quasi-experimental	Determine the effects of RWL on "pre-competition mood", grip strength, and power in lower extremities among collegiate wrestlers.	16 male division 1 collegiate wrestlers. Test subjects (TS) n = 16	TS were weighted 10 days before competition, 6 days, 2 days, and on the competition day (D-0). Test subjects regulated the amount of RWL by themselves. Brunel Mood Scale (BRUMS), POMS, grip strenght, and lower-body wingate. Grouped after TBW loss on D-0.	Weigh-in, USG-refractometry, Questionnaires: BRUMS and POMS, grip-dynamometer, lower-body wingate.	Almost significant mass loss ($p<0.056$). TS who lost >4% TBW showed a significant increase in confusion, anger, depression, and vigor ($p<0.05$). Amount of RWL correlates significantly with degree of confusion ($r=0.733$) and tension ($r=0.0568$). No significant difference in lower-body wingate or grip strength.
S. Timpmann et al. 2008, *"Acute effects of self-selected regimen of rapid body mass loss in combat sports athletes"*	Quasi-experimental	To assess the acute effects of the self-selected regimen of rapid body mass loss (RBML) on muscular performance and metabolic response to exercise in combat sports athletes.	17 male healthy well-trained combat sports athletes. Subjects (S) n = 17	Baseline and post-intervention tests. Baseline were performed hydrated at 7 days before weigh in, S were asked to lose >5% body of TBW. Muscle performance test and biochemical analyses during both trails.	Weigh-in, isokinetic dynamometer to determine peak torque of knee flexors and perform a muscle endurance test, biochemical analyses, hemoglobin, ammonia concentration, plasma volume.	Peak torque significantly lower than baseline at angular velocities of 1.57 rad·s–1 (6.7%; p = 0.013) and 3.14 rad·s–1 (10.2%; p = 0.008). Peak torque in relation to body weight remained intact. Lowered plasma volume. Significantly increased ammonia concentration ($p<0.001$), and significant increase of blood lactate ($p<0.001$) Pronounced increase level of urea (p = 0.003).

S. Mendes et al. 2013, *"Effect of rapid weight loss on performance in combat sport male athletes: does adaptation to chronic weight cycling play a role?"*	Quasi-experimental, non-equivalent control	Examine the effects of RWL up to 5% of TBW loss on high intensity intermittent performance in two distinct groups: experienced weight cyclers and non-weight cyclers.	18 male martial artists were divided into groups depending on their experience of RWL. Experienced weight cyclers (WC) n = 10 non-weight cyclers (non-WC) n = 8	Three test occations; orientation session, before weight reduction (baseline), and after weight reduction. Asked to make a weight reduction of 5% of TBW within 5 days. High intensity interval protocols were performed on arm ergoments.	Arm-ergometer, Hydrostatic weighing, blood samples.	Plasma lactate was significantly increased after testing in both groups both before and after RWL ($p<0.001$). However, there was no difference between the groups. The WC group does not seem to be better adapted to the side effects of RWL strategies.
V. Coswig et al 2015, *"Rapid Weight Loss Elicits Harmful Biochemical and Hormonal Responses in Mixed Martial Arts Athletes"*	Quasi-experimental, non-equivalent control group	Comparing biochemical and hormonal responses between MMA practitioners who exercise minimal weight reduction compared to those performing RWL.	17 professional MMA practitioners who competed at least on 2 official occasions. No Weight Loss (NWL) n = 12 RWL n = 5	Grouped by RWL habits. Before and after the match, 10ml blood sample was taken from the upper extremity of the practitioner. Magnesium, lactate, creatine kinase, lactate dehydogenase, and aspartate aminotransferase were investigated.	Weighing, blood samples.	Lactate concentration significantly elevated after match ($p<0.01$), no difference between groups. The glucose concentration was significantly altered ($p<0.001$), even between groups ($p<0.02$). And LDH significantly differed ($p<0.01$), also between groups ($p<0.001$).
A. Cengiz 2015, *"Effects of self-selected dehydration and meaningful rehydration on anaerobic power*	Quasi-experimental	Verify the effects of RWL on strength and power in both the upper and lower body, fatigue index, and heart rate recovery (HRR) close to important competitions, including 12-h recovery.	11 well trained wrestlers. Test subjects (TS) n = 11	After baseline, TS was asked to reduce 4% -5% TBW for a further weighin 4 days later. Upper body and lower-body wingate were performed on 3 occasions; At baseline, just before weeping, and 12-h after	Upper-body and lower-body wingate, pulse measurement, and fatigue index.	A significant difference between the test cases in the lower-body wingate ($p<0.007$). Peak power was significantly reduced after RWL ($p<0.012$). On the other hand, peak power returned to baseline after 12-h

and heart rate recovery of elite wrestlers"				weeping. Heart rate was monitored after each test session.		recovery. Fatigue index increased significantly after RWL ($p<0.002$). HRR changed significantly between occasions ($p<0.000$). Returned to baseline after 12-h recovery.
C. Hall et al. 2001, *"Effects of rapid weight loss on mood and performance among amateur boxers"*	Quasi-experimental	Identify perceptions and strategies about invitations. As well as investigate the effect of RWL on mood and boxing specific performance among amateur boxers.	16 experienced amateur boxers with at least 2 years of experience. Test subjects (TS) n = 16	Structured interviews to investigate perceptions and strategies of recruitment, also provide a border-specific test for the next step. In step two, the boxing specific test was performed, and POMS-A was used.	Structured interview, weighing, POMS-A.	Everyone changed their weight significantly ($p<0.001$). 73% reported that they lost their weight through exercise, about 2kg-3kg during the week. RWL strategies are associated with poor performance and negative mood profile ($p<0.05$).
D. Rejic et al. 2013, *"Rapid Weight Loss and the Body Fluid Balance and Hemoglobin Mass of Elite Amateur Boxers"*	Quasi-experimental, non-equivalent control group	Investigate effects of 5% or greater, body mass loss within a few days for body water (BW), blood volume (BV), and plasma volume (PV) contamination in elite amateur boxers.	17 male junior elite amateur boxers, divided according to weight reduction habits Weight-loss group (WLG) n = 10 Control (CG) n = 7	Baseline test 2 weeks before the competition, re-test 2 days before the competition for WLG, as well as tests 7 days after the competition for both groups. Anthropometric tests, as well as blood samples were taken.	Weight, bioelectric impedance analysis, venous blood samples.	No significant difference in body mass between the groups. Difference within the group WLG between the times ($p<0.001$). Observed a difference in body mass 5.6% ± 1.7% ($p<0.001$). Significant decrease in BW, BV, and PV ($p<0.001$),
M. Jlid et al. 2013, *"Rapid weight loss alters muscular*	Quasi-experimental	Evaluate the effects of RWL on postural control, muscular performance, and estimated fatigue	10 international elite freestyle wrestlers. Test subjects (TS) n = 10	Basel tests and after tests. Baseline 7 days before the competition, second occasion the night before the race. Anthropometric	Interview with dietician to examine eating habits, anthropometric measurements (length, weight, leg length), body	Significant decrease in calorie and water intake between occasions ($p<0.05$). HG and BS both absolute and relative strength

performance percieved extertion as well as postural control in elite wrestlers"		(RPE) of elite freestyle wrestlers.		measurements, along with isometric hand grip strength (HG), isometric back strength (BS), and dynamic postural control were tested. FP was also asked to enter RPE at knee-raising push-ups.	composition measurement, hand dynamometer, back and bend dynamometer, Star Excursion Balance Test (SEBT), RPE test.	decreased significantly (p<0.05). RPE increased significantly from 12.50 ± 1.26 points to 15.70 ± 1.25 points (p <0.001).
M. Talaei et al. 2017, *"The impact of rapid weight loss (4%) on leptin, adiponectin, and insulin resistance in elite adult free style wrestlers"*	Quasi-experimental	Study the effect of RWL in Iranian elite wrestlers on leptin, adipocetin, insulin resistance, and betacell function	15 Iranian young elite wrestlers. Test subjects (TS) n = 15	Baseline tests included anthropometric measurements as well as venous blood samples (pre-test). FP weighed and recorded the diet for 7 days. Then a RWL program was introduced where FP was asked to reduce> 4% TBW for 1 week. Blood samples 12-h and 36-h after dietary completion.	Anthropometric measurements, dietary protocols with weighing of food, blood samples, analysis of biochemical variables.	RWL> 4% of TBW has significant reducing effects on anthropometric parameters (p<0.04). Significant clearance of leptin levels (p<0.007), adiponectin and insulin no significant change, non-sustained after 12 h, but still a significant change in beta cell function (p<0.003)
L. Armstrong et al. 2006, *"No Effect of 5% Hypohydration on Running Economy of Competitive Runners at 23-C"*	Quasi-experimental	Examine the effects of hypohydration and running economics (RE) in relation to physiological responses	10 well-trained college runners. Test subjects (TS) N = 10	TS participated in four experiments on different days, two trials of euhydrated (EU), two attempts of hypohydrated (HY),> 5% of TBW. FP performed running tests, 3x10 minutes with 10 minutes resting, either 70% of VO2max or 85% of VO2max. Also, blood samples were left.	Anthropometric measurements, hydrostatic wave, treadmill including oxygen absorption apparatus, spirometer, USG refractor, blood samples, biochemical analyzes.	No significant difference between treatments for RE (EU 70%, 46.3 ± 3.2; HY 70%; 47.2 ± 3.8; EU 85%; 58.6 ± 2.8; HY 85%; 58.9 ± 4.1 mLxkg-1min-1); postexercise Plasma lactate concentration (EU 70%, 1.9 ± 0.6; HY 70%; 1.8 ± 0.6; EU 85%; 6.5 ± 3.5; HY 85%; 6.4 ± 3.5 mmol-1)

J. Finaud et al. 2006, *"Competition and Food Restriction Effects on Oxidative Stress in judo"*	Experimental	Investigate the effects of a one-day simulated judo contest (GS) after a week's RWL with regard to antioxidant status and oxidative stress.	20 male national judo competitiors Dietary group (DG) n = 10 Control (CG) n = 10	DG was asked to reduce> 5% of the TBW week before the competition. A test battery was performed at baseline, in the morning of the competition day, and 10 minutes after the completion of the competition.	Judo-specific drills, anthropometric measurements, diet diary, blood sample, biochemical analysis, determination of lag phase (LP) before free radical induced oxidation.	No difference at baseline in TBW between the groups. Within group DG, significant difference occurred at second measurement ($p<0.001$). Normal limit values for vitamins A, C, and E were noted. However, at DG, there was an increase in LP values ($p<0.05$) and uric acid concentration. GS induced a significant increase in Lp ($p<0.001$) in both DG + 40% and CG + 25%. GS also induced a significant increase in uric acid concentration CG 52% ($p<0.05$) and DG 66% ($p<0.01$)
D. Rejic et al. 2016, *"Rapid body mass loss affects erythropoiesis and hemolysis but does not impair aerobic performance in combat athletes"*	Quasi-experimental, non-equivalent control group	Check whether Hbmass, hemoglobin mass, is reduced after a rapid weight loss. If so, to find out if the reduction is due to impaired erythropoies and / or increased hemolysis. In addition, differences in thyroid gland and androgen hormone have been investigated.	28 male national and international martial artists, divided by intention to reduce more than >5% TWB or intent not to reduce weight at all. Weight-loss group (WLG) n = 14 Control (CG) n = 14	Baseline Test 2 weeks before the competition, re-tested 1-2 days before the competition for WLG, as well as post-competition tests when the practitioner returned to the usual diet and exercise routine, applied to both groups. Increasing treadmill protocols.	Test protocol performed on treadmill with spirograph, anthropometry, bioelectric impedance analysis, USG refractometer, and blood samples.	Hbmass was reduced (-.1%) significantly in WLG ($p<0.001$), 1.6% decrease also remained after the weight loss at the last measurement ($p<0.05$). Decreases in thyroid hormone and androgen status appeared after RWL. However, no aerobic performance reduction was found. Control group is

						monitored unaffected within all parameters.
I. Ozkan et al 2016, *"Dehydration, skeletal muscle damage and inflammation before competitions among the elite wrestlers"*	Quasi-experimental	Identify RWL and hydration levels before the competition of elite wrestlers, as well as determine muscular injury and inflammation levels after dehydration.	69 male Division A elite wrestlers with at least 5 years of experience in sports. Test subjects (TS) N = 69	TS was able to control its weight control on a self-contained basis and fill in a questionnaire about RWL habits. Grouped according to dehydration rate. Blood samples were taken one day before weeping.	Surveys to investigate RWL habits, blood samples.	The survey showed that 55.7% of TS underwent RWL before of the competition. When hydration status was investigated, Na+, BUN, and percentage of body weight loss were higher in TS that were not dehydrated ($p<0.05$). When muscular injury and inflammation were compared, there was a significant difference ($p<0.05$), but no difference between groups.
B. Matulevičiūtė et al. 2013, *"Effects of two different methods reducing body mass (rapid and medium rapid) on proffesional wrestlers' changes in body composition and force"*	Quasi-experimental, non-equivalent control group	Estimate effects of RWL methods, rapid and moderate, on professional wrestlers changes in body composition and power	72 male professional wrestlers were distributed by weight reduction strategies. No RWL, Control (CG) n = 47 Rapid weight reducer (RWL) n = 16 Moderate weight reducer (MWL) n = 9	Basel tests were performed on all groups as they were not in a weight reduction period. The second test opportunity was on the competition day. Practitioners were asked on their own to reduce the weight according to their weight class. Strength in hip flexors and shoulder abductors were tested.	Body composition measurements, bio-impedance Analysis, Power measuring through dynamometer.	The two weight reduction groups significantly reduced weight, RWL 4.5% and MWL 4.03% ($p<0.05$). Both groups also reduced power in both legs ($p<0.05$) and both arms ($p<0.05$).

W. Yang et al. 2015, *"Rapid Rather than Gradual Weight Reduction Impairs Hemorheological Parameters of Taekwondo Athletes through Reduction in RBC-NOS Activation"*	Quasi-experimental	Investigate whether rapid weight loss or gradual weight reduction inhibits hemorheological parameters as a result of inhibition of red blood cell (RBC) nitric oxide activation (RBC-NOS).	10 well-trained male taekwondo practitioners. Test subjects (TS) n = 10	The study is categorized by two cycles of weight reduction, including 4 days RWL and 4 weeks Gradual Weight Reduction (GWR). The two interventions were separated by a recovery phase.	Anthropometric measurements, bio impedance analysis, blood samples, RBC-NO analyzes.	Basal blood parameters were not affected by the two interventions. In contrast to GWR, the RWL group significantly reduced the activation of RBC nitrite at Pre-test 2 ($p<0.05$) and Pre-test 1 ($p<0.001$), and RBC-NOS Pre-test 2 ($p<0.05$). Also reduced RBC deformability ($p<0.05$) and RBC aggregation at post-test 1 ($p<0.05$) and post-test 2 ($p<0.01$)

3.3 Methods used

3.3.1 Questionnaires

Five articles used some form of self-reporting to monitor the athletes food intake through a dietary journal. Three articles used POMS, profile of mood states, which is a tool used to assess mood state through a series of associations. One article used BRUMS, Brunel Mood Scale, which is a reduced tool derived from POMS to assess mood states. Lastly one article used RESTQ-52 which is a questionnaire to measure stress and recovery rates in athletes.

3.3.2 Performance tests

Four articles used wingate test which is a cycle ergometer test to evaluate anaerobic performance. Two articles used hand grips strength dynamometers. Two articles used dynamometers for upper and lower extremities to determine power and torque. One article used counter movement-jump, barbell snatch, barbell clean. One article used Y balance test, which is a tool used to test a person's risk for injuries. One article used a judo specific test to determine sport specific performance through game simulation.

3.3.3 Physiological tests

Seven articles tested USG, urine specific gravity, which is a test that compares the density of urine to water to determine hydration status. Six articles used blood samples to test either variables; plasma lactate, plasma glucose, inflammation, Hb-mass, and red blood cell concentration. One article measured heart-rate recovery, which refers to the hearts ability to return to normal heart-rate after physical activity.

3.4 Synopsis of results

The results will be presented in such order that the evidence which was featured within the most studies and with the highest possible quality will be presented first, and in descending order – evidence supported by studies presenting similar results and with a lower quality.

3.4.1 Physiological effects

A frequently recurring finding amongst the selected studies where RWL has been implemented was an increased dehydration. This was strengthened by four articles of high quality (Durguerian et al. 2015; Artioli et al. 2010; Cullen et al. 2015a; Cullen et al. 2015b) and three articles of average quality (Rejic et al. 2016; Armstrong et al. 2006; Finaud et al. 2006) who found significantly elevated levels of USG, *Urine Specific Gravity*.

Further findings regarding physiological aspects; one high quality (Timpmann et al. 2008) and three average quality (Coswig et al. 2015; Mendes et al., 2013; Armstrong et al. 2006) studies found significantly elevated concentration of plasma lactate, and one high quality article (Artiolo et al. 2010) did not find any significant difference. Further findings by two average quality (Ozkan et al. 2016; Finaud et al. 2006) studies underline an elevated gradation of muscle damage, inflammation, and oxidative stress during RWL. One high quality article (Artiolo et al. 2010) found significantly lower plasma glucose content. One average quality article (Cengiz 2015) discovered a strong decrement in heart-rate recovery. Similarly a substantial decrease in hemoglobin mass of 4,1% was found by one average quality article (Rejic et al. 2016), also a decrement in androgen status and thyroid hormones found by another average quality article (Yang et al. 2015) which also found that RWL negatively affects hemorheological parameters and nitric oxide signaling in red blood cells.

Additional findings by three high quality (Cullen et al. 2015b; Sagyama et al. 2014; Artioli et al. 2010) and two average quality (Talaei et al. 2017; Cengiz 2015) articles presents evidence suggesting that the above mentioned effects was seemingly reversible after 4-12 hours if ad libitum recovery were conducted. However, regarding decrement in hemoglobin mass, even after several days of sufficient recovery procedures hemoglobin mass was still in the lower region, according to one average quality study (Rejic et al. 2016).

3.4.2 Psychological effects

In articles which also took the psychological effects in consideration it was well displayed that RWL have a negative effect on cognition and mood. Two high quality (Durguerian et al. 2015; Marttinen et al. 2011) and one average quality article (Hall et al. 2001) found a significantly negative change in mood using the POMS evaluation. One high quality (Durguerian et al. 2015) article found significantly elevated stress levels using RESTQ-52, and another high quality article (Marttinen et al. 2011) using BRUMS found a correlation between RWL and increased levels of confusion and tension. Usage of RWL where usually concurrent with significantly elevated degree of tiredness, confusion, emotional tension, stress, and over all associated with at a bad mood profile (Durguerian et al. 2015; Marttinen et al. 2011; Hall et al. 2001). Moreover does RWL seemingly have a negative impact on cognitive functions such as reaction time, visual learning, and memory according to a high quality article (Cullen et al. 2015b).

3.4.3 Sport specific effects

One common finding within three high quality article (Cullen et al. 2015a; Marttinen et al. 2011; Artioli et al. 2010) which included performance variables was that relative anaerobic peak power increased, one average quality article (Cengiz 2015) however found a significant decrease in anaerobic peak power after RWL. In one high quality study (Timpmann et al. 2008) the athletes decreased performance in absolute peak values. Other results strengthened by three high quality articles (Cullen et al. 2015a; Durguerian et al. 2015; Artioli et al. 2010) displayed retained performance where no significant change has occurred, this involves exercises such as; Counter Movement-Jump, clean, snatch, judo specific test, balance test. One article of high quality (Marttinen et al. 2011) showed no significant difference in absolute or relative grip strength, while one average quality article (Jlid et al. 2013) showed a significant decrease in grip strength.

In most articles where sports parameters have seemingly *not* been effected by RWL the authors tend to reflect upon the results in a concordant manor surrounding the notion that there could be a slight learning effect on seasoned athletes (Talaei et al. 2017; Rejic et al. 2016; Cengiz 2015; Durguerian et al. 2015; Cullen et al. 2015a; Cullen et al. 2015b; Yang et al. 2015; Sagyama et al. 2014; Artioli et al. 2010).

4. Discussion

The purpose of this study was to investigate effects of RWL on physiological aspects, psychological aspects, and sport specific performance. This study further aimed to investigate what methods are being used when studying the effects of RWL~~.~~ To acquire relevant data a systematic review was conducted to examine what scientific research had disentangled this far on the topic.

4.1 What are the physiological and psychological effects of RWL?

As seen in the results paragraph there were quite a lot of side-effects accompanying the use of RWL of >4% of total body weight. The most evident, and perhaps the least surprising, finding was that the athletes suffer from dehydration with significantly elevated levels of USG, (Rejic et al. 2016; Durguerian et al. 2015; Artioli et al. 2010; Cullen et al. 2015a; Cullen et al., 2015b; Armstrong et al. 2006; Finaud et al. 2006). This in itself one could find to be a sufficient indication that RWL is a suboptimal way of preparing for a competition. In addition the utilization of RWL also have a negative impact on both cognitive functions and mood (Durguerian et al. 2015; Marttinen et al. 2011; Hall et al. 2001), it even affects a central factor such as reaction time (Cullen et al. 2015b). With this information at hand the use of RWL strategies in connection with sports seem more than questionable. Further reflections on why these side-effects do not intimidate athletes and coaches from using and promoting RWL as a part of the sports seem appropriate.

Regarding the cultural aspects of the rooting of RWL this study could not draw any conclusion, however – another possible reason to take into consideration was that many of the negative physiological effects have been show to diminish after 4-12 hours if adequate recovery measures are implemented (Talaei et al. 2017; Cengiz 2015; Cullen et al. 2015b; Sagyama et al. 2014; Artioli et al. 2010). This on the other hand is a substantial risk factor because of the possibility of not having sufficient time between weight-in and the athletes initiated competition; nonetheless the amount of time in between might just be what “tricks” athletes into believing they are fully recovered. Some results however show that negative effects can remain for days after cessation of RWL and initiated recovery therewith (Rejic et al. 2016), and solely based on hemorheological parameters a limitation of performance capacity was suggested (Yang et al. 2015).

4.2 What are the sport specific effects of RWL?

The foremost evident finding that was supported was a maintained or increased relative peak anaerobic power (Cullen et al. 2015a; Marttinen et al. 2011; Artioli et al. 2010; Timpmann et al. 2008). Furthermore positive results in maintaining performance for factors such as; Counter Movement-Jump, clean, snatch, judo specific test, balance test (Cullen et al. 2015a; Durguerian et al. 2015; Artioli et al. 2010). A possible backlash towards this otherwise encouraging outcome was the fact that absolute peak power seem to decline (Cengiz 2015; Cullen et al. 2015a; Cullen et al. 2015b; Marttinen et al. 2011; Artioli et al. 2010; Timpmann et al. 2008), and earlier it was stated by Reale, Slater & Burke (2017), who conducted a meta-analysis, those performance variables not relative to body weight was impaired.

This leaves a quite ambiguous picture of the implications for sport specific performance one could be allowed to think. Although reflecting upon whether or not RWL have a positive outcome on sports performance might seem like a challenge, most of the articles discuss the possible long-term effects and conclude that regardless of minute short-term performance enhancement in some variables it is most probably not a sustainable environment for an elite athlete (Talaei et al. 2017; Rejic et al. 2016; Cengiz 2015; Durguerian et al. 2015; Cullen et al. 2015a; Cullen et al. 2015b; Yang et al. 2015; Sagyama et al. 2014; Artioli et al. 2010). This factor was not included in this systematic review however, but might be one of the more important aspects of determining if RWL is counterproductive for sports performance.

4.3 What methods are being used?

Although some articles did use the same methods there seem to be a lack of consensus regarding how RWL usually is examined. USG, blood samples, dietary journal, wingate, and POMS, however seem to be the most frequently used methods, yet only a small portion of the articles utilize these methods. The lack of unity amongst choice of methods impedes the possibility of drawing conclusions from the available data. The most frequently used methods do seem highly relevant to study the effects of RWL however.

The lack of unity might be a side-effect of the mixed population of test subjects, even though this review mostly includes articles who studied martial arts athletes. Nonetheless, to further study RWL some sort of standardization would be appropriate.

4.4 Quality of articles

Out of the 20 articles included only seven were considered to be of high quality, while the remaining 13 were considered to be of average quality. Out of those only four articles were considered to be of low risk of systematic bias, and the remainder of average risk of systematic bias. This meaning a majority of the articles were of average quality with an average risk of systematic bias, which in other words diminishes the evidence of this review.

There were two factors all through which affected the rating of most articles; selection bias, and treatment bias. This means that in most cases the test subjects were chosen because of certain characteristics and thereto the studies were not blinded.

A contributing factor to the low rating was of course study design. Most of these articles were considered quasi-experimental, this means they lack elements otherwise included in a true experimental design. Consequently these factors may effects the external validity of the results, especially since the participants were not chosen at random to represent a greater population. However, most studies were concordant as for people, places, time, and setting in comparison to where RWL usually is applied, which strengthens the external validity.

In addition, what was not processed in the screening tools was the sample size of each study. Most articles only include a handful of participants which makes the results easily skewed.

4.5 Methodological reflections

As a consequence of the chosen topic a few assessments have been necessary. The subject at hand was a fairly small area, research wise, and a great variety of methods and study designs have been used to examine the effects of RWL. This acknowledgement lead to inclusion criteria's which are considerably open and liberal, which further could lead to a diminished quality of the review – and moreover can undermine the reliability of the results. Nonetheless this review played an important part in examining a field which was severely lacking evidence based guidelines but its practice is widely spread amongst athletes and coaches.

Furthermore, the inclusion/exclusion criteria's, which were based on the behavior around RWL established with the information presented in the introduction, might have been open in some sense but too narrow in another. This review excluded articles who had been studying RWL below a minimum loss of 4% of TBW, in addition interventions that lasted longer than a week were also excluded. During the systematic screening, articles examining RWL in contexts of <4% loss of TBW were discovered as well as interventions lasting longer than one week. Other studies who examined the acute effects of dehydration were also excluded. The mentioned excluded articles might have contained valuable information regarding RWL implications – and with other, and perhaps better, inclusion criteria's designed to capture a wider range of articles with higher quality, a higher quality depiction of the evidence of the subject might have been possible. On the other hand the chosen criteria's are in alignment with the current perception of the actual applications of RWL in sports contexts.

Reconnecting to the latter mentioned, the actual application of RWL where noticeably a great effecting factor when deciding the criteria's. The inclusion of quasi-experimentally designed studies seemed reasonable in this context to be able to examine the effects of RWL as close to reality as possible. This however further led to another conundrum regarding methodological issues. Additional explorations of research methodology were needed – and in conclusion; screening templates for randomized studies do not enable a consistent classification across the full range of studies. These templates can lead to an inappropriate and overly simplistic classification of risk of bias within quasi-experimental studies (Hombrados & Waddington 2012). Quasi-experimental studies are otherwise not necessary of lower quality than true experiments, although usually considered to have a lesser internal validity, they however functions under different premises – premises that let the study examine a more natural situation (Hassmén & Hassmén 2008).

4.6 Future Research

The two foremost evident problems with the included articles were the low quality together with a lack of unity among methods used to examine the effects of RWL. For future research a more standardized protocol is needed to increase the quality, most study designs should lean towards a true experimental design. This because eliminating the risk of systematic bias is paramount for the field to make progress. And once again emphasizing the importance of a collective view of which methods should be applied, as of today's "standard" – USG, bloodsamples, wingate, and POMS, are relevant methods to use with methods already being used in mind.

Additional further research should include longitudinal studies examining the long-term effects of consecutive RWL, or weight cycling. Some articles already provide a somewhat depiction of long-term weight cycling, however it was not put in a sport specific context in a matter of athlete burnout, injury prevalence, and early ended sports carriers. This to define and strengthen the representation of the long-term implications of RWL on sports performance.

4.7 Practical implications

According to the given parameters one could deduce that bodyweight sensitive sports which are closed skill are better suited for the usage of RWL. The performance gain was exclusively in relation to bodyweight as presented in this review. To evade the negative effects on cognitive performance the task should have as many already set parameters as possible.

Nonetheless the possible problematics surrounding RWL still withstands, the information at hand can be of good use to inform decisionmakers about what future research to conduct to better determine practices regarding weight classes and weigh-ins. As seen amongst the American collegiate wrestlers the rules for weight cycling have been restricted as a consequence of the negative effects of RWL which costed three individuals their lives in 1997 (Davis et al. 2002). Similar procedures could be implemented in additional sports and regardless of which country the athlete practices the sport.

5. Conclusion

Although athletes were found dehydrated performance was still maintained in sport specific factors. However, this systematic review also found an overall lack of quality within the studies conducted. Sufficient scientific evidence was not found to draw reliable conclusions, additional studies of higher quality are needed for future reviews.

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Appendix 1 – Searches

Aim & Research questions

The aim of this study was to investigate the effects of RWL in relation to physiological, psychological, and sport specific performance. The study further aim to investigate the impact of using RWL strategies and if the utilization appear counterproductive for weight sensitive sports. To examine the above the following research questions have been used:

- What physiological and psychological effects can be found in concurrence with rapid weight loss.
- And how does the effect of rapid weight loss impact sports performance.

PubMed	**Found**	**Relevant**
Rapid weight loss and athletes	57	40
Rapid weight loss and sports	121	30
(Dehydration or hypohydration) and athletic performance	326	13
SportDiscus		
Rapid weight loss and athletes	118	43
Rapid weightloss and sports	186	12
(Dehydration or hypohydration) and athletic performance	319	14
Cochrane Librairy		
Rapid weight loss and athletes	6	2
Rapid weight loss and sports	4	
(Dehydration or hypohydration) and athletic performance	26	

Searches where conducted between Jan-Mar 2017

Appendix 2 – Quality screening tool

Modifierad granskningsmall för kvantitativa studier

1. Är studiens syfte tydligt beskrivet?	Ja	Nej
2. Finns frågeställningar beskrivna?	Ja	Nej
3. Är designen av studien relevant för att besvara frågeställningen?	Ja	Nej
4. Finns inklusions- och exklusionskriterier beskrivna?	Ja	Nej
5. Beskrivs det hur urvalet gått till?	Ja	Nej
6. Framgår det hur många deltagare som deltagit i studien?	Ja	Nej
7. Är undersökningsgruppen lämplig?	Ja	Nej
8. Beskrivs det vilka mätmetoder som använts?	Ja	Nej
9. Beräknas reliabiliteten?	Ja	Nej
10. Diskuteras validiteten?	Ja	Nej
11. Finns eventuellt bortfall beskrivna?	Ja	Nej
12. Finns etiska resonemang?	Ja	Nej
13. Diskuteras analys och tolkning av resultat?	Ja	Nej
14. Finns det en röd tråd genom hela artikeln?	Ja	Nej
15. Kan resultatet generaliseras till annan population?	Ja	Nej
16. Har resultatet klinisk betydelse?	Ja	Nej

Kvalitetsgränser:

Hög kvalitet: 13-16 poäng

Medel kvalitet: 8-12 poäng

Låg kvalitet: 0-7 poäng

Ja = 1 poäng

Nej = 0 poäng

(Forsberg & Wengström, 2013)

Appendix 3 – Risk of systematic bias screening tool

Granskningen av en studie gäller i första hand studiekvalitet, det vill säga risk för systematiska fel och risk för intressekonflikter (A). I den sammanvägda bedömningen av alla inkluderade studier enligt GRADE inkluderar man också studiernas överensstämmelse (B), överförbarhet (C), precision (D), publikationsbias (E), effektstorlek (F), dos–responssamband (G) och sannolikhet att effekten är underskattad (H).

Författare: ____________________ År: _________ Artikelnummer: __________

Alternativet "oklart" används när uppgiften inte går att få fram från texten. Alternativet "ej tillämpligt" väljs när frågan inte är relevant. Specificera i kommentarsfältet.

A. Granskning av studiens begränsningar – eventuella systematiska fel (bias)	**Ja**	**Nej**	**Oklart**	**Ej tillämpligt**
A1. Selektionsbias				
a) Användes en lämplig randomiseringsmetod?	☐	☐	☐	☐
b) Om studien har använt någon form av begränsning i randomiseringsprocessen (t ex block, strata, minimisering), är skälen till detta adekvata?	☐	☐	☐	☐
c) Var grupperna sammansatta på ett tillräckligt likartat sätt?	☐	☐	☐	☐
d) Om man har korrigerat för obalanser i baslinjevariabler, har det skett på ett adekvat sätt?	☐	☐	☐	☐
Kommentarer:				
Bedömning av risk för selektionsbias:	Låg / Medelhög / Hög			

A2. Behandlingsbias	**Ja**	**Nej**	**Oklart**	**Ej tillämpligt**
a) Var studiedeltagarna blindade?	☐	☐	☐	☐
b) Var behandlare/prövare blindade?	☐	☐	☐	☐
c) Var följsamhet i grupperna acceptabel enligt tillförlitlig dokumentation?	☐	☐	☐	☐
d) Har deltagarna i övrigt behandlats/exponerats på samma sätt bortsett från interventionen?	☐	☐	☐	☐
Kommentarer:				
Bedömning av risk för behandlingsbias:	Låg / Medelhög / Hög			

A. fortsättning	Ja	Nej	Oklart	Ej till-lämpligt
A3. Bedömningsbias (per utfallsmått)				
a) Var utfallsmåttet okänsligt för bedömningsbias?	☐	☐	☐	☐
b) Var de personer som utvärderade resultaten blindade för vilken intervention som gavs?	☐	☐	☐	☐
c) Var personerna som utvärderade utfallet opartiska?	☐	☐	☐	☐
d) Var utfallet definierat på ett lämpligt sätt?	☐	☐	☐	☐
e) Var utfallet identifierat/diagnostiserat med validerade mätmetoder?	☐	☐	☐	☐
f) Har utfallet mätts vid optimala tidpunkter?	☐	☐	☐	☐
g) Var valet av statistiskt mått för rapporterat utfall lämpligt?	☐	☐	☐	☐
h) Var den analyserade populationen (ITT eller PP) lämplig för den fråga som är föremål för studien?	☐	☐	☐	☐
Kommentarer:				
Bedömning av risk för bedömningsbias:	Låg / Medelhög / Hög			

A4. Bortfallsbias (per utfallsmått)				
a) Var bortfallet tillfredsställande lågt i förhållande till populationens storlek?	☐	☐	☐	☐
b) Var bortfallet tillfredsställande lågt i förhållande till storleken på utfallet?	☐	☐	☐	☐
c) Var bortfallets storlek balanserad mellan grupperna?	☐	☐	☐	☐
d) Var relevanta baslinjevariabler balanserade mellan de som avbryter sitt deltagande och de som fullföljer studien?	☐	☐	☐	☐
e) Var den statistiska hanteringen av bortfallet adekvat?	☐	☐	☐	☐
f) Var orsakerna till bortfallet analyserade?	☐	☐	☐	☐
Kommentarer:				
Bedömning av risk för bortfallsbias:	Låg / Medelhög / Hög			

A. fortsättning	Ja	Nej	Oklart	Ej till-lämpligt
A5. Rapporteringsbias				
a) Har studien följt ett i förväg publicerat studieprotokoll?	☐	☐	☐	☐
b) Angavs vilket/vilka utfallsmått som var primära respektive sekundära?	☐	☐	☐	☐
c) Redovisades alla i studieprotokollet angivna utfallsmått på ett fullständigt sätt?	☐	☐	☐	☐
d) Mättes biverkningar/komplikationer på ett systematiskt sätt?	☐	☐	☐	☐
e) Redovisades enbart utfallsmått som angivits i förväg i studieprotokollet?	☐	☐	☐	☐
f) Var tidpunkterna för analys angivna i förväg?	☐	☐	☐	☐
Kommentarer:				
Bedömning av risk för rapporteringsbias:	Låg / Medelhög / Hög			

A6. Intressekonfliktbias				
a) Föreligger, baserat på författarnas angivna bindningar och jäv, låg eller obefintlig risk att studiens resultat har påverkats av intressekonflikter?	☐	☐	☐	☐
b) Föreligger, baserat på uppgifter om studiens finansiering, låg eller obefintlig risk att studien har påverkats av en finansiär med ekonomiskt intresse i resultatet?	☐	☐	☐	☐
c) Föreligger låg eller obefintlig risk för annan form av intressekonflikt (t ex att författarna har utvecklat interventionen)?	☐	☐	☐	☐
Kommentarer:				
Bedömning av risk för intressekonfliktbias:	Låg / Medelhög / Hög			

(SBU, 2014)

Appendix 4 – Quality screening

Article	Points	Grade	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
J. Finaud et al. 2006, "Competition and Food Restriction Effects on Oxidative Stress in judo"	11	AVG	1	0	1	1	0	1	1	1	0	0	1	1	1	1	0	1
I. Ozkan et al 2016, *"Dehydration, skeletal muscle damage and inflammation before competitions*	11	AVG	1	0	1	1	1	1	1	1	0	0	1	0	1	1	0	1
S. Mendes et al. 2013, *"Effect of rapid weight loss on performance in combat sport male athletes:*	12	AVG	1	1	1	1	0	1	1	1	0	0	1	1	1	1	0	1
B. Matulevičiūtė et al. 2013, *"Effects of two different methods reducing body mass (rapid and me*	9	AVG	1	0	1	0	0	1	1	1	0	0	1	0	1	1	0	1
H. Sagyama et al. 2014, *"Effects of rapid weight loss and regain on body composition and energy e*	13	High	1	1	1	0	1	1	1	1	0	1	1	1	1	1	0	1
C. Hall et al. 2001, *"Effects of rapid weight loss on mood and performance among amateur boxers*	12	AVG	1	0	1	1	1	1	1	1	0	1	1	0	1	1	0	1
A. Cengiz 2015, *"Effects of self-selected dehydration and meaningful rehydration on anaerobic po*	12	AVG	1	1	1	0	1	1	1	1	0	0	1	1	1	1	0	1
R.Marttinen et al. 2011, *"Effects of self-selected mass loss on performance and mood in collegiate*	13	High	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1
S. Cullen et al. 2015(a), *"Lack of Effect of Typical Rapid-Weight-Loss Practices on Balance and Ana*	14	High	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1
L. Armstrong et al. 2006, *"No Effect of 5% Hypohydration on Running Economy of Competitive Rur*	12	AVG	1	1	1	0	1	1	1	1	0	0	1	1	1	1	0	1
D. Rejic et al. 2016, *"Rapid body mass loss affects erythropoiesis and hemolysis but does not impa*	11	AVG	1	0	1	0	1	1	1	1	0	0	1	1	1	1	0	1
W. Yang et al. 2015, *"Rapid Rather than Gradual Weight Reduction Impairs Hemorheological Parar*	9	AVG	0	0	1	0	0	1	1	1	0	0	1	1	1	1	0	1
M. Jlid et al. 2013, *"Rapid weight loss alters muscular performance percieved extertion as well as p*	12	AVG	1	0	1	0	0	1	1	1	1	1	1	1	1	1	0	1
D. Rejic et al. 2013, *"Rapid Weight Loss and the Body Fluid Balance and Hemoglobin Mass of Elite*	12	AVG	1	0	1	0	0	1	1	1	1	1	1	1	1	1	0	1
V. Coswig et al 2015, *"Rapid Weight Loss Elicits Harmful Biochemical and Hormonal Responses in M*	12	AVG	1	0	1	1	1	1	1	1	0	0	1	1	1	1	0	1
G. Artioli et al. 2010, *"Rapid weight loss followed by recovery time does not affect judo-related pe*	15	High	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
S. Cullen et al. 2015(b), *"The impact of making-weight on cognitive performance in apprentice joc*	14	High	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1
M. Talaei et al. 2017, *"The impact of rapid weight loss (4%) on leptin, adiponectin, and insulin resis*	12	AVG	1	0	1	0	1	1	1	1	0	1	1	1	1	1	0	1
A. Durguerian et al. 2015, *"Weight Loss, Performance and Psychological Related States in High-lev*	15	High	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
S. Timpmann et al. 2008, "Acute effects of self-selected regimen of rapid body mass loss in comb	13	High	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	1

Appendix 5 – Risk of systematic bias screening

	Selektionsbias	Behandlingsbias	Bedömningsbias	Bortfallsbias	Rapporteringsbias	Intressekonfliktsbias	Sammanvägd risk
A. Durguerian et al. 2015, *"Weight Loss, Performance and Psychological Related States in High-level Wei*	low	AVG	low	low	low	low	low
G. Artioli et al. 2010, *"Rapid weight loss followed by recovery time does not affect judo-related performa*	high	AVG	low	low	low	low	AVG
S. Cullen et al. 2015(a), *"Lack of Effect of Typical Rapid-Weight-Loss Practices on Balance and Anaerobic*	high	AVG	low	low	low	low	AVG
S. Cullen et al. 2015(b), *"The impact of making-weight on cognitive performance in apprentice jockeys"*	AVG	AVG	low	low	low	low	low
H. Sagyama et al. 2014, *"Effects of rapid weight loss and regain on body composition and energy expend*	high	AVG	low	low	low	low	AVG
R. Marttinen et al. 2011, *"Effects of self-selected mass loss on performance and mood in collegiate wrest*	high	AVG	low	low	low	low	AVG
S. Mendes et al. 2013, *"Effect of rapid weight loss on performance in combat sport male athletes: does a*	high	AVG	low	low	low	low	AVG
V. Coswig et al 2015, *"Rapid Weight Loss Elicits Harmful Biochemical and Hormonal Responses in Mixed M*	AVG	AVG	low	low	low	low	low
A. Cengiz 2015, *"Effects of self-selected dehydration and meaningful rehydration on anaerobic power an*	high	AVG	low	low	low	low	AVG
C. Hall et al. 2001, *"Effects of rapid weight loss on mood and performance among amateur boxers"*	high	AVG	low	low	low	low	AVG
D. Rejic et al. 2016, *"Rapid body mass loss affects erythropoiesis and hemolysis but does not impair aero*	high	AVG	low	low	low	low	AVG
M. Jlid et al. 2013, *"Rapid weight loss alters muscular performance percieved extertion as well as posturo*	high	AVG	low	low	low	low	AVG
M. Talaei et al. 2017, *"The impact of rapid weight loss (4%) on leptin, adiponectin, and insulin resistance*	high	AVG	low	low	low	low	AVG
L. Armstrong et al. 2006, *"No Effect of 5% Hypohydration on Running Economy of Competitive Runners a*	high	AVG	low	low	low	low	AVG
J. Finaud et al. 2006, "Competition and Food Restriction Effects on Oxidative Stress in judo"	low	AVG	low	low	low	low	low
D. Rejic et al. 2013, *"Rapid Weight Loss and the Body Fluid Balance and Hemoglobin Mass of Elite Amate*	high	AVG	low	low	low	low	AVG
I. Ozkan et al 2016, *"Dehydration, skeletal muscle damage and inflammation before competitions amon*	high	AVG	low	low	low	low	AVG
B. Matulevičiūtė et al. 2013, *"Effects of two different methods reducing body mass (rapid and medium r*	high	AVG	low	low	low	low	AVG
W. Yang et al. 2015, *"Rapid Rather than Gradual Weight Reduction Impairs Hemorheological Parameters*	high	AVG	low	low	low	low	AVG
S. Timpmann et al. 2008, "Acute effects of self-selected regimen of rapid body mass loss in combat spo	high	AVG	low	low	low	low	AVG