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**Article Title:** Regain in Body Mass After Weigh-In is Linked to Success in Real Life Judo Competition

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Abstract

We examined the relationship between the re-gain of body mass (BM) after weigh-in and success in real-life judo competition. Eighty-six (36♀/50♂) senior judoka volunteered for this observational study of an international judo competition. Subjects were weighed at the official weigh-in and one hour before their first competition fight (15-20 hours later). Regain in BM after weigh-in was compared between medal winners and non-medallists, winners and losers of each fight, males and females and across weight divisions. Heavyweights were excluded from analysis. Pre-fight BM was greater than BM at official weigh-in for both males and females, with % BM gains of 2.3±2.0 (p=<0.0001; ES= 1.59; CI95% [1.63, 2.98]) and 3.1±2.2 (p=<0.0001; ES=2.03; CI95% [2.30, 3.89]), respectively. No significant differences were found between weight divisions for post weigh-in BM re-gain. Differences in post weigh-in BM re-gain were significantly higher in medal winners than non-medallists for males and females combined (1.4±0.4% BM; p=0.0026; ES= 0.69; CI95% [0.05, 2.34]) and for males alone (1.5±0.6% BM; p=0.017; ES= 0.74; CI95% [0.02, 2.64]), but not for females (1.2±0.7% BM; p=0.096; ES=0.58; CI95% [-0.02, 2.31]). Differences in BM re-gain after weigh-in between winners and losers were significant across all fights (0.9±0.3% BM; p=0.0021; ES= 0.43; CI95% [0.31, 1.41]) but not for first round fights (0.8±0.5% BM; p=0.1386, ES=0.38; CI95% [-0.26, 1.86]). Winners showed a greater re-gain in BM post weigh-in than losers. This may reflect the greater magnitude of the BM loss needed to achieve weigh-in targets which also relates to the experience level of successful athletes.

Keywords: rapid weight loss, combat sport, performance
Introduction

Combat sports typically separate athletes into weight divisions in an attempt to create an ‘even playing field’ for size-matched opponents. An official weigh-in is held before competition to ensure each athlete’s weight is within the lower and upper limits of the weight division they contest for. However, the majority of combat sport athletes appear to undertake rapid weight loss practices before weigh-in (Artioli, Gualano et al. 2010, Brito, Roas et al. 2012, Franchini, Brito et al. 2012), with average losses equivalent to ~5% body mass (BM) being commonly reported however ranges vary between and within different combat sports (Artioli, Gualano et al. 2010, Kordi, Ziaee et al. 2011, Brito, Roas et al. 2012, Franchini, Brito et al. 2012). Acute “weight making” strategies, which predominantly reduce BM via losses of fluid (Fogelholm 1994), are used to provide the athlete with the theoretical benefit of fighting in a division that is lower than their habitual BM against smaller/lighter competitors; thus gaining a potential size and/or leverage advantage. This practice occurs in spite of warnings by health professionals (Oppliger, Case et al. 1996), as well as evidence that rapid weight loss of even 2% BM can cause an impairment in aerobic performance (Fogelholm 1994) with greater BM loss affecting anaerobic performance measures relevant to combat sport athletes (Horswill 1992, Franchini, Del Vecchio et al. 2011, Kraft, Green et al. 2012). The persistence of weight making may be due to the transient nature of negative performance effects and/or ingrained practices in combat sport culture (Pettersson, Pipping Ekström et al. 2013). Indeed, many combat sport athletes believe rapid weight loss is an integral part of their sport (Oppliger, Landry et al. 1993) and there are circumstances within combat sports that support or at least tolerate the involvement of such practices.

First, in combat sports, an athlete’s performance is measured relative to their opponent in an open environment. Therefore combat sport athletes don’t have to perform at their physiological best to win; they simply have to perform better than their opponents. The second factor favouring these practices is the period between the official weigh-in and the start of competition which
creates an opportunity for athletes to ingest foods and fluids to restore hydration and fuel status, attenuating the negative effects of rapid weight loss (Artioli, Iglesias et al. 2010, Franchini, Brito et al. 2012). In the sport of judo, the time between the official weigh-in and the start of the competition may be up to 20 hours, supporting the opportunity for severe weight loss practices. Recent rule changes in judo have tried to limit extreme weight making by stating athletes are not allowed to weigh more than 5% above their weight division at the time of random weight checks conducted the morning of competition.

It is of interest to investigate actual weight making practices of athletes in specific combat sports to document the magnitude of BM losses and factors that support the continuation of a “weight making culture”. However, the logistics of monitoring acute weight loss are difficult (athletes typically arrive only hours before weigh-in) and are likely to interfere with real-life choices. Additionally, chronic weight loss methods (e.g. body fat loss) overlap with acute weight loss strategies making them difficult to separate. Nevertheless, in studies of wrestling and taekwondo, the re-gain in BM between the official weigh-in and start of competition has been used as a surrogate measure of the magnitude of the acute weight loss needed to achieve a weigh-in target (Horswill, Scott et al. 1994, Kazemi, Rahman et al. 2011). To date, few studies have examined the relationship between post weigh-in weight re-gain and competitive success and none in Judo. Given the different physiological demands of judo (Franchini, Del Vecchio et al. 2011), its popularity worldwide and its prominence at the summer Olympic games (offering 56 medals), advancing empirical knowledge of this specific sport is valuable.

Accordingly, the aim of the present study was to measure the re-gain of BM between the official weigh-in and the first match (“Post weigh-in BM re-gain”) in a judo competition and examining its relationship to competitive success (chances of winning fights and medalling) among judo players as a whole and their various sub-groups.
Methods

This study investigated the relationship between post official weigh-in BM re-gain and competition success at an international judo competition. Males (n=50) and females (n=36) in the senior categories of the Australian Capital Territory International Judo Open (Judo Federation Australia) volunteered to participate in this study, providing written informed consent. The study was approved by the higher research ethics committee at the University of Sunshine Coast, Queensland, Australia.

The competition took place over three days, involving two official weigh-in processes and two days of competition across the various weight divisions. The first weigh-in took place in the afternoon of day one for those competing on day two and the second weigh-in took place in the afternoon of day two for those competing on day three. All athletes were required to weigh-in between 5-7pm the evening before competition. Competition started from 10am on each competition day and finished before 6pm.

Researchers collected BM measurements of judoka pre warm-up, one hour before their first fight, which represented a period of 15 to 20 hours from the official weigh-in. Both the first (official weigh-in) and the second (pre-fight) BM measurements were undertaken on the same scales (Tanita, Japan, BWB800S). Where possible judoka were weighed in the same clothing. In situations where this was not possible details of clothing were noted and later weighed separately to account for these differences.

Descriptive statistics have been used to report the change in BM from official weigh-in to competition in terms of absolute values (kg) and percentage BM. Further analyses were completed according to sex, weight division and competition success. A repeated measures two-way analysis of variance (ANOVA) with Bonferroni post-hoc tests was used to compare official weigh-in BM and pre-fight BM between males and females. For between-subject comparisons, Levene’s test of homogeneity was conducted followed by unpaired t-tests when single comparisons were made (i.e.
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between medallists and non-medallists; between winners and losers) and by one-way ANOVA with a Bonferroni post-hoc test when multiple comparisons were made (between weight divisions). In recognition of the multiple sampling of this data set, a Bonferroni correction was applied to all t-test findings, by reducing the level of significance to P<0.0125. Additionally, 95% confidence intervals (CI95%) and Cohen d effect sizes (ES) have been reported when appropriate. The magnitudes of these ES were classified as trivial (0–0.19), small (0.20–0.49), medium (0.50–0.79) and large (0.80 and greater) using the scale advocated by Cohen (Cohen 1992). All data are reported as mean ± SD.

No male heavyweights (>100kg division) were included in the analysis since weight making is not required for this division. Analysis was completed using PRISM v 6.0 (GraphPad Software, San Diego, California, USA).

Results

Eighty-six of 110 athletes who competed in the tournament participated in the study. This sample included 44 of 45 medal winners across the 12 weight divisions examined. Four medals (one gold, one silver and two bronze) were awarded for each division with the exception of the male <100kg and female <78kg divisions in which only three and two athletes competed respectively. A two ANOVA with Bonferroni post hoc comparisons tested the BM change of judo athletes from weigh-in to pre-fight amongst males and females (Table 1). A significant effect was found for sex, F (1, 84) = 34.28, p = < 0.0001, and time F (1, 84) = 136.2, p = <0.0001; there was no significant interaction between time and sex F (1, 84) = 0.2041, p = 0.6526.

Pre-fight BM was significantly greater than weigh-in BM for both males and females with mean BM gains of 2.3% BM (p=<0.0001; ES= 1.59; CI95% [1.63, 2.98]) and 3.1% BM (p=<0.0001; ES=2.03; CI95% [2.30, 3.89]), respectively. No significant differences were found between males and females in post weigh-in BM re-gain with either absolute BM or percentage BM (Table 1.).

Mean changes in percentage BM by weight divisions are displayed in Figure 1. There were no significant differences between weight divisions for either males (F (5, 41) = 0.5732, p = 0.72), or
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females (F (5, 30) = 1.016, p = 0.4258). Medium and large effect sizes were found between many of the divisions. The number of females gaining more than 5% BM was 1, 2, 1, 0, 2, and 0 for the under 48kg, 52kg, 57kg, 63kg, 70kg and 78kg divisions, respectively. For males this was 3, 2, 3, 1, 0, and 0 for the under 60kg, 66kg, 73kg, 81kg, 90kg and 100kg divisions, respectively. This accounts for 17.4% of all athletes, and 25% of all medal winners.

When separated into medallists and non-medallists, significant differences in percentage BM re-gain were evident for males and females combined at 1.4±0.5% BM (p=0.0026; ES= 0.69; CI95% [0.05, 2.34]) and for males alone at 1.5±0.6% BM (p=0.017; ES= 0.74; CI95% [0.02, 2.64]) (Figure 2.). Differences between medallists and non-medallists were not significant for females at 1.2±0.7% BM (p=0.096; ES=0.58; CI95% [-0.02, 2.31]) (Figure 2).

Percentage BM re-gain of winners and losers of bouts are displayed in Figure 3. Results were analysed for all fights during the competition, as well as first round fights only. As BM was measured before the first fight we can only be truly confident in BM discrepancies between winners and losers in this round, as BM may have changed between the first and subsequent rounds. When the first round fights were analysed the fighter who re-gained the most BM won in 65.6% of the fights, the fighter who regained the least BM won in 31.3% of the fights and in 3.1% of the fights both fighters regained the same BM. However, differences in BM changes of 0.8±0.5% BM were not significant between winners and losers (p=0.1386, ES=0.38; CI95% [-0.26, 1.86]). When all fights were grouped together differences in BM change of 0.8±0.3% BM were found to be significant (p=0.0021; ES= 0.43; CI95% [0.31, 1.41]). The fighter who re-gained the most BM won in 59.6% of the fights, the fighter who re-gained the least BM won in 39.4% of the fights and in 1.0% of the fights both fighters regained the same BM.

Discussion

This is the first study to examine the relationship between the re-gain in BM between official weigh-in and competition in judo athletes and competitive success. As expected, fighters gained a
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significant amount of BM between the official weigh-in and their first fight. Of note, differences in the magnitude of BM gain were found between medallists and non-medallists, particularly for males, and between winners and losers when comparing results across all fights. Significance was not reached when analysing only female bouts or when analysing only first round fights, although this may have been the case given a larger sample size, as similar patterns and effect sizes were evident. Specifically, the more successful athletes recorded the greatest amount of weight re-gain compared with their less successful counterparts. On the basis that weight re-gain is a surrogate measure for the magnitude of BM loss before the official weigh-in, our findings suggest that successful judoka undertake more severe rapid weight loss practices and/or that more severe rapid weight loss practices provide fighters with a weight advantage which is associated with success in judo.

The findings of this study are in agreement with existing literature on weight category sports which reports that athletes compete at a BM that is significantly heavier than their official weigh-in BM (Horswill, Scott et al. 1994, Kazemi, Rahman et al. 2011). When interpreted in the context of previous (self-reported) data (Artioli, Gualano et al. 2010, Brito, Roas et al. 2012, Franchini, Brito et al. 2012), our results confirm that judoka undertake rapid weight loss before weigh-in, then attempt to reverse this loss before competition. In contrast to previous studies (Horswill, Scott et al. 1994, Kazemi, Rahman et al. 2011), we failed to detect differences in the magnitude of BM re-gain between males and females, or across weight divisions. However different patterns of practice with medium and large effect sizes were evident across weight divisions.

The findings of this study suggest a relationship exists between post weigh-in BM re-gain and competition success. Significant differences in BM re-gain were observed between medallists and non-medallists, and between winners and losers of each fight. These clear findings are in contrast to mixed results from the literature on competition practices of wrestlers and taekwondo athletes (Horswill, Scott et al. 1994, Wroble and Moxley 1998, Kazemi, Rahman et al. 2011). Previous studies have reported a competition advantage for athletes who re-gain the most BM among high
school wrestlers (Wroble and Moxley 1998), but not in higher level collegiate wrestlers (Horswill, Scott et al. 1994). It is acknowledged that success in combat sports such as judo and wrestling is determined by multiple factors including aerobic and anaerobic fitness, strength, power, psychological and emotional state and perhaps most importantly skill and technical proficiency (Callister, Callister et al. 1991, Horswill 1992). Among high school athletes, where many of these areas are not well developed, BM, power and strength may contribute more to an athlete’s overall attributes than in more experienced athletes. Furthermore, in the case of the study of elite collegiate wrestlers, which took place at the national championships of a highly selective competition, it is likely that this cohort consisted of a more homogenous group of already successful athletes. Indeed, in this study, the post-weigh increases in BM reported for winners and losers were substantially higher (5.3±2.0% vs 5.3±2.4% respectively), than that reported in the study of high school wrestlers (2.4±1.8% vs 1.9±1.6%). Such differences are in line with previous research suggesting higher calibre elite athletes engage in greater levels of rapid weight loss (and thus likely BM re-gain after weigh-in) than their junior counterparts (Horswill 1992, Artioli, Gualano et al. 2010, Brito, Roas et al. 2012, Franchini, Brito et al. 2012).

While our study extended the investigation of the relationship between post weigh-in BM re-gain and success to a sport not previously examined, we note also that the rules of judo competition allow a subtle but important difference in determination of success to be included into this body of research. While examining the outcome of individual fights provides one measure of success, many fights are decided by a judge’s decision and although judges are trained and experienced, they are not infallible. Indeed, the subjectivity of the referees’ decisions, a fighters’ individual tactics and the random nature of the competition draw in elimination tournaments introduces statistical noise into the interpretation of ‘competitive success’. However, since judo utilises a repechage system which allows fighters who lose to gold medallists in the early rounds to be reintroduced into competition, examination of the results of the entire competition (i.e. who wins
a medal and who does not) provides a less noisy model of competition success and thus enables stronger conclusions to be made.

Although the event involved in the present study was a high level competition involving experienced competitors and allowing international entrants, the lack of a qualification requirement allowed the attendance of athletes of lower calibre and experience. Therefore, although our results confirm a difference in weight making practices according to the success of the athletes, a limitation is that we cannot establish a cause and effect relationship. Indeed, it is likely that winners of individual fights and medallists were more successful in both their competitive skills and their ability to manipulate BM to reach a weight division goal than their less successful counterparts. Self-selection bias may mean that skilled combat sport athletes who are unable to manage weight making practices may drop out of the sport. While not in use at the present competition, the rule which enforces random weight checks the morning of competition forbidding athletes re-gaining more than 5% BM following weigh-in may have affected the results of our study if enforced. When this rule is enacted; athletes have the opportunity to reduce their BM to within the 5% limit avoiding disqualification. To account for this hypothetical situation, we re-analysed the data reducing BM re-gain values which were greater than 5%, to 5%. Whilst p values, means and standard deviations changed slightly, all of the previous significant findings remained. Similarly, as the male <100kg division and female <78kg divisions only contained three and two competitors respectively, all were awarded medals and this may have effected statistical significance. Thus we reanalysed the data omitting these values and again the significant findings remained.

**Novelty statement**

This study is the first to measure post official weigh-in BM re-gain in judo athletes in real-life competition. While the present findings cannot confirm that the magnitude of the re-gain in BM after official weigh-in is causative of success in judo, clear differences were revealed between
successful and non-successful athletes, in terms of the outcome of individual fights and overall competition success.

**Practical application**

Elite judo athletes engage in acute BM loss practices before official weigh-in and re-gain a substantial amount of BM prior to fighting. Physiologists and sports nutrition professionals should work with coaches and athletes to devise optimal methods of BM manipulation which minimise any performance decrements, while ensuring the health and wellbeing of the athlete. Additionally strategies may need to be developed to help judo athletes adhere to the rule governing random BM checks on the morning of competition which prohibit a BM gain above 5% of an athlete’s weight division.

**Acknowledgments, authorships, declarations of funding sources and conflicts of interest**

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The study was designed by Reid Reale (RR), Gary Slater (GS), Louise Burke (LB) and Gregory Cox (GC); data were collected and analysed by RR and LB; data interpretation and manuscript preparation were undertaken by RR, GC and LB. All authors approved the final version of the paper.

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**Conflict of Interest**

All the authors declare that they have no conflict of interest derived from the outcomes of this study.
References


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Figure 1 – Post weigh-in weight re-gain between weight divisions for females (A) and males (B). Analysis of variance revealed no significant differences between weight divisions.
Figure 2 – Post weigh-in weight re-gain between medal winners and non-medallists for; females (A); males (B); and all competitors (C). Unpaired t-tests revealed significant differences for all competitors and for males, but not for females. (* p = 0.017, ** p = 0.0026)
Figure 3 – Post weigh-in weight re-gain between winners and losers for; first round fights only (A) and all fights (B). Unpaired t-tests revealed significant differences when all fights were analysed, but not in first round fights. (** p = 0.0021)
Table 1 Weigh-in and pre-fight body mass by sex (mean ±SD)

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=</td>
<td>50 (58%)</td>
<td>36 (42%)</td>
<td>86</td>
</tr>
<tr>
<td>Weigh-in BM (kg)</td>
<td>72.1±11.4</td>
<td>58.7±8.6</td>
<td>66.5±12.3</td>
</tr>
<tr>
<td>Pre-fight BM (kg)</td>
<td>73.8±11.7*</td>
<td>60.5±8.8*</td>
<td>68.2±12.4</td>
</tr>
<tr>
<td>BM change (kg)</td>
<td>1.6±1.4</td>
<td>1.8±1.2</td>
<td>1.7±1.3</td>
</tr>
<tr>
<td>BM change (%)</td>
<td>2.3±2.1</td>
<td>3.1±2.1</td>
<td>2.6±2.1</td>
</tr>
</tbody>
</table>

* Denotes significant difference from weigh-in BM