The Impact of Making Weight on Physiological and Cognitive Processes in Elite Jockeys

Eimear Dolan, SarahJane Cullen, Adrian McGoldrick, Giles D. Warrington

Purpose: To examine the impact of making weight on aerobic work capacity and cognitive processes in a group of professional jockeys. Methods: Nine male jockeys and 9 age-, gender-, and BMI-matched controls were recruited to take part in two experimental trials, conducted 48 hr apart. The jockeys were asked to reduce their body mass by 4% in the 48 hr between trials, and controls maintained usual dietary and physical activity habits between trials. Aerobic work capacity was assessed by performance during an incremental cycle ergometer test. Motor response, decision making, executive function, and working memory were assessed using a computerized cognitive test battery. Results: The jockey group significantly reduced their body mass by 3.6 ± 0.9% (p < .01). Mean urine specific gravity (Usg) readings increased from 1.019 ± 0.004–1.028 ± 0.005 (p < .01) following this reduction in body mass. Peak work capacity was significantly reduced between trials in the jockey group (213 ± 27 vs. 186 ± 23 W, p < .01), although VO2peak (46.4 ± 3.7 vs. 47.2 ± 6.3 ml·kg·min⁻¹) remained unchanged. No changes were identified for any cognitive variable in the jockey group between trials. Conclusion: Simulation of race day preparation, by allocating a weight that is 4% below baseline body mass caused all jockeys to report for repeat testing in a dehydrated state, and a reduction in aerobic work capacity, both of which may impact on racing performance.

Keywords: dehydration, cognitive function, jockeys

“Making weight” refers to the practice of reducing body mass before competition and is typically undertaken for performance, legislative, or aesthetic reasons (Fogelhom et al., 1993). Horse racing is a unique example of a weight-category sport, whereby jockeys are allocated a body mass that they must attain for specific races. Designated weights are based on the ability and characteristics of the horse and not the rider, meaning that jockeys must align their body mass with that allocated to the specific horse that they ride in each race. Rapidly reducing body mass before competition appears to be an integral feature of horse racing (Dolan et al., 2011; Labadarios., 1993; Leydon & Wall, 2002; Moore et al., 2002). The primary methods of rapid weight loss reported as commonly used by jockeys are dehydration through a variety of mechanisms, including the use of saunas and exercising while wearing heavy clothing or sweat suits along with severely restricted fluid and food intake (Dolan et al., 2011). Such methods of weight regulation are consistent with research conducted in other weight-category sports, such as wrestling, boxing and judo (Burge et al., 1993; Oppliger et al., 1996) and are reported as having a negative impact on athletic performance (Filaire et al., 2001; Slater et al., 2005) and physiological (Burge et al., 1993; Umeda et al., 2004) and cognitive (Choma et al., 1998) processes. Such detriments are likely to occur through a combination of factors related to dehydration and nutritional imbalance. It has been suggested, however, that the impact of making weight is dependent on the time provided between weigh-in and competition and the recovery strategies employed during this time (Slater et al., 2005). This recovery opportunity is not afforded to jockeys, however, as they are required to weigh-in immediately before each race to ensure that they have met the designated body mass immediately before, and if placed, again after each race that they ride. This means that jockeys are not afforded the opportunity to replenish fluid and fuel stores that may have been depleted while making weight. The cross-sectional data that has been reported to date appears to indicate that striving to attain the required and fluctuating weights throughout the protracted racing season poses a major challenge to these athletes (Dolan et al., 2011; Warrington et al., 2009). Data from this research group have previously shown a high degree of racing-related injury (Warrington et al., 2009), dietary imbalance and regular use of strategies designed to induce rapid weight loss (Dolan et al., 2011), low bone mass (Dolan et al., 2012a) and an increased rate of bone turnover, and altered expression of biomarkers related to growth and metabolism (Dolan et al., 2012b). Limited research on the acute...
impact of making weight in jockeys is available, however, and so the aim of this study was to examine the effects of acute weight loss of the magnitude typically associated with race-day preparation on aerobic work capacity and cognitive function in jockeys.

Methods

Study Design Overview

Eighteen male participants were recruited to take part in this study (9 fully licensed male jockeys and 9 healthy male controls). The 9 jockeys were comprised of 5 national hunt (NH) and 4 flat riders. Approximately 263 jockeys were registered in Ireland during the time in which recruitment took place (139 NH, 62 flat, and 65 apprentices). Jockeys were recruited via advertisement at local racetracks. Control participants were recruited via email advertising to staff and students at a local university. The control group was a convenience-based sample and was recruited to provide an indication of test performance in the absence of a making weight intervention. The control group was age-, gender-, and BMI-matched to the jockey group. All jockeys and control participants were required to report for three separate trials: cognitive test habituation trial, baseline trial, and experimental trial. Trials 2 and 3 were conducted 48 hr apart, during which time the jockey group participants were required to reduce their body mass by 4% of their baseline measure using what means they typically would for racing. The control group was instructed to maintain usual dietary and physical activity habits between trials. This protocol was based on the results of a preliminary questionnaire designed to elicit information regarding typical race-day weight loss practices in jockeys. Jockeys were not provided with any specific instructions regarding weight loss techniques, as the intent of this particular protocol was to simulate actual race preparation practices as closely as possible. Hydration status, body composition, cognitive function, and peak aerobic work capacity (VO2peak) were measured.

Preliminary Questionnaire

Before implementation of this study, a questionnaire was completed by 24 male jockeys (10 Flat and 14 National Hunt) at racecourses around Ireland, from which the protocol (extent of weight loss and time allowed) for this study was determined. Participants provided information regarding typical nonracing and racing body mass and the greatest amount of mass lost before a race. Nonracing body mass was defined as the body mass that they typically rode at. This information was intended to provide an approximation of typical practices in this group, although variations are likely to occur, given the fluctuating nature of the body mass targets to be attained. Typical and lowest racing body mass were calculated as a percentage of usual self-reported nonracing body mass. Participants also provided information regarding the typical amount of time provided to achieve the stipulated weight standards.

Hydration Assessment

Hydration status was assessed by measurement of urine specific gravity (Usg) using the TS400 refractometer (Leica Microsystems, Germany). A value of 1.020 was accepted as the threshold of euhydration with values equal to or greater than this taken as being indicative of a dehydrated state (Armstrong, 2005; Oppliger & Bartok, 2002; Sawka et al., 2007).

Body Composition

Body mass and stature were assessed using standard procedures. Body mass was assessed in minimal clothing and reported to the nearest 100 g using a portable digital scales (Salter, Germany). Stretched stature was measured to the nearest mm using a portable stadiometer (Salter, Germany). Subcutaneous adipose tissue content was measured by skinfold assessment of the following seven sites: biceps, triceps, subscapular, suprailiac, abdominal, mid-thigh, medial calf. Body density was estimated using the regression equation based on the work of Withers et al. (1987) and then converted to % body fat using the equation proposed by Siri. (1956).

Weight Loss Techniques

All jockeys and control participants were asked to record dietary intake for the 48 hr between trials by completion of an estimated food diary. Participants were instructed to record the type, brand, quantity, and timing of all food intake. Where precise quantities were not provided, this was estimated based on standard UK portion sizes. In addition, jockeys were asked to record any strategies used to actively reduce body mass in the 48 hr between
trials. Precise instructions were provided to each participant regarding maintenance of this diary. All diaries were analyzed by the same technician using a validated dietary analysis package (Dietplan 6.3, Forestfield Software Ltd, Sussex, UK). The theoretical physical activity level (PAL) which reported intakes could be expected to sustain (Goldberg et al., 1991), was calculated based on estimated resting metabolic rate (Mifflin et al., 1990).

Cognitive Function
Cognitive function was assessed using a computerized test battery which included four tests measuring cognitive processes considered key for riding racehorses. These were speed of motor response, speed of decision making, executive function and working memory. A quantitative measure of each was provided by completion of tests of simple and choice reaction times (Erlanger et al., 2003), stroop (Sibley et al., 2006), and rapid visual information processing (RVIP; Smit & Rogers., 2000) respectively. Simple and choice reaction times were recorded as time (ms) to respond to the appearance of a single, or one of two, colored discs on the screen respectively. The stroop test recorded the time taken (ms) to react to both a baseline and an interference test trial. RVIP was recorded as time (ms) taken to respond to a sequence of three odd or three even numbers from the appearance of a series of digits between 1 and 9. The number of correct responses and errors were recorded, as well as time taken to respond. The entire test battery was conducted on the same laptop computer for all participants, and lasted approximately 15 min. Each specific cognitive function test was preceded by a brief preparatory trial. Habituation to the cognitive function test battery took place in a separate session whereby participants completed the entire test battery three times, in accordance with previous research (Collie et al., 2003). Efficacy of habituation was tested by conducting a repeated-measures ANOVA, whereby no further learning effect was deemed to have occurred if no significant change \(p < .05\) was identified between the third habituation trial and the baseline trial. All data were analyzed excluding any simple reaction time response > 500ms or any choice reaction time response > 750ms, or any response time that varied by more than two standard deviations from the mean.

Aerobic Work Capacity
Peak aerobic work capacity (\(VO_{2\text{peak}}\)) was measured using an incremental test on a Monark Ergomedic 828E cycle ergometer (GIH, Sweden). The test protocol began with a two minute warm up at 60 W followed by 3 min stages commencing at 60 W and increasing in 30 W increments until volitional exhaustion. The respiratory response was measured via indirect calorimetry using the Innocor Metabolic Cart (Innovision, Denmark). Oxygen uptake (\(VO_2\)), expired carbon dioxide (\(VCO_2\)) and the respiratory gas exchange ratio (RER) were continuously recorded throughout the test by the photoacoustic spectroscopy method. Heart rate was continuously measured throughout the test via telemetry using a Polar heart rate monitor (Polar Vantage NV, Port, Washington, NY). A subjective rating of perceptual effort was measured according to Borg’s rating of perceived exertion (RPE) scale (Borg, 1982).

Statistical Analysis
Normality of data distribution was determined using the Shapiro-Wilk test. Differences between the experimental and control groups were identified using an independent samples \(t\) test, or Mann Whitney \(U\) test depending on data distribution. Prepost within-group differences were assessed using a paired sample \(t\) test or Wilcoxon signed ranks test. Significance was accepted at the level of \(p < .05\). All data are presented as mean ± SD.

Results

Preliminary Questionnaire
A summary of the information from the weight loss questionnaire is presented in Table 1.

Anthropometric Data
Descriptive and anthropometric data of all participants are presented in Table 2. Groups were age, gender and BMI matched. Mean jockey body mass was reduced by 2.1 ± 0.5 kg between the test trials \((p < .01)\), equating to a mean loss of 3.6 ± 0.9%. Control participants maintained mean body mass between test trials.

Hydration Status
No baseline differences in hydration status, as measured by urine specific gravity were demonstrated between the groups. Both groups were categorized as being in a state of mean euhydration at the baseline trial \((U_{sg} < 1.020)\). Mean jockey Usg significantly increased following the reduction in body mass from 1.019 ± 0.004–1.028 ± 0.005 \((p < .01)\). All jockeys returned to complete the second trial in a state of dehydration ranging from 1.020–1.036. Control participants maintained a state of mean euhydration between test trials.

Weight-Loss Techniques
All jockeys \((n = 9)\) reported restricted fluid and energy intake as the primary means of body mass reduction. Sixty-seven percent \((n = 6)\) used additional acute means of body mass reduction. For example, 44% \((n = 4)\) of jockeys employed active dehydrating methods such as exercising while wearing heavy clothing to induce sweating, while 33% \((n = 3)\) used passive dehydration mechanisms (sweating induced through the use of saunas or hot baths). Mean jockey kilocalorie intake over the 48 hr period was 955 ± 357 kcal·day⁻¹ and a significant reduction in energy intake was demonstrated between day one and two of energy restriction (Day 1: 1488 ±
Twenty-two percent of jockeys (n = 2) abstained absolutely from all foods and fluids in the 24 hr preceding the retrial. Mean jockey total energy intake was sufficient to support a theoretical physical activity level (PAL) of 0.6 ± 0.2 when considered relative to estimated resting metabolic rate (RMR). When broken down into day one and day two energy intakes were sufficient to support a PAL of 1.0 ± 0.5 and 0.3 ± 0.2 respectively.

Cognitive Function

All cognitive results are presented in Table 3. Control participants showed a significant reduction in response time in the stroop test between test trials (see Table 3). The jockeys showed no significant cognitive changes between trials.

Aerobic Work Capacity

A summary of measured resting and peak physiological values are presented in Table 4. No differences were identified for any resting variable either between trials or between groups, although a trend toward a significantly decreased RER following the 4% reduction in body mass was identified within the jockey group (p = .076).

A number of differences were shown between the groups for baseline peak values. In particular control participants showed a significantly greater absolute peak aerobic capacity (VO₂ l·min⁻¹) and peak power output (PPO: watts) during the incremental cycling test at baseline than their jockey counterparts. This difference was removed when aerobic capacity and peak power output were expressed relative to body mass (ml·kg·min⁻¹ and
No differences were shown for any peak physiological variable between the test trials for the control group. No change in VO\(_2\)peak was identified in the jockey group between the test trials, although PPO—expressed both as watts and watts·kg\(^{-1}\)—was significantly reduced following weight reduction in this group (see Table 4). In addition, a trend toward a significantly increased peak heart rate was identified between trials in the jockeys (\(p = .061\)).

Submaximal VO\(_2\) (ml·kg·min\(^{-1}\)), recorded at set workloads (60, 90, 120 and 150 W) showed a significant increase following the reduction of body mass in the jockey group, appearing to indicate an increased oxygen demand at each workload (see Figure 1).
Heart rate response was elevated at each submaximal workload following the 4% reduction in body mass and this was shown to be significant at 120 and 150 W ($p < .05$; see Figure 2). In addition a trend toward significance was shown between test trials at 90 W ($p = .069$). Subjective reporting of perceived exertion (RPE) was also shown to be significantly increased at 150 W ($p < .05$). No between-trial differences were demonstrated within the control group for any physiological variable at any set workload.
Discussion

The aim of this study was to simulate typical race day preparation by allocating a specific weight (4% below baseline body mass) to each jockey, and examining the impact of attainment of this weight allocation on aerobic work capacity and cognitive function. Results indicate that a 4% reduction of body mass in 48 hr appeared to cause an increase in submaximal cardiovascular strain and reduced aerobic work capacity during an incremental cycle ergometer test. In contrast, no such decrements were shown to cognitive performance. Attainment of the specific weight allocation was achieved by limiting energy intake, and inducing dehydration, both of which are likely to have contributed to the reduced aerobic work capacity demonstrated.

Participants reduced body mass by 2.1 ± 0.5 kg within the 48 hr time frame allocated, representing a 3.6 ± 0.9% decrease from baseline. Results from the hydration and nutritional analysis suggest that this body mass loss may have been predominantly derived from body water and substrate stores. Mean Usg levels between trials showed a significant increase from 1.019 ± 0.004–1.028 ± 0.005 (p < .01). The high levels of dehydration reported within the current study are consistent with those previously reported in a group of flat jockeys on a competitive race day (Warrington et al., 2009) and are likely to impact on physiological function through a number of potential mechanisms, including reduced plasma volume (Coyle., 2004) or an anticipatory reduction in muscle force production in response to an increase in core body temperature (Tucker et al., 2004). Reported energy intake in the jockey group over the two days of body mass loss was shown to be insufficient to support even the most basic of metabolic processes (Mifflin et al., 1990) let alone match the daily energy demands of an active jockey preparing for competition. Previous pilot data appear to indicate that total daily expenditure on a competitive flat race day is high (3952 ± 577 kcal·day−1; Dolan et al., 2011; Indicate that total daily expenditure on a competitive preparing for competition. Previous pilot data appear to alone match the daily energy demands of an active jockey basic of metabolic processes (Mifflin et al., 1990) let was shown to be insufficient to support even the most dehydration, both of which are likely to have contributed to the reduced aerobic work capacity demonstrated.

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Limited research is currently available, regarding the impact of making weight on cognitive function, despite the importance of cognitive processes to sports performance. Landers et al. (2001) showed no cognitive impairments in a group of high-school wrestlers, following a 5% reduction in body mass. Choma et al. (1998) however, reported a significant decrease in short term memory following a 6.2% reduction in body mass within one week in a group of collegiate wrestlers. In addition, Labadarios (1993) previously reported that impairments to cognitive function occur in a dose response manner with body mass loss in jockeys. That study provided limited information on the methodologies and protocols used however, so limiting the interpretation and applicability of results. In addition, some studies examining the specific impact of dehydration (a known consequence of making weight) on cognitive function do appear to show a detrimental effect (Cian et al., 2001; Gopinathan et al., 1988; Tomporowski et al., 2007). This may have particular relevance for jockeys, given the speed and intensity of this sport. Cognitive skills such as decision making, reaction times and concentration could have a marked influence on the ability of the jockey to react to situations as they occur within the race. Potential situations include the action of the extremely powerful and unpredictable animal that they are riding and the positioning of all others riders in the race. None of the tested cognitive parameters were shown to be affected following the reduction of body mass in the current study however. A number of potential explanations are available, which may explain this finding. In particular, a limitation of many of the available studies involving dehydration and cognitive function is that the methods used to induce dehydration, namely heat and exercise (Cian et al., 2001; Gopinathan et al., 1988; Tomporowski et al., 2007) may be considered as individual physiological stressors, making isolation of the specific effects of dehydration difficult (Grandjean & Grandjean., 2007). Cognitive testing in this study was conducted before the exercise test, in an attempt to control for the confounding influence of exercise on cognitive performance. That no differences in cognitive performance were identified in this study is in agreement with the work of Szinnai et al., (2005) who showed no change to cognitive function following dehydration of 2.6% induced by 24 hr of water deprivation in healthy male and female participants. In addition, cognitive function in a study by Cian et al., (2001) was shown to be normalized 3.5 hr after dehydration induced through either passive exposure to heat or treadmill exercise, despite the continued level of hypohydration experienced. The previous literature in this area seems to suggest that dehydration per se may not be the primary limiting factor in cognitive performance at the levels currently studied, but that the actual methods used to induce dehydration may contribute to observed decrements. In addition, jockeys compete at weight throughout the year. The length and intensity of the season, and frequency of use of weight loss practices (Dolan et al., 2011) may have caused an attenuation of detrimental response, through a potential habituation to this cognitive stressor. A potential confounding factor to the cognitive results reported here is the significant change identified for stroop performance in the control group, despite the absence of intervention. No mechanistic explanation can be made for this potentially spurious finding. Further research within the domain of body mass loss and cognition in this group may be required to more fully examine this issue. Specifically, ongoing research
should focus on sport-specific cognitive parameters, and test batteries should be extended to include examination of the subjective and perceptual response of the athlete to making weight.

Although the precise physical demands of horse-racing have yet to be determined, it is thought to be a physically demanding sport (Trowbridge et al., 1995), placing a marked stress on the aerobic energy system. Cullen et al. (2012) reported that jockeys are required to perform at close to their physiological limit during a simulated flat race of 1,400m (75 ± 11% VO_{2peak} and 86 ± 7% HR peak). Eighteen male trainee jockeys participated in this study, and were required to ride a race-horse simulator, for the time taken to cover a distance of 1,400m at a maximum velocity of 30 kph For the time period equivalent to the final 300m of the race, the participants were encouraged to provide maximal effort, and to use a single hand grip to enable use of the whip.

Results from the current study appear to indicate a reduced aerobic work capacity and an increase in submaximal cardiovascular strain experienced, following the 4% reduction in body mass. Aerobic work capacity, as indicated by the VO_{2peak} during the incremental cycle ergometer test, did not change between trials. The peak power output (PPO; watts and watts·kg\(^{-1}\)) at which this peak was achieved was significantly reduced in the jockey group following the reduction in body mass however, appearing to indicate a reduction in aerobic work capacity. VO_{2} and heart rate results showed that a similar or greater magnitude of submaximal cardiovascular strain was experienced in the retrial, despite the reduction in PPO. It is likely that both dehydration and low energy intake had a role to play in the impairment to aerobic work capacity demonstrated which is in accordance with previous research (Casa et al., 2000; Cheung & McLellan., 1998; Coyle., 2004; Ebert et al., 2007; Oliver et al., 2007). The protocol employed within the current study was not designed to elucidate between these factors however, but to simulate actual race-day preparatory practices, and so it is unknown whether dehydration or energy imbalance had a predominant effect. Further research is required so to identify the precise mechanisms through which making weight may impact on physiological processes.

No significant change for any resting physiological variable was shown between trials for either the jockey or control group (see Table 3) although RER did show a trend toward decrease following the 4% reduction in body mass in the jockey group (p = .076). Decreased RER following dehydration induced rapid weight loss has previously been demonstrated in a group of competitive runners (Armstrong et al., 2006) and moderately active males (Cheung & McLellan., 1998) and may indicate a metabolic shift toward increased lipid oxidation. No further additional or significant changes in RER were demonstrated between trials in the current study however, and further research may be required to investigate the impact of body mass loss on substrate selection in this group. Examination of submaximal physiological data revealed a significant increase in both oxygen uptake (ml·kg·min\(^{-1}\)) and heart rate response at set workloads (60, 90, 120 and 150 W) demonstrating an increase in submaximal physiological strain and a reduced aerobic work efficiency demonstrated which is consistent with that reported in the related literature (Armstrong et al., 2006; Ebert et al., 2007; Moquin & Mazzeo., 2000).

A number of limitations are present within this study which may have impacted on the interpretation of results. A crossover design, whereby the jockeys had acted as their own controls, or where the control group were themselves jockeys, may have enabled an enhanced isolation of results shown, to the specific impact of reducing body mass. The length and intensity of the racing season, relatively small number of jockeys registered in Ireland and the invasive nature of testing did however limit access to this specific athletic group and so a convenience sample of age, gender and BMI matched participants was recruited. Food diaries, while practical for small group samples may be inaccurate as participants may under-report or misinterpret actual intake. In addition, it is likely that both dehydration and low energy intake had a role to play in the reduced aerobic efficiency and work capacity demonstrated here. The study design employed however aimed to examine the impact of weight reduction as typically experienced by this group, and so did not allow isolation of the independent influences of these parameters. Due to logistical and methodological issues, the sample size in this study was small, which may have affected identification and interpretation of subtle changes in physiological and cognitive function, as a small sample size may increase the possibility of spurious findings, due to issues with the range of data distribution. As cited however, the unique nature of this athletic group, and invasive nature of test intervention limited access to study participants. The application of test protocols to racing may be limited, but specific, valid, and reliable tests of racing performance are currently unavailable, although research in this area is ongoing. The results of the current study provides novel evidence of the impact of making weight on the more basic physiological and cognitive processes in a unique athletic population however, so providing a platform on which future, more sport specific research may be based.

**Conclusion**

Results from this study demonstrate that simulation of race-day preparation through allocating a specific weight of 4% below baseline body mass, to be attained within 48 hr, caused a reduction in aerobic work capacity in a group of professional jockeys. In contrast, no such differences were observed for cognitive function. The rapid weight loss practices adopted by the jockeys which focused predominantly on dehydration and restricted energy intake, were the likely causes of much of this impairment to physiological function—although precise mechanisms remain to be identified. The limited research available to date suggests that horse racing is a physiologically demanding activity, causing jockeys to
work close to their VO2peak. The reduced peak and submaximal aerobic capacity observed in the jockey group following the reduction in body mass may impact on racing performance in this physically demanding sport. In addition, racing is known to be an extremely high-risk sport (Hitchens et al., 2009), with a high incidence of falls and racing-related injury (Rueda et al., 2010). Making weight caused jockeys to return to the experimental trial in a dehydrated and apparently energy deficient state, with attenuations to physiological processes, all of which may have both performance and safety related implications for the jockey. Where feasible, jockeys should therefore be encouraged to adopt more gradual weight loss practices of a lesser magnitude before competition. Typical race-riding allocations have been reported as being lower than that which jockeys are capable of comfortably achieving, however (Warrington et al., 2009), and the appropriateness of current racing weight ranges must be called into question. In addition, research as to the specific demands of racing and development of more specific tests of racing performance may be required to inform best practices required to optimize preparation for competition and performance in this group.

Declaration of Funding

This research was supported by an unrestricted grant from the Irish Turf Club. The authors have nothing to disclose regarding any potential conflicts of interest.

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