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Longitudinal Changes in Body Composition and Resting Metabolic Rate in Male Professional Flat Jockeys: Preliminary Outcomes and Implications for Future Research Directions.

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ABSTRACT

Jockeys are unique given that they make-weight daily and therefore often resort to fasting and dehydration. Through increasing daily food frequency (during energy deficit), we have reported short-term improvements in jockey's body composition. Whilst these changes were observed over 6 –12 weeks with food provided, it is unclear if such improvements can be maintained over an extended period during free-living conditions. We therefore assessed jockeys over 5 years using DXA, RMR & hydration measurements. Following dietary and exercise advice, jockeys reduced fat mass from baseline of 7.1 ± 1.4 kg to 6.1 ± 0.7 kg and 6.1 ± 0.6 kg ($p < 0.001$) at years 1 and 5 respectively. Additionally fat free mass was maintained with RMR increasing significantly from 1500 ± 51 kcal.day^{-1} at baseline to 1612 ± 95 kcal.day^{-1} & 1620 ± 92 kcal.day^{-1} ($p < 0.001$) at years 1 and 5 respectively. Urine osmolality reduced from 816 ± 236 mOsmol.L^{-1} at baseline to 564 ± 175 mOsmol.L^{-1} & 524 ± 156 mOsmol.L^{-1} ($p < 0.001$) at years 1 and 5, respectively. The percent of jockeys consuming a regular breakfast significantly increased from 48% at baseline to 83% ($p = 0.009$) & 87% ($p = 0.003$) at years 1 and 5, alongside regular lunch from 35% to 92% ($p < 0.001$) & 96% ($p < 0.001$) from baseline to years 1 and 5, respectively. In conclusion, we report that improved body composition can be maintained in free-living jockeys over a 5-year period when appropriate guidance has been provided.

Key words: Jockey, body composition, RMR, hydration, meal frequency

INTRODUCTION

Professional jockeys are unique in weight restricted sports given that when race riding, they are required to make weight daily. Typically, this will require riding at different weights throughout the day since jockeys often have multiple rides which at certain meetings can be as many as 10 rides (O'Reilly et al., 2017). Unlike combat sports, jockeys are not afforded the opportunity to rehydrate after initial weight check (Burke et al., 2021) and must report the same weight or within 1 lb post-race of the pre-race weight (Wilson, Drust, et al., 2014) and therefore often compete in a dehydrated and under-fuelled condition. Within these unique circumstances, it has been well documented that jockeys may resort to prolonged fasting and severe dehydration to achieve the stipulated race weights (Caulfield & Karageorghis, 2008; Dolan et al., 2011; King & Mezey, 1987; Labadarios et al., 1993; O'Reilly et al., 2017; Wilson, Drust, et al., 2014); practices that appear culturally engrained within the sport (Martin et al., 2017).

Over the past decade our research group and others have challenged this reliance on unhealthy practices and devised safer alternatives for jockeys aiming to maintain race weight. Indeed, in a 9-week case-study intervention of 30-min daily steady-state exercise (65 - 70% maximum heart rate) and targeted nutritional education consisting of high protein/high fibre foods consumed at multiple points throughout the day, whilst maintaining a daily energy deficit of 500 – 800 kcal.d^{-1}, we reported a professional jump jockey reduced fat mass (FM) by 7.0 kg (Wilson et al., 2012). This new diet contrasted with a typical jockeys’ diet, which has been suggested to consist of one convenience snack before noon and a large meal comprising energy-dense foods of an evening with prolonged fasting between (Wilson et al., 2015). The revised diet and exercise plan resulted in the jockey being able to make minimum race weight in Great Britain (GB) jump racing (64.0 kg) for the first time without the need to resort to deleterious practices. Following this pilot work, further research on 10 British-based professional jockeys reported a mean loss of 2.5 kg body mass (BM) through adherence to the diet and exercise advice outlined in the initial pilot work. In this study meals and snacks were provided to the jockeys to ensure adherence to the diet plan. This intervention was designed to illicit a 500 – 800 kcal^{-1} daily energy deficit and formulated from measures of daily energy expenditure previously reported in professional jockeys (Wilson et al., 2013). Whilst FM significantly decreased, fat free mass (FFM) was maintained, with a significant increase in resting metabolic rate (RMR) and improved hydration status. The findings in this study are now the basis for 'best' nutritional recommendations for jockeys by stakeholders within the racing industry (Martin et al., 2017).

Whilst our previous findings suggest that short-term exercise and nutritional interventions to illicit a daily energy deficit can demonstrate positive changes in body composition, hydration and RMR in jockeys, it is also important to evaluate if these can be maintained over a longer period and in free-living conditions. The current study therefore assessed body composition, RMR, hydration and meal and snack frequency following the provision of dietary and exercise advice, to ascertain if the improvements observed in short-term studies can be maintained over an extended period than our previous work and during free-living conditions.

METHODS

Participants

Twenty-three male professional flat jockeys (age: 32 ± 7 years; stature: 165.0 ± 6.9 cm; BM: 56.0 ± 2.9 kg) were recruited for the study. Criteria for inclusion were jockeys licensed to race ride in GB, who could attend the laboratory on more than one occasion for retests following baseline assessment. Although female jockeys did visit the laboratory for testing during the study period, no female jockey met the full inclusion criteria of returning to be re-assessed following baseline assessment, and therefore such data is not included. All male jockeys were injury free and race riding at the time of this study. Additionally, all jockeys were non-smokers and not known to be taking any medications.

Study Design

Assessments of body composition, RMR, hydration status and self-reported meal and snack frequency were collected over a 5-year period. Initial study design included jockeys to undergo retesting on an annual basis for the full study period and following their baseline assessment. During this time and due to COVID restrictions preventing annual testing at our laboratories, all jockey's data assessed is for those participants who returned throughout the study period for follow up on two additional occasions, with the second visit occurring once restrictions were removed (e.g., baseline = 0 – 12 months; follow up 1 (FU 1) = 13 – 24 months; and follow up 2 (FU 2) = 46 – 60 months). Prior to initial testing, jockeys were given participant information and provided written informed consent as mandated by National Research Ethics Service approval (14/NW/0155).

Experimental procedures

On each testing visit and following a 12 hour overnight fast, jockeys provided a mid-flow urine sample for assessments of urine osmolality using a handheld refractometer (Osmocheck; Vitech Scientific, West Sussex, UK) (Sparks & Close, 2013). Jockeys then underwent measures of stature and BM using a dual scale and stadiometer (SECA 702 and 123 GmbH, Hamburg, Germany), whilst barefoot and wearing minimum undergarments. Jockeys then had whole body composition assessed via Dual X-Ray Absorptiometry (DXA-QDR Series Discovery, Horizon Hologic, Marlborough, USA) following best practice guidelines (Nana et al., 2016). Following a period of rest in a supine position for 5 minutes, jockeys participated in an RMR assessment via indirect calorimetry (RMR_{meas}; GEM Nutrition, Daresbury, UK) calibrated via known concentrations of O_2/CO_2 = an established respiratory exchange ratio of 0.67 and utilising the same protocol as previously described (Wilson et al., 2015). Additionally, predicted RMR (RMR_{pred}) (Cunningham, 1980) was established from DXA derived estimates of FFM. An RMR ratio (RMR_{ratio}) was then calculated by dividing $RMR_{meas,}$ by RMR_{pred}, whereby values of <0.90 were classified to define any instances of potential energy deficiency (Sterringer & Larson-Meyer, 2022).

Following these assessments, jockeys were individually interviewed by a Sport & Exercise Registered (SENr) Nutritionist regarding their current weight-making strategies and completed a 24-hour meal and snack recall. From this self-reported information, meal and snack frequency was chronologically classified as breakfast, morning snack, lunch, evening snack, and dinner (see Figure 4). During the initial baseline interview, jockeys were given advice on the health and performance benefits of 1) eating regularly whilst still maintaining an energy deficit to control race riding body weight; 2) focusing on high protein and high fibre based foods to increase satiety (Martin et al., 2017) rather than a reliance upon convenience high sugar foods (Wilson et al., 2018; Wilson et al., 2013) and 3) maintaining hydration with regular fluid intake rather than intentional dehydration (Wilson, Drust, et al., 2014). All jockeys then received nutritional information in sheet format for 'best' weight-making practices (high fibre/high protein) and as described in our earlier work (Wilson et al., 2015). Jockeys were also advised to undertake 30 minutes of steady-state aerobic exercise daily, to increase energy expenditure as utilised successfully in our previous work in weight reduction for professional jockeys (Wilson et al., 2012; Wilson et al., 2015) and to help create a daily energy deficit. The dietary sheet information also included illustrated convenience foods to minimise. Additionally, a hydration chart was included for jockeys to self-assess urine colour as an indicator of hydration status. It was advised that optimal food consumption be every 3 hours, with (recommended) fluid consumption *ad-libitum*, as per previous research within professional jockeys (Wilson et al., 2012; Wilson et al., 2015) and combat sport athletes (Langan-Evans et al., 2021; Morton et al., 2010). All information was in lay-friendly language and the jockeys were afforded the opportunity to ask any questions on information that was not understood and/or related to this alternative approach.

Upon follow up, jockeys were re-interviewed by the same accredited nutritionist for 24-hour meal and snack frequency recall and were again provided with the original advice sheets and with the same daily exercise advice. For FU 1 and 2, jockeys were requested to return approximately the same time as during the initial visit (i.e., morning between 0900-1100 am).

For the baseline period of testing, n = 43 male professional flat jockeys attended the laboratory, with n = 27 returning for FU 1 (~63%) and n = 23 (~54%) for FU 2. Those jockeys who did not return on one or both occasions were contacted via telephone and/or text message regarding discontinuing the study. Responses were confined to five categories; retired, happy (with current dietary practices), unhappy (with suggested practices from the study), financial, and unknown. (Figure 1).

Statistical analyses

Data for those participants who attended all 3 visits to the laboratory were analysed for potential differences in body composition (i.e., BM, FFM, FM, body fat percentage), hydration status (urine osmolality), RMR_{meas}/RMR_{pred} and number of main meals and snacks between baseline, FU 1 and FU 2. All analyses were conducted in Statistical Package for the Social Sciences (SPSS® version 28; IBM®, SPSS Inc, Chicago, IL, USA). Descriptive statistics inclusive of mean ± *SD*, 95 % confidence intervals (95 % CI) and frequency are provided for all data where appropriate, with the alpha level of significance established at $p < 0.05$. Ratio data were initially examined for normality and outliers utilising histograms, boxplots and Shapiro-Wilks tests. Parametric one-way within subject repeated measures ANOVAs with sphericity assessed via the Mauchly test and non-parametric Friedman's tests were utilised for normally and non-normally distributed data, respectively. During any relevant post hoc analysis, Bonferroni corrections were employed for multiple pairwise comparisons. Additionally, partial eta squared (η^2) effect sizes were also calculated utilising the following quantitative criteria to explain the practical significance of the findings: trivial <0.2, small 0.21–0.6, moderate 0.61–1.2, large 1.21–1.99, and very large ≥2.0 (Hopkins et al., 2009). Given the ordinal nature of the meal and snack frequency data, Cochran's Q tests were performed to determine if the percentage of participant responses differed across visits. Sample size was adequate to use the χ^2 distribution approximation and pairwise comparisons were performed using Dunn's procedure with a Bonferroni correction for multiple comparisons presented as adjusted *p* values.

RESULTS

Body composition and hydration status of GB-based professional flat jockeys can be seen in Figure 2. There was a *small* difference in total BM between testing visits (Figure 2A; $p < 0.001$; $\eta^2 = 0.54$), with FU 1 (54.8 ± 2.5 kg; $p < 0.001$; 95% CI = 0.7 to 1.6 kg) and FU 2 (54.9 ± 2.5 kg; $p < 0.001$; 95% CI = 0.7 to 1.5 kg) both 1.1 ± 0.2 and 1.0 ± 0.2 kg lower than baseline (55.9 ± 2.9 kg) respectively, with no differences between follow up visits (0.1 ± 0.1 kg; $p = 0.63$; 95% CI = -0.2 to 0.1 kg). Figure 2B highlights there were no differences in FFM (0.1 ± 0.1 kg; $p = 0.48$; $\eta^2 = 0.03$) between baseline (45.5 ± 2.3 kg), FU 1 (45.4 ± 2.3 kg) and FU 2 (45.4 ± 2.2 kg). However, changes in FM also exhibited a *small* difference between testing visits (Figure 2C; $p < 0.001$; $\eta^2 = 0.54$), with FU 1 (6.1 ± 0.6 kg; $p < 0.001$; 95% CI = 0.6 to 1.5 kg) and FU 2 (6.1 ± 0.5 kg; $p < 0.001$; 95% CI = 0.5 to 1.4 kg) both 1.0 ± 0.7 kg lower than baseline (7.1 ± 1.4 kg), with no differences between follow up visits (0.1 ± 0.1 kg; $p = 0.34$; 95% CI = -0.2 to 0.1 kg). These outcomes resulted in a *small* difference across body fat percentages (Figure 2D; $p < 0.001$; $\eta^2 = 0.44$), whereby baseline (12.8 ± 2.3%) is 1.0 ± 0.8% higher than both FU 1 (11.8 ± 1.5%; $p = 0.001$; 95% CI = 0.5 to 1.5%) and FU 2 (11.8 ± 1.5%; $p = 0.001$; 95% CI = 0.5 to 1.6%), with no differences between follow up visits (0.1 ± 0.1%; $p = 0.63$; 95% CI = -0.2 to 0.3%). Urine osmolality was also higher by a *small* difference (Figure 2E; $p < 0.001$; $\eta^2 = 0.56$) at baseline (816 ± 236 mOsmol.L^{-1}) in comparison to both FU 1 (564 ± 175 mOsmol.L^{-1}; $p < 0.001$; 95% CI = 159 to 344 mOsmol.L^{-1}) and FU 2 (524 ± 156 mOsmol.L^{-1}; $p < 0.001$; 95% CI = 194 to 388 mOsmol.L^{-1}) by 252 ± 62 and 291 ± 80 mOsmol.L^{-1} respectively, yet also with no differences between follow up visits (40 ± 18 mOsmol.L^{-1}; $p = 0.26$; 95% CI = -32 to 111 mOsmol.L^{-1}).

Figure 3 highlights a comparison of RMR$_{meas,}$ RMR$_{pred}$ and RMR$_{ratio}$ of GB-based professional flat jockeys, demonstrating no differences in RMR$_{pred}$ (2.0 ± 2.0 kcal.day-1; $p = 0.49$; $\eta^2 = 0.03$) between baseline (1500 ± 51 kcal.day^{-1}), FU 1 (1499 ± 49 kcal.day^{-1}) and FU 2 (1498 ± 50 kcal.day^{-1}). However, there were *moderate* differences between testing visits in RMR$_{meas}$ ($p < 0.001$; $\eta^2 = 0.72$) whereby FU 1 (1612 ± 95 kcal.day^{-1}; $p < 0.001$; 95% CI = 69 to 123 kcal.day^{-}

[1]) and FU 2 (1620 ± 92 $kcal.day^{-1}$; $p < 0.001$; 95% CI = 77 to 132 $kcal.day^{-1}$) were both 96 ± 12 and 104 ± 14 $kcal.day^{-1}$ higher than baseline (1516 ± 106 $kcal.day^{-1}$), with no differences between follow up visits (8 ± 2 $kcal.day^{-1}$; $p = 0.06$; 95% CI = -1 to 17 $kcal.day^{-1}$). This results in an increase in RMR_{ratio} from baseline to a consistent value across FU 1 and 2.

Following initial and subsequent 24-hour meal and snack recalls, self-reported main meal and snack frequencies categorised as all intakes consumed within a day, differed between baseline and both follow up visits (2 intakes vs 4 intakes per day, respectively), but not between follow ups. Figure 4 highlights the frequency of each main meal and snack intake across all visits. The percentage of jockeys who consumed breakfast was different between visits $\chi2(2) = 13.273$, $p < 0.001$, with an increase of 82.6% at FU 1 ($p = 0.009$) and 87.0% at FU 2 ($p = 0.003$) when compared to 47.8% at baseline. Additionally, the percentage of jockeys who consumed lunch was also different between visits $\chi2(2) = 21.529$, $p < 0.001$, with an increase of 91.3% at FU 1 ($p < 0.001$) and 95.7% at FU 2 ($p < 0.001$) when compared to 34.8% at baseline. However, there were no differences between visits for the percentage of jockeys who consumed dinner (all; $p = 1.00$). Finally, there were differences in the percentage of jockeys who consumed an evening snack across visits $\chi2(2) = 11.231$, $p = 0.004$, with an increase of 39.1% at FU 1 ($p = 0.02$) and 43.5% at FU 2 ($p = 0.007$), when compared to 4.3% at baseline. Nonetheless and despite an increase of 52.2% and 56.5% at FU 1 and 2 when compared to 30.4% at baseline, there were no significant differences for jockeys who consumed a morning snack across visits ($p = 0.16$).

DISCUSSION

The aim of the present study was to assess if dietary changes that have reported positive results in acute studies are maintainable over an extended period in free-living jockeys. To this end, we recruited 23 male GB-based professional flat jockeys and assessed physiological markers relative to weight-making on three separate occasions over the course of 5 years. We provide novel findings within a jockey population with longitudinal positive changes in BM and body composition, increased RMR, decreased urine osmolality and increased meal and snack frequency following an initial assessment and the provision of 'best' weight-making nutritional and daily steady-state aerobic exercise education. These data suggest that jockeys can maintain beneficial changes for weight-making during free-living conditions and beyond initial re-assessment.

The current study reports an initial reduction in FM without any loss of FFM from baseline to follow up testing, with a maintenance of these improved markers at both 1 and 5 years post-initial testing. Importantly, measures were conducted with no additional interaction with researchers outside of the baseline and follow up measures, thereby placing the responsibility on the individual jockey to control FM and FFM. Previously, we have reported the positive benefits of reducing FM in jockeys to negate the need to dehydrate and maintaining FFM whilst consuming a hypocaloric diet that can result in improved physicality, and potentially, for injury prevention (Pasiakos et al., 2013). Given the occupational risks associated with the sport in that racehorses can reach peak speeds of >70 $km \cdot hr^{-1}$ (Turner et al., 2002), and considering that as little as 2% reduction in BM through rapid weight loss can significantly compromise a jockey's strength (Wilson, Hawken, et al., 2014), the findings here appear relevant to jockey safety in competition.

In addition to the importance of maintaining FFM whilst in an energy deficit for performance and injury prevention as discussed, it is also important to note that FFM is well-established as a major determinant of RMR (Müller et al., 2002; Zurlo et al., 1990) given it negates the influences of age, gender, body weight and body fat upon RMR (Fontaine et al., 1985). Here, we report a significantly increased RMR_{meas} from initial testing to both follow up visits of ~100 $kcal.day^{-1}$, and independent of changes to FFM. Moreover, no difference in RMR_{pred} between baseline and subsequent follow ups were observed further highlighting the positive change in RMR_{meas}. Additionally, RMR_{ratio} was established by the division of RMR_{meas} and RMR_{pred} and where values of <0.90 indicate potential energy deficiency (Torstveit et al., 2018). Values for

RMR_{ratio} reported an increase from baseline, whereby three jockeys were classed as being energy deficient, to a consistent value across FU 1 and 2 and no jockeys being classed as energy deficient.

In explaining potential reasons for the increased RMR_{meas} reported here, this may have occurred due to the advised addition of daily aerobic exercise. Indeed, modulations of RMR due to increased physical activity and independent of changes to FFM tissues, have been attributed to enhanced cellular respiration, heightened energy flux, augmented protein turnover and increased activity of the sympathetic nervous system (Speakman & Selman, 2003; Stiegler & Cunliffe, 2006). The findings here agree with the increased RMR_{meas} reported from our previous dietary intervention comprising 3 meals and 2 snacks per day and an increase in daily exercise energy expenditure (Wilson et al., 2015). Furthermore, this study also followed the same format of advised nutritional options and increasing meal and snack frequency and daily exercise as our case study, where a jockey reduced FM by 7.0 kg in a 9-week period.

Whereas increased meal and snack frequency and positive changes in body composition are still a topic of debate in humans *per se*, interestingly, there does appear evidence of benefits for athletic populations particularly (La Bounty et al., 2011). In the limited studies to date, Bernadot et al, (2005) reported significantly greater body fat percentage loss (<1.03%) and increased FFM (>1.2 kg) for college athletes consuming 250 kcal snacks after main meals for 2 weeks, versus athletes consuming a non-caloric placebo. Interestingly, these positive changes in body composition reverted to baseline within 4 weeks of the 250 kcal snacks being removed (Benardot et al., 2005). In earlier work, Iwao and colleagues (1996) reported boxers (n = 6) consuming a hypercaloric diet of 1200 kcal per day as 6 feeds, experienced less loss of FFM versus boxers (n = 6) consuming the same energy intake across 2 meals. Whilst there was no significant difference in BM between groups, the boxers eating less frequently reported higher measures of urinary 3-methylhistidine/creatinine and the authors cite this as evidence of greater myoprotein catabolism even when the same diet is consumed (Iwao et al., 1996). In our own previous work where jockeys were prescribed a hypocaloric diet consumed as 5 feeds and evenly spaced throughout the day, we report a maintenance of FFM over 6 weeks, which may therefore highlight the importance of increasing meal and snack frequency for muscle protein synthesis in the presence of a daily energy deficit. Whilst the actual mechanisms behind the maintenance of FFM reported in the present study are unknown, nonetheless, the present data clearly show that jockeys were able to make positive changes in body composition that are maintained over a 5-year period without routine assessments in free-living conditions.

Initial findings here demonstrated that the jockeys were typically dehydrated at baseline, with mean urine osmolality of >700 mOsmol (Sawka et al., 2005). Dehydration is a common practice used by jockeys to make racing weight and typically through rapid weight loss achieved by exercising in a sweat suit and heavy clothing (Dolan et al., 2011; O'Reilly et al., 2017; Wilson, Hawken, et al., 2014). Simulated riding performance (Wilson, Hawken, et al., 2014) and cycle ergomter (Dolan et al., 2013) have both been shown to be impaired in jockeys following 2 and 4% dehydration, respectively. Given that jockeys have been reported to reduce BM through intentional sweating of up to 7% through rapid weight loss on a race day (Wilson et al., 2012), the performance detriments in competition may be magnified. Previous work has also highlighted the potential for increasing the occupational hazards associated with riding racehorses at high speeds and over obstacles (Turner et al., 2002) through reduced strength when dehydrated (Dolan et al., 2013). Importantly, the current study reports that from initial ‘dehydrated’ classification at baseline, most of those jockeys returning for retests did so in a hydrated state, following the provision of ‘healthier’ dietary advice. Whilst accepting this finding was established in a laboratory setting and not at the racecourse, it still provides positive proof for jockeys that they are able to reduce BM and maintain this lower weight and do so whilst being hydrated.

Whilst the present study provides novel findings that jockeys improve body composition, RMR_{meas}, hydration status, and increase meal and snack frequency following the provision of dietary and exercise advice, it is not devoid of limitations. Notably, this study did not control dietary intake or the recommended daily exercise advice modality, and therefore we do not know if indeed jockeys were in a daily energy deficit? However, given that a key aim of the study was to assess jockeys in free-living conditions, and to maintain ecological validity, we therefore employed a 24-hour meal and snack frequency recall as a tool to assess the frequency of food intake specifically, and as not to be constrained by food diaries and/or 'snap and send'. Moreover, whereas the usefulness of 24-hour recall as an accurate assessment of energy intake in athletes appears particularly limited against measures of doubly labelled water (Foster et al., 2019) or when compared with 24-hour portable metabolic monitor data in jockeys (O'Loughlin et al., 2013), it is reported as a reliable method that correlates positively with meal and snack frequency in self-reported diaries over longer periods and habitual eating behaviour in athletes (Sunami et al., 2016). Likewise, to maintain the jockey's independence, we only requested that the jockeys provide verbal feedback regarding adherence to the recommended daily exercise, and which collectively we can summarise that the jockeys did confirm on both follow up occasions. Another notable limitation is the group of jockeys who did not return for follow up testing after baseline. However, whilst only 23 of the initial cohort (n = 43) did complete the study, this is representative of 54% of the initial total group and therefore it may be viewed that the majority felt it important to return on more than one occasion for retesting. Indeed, in accounting for the non-returning jockeys, the main reason reported to the researchers was being 'happy' (n = 7) with their current weight-making practices and that the advice provided had had a positive effect in helping those jockeys make and maintain race riding weight (Figure 1). For the smaller number of 'unhappy' jockeys (n = 2), it was communicated that they did report finding it difficult to maintain the regime, although no (potentially) confounding factors were discussed or explored. As such, it may therefore be that those jockeys may have reverted to previous practices for weight-making and, in the likely event, we fully acknowledge that such recommendations as proposed in this study may not be suited to all jockeys without further exploration into any confounding factors that may act as a barrier.

To conclude, the findings of the present study demonstrate that professional jockeys may improve body composition, RMR, hydration and eat more regularly following provision of educational advice and resources. These improvements were maintained over an extended period and in free-living conditions and suggest that jockeys may be positively influenced by targeted nutritional and exercise education. Given the main limitations highlighted, we would therefore suggest that future similar research include minimum assessments of energy intake and energy output to ascertain 'typical' daily energy balance, that could still maintain ecological validity in free-living athletes. This may then help to further strengthen any similar positive findings from such studies, as to the positive changes reported here. Additionally, further exploration into reasons that jockeys 'drop out' may act to enhance future work and perhaps help remove barriers to adherence, that again, may further benefit jockeys and the sport of horseracing long-term.

AUTHORSHIP

GW undertook all laboratory measurements. **CLE** undertook metabolic analysis, figure design, statistical analysis and manuscript review. **DM** undertook behavioural analysis and overall manuscript review. **AK** assisted with figure design, manuscript design and manuscript review, **JPM** contributed to manuscript design and manuscript review. **GLC** oversaw dietary recall, contributed to figure design, manuscript design and manuscript review.

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