Does sex of the jockey influence racehorse physiology and performance.

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Abstract

Background

Studies assessing the effect of the rider's sex on racehorse performance and physiology during training have not been reported, mostly due to the paucity of available data for female participants within the sport. Here, using a validated system (the 'Equimetre'™) that records all parameters simultaneously, we objectively report the effect of rider's sex on racehorse cardiovascular (heart rate, heart rate recovery) and biomechanical parameters (stride length and frequency) at various exercise intensities (slow canter to hard gallop).

Methods

530 Thoroughbreds, varying in age (2-7 years old) and sex (including geldings), from one racing yard in Australia, completed a total of 3,568 exercise sessions, monitored by a single trainer, on varying track surfaces (sand, turf, or fibre). 103 different work riders (male, n=66; female, n=37) of which n=43 were current or past registered professional jockeys, were used. Data were analysed using analysis of variation (ANOVA) or mixed-effect models, as appropriate.

Results

Sex of the rider did not influence racehorse speed (P=0.06) nor stride length (P=0.42) at any training intensity. Heart rate and peak heart rate increased with training intensity (P<.001), with no difference according to sex of rider (P=0.73). Heart rate recovery after exercise appeared influenced by rider sex, but only when the usual training intensity on each surface was reversed, suggesting an interaction between racehorse anticipation of exercise and rider sex. Male jockeys had slightly higher strike rate in races in Australia, but not the UK.

Conclusions

This study demonstrates no overt effect of rider sex on racehorse performance and physiology.

Background

In human elite sport, athletes are almost invariably segregated by sex. Male athletes tend to perform at a faster, higher, and stronger level due to a combination of various physical and morphological advantages. Men usually have greater lean mass (and thus less body fat), aerobic and cardiovascular dimensions (e.g. heart size and cardiac output [1]), suggesting that male athletes have a predisposed capacity for exercise. However, when matched on performance in a timed race, whilst the men were taller, heavier, and had higher haemoglobin concentration than females, the sexes did not differ in percentage of body fat or in VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$), HR, respiratory exchange ratio, or ventilatory equivalent of oxygen during submaximal running or at maximal exercise (P>.05) [2]. Therefore, when controlling for obvious physical differences, performance physiology may not differ. Clearly in sports where greater physical strength and lean mass is important, then it is axiomatic that men will have an advantage.

In any sport, the difference between winning or losing can simply be the psychological status of athletes. Psychological profiling of men highlighted greater self-confidence scores for performance, indicating that men are more suited to competitive sports than women [3]. Men also demonstrated less pre-competitive anxiety than females [4]. Both self-confidence and facilitative anxiety are essential qualities for elite athletes, perhaps allowing for greater focus, translating to superior performance [5]. For many sports, where the competitive advantage is less on the physical attributes of the individual but more on skill level or ability to control some other machine (e.g., motorbike racing, sailing) or animal (e.g., equestrianism – dressage, show jumping, eventing), then males and females can compete against each other on equal terms.

In horse-racing, both male and female horses and male and female jockeys compete against each other in the majority of races. Many of these race meetings are 'handicapped', allowing horses of varied ability to participate. In such races, each horse is attributed a predetermined weight to carry (jockey plus saddle, with added weights where necessary) determined by the racing regulatory board, while certain horses with a better racing record are allocated higher weights in order to further equalise any perceived performance advantage. In other equestrian sports where there is no attempt to control for perceived differences between sexes (both animal and human) such as show-jumping [6, 7] or eventing [8], there is no evidence to suggest any influence of the riders' sex on performance such as total prize money won.

In the majority of equestrian activities, particularly at the recreational level, riders are predominantly female [9]. However, at higher levels of competition, including elite, the ratio of female to male riders begins to equalize and occasionally reverse (more males than females). An exception is professional rodeo, where there are many more male elite riders competing compared to female. This is presumably because of the unique demands of the competition, and the wear and tear on riders is perhaps better tolerated by male riders [10]. However, one other example and an outlier, is horse racing where a far greater proportion of registered racing riders are male (e.g. see https://www.britishhorseracing.com/racing/participants/jockeys/), but the demands of the event are unlikely to be influenced by sex. In recent years, despite an increase in participation rates for female jockeys, the proportion of female:male jockeys riding at the elite level in racing nations such as England, France and the USA remains low [11]

In Australia, different licence categories exist for jockeys participating in flat racing: apprentice, full-licence (professional), amateur or licenced to ride in steeplechases. Any rider may register as an official 'apprentice', but to become a fully-licenced professional they must successfully navigate through a long apprenticeship, followed by gradual participation in increasingly more competitive races. For example, many amateur jockeys, only ever ride in 'picnic' or amateur race meetings, often at a heavier weight than elite races [12, 13]. Fully licenced professional jockeys will often ride alongside work-riders in stables during regular training sessions for the racehorses. A great many more work-riders are female. Therefore, the training of racehorses offers a rare opportunity to objectively explore whether the sex of the rider may influence any aspect of racehorse physiology during training sessions that are often conducted at race-speed.

Analysis of betting behaviour on races in the UK and Ireland [14], or USA [15], was studied as an indirect proxy for public confidence in the ability of male or female jockeys to win races. In the UK and Ireland, a slight underestimation of the ability of female jockeys to win was found between the years 2003-2013 (i.e. female jockeys won +0.3% more races than estimated from the subjective assessment of the quality of the racehorse) [14]. In the USA, the opposite was found for better quality 'stakes' races (-2.0% [15]). On race day, jockeys must control both their own riding performance as well as that of the horse, running at top speeds exceeding 60 km/h [16, 17]. Attributes such as strength, strength endurance, balance, reaction time and flexibility were identified in successful riders [18, 19]. However, whilst factors such as the individual race and weight carried could have an effect on racing time [20], a recent study found no significant difference of jockey sex on overall race outcomes [11]. An updated analysis of race outcomes in 2021 (i.e. proportion wins from total number of race starts) will be able to observe whether there remains any significant difference in the sex of rider and race outcomes.

The rider and horse form an interdependent partnership, which is thought to have an influence on competitive success. Indeed, physiological changes, such as the increase in heart rate with competition, alter in parallel in both horse and rider, but these can become dissociated when psychological aspects are further imposed, such as performing in front of a crowd (influences sympathetic activity in the human but not horse [21]). It is well known that in human athletes during sporting events, cortisol production increases as a result of heightened anxiety or anticipation of the event, to the benefit of their performance [22]. One study reported a similar increase in cortisol during competition in horses [23]. Thus, multiple factors may explain equine performance, including sex of the rider. Indeed, anxiety, anticipation and other more variable psychological factors in the jockey could, in theory, be transmitted through to the horse being ridden to ultimately influence their performance. Males and females are different with respect to their overall psychology and how they approach competition [24]. To our knowledge, no study has objectively examined the effect of rider's sex on objective measures of racehorse performance and physiology during easy canters or hard, race-speed gallop training sessions.

Hence in the present study, the first of its kind to date, we have conducted an observational study, using a validated fitness tracking device to report on the effect of rider sex on racehorse cardiovascular (e.g. heart rate [HR] and heart rate recovery [HRR]) and locomotory (stride length and frequency) responses to in-field training at a major training yard in Australia. Horses of varying age and sex were tracked longitudinally as they trained on varying surfaces throughout the year. Riders who participated in the study were either regular work-riders who had never registered as a professional race jockey or were either current or past, professionally registered jockeys. The primary outcome of the study was to ascertain whether the sex of the rider influenced any aspect of racehorse speed (slow canter to hard gallop), cardiovascular function (e.g recovery of heart rate) or locomotion (e.g. stride length).

Methods

Horses and work riders. Ethical approval for this study was obtained from the University of Nottingham (School of Veterinary Medicine and Science) Research Ethics Committee (REC code: 3270 201029). The study is a retrospective, observational study using a dataset collected from a single racing yard in Australia. The study population represented a convenience sample and comprised 530 Thoroughbred racehorses of between 2 – 7 years of age and included males (colts/stallions; n= 32), females (fillies/mares; n=59) or geldings (n=39). The racehorses were all regarded by the trainer as race fit; that is, actively in-training to sustain fitness levels and compete in races during the study period (March 2020 to September 2021). There were 103 different work riders of which n=37 were female (n=8 were current or past registered professionals on https://www.racing.com/jockeys; n=29 were not registered) and n=66 were male (n=35 current or previous registered professionals, n=31 were not registered).

Equipment. All horses were equipped with a commercialized equine fitness tracker (‘Equimetre’™, Arioneo Ltd, France) during and after exercise. Horses wore their regular tack and were exercised by a randomly allocated work rider. The device was fitted prior to training by persons accustomed to the device. An electrode was fastened at the girth and the second secured under the saddle pad in the natural dip of the back, as previously described (ter Woort, 2021). The fitness tracker recorded physiological and locomotory parameters during designated periods of trot, canter and gallop. All trainers and local data analysts had previously integrated the Equimetre™ into their work regimes.

Training. The trainer directed each rider to work their respective horse according to given target timings for set distances, determined by a sound and light system fixed to the riders’ helmet signalling to them the time taken to cover each furlong (200m). Each training session was evaluated based on the trainer’s observation on the track, riders’ feedback following exercise and the fitness tracker recordings (‘Equimetre’™, Arioneo Ltd, France). Following exercise, all horses were systematically placed on a horse walker or walked in hand to recuperate until heart and respiratory rate had returned to a natural ‘baseline’. The training locations were on racetracks or training centres with a choice of surface including sand, turf or fibre. These latter aspects were also recorded for each training session. Using the Equimetre, data were available on speed (i.e. time taken to cover 200m in seconds) recorded for each 200m segment (at 200, 400, 600, 800, 1000, 1200 and 1400m using GNSS (GPS+Glonass+Galileo) satellite data). From this data, the Equimetre also calculated the fastest 200, 400, 600, 800 or 1000m segment. Using the ‘fastest 200m’ recorded, a data-driven categorisation of speed during the session from slow/medium/hard-canter to slow/medium/hard-gallop was adopted. Descriptive information on each training session was checked, and any sessions with missing information on the jockey was discarded.

Data collection. All data collection occurred between March 2020 to September 2021. A total of 3,568 training sessions were available with the rider recorded, with each racehorse completing 5 (2-10), median (first-third interquartile range [IQR]) training sessions. All 530 racehorses completed at least one training session, 134 racehorses completed n=10, 22 racehorses completed n=20 training sessions. Few racehorses completed ≥25 training sessions, therefore these were grouped. Month of training session was recorded for both years. From the exact date of training, the number of training sessions, and the interval between them, could also be recorded for each horse. The Equimetre recorded aspects of each horse's cardiovascular responses to exercise (e.g. heart rate, HR) during trot, canter, gallop, peak heart rate (HRpeak) and HR during recovery (HR at 15 or 30 mins or at the end of the designated training session) and aspects of locomotion (stride length and stride frequency). From these live data that were instantly recorded by the device, further analyses were able to be conducted *post-hoc* that pertained to each training session such as the deltaHR (or rate of early recovery) ([HRpeak – HR at 15min recovery]/15), HR area under the curve (or overall recovery) (HRauc; ([HRpeak +HR at 15min]/2)+([HR at 15min+HR at 30min]/2)+ ([HR at 30min+HR at end of session]/2)). All AUC were calculated according to the trapezoid rule in Graphpad Prism (Graphpad Prism 9, Graphpad Software, La Jolla, USA). Final datasets were cleaned and checked for artifacts in MS Excel. Environmental temperature and precipitation were recorded as potential covariates in any analyses.

Race results. For Australia, data for the 2021 racing season in Victoria state, involving all race meetings, were extracted online from https://www.racing.com/jockeys/. Aspects of the dataset such as venue, distance, track and class were not taken into consideration. Comparative data in the United Kingdom during the 2021 racing season, exclusively for flat race meetings, were provided by The British Horseracing Authority https://www.britishhorseracing.com/racing/participants/jockeys/. Both datasets included: Australia, n=169 registered jockeys (male, n=114, female, n=55); UK, n=436 registered jockeys (male, n=307, female, n=129). Overall, the combined dataset included a total of 52,464 race starts with all jockeys registered completing at least n=1 professional race. Recorded data included wins and strike rate (number of wins per total number of starts expressed as a percentage) for individual jockeys and, for Australia only, achieving a podium place (1st, 2nd or 3rd).

Statistical analysis

Any descriptive data (e.g. continuous variables) that were normally distributed (e.g. speed, stride length, stride frequency) are presented as mean (± 1 standard deviation [SD]). Similar data that were not normally distributed or categorical are presented as median (1st - 3rd interquartile range) or as percentage (of total number) for categorical variables. Data distribution was checked either by standard tests (e.g. Shapiro-Wilk test) or checking of residuals post analysis. If necessary, data were log-transformed ($\log_{10}$) to normalise the distribution of the data prior to analysis. For some analyses, where assumptions for analysis of variance could not be met due to missing data (e.g. missed speed or HR recordings), then a different approach was taken so as not to exclude that individual from all analyses. These data were analysed by linear mixed models (restricted maximum likelihood; REML), which adopts a flexible approach to estimating treatment effects (e.g. assumes 95% CI for small sample sizes and adjusts accordingly) and assumes that any missing data were randomly distributed amongst treatment groups. Any factors that were not part of the design but may influence the outcome were included as covariates in any analysis (e.g. interval between training session in days, training month, temperature, precipitation). Repeated training sessions for each horse were analysed, if possible, using repeated-measures analysis of variance. For outcomes with multiple missing data points then time was added as a fixed effect in the model (e.g. incremental training sessions) with horse ID as a random effect in the model to account for the reduced within-animal variation. Similarly, training centre/location was added as a further random effect when they had tracks of differing surfaces at the same location. The race win strike rate was analysed by logistic regression with a logarithm-link function, and sex of the rider as the only fixed effect. Data for both countries were combined to increase sample size, but country was included as a fixed effect for potential secondary outcomes. All data were analysed using Genstat v21 (VSNi Ltd, Rothampsted, Harpenden, UK). Statistical significance was accepted at P<0.05.

Results

Descriptive data of the cohort; number, type and intensity of training session by sex of work-rider

Female riders completed a higher proportion of the total number of training sessions in this cohort (n=1868 of 3568, 52.4%). The number of training sessions ridden by female riders was 19 (4 – 76) versus 9 (3 – 23) for male riders. The average distance horses were exercised was not different according to sex of the rider, female, 1981 (1701 – 2155m); male, 1861 (1564 – 2160) metres, median (IQR). As the speed of the session increased from slow canter to hard gallop, the proportion male riders increased (Figure 1a). Data for training sessions using an Equimetre were available from March 2020 to September 2021. Sessions were conducted on all three surfaces (fibre, turf and sand) throughout the year and gradually increased in frequency, reaching a maximum number of sessions (>400) in July-August 2021 (Figure 1b). Similarly, the number of training sessions stratified by training intensity (i.e. soft canter to hard gallop) followed the pattern of total training sessions over the course of both years with no marked variation in any particular month (Figure 1c). However, when considering the track surface chosen for specific training intensities then it was clear that the overwhelming majority of canters and gallops were conducted on sand and turf, respectively (Figure 1d). Since few training sessions were conducted on fibre (all-weather), for further analyses of horse-level variation in cardiovascular or locomotory parameters then only sand and turf were considered, and these were analysed separately. For each track surface, variation in training intensity existed but, for example, only n=3 (of 1381, 0.2%) hard gallops were conducted on sand, and only n=28 (of 2165, 1.2%) soft canters were conducted on turf.

R acehorse speed, stride length and effect of training on differing surfaces by sex of work-rider:

Racehorses increase speed by partially increasing stride frequency (by ~ 19% and 20% for horses ridden by female and male riders, respectively) but with a far greater increment in stride length, which increases by ~56% and 57%, respectively; Table 1). The increment in speed with training intensity is not linear; that is, near maximal speeds are achieved at 'soft gallop' with only small increases thereafter (Table 1). The mean time taken for any 200m segment (i.e. each furlong) gradually decreases, the further the training distance, with no effect of rider sex on either turf or sand (Figure 2a,b). Stride length also increased with training intensity in a curvilinear fashion on both training surfaces, with no effect of sex of the rider (Table 1, Figure 2c,d). When training sessions were grouped according to the first 10 conducted versus the next 11-20+, and age of horse was adjusted for, all heart rates recorded for each horse were analysed in a repeat-measures analysis from trot through canter to peak HR then a small, but statistically significant signal for lower HR during canter and soft-medium gallop on turf (Figure 2e) and sand (Figure 2f).

Table 1
Descriptive data for the complete cohort of racehorses training at a single racing yard in Australia

Parameter	Rider Sex	Soft Canter	Med Canter	Hard Canter	Soft Gallop	Med Gallop	Hard Gallop	*P*-value *sex*
Best 200m (secs)	Male	20.9 ± 2.2	15.9 ± 1.2	12.9 ± 0.5	11.8 ± 0.2	11.3 ± 0.1	10.8 ± 0.2	0.16
	Female	21.1 ± 2.2	16.3 ± 1.2	13.1 ± 0.6	11.8 ± 0.2	11.3 ± 0.1	10.8 ± 0.2	
Best 600m (secs)	Male	65.8 ± 9.5	49.7 ± 3.9	41.0 ± 2.0	37.4 ± 1.1	35.6 ± 0.8	34.2 ± 0.9	0.07
	Female	66.5 ± 8.3	51.0 ± 4.4	41.4 ± 2.8	37.6 ± 1.1	35.9 ± 0.9	34.5 ± 1.0	
Max speed (kph)	Male	35.5 ± 3.5	46.1 ± 3.4	56.1 ± 2.6	61.0 ± 1.0	63.7 ± 0.7	66.5 ± 1.4	0.20
	Female	35.1 ± 3.4	45.0 ± 3.4	55.7 ± 2.6	61.0 ± 1.1	63.6 ± 0.8	66.5 ± 1.4	
Peak heart rate (bpm)	Male	196 ± 24	216 ± 20	218 ± 15	218 ± 18	218 ± 20	218 ± 17	0.29
	Female	195 ± 24	210 ± 22	218 ± 16	217 ± 17	216 ± 12	215 ± 13	
Heart rate at 15min (bpm)	Male	61 ± 11	72 ± 15	83 ± 15	93 ± 18	95 ± 19	101 ± 18	0.89
	Female	61 ± 11	67 ± 14	85 ± 17	94 ± 18	97 ± 16	102 ± 16	
HR recovery auc (units)	Male	165 ± 23	188 ± 29	203 ± 33	217 ± 38	216 ± 43	218 ± 47	0.02
	Female	168 ± 23	184 ± 28	212 ± 30	223 ± 38	226 ± 36	229 ± 41	
Stride frequency (strides per sec)	Male	2.05 ± 0.07	2.17 ± 0.09	2.28 ± 0.09	2.35 ± 0.08	2.39 ± 0.08	2.44 ± 0.09	0.73
	Female	2.04 ± 0.10	2.17 ± 0.10	2.29 ± 0.09	2.35 ± 0.07	2.40 ± 0.08	2.45 ± 0.08	
Stride length (meters)	Male	4.87 ± 0.43	5.92 ± 0.36	6.87 ± 0.33	7.27 ± 0.25	7.47 ± 0.25	7.62 ± 0.30	0.07
	Female	4.83 ± 0.41	5.78 ± 0.38	6.77 ± 0.36	7.24 ± 0.23	7.43 ± 0.23	7.61 ± 0.28	

Table. Values are Mean ± 1SD for continuous data recorded by 'Equimetre' (n=530 different racehorses, n=3568 different training sessions). Data were available throughout the year. Training intensity (soft/med/hard canter; soft/med/hard gallop) was derived from calculating sextiles of the fastest furlong (200m interval) for the overall dataset. Data were analysed by linear mixed models (REML) for the main effect of jockey sex, training type and their pre-specified interaction. Due to multiple training sessions for each racehorse and each rider, their individual ID's were included in the statistical model as nested, random effects. All data analyses were conducted using Genstat v20 (VSNi, UK).

Racehorse cardiovascular responses to incremental training intensity by sex of work-rider: During warm-up, heart rate (HR) for the racehorses in first recorded trot, according to sex of the rider, was: male, 131 ± 1.1 vs. female, 127 ± 1.1 beats/min, $P = 0.02$. During first canter, HR of the horses increased as expected, eliminating any difference by sex of the rider: male, 168 ± 1.4 vs. female, 166 ± 1.4 beats/min, $P = 0.38$ (Figure 3a,b). Incorporating heart rate peak, which was not significantly different according to sex of the rider (Figure 3c), with recovery of racehorse heart rate (predominantly over the first 15min after the training session), through 30mins after then end of the session (i.e. the walk back to stables;) allows for the overall area-under-the-response-curve (AUC) to be calculated for the session or for overall recovery (Figure 3d). Over the period of greatest rate of recovery (i.e. to 15mins), the delta HR ([peakHR minus HR at 15mins]/15) appeared influenced by sex of the rider on turf, but not sand (Figure 3e). That is, for the relatively slower training sessions conducted on turf then horses appeared to recover faster with a male rider. Delta heart rate is primarily driven by the peak heart rate achieved, which itself is influenced by the training intensity. Therefore, this analysis, and the potential signal for an effect of sex of the rider was further drawn out in AUC analyses at 15min recovery (more influenced by peak HR) and from 15 to 30min recovery (less influenced by peak HR).

Racehorse recovery of heart rate after incremental training intensity by sex of work-rider

Overall racehorse recovery of heart rate, with larger numbers indicating a greater area and thus more beats/min, was influenced by the sex of the rider but *only* at certain training intensity on specific track surfaces (Figure 4a-d). That is, on turf where the majority of fast gallops are conducted, then racehorses appeared to recover more slowly at 15 and 30min (larger AUC for HR) with a male rider, but the trend was only observed during soft-medium canters i.e. at the paces rarely, but not unusually (n=119 canters on turf) conducted on that surface (Figure 4a,c). In contrast, the opposite was observed on sand; there was a trend for racehorses to recover more quickly with male riders, but only after medium-hard gallops (n=68 gallops on sand; Figure 4b,d). Accumulation of training sessions had little effect on the rate of recovery of heart rate (Figure 4e,f). In summary, sex of the rider being male only influenced recovery of racehorse heart rate when horses were exercised at the training intensity rarely conducted on that particular surface e.g. during steady cantering on turf, where most gallops occur and during hard gallops on sand, where the majority of canters were conducted.

Race results: There were far more registered male professional jockeys than female in both UK and Australia. Overall, in Australia, male jockeys had a small, but significantly greater winning strike-rate (number of wins per total number of rides, in percentage) compared to female jockeys (female, 9.9 ± 0.5%; male, 11.0 ± 0.2%: F-prob, 0.03), predominantly due to a greater winning-rate in Australia (female, 7.9 ± 0.8 vs. male, 10.4 ± 0.4%) compared to the UK (female, 10.7 ± 0.7 vs. male, 11.3 ± 0.2%). In Australia, there was no difference between male and female jockeys achieving a top three 'podium' position (female, 25 (10 – 35) %; male, 27 (18 – 35) %, Mann-Whitney U test, P=0.20).

Discussion

In the traditionally male-dominated sport of horseracing, it has been commonly assumed that female jockeys cannot compete equally against their male counterparts. Physical strength, body shape and tradition were reported by Roberts & MacLean as perceived reasons of restricted opportunities for female jockeys [25]. Similarly, another study outlined the intimidating nature of the weighing room, which may represent a substantial barrier for female participation in the sport of racing [26]. Thus, in 2018, the French racing jurisdiction France Galop, implemented a 2kg weight allowance for female jockeys, resulting in many more racehorses being ridden by female jockeys [27]. Nevertheless, a minority of female jockeys remains, and is surprising given the high media and public interest in horse racing as a spectator sport, and the high levels of participation of women in other amateur and elite equestrian activities [28, 29]. No study has directly, and objectively, compared the performance of female *versus* male jockeys in terms of effects on important characteristics of the racehorse (e.g. speed, stride length, cardiovascular response). Here, in an observational study reporting on aspects of racehorse speed, stride and cardiovascular responses we show no overt effects of rider sex on any aspect of racehorse speed or stride length, during various training intensities. However, when the converse training intensity was conducted on the opposite training surface (e.g. slow canters on turf or fast gallops on sand, both of which were unusual) then small, but significant physiological effects – reduced or greater rates of recovery of racehorse heart rate, respectively – were observed. We also show that female jockeys have very similar racing success, compared to male jockeys. Thus, we can conclude with confidence that in our study we show no overt effects of rider sex on racehorse physiology in training, and on performance when racing.

Descriptive data of the cohort; number, type and intensity of training sessions by sex of work-rider

In this study, there was a clear difference in the proportion of training sessions completed by male or female work-riders. Despite a lower number of female (n=37) compared to male riders (n=64), female riders completed a higher number of training sessions (52.4%) than male riders (47.6%). This contrasts with a previous study, and our current data, where in actual races, there are fewer female riders getting proportionately fewer race rides [30]. Thus, despite female riders completing many more work-rides in training, fewer progress to the professional ranks, securing race-rides. This observation questions equal racing opportunities between female and male jockeys. Indeed, even in training rides then some sex-bias is apparent: as the intensity of the training session increases, far more male riders are used, with female work-riders completing most slower, canter sessions. This variation may be explained by an unconscious bias made by trainers; the assumption that male riders with greater strength are more suited to higher work intensities. However, our data suggest that there is no evidence to support this contention; for all training intensities as directed by the trainer, we found no difference in the fastest 200m between racehorses ridden by a male or female work-rider (across 3,568 training sessions).

Could the faster training sessions be preferentially ridden by registered professional jockeys of which many more are men? Yes. In our dataset, a far greater proportion of 'gallop' sessions were conducted by past or current race registered male professional jockeys (male, 31.8% vs. female, 4.5%). This could reflect trainers choosing to use riders with greater race experience to recapitulate a race environment in training. In Australia, the majority of high-intensity workouts (i.e. gallops) were conducted on turf, while canters were completed on sand. This is consistent with the findings of Morrice-West et al. [31], who surveyed Australian trainers on the use of track surfaces for training. Sand or synthetic 'all-weather' surfaces were commonly used for slow workouts, while gallop work was conducted on turf. It is likely, therefore, that racehorses anticipate certain training intensities according to the track surface. Supporting this contention, in our study, heart rate at trot prior to galloping on grass was 124 ± 26 beats/min (mean ± S.D.) versus 114 ± 26 beats/min prior to a gallop on sand, where most canters occur. Racehorses no doubt anticipate the type of training session they are about to conduct.

Racehorse speed, stride length and training surfaces by sex of work-rider

To increase speed from canter to gallop, horses increase frequency of their stride to an extent, but predominantly speed increases due to increased stride length, as reported here and previously by others [32]. Our results showed that near maximal speeds (55-60kph) were attained at a training intensity of 'soft-gallop' and only minimally increased thereafter. We acknowledge that speed can be affected by the track condition (i.e. a harder turf or relatively softer sand [33]), which was not measured in this study, but the size of our dataset would limit these relatively small effects. In our study, the mean time taken for a horse to cover a furlong (200m) did not differ according to the sex of the work rider. As expected, the longer the training session was (for example, from 1500m to 3000m), then the average time taken to cover each furlong gradually increased (see Figure 2a,b), suggesting a gradual slowing. Interestingly, riding style can influence racehorse speed; a crouched posture reduces aerodynamic drag and can improve racing times by up to 5-7% [34]. Whilst this was not measured in the current study, we assume that male and female work-riders, usually with worn body protectors, do not adopt different postures in training.

Stride length increased with training intensity but was not affected by the work rider's sex. Information on the riders' weights was not obtained for the study. Nevertheless, we appreciate that an increment in the rider's weight has the potential to reduce the stride length of horses and alter performance [35]. The rider's experience, registered race professional *versus* non-registered race professional was accounted for and no marked effect on speed or stride was highlighted. These findings run counter to those of Kapaun et al [36], who found that horses ridden by the professional rider had the highest trotting speed and the longest stride length compared to horses mounted by a hobby-rider. The effect of accumulated training sessions on heart rates of horses on both turf and sand, revealed greater fitness levels (i.e. lower heart rate for the same intensity) in horses having completed 11-20+ workouts. Age of the horse was included as a cofounder, which couldn't have influenced our results for this observation. Indeed, heart rates during submaximal exercise provide a means of monitoring the adaptation of the cardiovascular system to chronic exercise, commonly referred as the 'fitness" status of an athlete [37]. Foreman [38] drew similar conclusions in Thoroughbreds undergoing exercise testing at different intensities; heart rate was lower following a conventional training program.

Racehorse cardiovascular responses to incremental training intensity by sex of work-rider

Racehorse training implies the cooperative effort of two distinctive individuals: horses and humans. Indeed, in any equestrian discipline including racing, positive interaction between horse and rider is paramount to cope with the emotional and physical challenges of the demands of training. However, no study has reported any equine cardiovascular responses as a result of an interaction with the rider. In this study, no effect of sex of the rider on racehorse heart rate, nor the peak of heart rate, during training at differing intensities was noted. That is, when male and female work-riders are instructed to exercise the racehorses at tempo (canters) or race-pace (gallops) then both do just that. There is no measurable difference between rider sex on racehorse speed or on racehorse cardiovascular response. The outcome is indistinguishable whether ridden by a male or female work-rider. However, it has been shown that rider 'emotion/nerves' can be faithfully transmitted to the horse. For example, when exposed to a novel stimulus [39] or mounted for the first time by a novel rider [40], horses respond with an increase in heart rate. When the rider, but not horse, knows in advance that a novel stimulus/object, that is known to cause the horse to startle, is about to be encountered, the increment in rider heart rate in anticipation is matched by an increment in the horses heart rate [41]. Such acute fight-or-flight responses, most likely mediated by catecholamines and the stress hormone, cortisol, will facilitate improved training responses via energy mobilisation [42] and activated behavioural responses [43].

Racehorse recovery of heart rate after incremental training intensity by sex of work-rider

In our study, when assessing each individual horse in a repeated-measures analysis from peak heart rate through cardiovascular recovery to 15, 30 minutes to the last recorded heart rate that was back to, or below, baseline then a small signal suggestive of some effect of rider sex was noted. After sessions of slow canter on turf – the surface where nearly all gallops occurred – then heart rate area-under-the-curve or overall recovery was higher with a male rider onboard. After sessions of hard gallop on sand – the surface where nearly all canters occurred – then heart rate area-under-the-curve was lower with a male rider onboard. Could male work-riders, more so than female, anticipate the 'expected' training-intensity on a given surface and their higher or lower heart rate be transmitted faithfully to the horse? Without simultaneous measurement of work-rider heart rate, we cannot answer this question but it is intriguing and has been noted in other circumstances [44]. Perhaps male work-riders 'push' the horses more (i.e. reaching the horses peak HR sooner) on turf, despite instructions to exercise horses at low speed. However, we observed no difference in average speed between rider sex at differing training intensities on each surface. It is also possible that for faster sessions on sand (it is unlikely to have happened for slow canters on turf) that changes in work rider for the main galloping session may have provoked changes in the horses' heart rate. Nevertheless, this is only likely to have occurred for faster gallop sessions on sand, where we observed relatively faster recovery of heart rate with male riders aboard.

Race results

Using data publicly available online and expanding our analyses to two countries in order to increase the sample size, we questioned whether there was any overt difference in strike-rate during actual flat races between male and female jockeys, when accounting for the large difference in number of jockeys registered and number of races entered. Our results confirmed the existing trend of sex disparity between jockeys that is currently observed within the racing industry. When accounting for a larger proportion of male jockeys, a small but significantly greater winning strike-rate (~1%) was found in male compared to female jockeys in Australia, but not in the UK. This may be partly explained by the inability to focus solely on flat racing results, as no distinction could be made online for the available data in Victoria state, Australia. Regardless, the difference disappeared in Australia when considering if the horse/jockey achieved a first, second or third placing. Therefore, on balance, according to objective data then male riders do not win many more races than female jockeys. The ~1% difference is likely attributable to male riders getting more rides on better horses more likely to win in the first place. Furthermore, the quality of the race could not be taken into account and we were not able to get all the starting odds for the 52,000+ races we had data for and thus cannot adjust for this factor.

The study has several limitations, which should be acknowledged. First, there is a risk of selection bias due to the method of convenience sampling. However, the large sample size should minimise any slight effects of possible selection bias. Secondly, the study design is retrospective and descriptive. As a result, there are missing data for some riders and horses, along with other variables that have not been considered such as rider's weight. Nevertheless, using mixed-effect models to analyse the data with due incorporation of possible confounders such as racetrack and with individual racehorse and work-rider included as random effects, should mean that any missing data are distributed at random, minimising any inherent bias. Equally, whilst we have not accounted for differences in the 'quality' of each racehorse in our analyses, there are potentially other variables associated with the horses that we may not have been able to account for, that may influence an individual racehorse's response to training such as the fitness level of each horse and differences in pedigree. Although, again, these effects are estimated to be minimal in our opinion. The number of training sessions available for each rider was not balanced; many riders had only participated in <5 training sessions. Ideally, future prospective studies of a similar nature should source more observations per rider, if possible. Although it should be noted that many of the riders in our dataset, both male and female, had >100 sessions. Additionally, future studies could include the horse's body weight, plasma lactate and cortisol and aspects of the rider's physical status which could provide more insight into the interaction between riders and horses on performance and physiology in response to training over time. In addition, we acknowledge that the choice of combination for exercise intensity and track surface may have been opted by the trainer to alleviate any mitigating risks for the horse i.e. choice of 'soft' surface for a horse presenting poor hoof quality. Again, however, these instances would be expected to be relatively rare and the size of our dataset would mask such rare bias.

Perspectives and Significance

This is the first study to explore the effect of the sex of rider on racehorse performance physiology during training. Using measurements from objective fitness tracking systems, no marked sex differentials between work riders were observed on racehorse physiological responses (cardiovascular and locomotory parameters) or speed during training. Further research could expand on performance profiling in both male and female riders across different racing nations and types of racing (e.g. National Hunt or jump-racing). Our analyses also explored existing disparity between sex for racing opportunities. The study's implications may breakdown any discriminatory barriers, improving the access of female jockeys to quality mounts and racing events. A clear opening emerges for the growing inclusion of female riders in the racing profession, as their underrepresentation remains tangible at the elite sporting level. This data can now reliably inform trainers and owners on the equal athletic potential of female riders for racing endeavours. New perspectives arise to shift traditional male-dominated perception, attitude and behaviour of the greater public. By using a relatively small dataset, we were able to show the absence of an effect of rider's sex on racehorse's response to training, for example, with increased workload, speed appears to be relatively unchanged for both sexes.

Declarations

Ethics approval and consent to participate

Ethical approval for this study was obtained from the University of Nottingham (School of Veterinary Medicine and Science) Research Ethics Committee (REC code: 3270 201029).

The study is a retrospective, observational study of physiological data held in a database by an external company. The company work with racehorse trainers whom collect data from individual horses that are owned by different individuals. Consent to use the anonymised data for research purposes is obtained between owners, racehorse trainers and the company.

Consent for publication

Not applicable.

Availability of data and materials

All data available on reasonable request from the corresponding authors.

Competing interests

Charlotte Schrurs is self-funding her PhD. All data were collected by Arioneo Ltd. David S Gardner is funded by The School of Veterinary Medicine and Science, University of Nottingham. Guillaume Dubois is an employee of Arioneo Ltd and had no influence on the reporting of results as presented. Emmanuelle Van Erck-Westergren is an Equine Sports Medicine specialist and consultant for Arioneo Ltd.

Funding

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Authors' contributions

C.S. and D.S.G. designed and conducted the research and co-wrote the manuscript. D.S.G. and C.S. conducted the statistical analyses. All authors critically evaluated the paper. C.S. and D.S.G. have primary responsibility for its final content.

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Figures

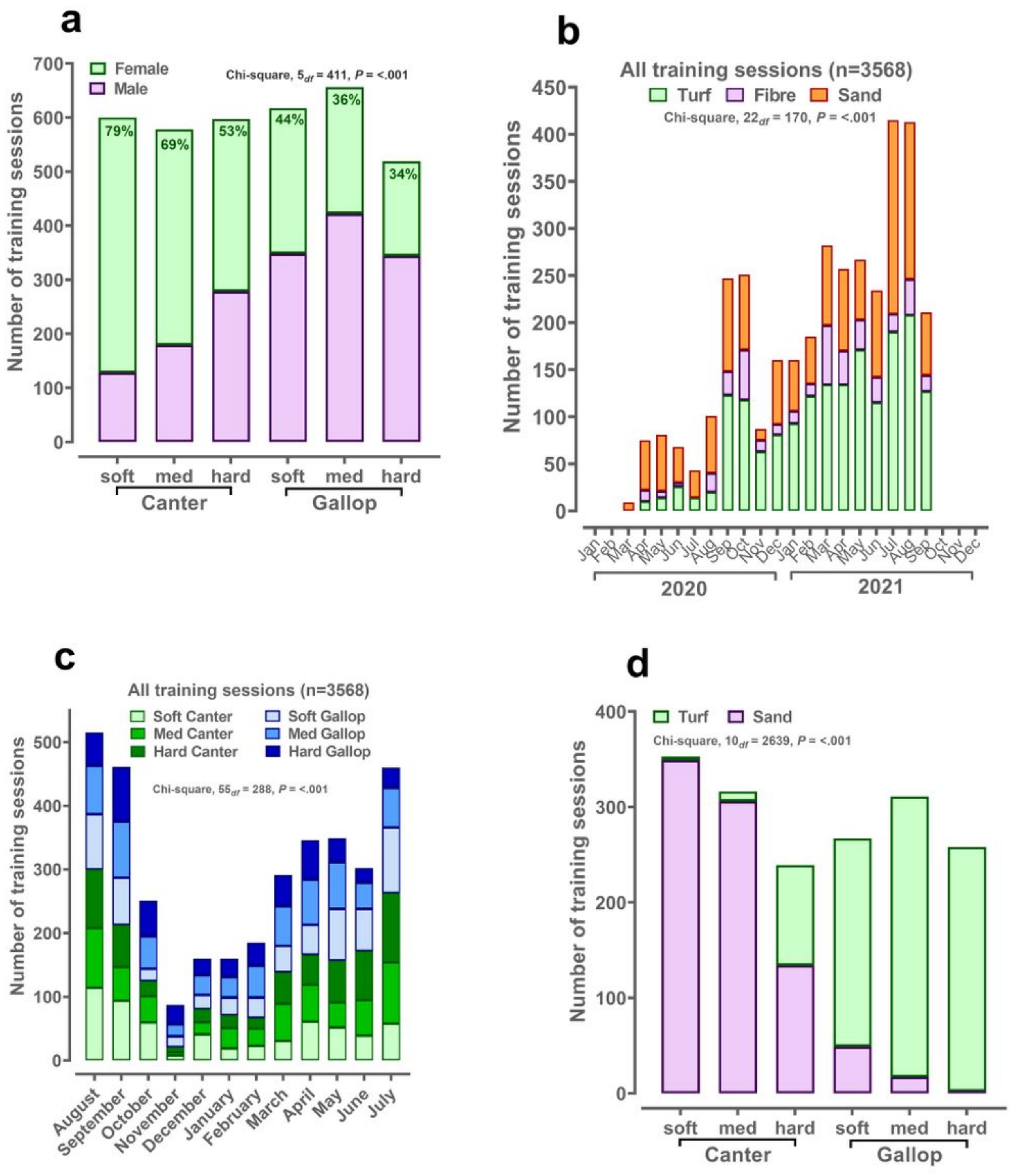

Figure 1

Classification of the number, type and intensity of training sessions

Data are numbers of training sessions stratified by training intensity, month of the year or track surface. A total of 3568 training sessions were included in this dataset from a single trainer in Australia. Data were available throughout the year. Training intensity (soft/med/hard canter; soft/med/hard gallop) was derived from calculating sextiles of the fastest furlong (200m interval) for the overall dataset. Statistics were generated by analysing proportions (percentage of group total) by chi-square (Genstat v20, VSNi, Rothampsted, UK).

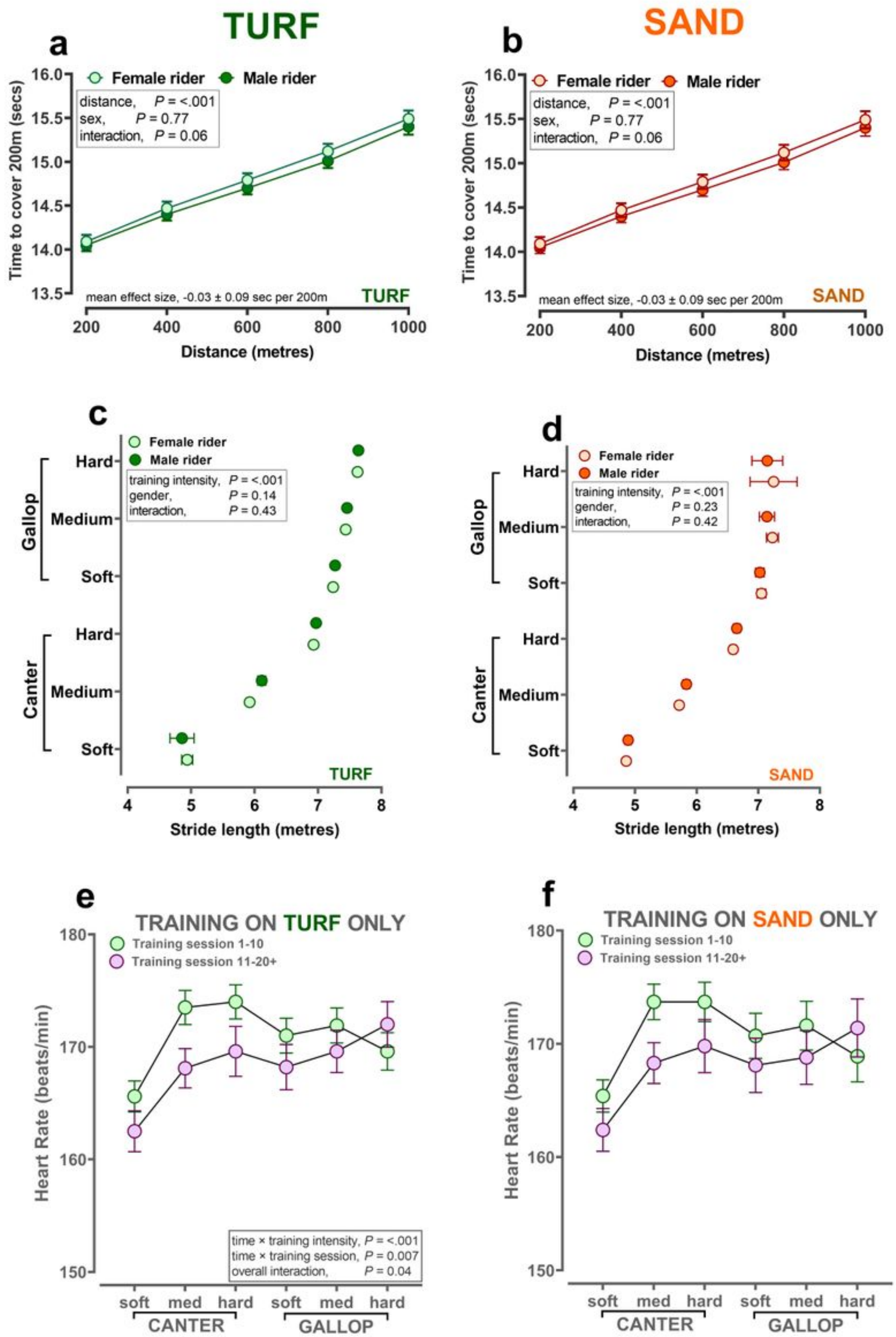

Figure 2

Speed, stride and influence of multiple training sessions on different track surfaces by sex of work rider

a-f: Values are predicted mean ± S.E.M. for continuous data recorded by 'Equimetre' in a cohort of racehorses in Australia (n=130 different racehorses, n=1,754 different training sessions). Data were available throughout the year. Training intensity (soft/med/hard canter; soft/med/hard gallop) was derived from calculating sextiles of the fastest furlong (200m interval) for the overall dataset. The statistical model generated predicted means (± S.E.M.) with the pre-specified interaction, training intensity × rider sex (or training session, **e,f**) fitted last after inclusion of rider registration status and track surface as fixed effects, HorseID and rider name as random effects, since both horses and riders completed multiple sessions. All data analyses were conducted using Genstat v20 (VSNi, UK) and graphs produced using Graphpad Prism v9.0 (La Jolla, USA).

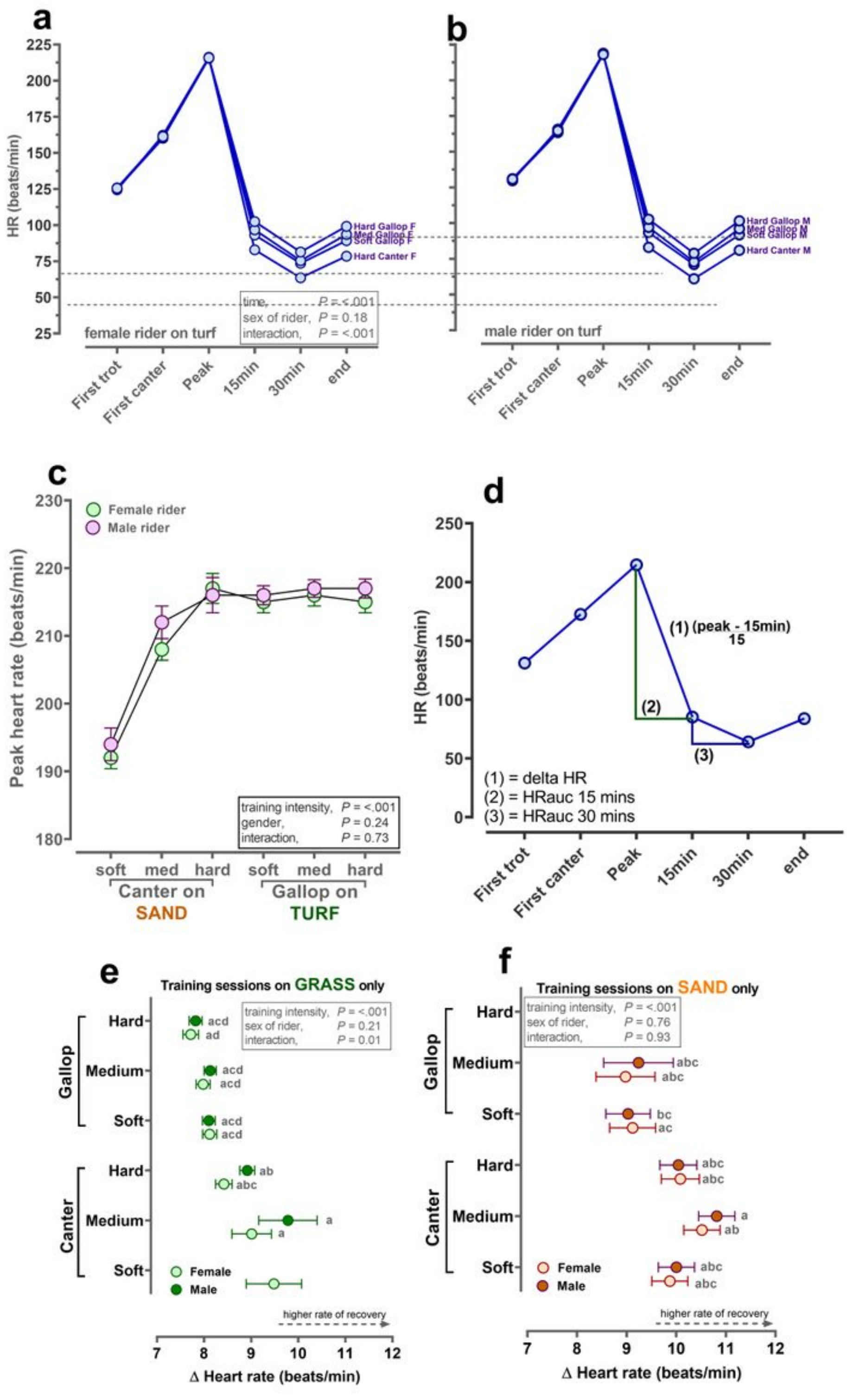

Figure 3

Racehorse heart rate on different track surfaces by sex of work rider

a,b,c,e,f: Values are predicted mean ± S.E.M. for continuous data recorded by 'Equimetre' in a cohort of racehorses in Australia (n=130 different racehorses, n=1,754 different training sessions). Data were available throughout the year. Training intensity (soft/med/hard canter; soft/med/hard gallop) was derived from calculating sextiles of the fastest furlong (200m interval) for the overall dataset. The statistical model generated predicted means (± S.E.M.) with the pre-specified interaction, training intensity × rider sex fitted last after inclusion of rider registration status and track surface as fixed effects. HorseID and rider name were included as random effects, since both horses and riders completed multiple sessions. d) describes calculation of delta HR and HR area-under-the-response-curve. All data analyses were conducted using Genstat v20 (VSNi, UK) and graphs produced using Graphpad Prism v9.0 (La Jolla, USA).

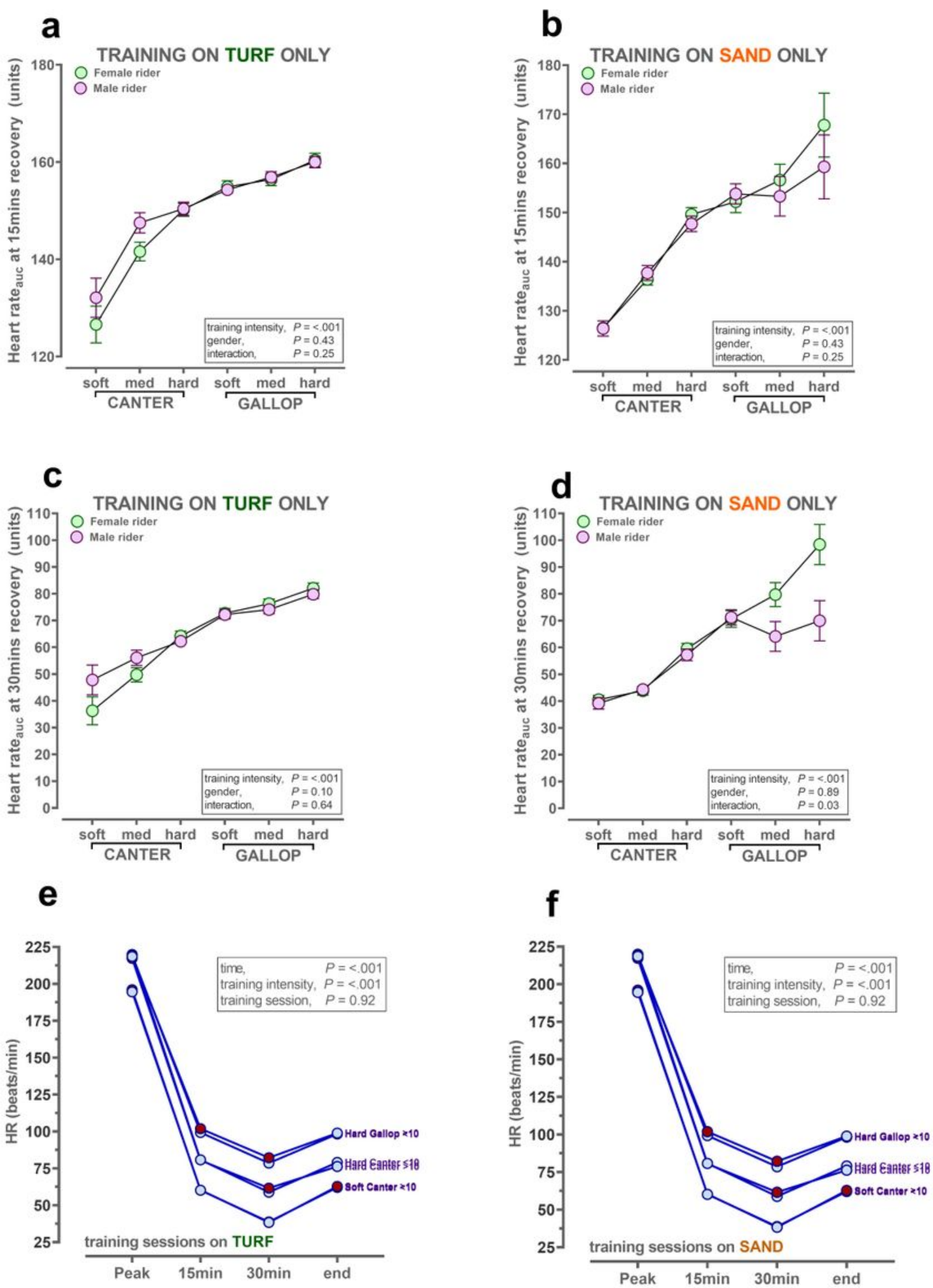

Figure 4

Recovery of racehorse heart rate on different track surfaces by sex of work rider

a,b,c,d: Values are predicted mean ± S.E.M. for continuous data recorded by 'Equimetre' in a cohort of racehorses in Australia (n=130 different racehorses, n=1,754 different training sessions). Data were available throughout the year. Training intensity (soft/med/hard canter; soft/med/hard gallop) was derived from calculating sextiles of the fastest furlong (200m interval) for the overall dataset. The statistical model generated predicted means (± S.E.M.) with the pre-specified interaction, training intensity × rider sex fitted last after inclusion of rider registration status and track surface as fixed effects. HorseID and rider name were included as random effects, since both horses and riders completed multiple sessions. HR area-under-the-response-curve (AUC) calculated as described in methods. All data analyses were conducted using Genstat v20 (VSNi, UK) and graphs produced using Graphpad Prism v9.0 (La Jolla, USA).