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Are physiological attributes of jockeys predictors of falls?: A controlled Tasmanian pilot study.

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ABSTRACT

Objectives: This pilot study describes the physiological attributes of jockeys and track-work riders in Tasmania and investigates whether these attributes are associated with falls.

Methods: All jockeys and track-work riders licensed in Tasmania were invited to participate. The study group consisted of 8 jockeys (2 female, 6 male) and 20 track-work riders (14 female, 6 male). Measures of anthropometry, balance, reaction time, isometric strength, vertical jump, glycolytic and aerobic fitness, flexibility and body composition were conducted. Tests were designed to assess specific aspects of rider fitness and performance relevant to horse racing. For a subset of participants, we obtained information on falls and injuries. We used Poisson regression to estimate incidence rate ratios.

Results: Jockeys had better balance, faster mean reaction time, lower fatigue index, and a higher estimated $\dot{V}O_{2\,max}$ than their track-work riding counterparts. Jockeys were also younger and smaller in stature than track-work riders and, when differences in body mass were taken into account, they had greater muscular strength and muscular (alactic) power. Important factors found to be associated with falls were lower aerobic and anaerobic fitness, greater muscular strength and power, and riding with the full foot in the stirrup irons compared to riding on the ball of the foot.

Conclusion: This pilot study shows that physiological attributes of jockeys and track-work riders can predict their risk of falling and are measurable using methods feasible for large-scale field work.

Key Words (MeSH)

horse, muscle strength, fitness, body composition, bone density, injury

ARTICLE SUMMARY

Article focus

- Riding racehorses is a physically demanding and hazardous occupation, with most injuries to jockeys caused by falls.
- This study aims to investigate the association between physiological attributes and risk of falls for jockeys and track-work riders.

Key messages

- Lower anaerobic and aerobic fitness and higher muscular strength and power were associated with greater risk of falls.
- Placement of the foot in the stirrup irons was also found to be associated with falls.
- This pilot study has confirmed that it is feasible to measure physiological attributes of jockeys and track-work riders that are predictive of the risk of falling.

Strengths and limitations

- This was the first study to investigate whether physiological attributes are associated with falls to jockeys and track-work rides.
- Tests were deliberately restricted to those that could be conducted with robustly constructed and transportable equipment.
- We were able to recruit only a small number of participants, but our sample comprised 44% of the jockey population and 24% of the track-work rider population licensed in Tasmania.
- Some refinements to the testing methodology are needed.

INTRODUCTION

The profession of a jockey or track-work rider in the thoroughbred racing industry is physically demanding. Riding race horses, during track-work or during a race, places demands on all three energy pathways (alactic, lactic and aerobic). Strength, strength endurance, balance, reaction time and flexibility are all considered to be important attributes of a successful rider.[1, 2]

A professional jockey in Australia may have as many as 1000 race rides per year, and may ride in races that range in distance from 800m to 3600m in races without jumps ("on the flat") or from 2800m to 5500m in races over jumps. Jockeys may also undertake track-work riding. Track-work may involve riding many horses in training, and at varying intensities from walking a horse, slow or fast work, jump outs (practice jumping out of the barriers and galloping over a short distance) or barrier trials (unofficial races generally over shorter distances and with fewer starters, in which a horse or jockey may be assessed for suitability to compete in official races). Track-work riders are not able to ride in professional races unless they are a licensed jockey, and are generally heavier in weight than jockeys who need to be able to ride at weights as low as 51kg (flat races) or 64kg (jumps races).

There have been several studies describing the physical attributes and dietary habits of jockeys,[1, 3-7] and the demands of riding in races.[1, 8] The physiological attributes of grooms and exercise riders,[9] and the physiological demands of riding for equestrian and recreational horse riders[2, 10-14] have also been described. There is limited information on the fitness of jockeys, however, and no study has reported the fitness characteristics of track-work riders despite their integral role within the racing industry. The feasibility of undertaking measurements of the physiological attributes of this highly mobile occupational group, using techniques suitable for large-scale fieldwork, has not been demonstrated.

Further, there has been no investigation of the association between physiological attributes and risk of falls for jockeys and track-work riders. Riding racehorses is a hazardous occupation and most injuries to jockeys are caused by falls.[15] We have investigated risk factors for race-day jockey falls in flat racing using race-day data, and found that jockey-related factors included female sex of jockey, being an apprentice jockey, holding an amateur licence, and having fewer previous rides at a meeting.[16] We hypothesise that some physiological attributes of jockeys may also contribute to risk of falling. Given the lack of information on this occupational group, we undertook a study to describe the physiological attributes of jockeys and track-work riders licensed to ride in Tasmania and conducted a preliminary investigation into whether these attributes are associated with falls.

METHODS

All jockeys (n=18; 6 apprentice, 12 full-licensed) and track-work riders (n=85) licensed to ride in Tasmania, the island state of Australia, were invited to participate. Reasons for non-participation included riders not currently or regularly riding, injury or illness, living interstate or being ineligible by reason of age (we excluded riders older than 50 years). The final study group consisted of 8 jockeys (2 female full-licensed, 4 male apprentice, 1 male full-licensed and 1 male full-licensed jumps jockey) and 20 track-work riders (14 female, 6 male). This represents 44% of the jockey population and 24% of the track-work rider population in Tasmania.

The study was approved by the Human Research Ethics Committee (Tasmania)(Reference Number H0009692).

Each participant was tested at one of three different locations in Tasmania - Menzies Research Institute (Hobart), University of Tasmania Exercise Research Laboratory (Launceston) and the Devonport Racing Club (Devonport). The same equipment was transported to and used at each location. All tests were supervised by the same technician.

Tests were selected on their practicality and portability and based on previous studies of horse riders[1, 2, 8, 10-14] and performance attributes of athletes.[17] These tests were designed to assess specific aspects of fitness that may be relevant to the requirements of thoroughbred racing and track-work riding.

Participants were provided with an outline of the test protocols prior to formal testing. Participants were required to be in good health and fully recovered from previous injuries. For jockeys, testing did not occur on the day before or after race–day, or at times of significant body mass wasting.

Height was measured to the nearest 0.1cm using a Leicester Height Measure (Invicta, Leicester, UK). Body mass was measured to the nearest 0.1kg using a Heine Portable Professional Scale (Heine, Dover, NH, USA). Body mass index (BMI) was calculated. Body composition (total percent body fat) and bone mineral density ($g.cm^{-2}$) were measured by the technique of dual-energy X-ray absorptiometry (DXA) using one Lunar DPX densitometer (Lunar, Madison, WI). Only 11 of the participants underwent a DXA scan, and therefore these results were not included in the falls analysis.

To measure dynamic unipedal balance, the participant was required to balance in a 'standing-stork' pose (shoes removed, one leg lifted, placing the toes of that foot against the knee of the opposite leg) on a 65mm foam insert (Airex® Balance-Pad Plus, Alcan Airex AG, Switzerland) for as long as possible. A stopwatch was used to record the time that the participant held position. The test was repeated three times on each leg. The best result for each leg was used in analysis.

The sit and reach test was used to measure flexibility of the lower back, hips and hamstring muscles and the back and hip joints. Participants placed their feet flat against a 30cm high box with shoes and socks removed and attempted to reach forward as far as possible with knees fully extended. The level of the feet was recorded as the baseline, with positive scores (in cm) achieved beyond this point. Participants were permitted three trials and the best result was recorded.[18, 19]

Reaction time was assessed in milliseconds using a hand-held electronic timer with a light as the stimulus, and with depression of a switch by the finger as the response (Balance Systems, Sydney, NSW). Ten practice trials were undertaken, followed by ten experimental trials.[20]

Strength was measured using isometric dynamometers. Grip strength was measured using a hand-grip dynamometer (Smedley's TTM 100kg, Tokyo), and shoulder and arm strength using a shoulder/arm dynamometer (TTM 100kg, Tokyo). This involved both push strength (maximal voluntary isometric contraction of the shoulder flexors/adductors) and pull strength (maximum voluntary isometric contraction of the shoulder extensors/abductors). Results were recorded to the nearest 0.5kg. Leg and back strength was measured using a leg/back dynamometer (Gloria TTM 300kg, Tokyo). Participants performed a maximum voluntary isometric contraction of the knee and hip extensors, with the knees flexed at 115^o while maintaining a vertical spine position. The result was recorded to the nearest 1kg. Three trials were conducted for all strength tests with the best result used for analysis.

To measure explosive leg power, the standing vertical jump (counter movement jump) was conducted using a Yardstick® (Swift Performance Equipment, Lismore, New South Wales). The best trial was recorded and reported in centimetres jumped.[19] From this result, peak and mean alactic power were calculated using the Harman formulas.[21]

Anaerobic (lactic) fitness was assessed by the 30 second cycle test using an air-braked ergometer (Exertech, EX-10, Repco, Huntingdale, Australia).[22] Mean and peak lactic power were recorded in watts (W) and watts per kilogram of body mass ($W.kg^{-1}$). The fatigue index (percentage decline in power compared with the peak power output) was calculated.

Aerobic fitness was assessed using the YMCA submaximal exercise test performed on a friction-braked cycle ergometer (Monark Ergomedic 828E, Varberg, Sweden) to estimate maximal oxygen uptake ($\dot{V}O_{2\,max}$, $ml.kg^{-1}.min^{-1}$).[17]

The participants were asked how they positioned their feet in the stirrup irons when riding (riding style). They were classified as riding with their full foot lodged firmly in the irons (full foot), or with the ball of their foot in the irons (ball of foot), or with only the toe of their boot in the iron (toe-in-iron).

Incident data on falls of licensed Tasmanian track-work riders during track-work were collected by participants completing a diary for 12 months following their fitness assessment. The follow-up period was 1 March 2008 to 31 May 2009. The participants were instructed to record, on a monthly basis, the average number of track-work rides per week. For each fall, participants were asked to complete an incident report form. Of the track-work riders, 7 returned their diaries.

None of the jockeys returned their track-work diaries. However, we did obtain incident data on falls by the 7 licensed flat racing jockeys at race meetings. The data were collated through a search of stewards' reports provided by Racing Services Tasmania (RST), the principal racing authority of that state. Racing Information Services Australia (RISA) provided comprehensive data on every race meeting run by RST. These data were merged with the incident falls data. Details are provided elsewhere.[15] To match the number of rides taken by track-work riders, we included race rides during the period 1 June 2007 to 31 May 2009.

Anthropometric (height, mass, BMI, % body fat and BMD) and fitness (aerobic, anaerobic, muscular strength and power, flexibility, balance and reaction time) measures of jockeys and track-work riders were compared using regression analysis. Right-skewed data were log transformed prior to analysis.

Univariable Poisson regression was used to estimate incidence rate ratios (IRR) with 95% confidence intervals (CI) by modelling the logarithm of the mean number of falls as a function of covariates, with the logarithm of the number of rides as an offset. Interaction of licence type was assessed from the coefficients of product terms. Effect modification was considered present if the test of the coefficient of a product term yielded a p value less than

0.05 in a dataset expanded with 9 duplicates. Results for variables that showed significant interaction with licence type are reported separately (Table 3) from those where interaction was not present (Table 2).

RESULTS

Participant age and anthropometric characteristics are described in Table 1. Jockeys were younger in age, shorter in height, lower in mass and BMI, and had lower percentage total body fat and total bone mineral density than track-work riders.

The participant groups were similar in measures of grip strength, shoulder pull strength, and leg and back strength. Jockeys had better balance, faster reaction time, lower fatigue index, and a higher estimated $\dot{V}O_{2\,max}$, but were less flexible and had lower shoulder push strength, than track-work riders. Additionally, jockeys had greater muscular strength and power, once accounting for the body mass (per kg) of the participant. Detailed results are available in a Supplementary Appendix.

Table 1: Descriptive characteristics of jockeys and track-work riders in Tasmania

Study factor	**Jockeys (n=8)**	**Track-work riders (n=20)**
Age (years)		
Median	27.00	36.50
Mean (± SD)	28.75 (10.10)	33.20 (11.08)
Range	18, 41	15, 47
Height (cm)		
Median	163.45	168.25
Mean (± SD)	163.39 (7.08)	166.51 (7.36)
Range	154.4, 174.9	156.6, 179.5
Mass (kg)		
Median	51.75	65.90
Mean (± SD)	55.08 (5.87)	67.32 (12.51)
Range	50.5, 66.3	44.2, 90.5
BMI		
Median	20.63	24.00
Mean (± SD)	20.62 (1.58)	24.13 (3.28)
Range	18.45, 23.27	18.02, 30.52
Body fat (%)[a]		
Median	15.90	29.45
Mean (± SD)	13.98 (3.52)	28.15 (8.21)
Range	8.50, 16.90	17.00, 37.60
BMD ($g.cm^{-2}$)[a]		
Median	1.167	1.273
Mean (± SD)	1.157 (0.068)	1.312 (0.103)
Range	1.085, 1.246	1.206, 1.473

[a] Subset of data (n=5 jockeys; n=6 track-work riders).

Table 2 presents unadjusted and adjusted (for age and sex) incidence rate ratios of physiological attributes associated with falls for factors that did not differ between jockeys and track-work riders. Seven track-work riders returned their fall and injury diaries. The track-work riders reported a total of 24 falls from 2,996 rides (0.80 falls per 100 rides). Of these falls, 13 (54%) resulted in an injury being sustained. A total of 13 falls from 2,978 race rides (0.44 falls per 100 rides) were experienced by the jockeys in our study. Of these falls, 3 (23%) resulted in an injury being sustained.

Table 2: Unadjusted and adjusted incidence rate ratios of factors associated with race-day falls by flat racing jockeys (n=7) from 1 June 2007 to 31 May 2009, and with falls during track-work for track-work riders (n=7) from 1 March 2008 to 31 May 2009.

Study factor	Falls	Rides	Unadjusted IRR (95% CI)	Adjusted IRR (95% CI)[a]
Licence				
Jockey	13	2,978	1.00	1.00
Track-work rider	24	2,996	1.84 (0.90, 3.74)	3.54 (2.07, 6.06)[d]
Sex				
Male	15	2,519	1.00	1.00
Female	22	3,455	1.07 (0.52, 2.19)	0.45 (0.17, 1.20)
Age	37	5,974	1.03 (1.00, 1.06)	1.05 (1.01, 1.10)[b]
BMI	37	5,974	1.12 (1.02, 1.21)[b]	1.15 (1.08, 1.23)[d]
Log of balance pooled (sec)	37	5,974	0.87 (0.59, 1.28)	1.28 (0.95, 1.72)
Flexibility (cm)	37	5,974	0.99 (0.94, 1.04)	0.96 (0.91, 1.01)
Muscular strength and power				
Push strength (kg)	37	5,974	1.00 (0.97, 1.03)	1.01 (0.97, 1.04)
Pull strength (kg)	37	5,974	1.03 (0.98, 1.09)	1.09 (1.04, 1.14)[d]
Leg/back strength (kg/10)	37	5,974	1.11 (1.00, 1.23)[b]	1.07 (1.01, 1.14)[b]
Absolute jump height (cm)	37	5,974	0.97 (0.92, 1.02)	0.93 (0.85, 1.01)
Mean power (Watts.kg^{-1})	37	5,974	1.19 (0.94, 1.50)	1.14 (0.91, 1.42)
Anaerobic fitness				
Mean power (Watts.kg^{-1})	37	5,974	0.90 (0.77, 1.05)	0.85 (0.67, 1.09)
Peak power (Watts.kg^{-1})	37	5,974	0.91 (0.82, 1.00)	0.87 (0.74, 1.02)
Total work (hectojoules.kg^{-1})	37	5,974	0.78 (0.46, 1.32)	0.83 (0.34, 1.98)
Fatigue index (%)	37	5,974	0.97 (0.96, 0.99)[d]	0.98 (0.96, 1.00)
Aerobic fitness				
$\dot{V}O_{2\,max}$ (ml.kg^{-1}.min^{-1})	37	5,974	0.97 (0.93, 1.01)	0.93 (0.90, 0.97)[d]
Riding style				
Ball of foot (n=9)	19	4,176	1.00	1.00
Toe-in-iron (n=2)	5	684	1.61 (0.99, 2.61)	1.12 (0.60, 2.08)
Full foot (n=3)	13	1,114	2.56 (1.31, 5.04)[c]	2.37 (1.46, 3.85)[d]

[a]Adjusted for age and sex; [b] $p<0.05$; [c] $p<0.01$; [d] $p<0.001$.

Table 2 shows that lower aerobic fitness was associated with greater risk of falls. The associations of measures of anaerobic fitness were not statistically significant but, became significant when we expanded the dataset from n=14 to n=28 (peak power per kg of body mass, fatigue index) or to n=42 (mean power per kg of body mass) by duplicating observations.

Greater shoulder pull strength and greater leg and back strength were also associated with a higher incidence of falls (Table 2). Other measures of muscular strength differed by licence type. Table 3 shows that jockeys who had lower grip strength or higher peak alactic power had a higher fall incidence than other jockeys, with the opposite being the case for track-work riders.

Table 3: Adjusted incidence rate ratios of factors associated with falls that differed by jockey and track-work riders

Study factor	Jockey IRR (95% CI)[a]	Track-work rider IRR (95% CI)[a]
Mass (kg)	0.82 (0.81, 0.83)[d]	1.05 (1.02, 1.07)[d]
Height (cm)	0.92 (0.89, 0.96)[d]	1.05 (0.92, 1.19)
Muscular strength and power		
Grip strength (pooled)	0.81 (0.73, 0.89)[d]	1.12 (1.08, 1.16)[d]
Peak power (Watts.kg^{-1})	1.08 (1.04, 1.13)[d]	0.95 (0.94, 0.96)[d]

[a]Adjusted for age and sex; [b] $p<0.05$; [c] $p<0.01$; [d] $p<0.001$.

Placement of the foot in the stirrup irons was associated with falls. Both jockeys and track-work riders that ride with the full foot in the stirrup irons had a higher fall incidence than did those riding with the ball of the foot in the irons (Table 2).

DISCUSSION

In this investigation of the physiological attributes of jockeys and track-work riders in Tasmania, we found that jockeys had better balance, faster mean reaction time, lower fatigue index, and a higher estimated $\dot{V}O_{2\,max}$. They were younger and smaller in stature than track-work riders and, when differences in body mass were taken into account, they had greater muscular strength and alactic power (derived from the vertical jump). Furthermore, in a study of falls experienced by jockeys on race-days and by track-work riders during track-work, we found older age, higher BMI, greater shoulder pull and greater leg and back strength, lower aerobic fitness, and riding with the full foot in the stirrup irons, were factors associated with an increased incidence of falls. Additionally, jockeys who were lower in mass, shorter in height, weaker in grip strength or had greater peak alactic power (per kg of body mass) had a higher fall incidence than other jockeys, with the reverse being the case for track-work riders.

The anthropometric attributes of jockeys reported in this study were generally similar to those of New Zealand and Irish jockeys reported in previous studies,[5-7] but the track-work riders more closely resembled the anthropometric characteristics of participants in equestrian studies.[11, 14] The grip strength of the jockeys and track-work riders was similar to that of participants in a study of Irish jockeys,[6] but higher than that of participants in an equestrian study.[14] Both groups also had above average relative $\dot{V}O_{2\,max}$ and average flexibility compared to normative data,[17] and greater anaerobic (lactic) power than those from an equestrian study.[14] We do not have normative data on balance or reaction times for this age group with which to make comparisons.

In this study, lower anaerobic and aerobic fitness were associated with greater risk of falls. Only the association with aerobic fitness was statistically significant but, if our participants are representative of jockeys and track-work riders in general, the association with measures of anaerobic fitness would have been statistically significant for peak power per kg of body mass and for fatigue index if the dataset had been just two times greater and significant for mean power per kg of body mass if the dataset had been three times greater. This is the first report of a finding that fitness is associated with falls by jockeys and track-work riders, but it is consistent with findings for injuries to other occupational groups including manual material handlers[23] and military personnel.[24, 25]

Paradoxically, we found that higher muscular strength and power were positively associated with falls. This was seen for shoulder pull strength and leg and back strength, for peak alactic power in jockeys, and for grip strength in track-work riders. This may be due to riders with greater strength and power being placed on difficult or fractious horses because it is generally industry practice to, where possible, not assign this task to less experienced riders. Possibly consistent with this finding, industrial workers with greater isometric strength have been reported to be at greater risk of back problems.[26] On the other hand, opposite results were found for grip strength of jockeys and for peak alactic power of track-work riders in our study and, in view of the inconsistencies, we can not discount the possibility that the inverse associations with muscular strength and power are chance findings.

Placement of the foot in the stirrup irons was found to be associated with falls for both jockeys and track-work riders. Those riding with the full foot in the stirrup irons had a higher fall incidence than those riding with the ball of the foot in the irons. We also found a small and statistically insignificant increase in risk for those who ride with their toe in the iron. Due to safety concerns, all principal racing authorities in Australia require apprentices to ride with at least their ball of their foot in the irons until they have gained adequate experience (Ring 2010 pers. comm.). We had too few inexperienced riders in our study to investigate this issue.

This study adds to the limited information available on the physiological attributes of jockeys, and is the first study to report comprehensively on the physiological characteristics of track-work riders. A strength of this study was the comprehensive range of tests that was implemented. Additionally, this allowed us to assess the feasibility of applying this battery of tests in large-scale fieldwork with this highly mobile occupational group, and we were able to get some confirmation that doing so was practicable. In a novel contribution, this was the first study to investigate whether these attributes are associated with falls to riders in both licence groups and we found that measurements of fitness and riding style were predictors of falls. So too were the measurements of muscular strength and power, albeit in an unexpected direction.

However, some limitations of this study should be borne in mind. Because our intention was to investigate methods appropriate for large-scale fieldwork, we deliberately restricted tests to those that could be conducted with robustly-constructed and transportable equipment. We did not use more sensitive equipment that may be more accurate. Due to difficulties in recruitment, we obtained only a small number of participants, but our sample comprised 44% of the jockey population and 24% of the track-work rider population licensed in Tasmania. Other studies involving jockeys have also reported low response proportions,[3, 27] and this is probably due to the working life of jockeys that necessitates considerable travel. Race meetings are conducted less regularly in Tasmania than in large metropolitan areas in Australia, and thus the jockeys in this current study may be more representative of the average jockey in Australia than of elite jockeys who ride in races more often. That we had a high proportion of females among track-work riders, and a low proportion of females among jockeys, is nevertheless consistent with the population frequencies. Furthermore, only 35% of track-work riders returned their fall and injury diaries and none of the jockeys returned theirs. It is possible that those who experienced more falls or injuries were more likely to return their diaries, leading to possible bias in the results if they also differed in respect of the factors associated with falls. Lastly, our experience has suggested some refinements to the testing methodology are needed. To obtain better measurements of $\dot{V}O_{2\,max}$, portable gas analysis could be employed during racing and track-work. A more complex stimulus reaction time test, such as a go/no-go or choice reaction time,[28] should be employed because the simple reaction time test we used was not sufficiently sensitive to differentiate between groups and individuals. Furthermore, a riding-relevant balance test or core-stability test with higher specificity is required.

CONCLUSION

Riding thoroughbred racehorses is a hazardous occupation. This pilot study has confirmed that it is feasible to measure physiological attributes of jockeys and track-work riders that are predictive of the risk of falling. We have investigated risk factors for falls among jockeys using routinely collected race-day data[16] but without the insights that may be possible from actual measurements of the jockeys. What is now required is a large-scale study of the physiological attributes of jockeys, that can provide the evidence base for improvements to apprentice training and remedial riding programmes designed to remedy deficits in physiological performance that lead to falls and possibly to establish minimum standards of performance for jockey licencing.

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COMPETING INTERESTS

None declared.

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AUTHOR CONTRIBUTIONS

All authors contributed to analysis and interpretation of data, review and revision of the manuscript critically for important intellectual content, and provided final approval of the version to be published. Additionally, Peta Hitchens, Leigh Blizzard, and James Fell contributed to conception and design of the study, acquisition of data and drafting of the manuscript. I confirm that this manuscript is an independent contribution, has been read and approved by all co-authors.

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LICENCE FOR PUBLICATION STATEMENT

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

Note: Page numbers are those displayed in the top left/right corner of the submission pdf.

	Item No	Recommendation	Page No.
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Title page
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5, 6 & 9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-9
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-9
Bias	9	Describe any efforts to address potential sources of bias	Potential bias discussed on page 16
Study size	10	Explain how the study size was arrived at	5 (pilot)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	n/a
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	n/a
		(*e*) Describe any sensitivity analyses	n/a
Results			
Participants	13	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5 & 9

		(b) Give reasons for non-participation at each stage	5 & 9
		(c) Consider use of a flow diagram	n/a
Descriptive data	14	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
Outcome data	15	Report numbers of outcome events or summary measures	11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Table 3
Discussion			
Key results	18	Summarise key results with reference to study objectives	13-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	17 (feasible to conduct large-scale study)
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

Are physiological attributes of jockeys predictors of falls?: A controlled pilot study.

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Are physiological attributes of jockeys predictors of falls?: A controlled pilot study.

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ABSTRACT

Objectives: This pilot study describes the physiological attributes of jockeys and track-work riders in Tasmania and investigates whether these attributes are associated with falls.

Methods: All jockeys and track-work riders licensed in Tasmania were invited to participate. The study group consisted of 8 jockeys (2 female, 6 male) and 20 track-work riders (14 female, 6 male). Measures of anthropometry, balance, reaction time, isometric strength, vertical jump, glycolytic and aerobic fitness, flexibility and body composition were conducted. Tests were designed to assess specific aspects of rider fitness and performance relevant to horse racing. For a subset of participants (n=14), we obtained information on falls and injuries. We used Poisson regression to estimate incidence rate ratios.

Results: Jockeys had better balance, faster mean reaction time, lower fatigue index, and a higher estimated $\dot{V}O_{2\,max}$ than their track-work riding counterparts. Jockeys were also younger and smaller in stature than track-work riders and, when differences in body masswere taken into account, they had greater muscular strength and muscular (alactic) power. Important factors found to be associated with falls were lower aerobic and anaerobic fitness, greater muscular strength and power, and riding with the full foot in the stirrup irons compared to riding on the ball of the foot.

Conclusion: This pilot study shows that physiological attributes of jockeys and track-work riders can predict their risk of falling and are measurable using methods feasible for large-scale field work.

Key Words (MeSH)

Horse riding, muscle strength, fitness, body composition, bone density, injury

ARTICLE SUMMARY

Article focus

- Riding racehorses is a physically demanding and hazardous occupation, with mostinjuries to jockeys caused by falls.
- This study aims to investigate the association between physiological attributes andrisk of falls for jockeys and track-work riders.

Key messages

- Lower anaerobic and aerobic fitness and higher muscular strength and power wereassociated with greater risk of falls.
- Placement of the foot in the stirrup irons was also found to be associated with falls.
- This pilot study has confirmed that it is feasible to measure physiological attributes ofjockeys and track-work riders that are predictive of the risk of falling.

Strengths and limitations

- This was the first study to investigate whether physiological attributes are associatedwith falls to jockeys and track-work rides.
- Tests were deliberately restricted to those that could be conducted with robustlyconstructedand transportable equipment.
- We were able to recruit only a small number of participants, but our samplecomprised 44% of the jockey population and 24% of the track-work rider populationlicensed in Tasmania.
- Some refinements to the testing methodology are needed.

INTRODUCTION

The profession of a jockey or track-work rider in the thoroughbred racing industry is physically demanding. Riding race horses, during track-work or during a race, places demands on all three energy pathways (alactic, lactic and aerobic). Strength, strength endurance, balance, reaction time and flexibility are all considered to be important attributes of a successful rider.[1, 2]

A professional jockey in Australia may have as many as 1000 race rides per year, and may ride in races that range in distance from 800m to 3600m in races without jumps ("on the flat") or from 2800m to 5500m in races over jumps. Jockeys may also undertake track-work riding. Track-work may involve riding many horses in training, and at varying intensities from walking a horse, slow or fast work, jump outs (practice jumping out of the barriers and galloping over a short distance) or barrier trials (unofficial races generally over shorter distances and with fewer starters, in which a horse or jockey may be assessed for suitability to compete in official races). Track-work riders are not able to ride in professional races unless they are a licensed jockey, and are generally heavier in weight than jockeys who need to be able to ride at weights as low as 51kg (flat races) or 64kg (jumps races).

There have been several studies describing the physical attributes and dietary habits of jockeys,[1, 3-7] and the demands of riding in races.[1, 8] The physiological attributes of grooms and exercise riders,[9] and the physiological demands of riding for equestrian and recreational horse riders[2, 10-14] have also been described. There is limited information on the fitness of jockeys, however, and no study has reported the fitness characteristics of track-work riders despite their integral role within the racing industry. The feasibility of undertaking measurements of the physiological attributes of this highly mobile occupational group, using techniques suitable for large-scale fieldwork, has not been demonstrated.

Further, there has been no investigation of the association between physiological attributes and risk of falls for jockeys and track-work riders. Riding racehorses is a hazardous occupation and most injuries to jockeys are caused by falls.[15] We have investigated risk factors for race-day jockey falls in flat racing using race-day data, and found that jockey-related factors included female sex of jockey, being an apprentice jockey, holding an amateur licence, and having fewer previous rides at a meeting.[16] We hypothesise that some physiological attributes of jockeys may also contribute to risk of falling. Given the lack of information on this occupational group, we undertook a study to describe the physiological attributes of jockeys and track-work riders licensed to ride in Tasmania and conducted a preliminary investigation into whether these attributes are associated with falls.

METHODS

We invited the participation of every jockey (n=18; 6 apprentice, 12 full-licensed) and track-work riders (n=85) who was licensed to ride in Tasmania, the island state of Australia, were invited to participate. Reasons for non-participation included riders not currently or regularly riding, injury or illness, living interstate or being ineligible by reason of age (we excluded riders older than 50 years). The final study group consisted of all of those who made themselves available:8 jockeys (2 female full-licensed, 4 male apprentice, 1 male full-licensed and 1 male full-licensed jumps jockey) and 20 track-work riders (14 female, 6 male). This represents 44% of the jockey population and 24% of the track-work rider population in Tasmania.

The study was approved by the Human Research Ethics Committee (Tasmania)(Reference Number H0009692).

Each participant was tested at one of three different locations in Tasmania - Menzies Research Institute (Hobart), University of Tasmania Exercise Research Laboratory (Launceston) and the Devonport Racing Club (Devonport). The same equipment was transported to and used at each location. All tests were supervised by the same technician.

Tests were selected on their practicality and portability and based on previous studies of horse riders[1, 2, 8, 10-14] and performance attributes of athletes.[17] These tests were designed to assess specific aspects of fitness that may be relevant to the requirements of thoroughbred racing and track-work riding.

Participants were provided with an outline of the test protocols prior to formal testing. Participants were required to be in good health and fully recovered from previous injuries. For jockeys, testing did not occur on the day before or after race–day, or at times of significant body mass wasting.

Height was measured to the nearest 0.1cm using a Leicester Height Measure (Invicta, Leicester, UK). Body mass was measured to the nearest 0.1kg using a Heine Portable Professional Scale (Heine, Dover, NH, USA). Body mass index (BMI) was calculated. Body composition (total percent body fat) and bone mineral density ($g.cm^{-2}$) were measured by the technique of dual-energy X-ray absorptiometry (DXA) using one Lunar DPX densitometer (Lunar, Madison, WI). Only 11 of the participants underwent a DXA scan, and therefore these results were not included in the falls analysis.

To measure dynamic unipedal balance, the participant was required to balance in a 'standing-stork' pose (shoes removed, one leg lifted, placing the toes of that foot against the knee of the opposite leg) on a 65mm foam insert (Airex® Balance-Pad Plus, Alcan Airex AG, Switzerland) for as long as possible. A stopwatch was used to record the time that the participant held position. The test was repeated three times on each leg. The best result for each leg was used in analysis.

The sit and reach test was used to measure flexibility of the lower back, hips and hamstring muscles and the back and hip joints. Participants placed their feet flat against a 30cm high box with shoes and socks removed and attempted to reach forward as far as possible with knees fully extended. The level of the feet was recorded as the baseline, with positive scores (in cm) achieved beyond this point. Participants were permitted three trials and the best result was recorded.[18, 19]

Reaction time was assessed in milliseconds using a hand-held electronic timer with a light as the stimulus, and with depression of a switch by the finger as the response (Balance Systems, Sydney, NSW). Ten practice trials were undertaken, followed by ten experimental trials.[20]

Strength was measured using isometric dynamometers. Grip strength was measured using a hand-grip dynamometer (Smedley's TTM 100kg, Tokyo), and shoulder and arm strength using a shoulder/arm dynamometer (TTM 100kg, Tokyo). This involved both push strength (maximal voluntary isometric contraction of the shoulder flexors/adductors) and pull strength (maximum voluntary isometric contraction of the shoulder extensors/abductors). Results were recorded to the nearest 0.5kg. Leg and back strength was measured using a leg/back dynamometer (Gloria TTM 300kg, Tokyo). Participants performed a maximum voluntary isometric contraction of the knee and hip extensors, with the knees flexed at 115^{o} while maintaining a vertical spine position. The result was recorded to the nearest 1kg. Three trials were conducted for all strength tests with the best result used for analysis.

To measure explosive leg power, the standing vertical jump (counter movement jump) was conducted using a Yardstick® (Swift Performance Equipment, Lismore, New South Wales). The best trial was recorded and reported in centimetres jumped.[19] From this result, peak and mean alactic power were calculated using the Harman formulas.[21]

Anaerobic (lactic) fitness was assessed by the 30 second cycle test using an air-braked ergometer (Exertech, EX-10, Repco, Huntingdale, Australia).[22] Mean and peak lactic power were recorded in watts (W) and watts per kilogram of body mass ($W.kg^{-1}$). The fatigue index (percentage decline in power compared with the peak power output) was calculated.

Aerobic fitness was assessed using the YMCA submaximal exercise test performed on a friction-braked cycle ergometer (MonarkErgomedic 828E, Varberg, Sweden) to estimate maximal oxygen uptake ($\dot{V}O_{2\,max}$, $ml.kg^{-1}.min^{-1}$).[17]

The participants were asked how they positioned their feet in the stirrup irons when riding (riding style). They were classified as riding with their full foot lodged firmly in the irons (full foot), or with the ball of their foot in the irons (ball of foot), or with only the toe of their boot in the iron (toe-in-iron).

Incident data on falls of licensed Tasmanian track-work riders during track-work were collected by participants completing a diary for 12 months following their fitness assessment. The follow-up period was 1 March 2008 to 31 May 2009. The participants were instructed to record, on a monthly basis, the average number of track-work rides per week. For each fall, participants were asked to complete an incident report form. Of the track-work riders, 7 returned their diaries.

None of the jockeys returned their track-work diaries. However, we did obtain incident data on falls at race meetingsby the 7 licensed flat racing jockeys. The one jumps jockey did not have any race rides recorded during the study period.The data were collated through a search of stewards' reports provided by Racing Services Tasmania (RST), the principal racing authority of that state. Racing Information Services Australia (RISA) provided comprehensive data on every race meeting run by RST. These data were merged with the incident falls data. Details are provided elsewhere.[15] To match the number of rides taken by track-work riders, we included race rides during the period 1 June 2007 to 31 May 2009.

Anthropometric (height, mass, BMI, % body fat and BMD) and fitness (aerobic, anaerobic, muscular strength and power, flexibility, balance and reaction time) measures of jockeys and track-work riders were compared using regression analysis. Right-skewed data were log transformed prior to analysis.

Univariable Poisson regression was used to estimate incidence rate ratios (IRR) with 95% confidence intervals (CI) by modelling the logarithm of the mean number of falls as a function of covariates, with the logarithm of the number of rides as an offset. Interaction of licence type was assessed from the coefficients of product terms. Effect modification was considered present if the test of the coefficient of a product term yielded a p value less than 0.05 in a dataset expanded with 9 duplicates. Results for variables that showed significant interaction with licence type are reported separately (Table 3) from those where interaction was not present (Table 2).

To make an assessment of the possible significance of anaerobic fitness factors in a fully powered main study, we expanded the dataset from n=14 to n=28 (to assess the effects of peak power per kg of body mass and fatigue index) and to n=42 (to assess the effect of mean power per kg of body mass) by duplicating observations.

RESULTS

Participant age and anthropometric characteristics are described in Table 1. Jockeys were younger in age, shorter in height, lower in mass and BMI, and had lower percentage total body fat and total bone mineral density than track-work riders.

The participant groups were similar in measures of grip strength, shoulder pull strength, and leg and back strength. Jockeys had better balance, faster reaction time, lower fatigue index, and a higher estimated $\dot{V}O_{2\,max}$, but were less flexible and had lower shoulder push strength, than track-work riders. Additionally, jockeys had greater muscular strength and power, once accounting for the body mass (per kg) of the participant. Detailed results in relation to the physiological attributes of jockeys and track-work riders are available in a Supplementary Appendix.

Table 1: Descriptive characteristics of jockeys and track-work riders in Tasmania

Study factor	Jockeys (n=8)	Track-work riders (n=20)
Age (years)		
Median	27.00	36.50
Mean (± SD)	28.75(10.10)	33.20(11.08)
Range	18, 41	15, 47
Height (cm)		
Median	163.45	168.25
Mean (± SD)	163.39 (7.08)	166.51 (7.36)
Range	154.4, 174.9	156.6, 179.5
Mass (kg)		
Median	51.75	65.90
Mean (± SD)	55.08 (5.87)	67.32 (12.51)
Range	50.5, 66.3	44.2, 90.5
BMI		
Median	20.63	24.00
Mean (± SD)	20.62 (1.58)	24.13 (3.28)
Range	18.45, 23.27	18.02, 30.52
Body fat (%)[a]		
Median	15.90	29.45
Mean (± SD)	13.98 (3.52)	28.15 (8.21)
Range	8.50, 16.90	17.00, 37.60
BMD ($g.cm^{-2}$)[a]		
Median	1.167	1.273
Mean (± SD)	1.157 (0.068)	1.312 (0.103)
Range	1.085, 1.246	1.206, 1.473

[a] Subset of data (n=5 jockeys; n=6 track-work riders).

Table 2 presents unadjusted and adjusted (for age and sex) incidence rate ratios of physiological attributes associated with falls for factors that did not differ between jockeys and track-work riders. Seven track-work riders returned their fall and injury diaries. The track-work riders reported a total of 24 falls from 2,996 rides (0.80 falls per 100 rides). Of these falls, 13 (54%) resulted in an injury being sustained. A total of 13 falls from 2,978 race rides (0.44 falls per 100 rides) were experienced by the jockeys in our study. Of these falls, 3 (23%) resulted in an injury being sustained.

Table 2: Unadjusted and adjusted incidence rate ratios of factors associated with race-day falls by flat racing jockeys(n=7) from 1 June 2007 to 31 May 2009,and with falls during track-work for track-work riders (n=7) from 1 March 2008 to 31 May 2009.

Study factor	**Falls**	**Rides**	**Unadjusted IRR (95% CI)**	**Adjusted IRR (95% CI)[a]**
Licence				
Jockey	13	2,978	1.00	1.00
Track-work rider	24	2,996	1.84 (0.90, 3.74)	3.54 (2.07, 6.06)[d]
Sex				
Male	15	2,519	1.00	1.00
Female	22	3,455	1.07 (0.52, 2.19)	0.45 (0.17, 1.20)
Age	37	5,974	1.03 (1.00, 1.06)	1.05 (1.01, 1.10)[b]
BMI	37	5,974	1.12 (1.02, 1.21)[b]	1.15 (1.08, 1.23)[d]
Log of balance pooled (sec)	37	5,974	0.87 (0.59, 1.28)	1.28 (0.95, 1.72)
Flexibility (cm)	37	5,974	0.99 (0.94, 1.04)	0.96 (0.91, 1.01)
Muscular strength and power				
Push strength (kg)	37	5,974	1.00 (0.97, 1.03)	1.00 (0.96, 1.04)
Pull strength (kg)	37	5,974	1.03 (0.98, 1.09)	1.09 (1.04,
Leg/back strength (kg/10)	37	5,974	1.11 (1.00, 1.23)[b]	1.05 (0.98, 1.13)
Pooled grip strength (kg)	37	5,974	1.05 (0.96, 1.13)	1.02 (0.96, 1.09)
Absolute jump height (cm)	37	5,974	0.97 (0.92, 1.02)	0.93 (0.85, 1.01)
Mean power (Watts.kg^{-1})	37	5,974	1.19 (0.94, 1.50)	1.14 (0.91, 1.42)
Anaerobic fitness				
Mean power (Watts.kg^{-1})	37	5,974	0.90 (0.77, 1.05)	0.85 (0.67, 1.09)
Peak power (Watts.kg^{-1})	37	5,974	0.91 (0.82, 1.00)	0.87 (0.74, 1.02)
Total work (hectojoules.kg^{-1})	37	5,974	0.78 (0.46, 1.32)	0.83 (0.34, 1.98)
Fatigue index (%)	37	5,974	0.97 (0.96, 0.99)[d]	0.98 (0.96, 1.00)
Aerobic fitness				
$\dot{V}O_{2\,max}$ (ml.kg^{-1}.min^{-1})	37	5,974	0.97 (0.93, 1.01)	0.93 (0.90, 0.97)[d]
Riding style				
Ball of foot (n=9)	19	4,176	1.00	1.00
Toe-in-iron (n=2)	5	684	1.61 (0.99, 2.61)	1.12 (0.60, 2.08)
Full foot (n=3)	13	1,114	2.56 (1.31, 5.04)[c]	2.37 (1.46, 3.85)[d]

[a]Adjusted for age and sex; [b] $p<0.05$; [c] $p<0.01$; [d] $p<0.001$. Note: the adjusted measures of muscular strength have also been adjusted for body mass.

Table 2 shows that lower aerobic fitness was associated with greater risk of falls. Greater shoulder pull strength was also associated with a higher incidence of falls (Table 2). The effect of some measures of body composition and muscular power differed by licence type. Table 3 shows that jockeys with higher peak alactic power had a higher fall incidence than other jockeys, with the opposite being the case for track-work riders.

Table 3: Adjusted incidence rate ratios of factors associated with falls that differed by jockey and track-work riders

Study factor	Jockey IRR (95% CI)[a]	Track-work rider IRR (95% CI)[a]
Body mass (kg)	0.82 (0.81, 0.83)[d]	1.05 (1.02, 1.07)[d]
Height (cm)	0.92 (0.89, 0.96)[d]	1.05 (0.92, 1.19)
Muscular power		
Peak power (Watts.kg^{-1})	1.08 (1.04, 1.13)[d]	0.95 (0.94, 0.96)[d]

[a]Adjusted for age and sex; [b] p<0.05; [c] p<0.01; [d] p<0.001. Interactions by licence type: body mass(p<0.001), height (p<0.001), peak power (p<0.001).

Placement of the foot in the stirrup irons was associated with falls. Both jockeys and track-work riders that ride with the full foot in the stirrup irons had a higher fall incidence than did those riding with the ball of the foot in the irons (Table 2).

DISCUSSION

In this investigation of the physiological attributes of jockeys and track-work riders in Tasmania, we found that jockeys had better balance, faster mean reaction time, lower fatigue index, and a higher estimated $\dot{V}O_{2\,max}$. They were younger and smaller in stature than track-work riders and, when differences in body masswere taken into account, they had greater muscular strength and alactic power (derived from the vertical jump). Furthermore, in a study of falls experienced by jockeys on race-days and by track-work riders during track-work, we found older age, higher BMI, greater shoulder pull strength, lower aerobic fitness, and riding with the full foot in the stirrup irons, were factors associated with an increased incidence of falls. Additionally, jockeys who were lower in mass, shorter in height, or had greater peak alactic power (per kg of body mass)had a higher fall incidence than other jockeys, with the reverse being the case for track-work riders.

The anthropometric attributes of jockeys reported in this study were generally similar to those of New Zealand and Irish jockeys reported in previous studies,[5-7] but the track-work riders more closely resembled the anthropometric characteristics of participants in equestrian studies.[11, 14] The grip strength of the jockeys and track-work riders was similar to that of participants in a study of Irish jockeys,[6] but higher than that of participants in an equestrian study.[14] Both groups also had above average relative $\dot{V}O_{2\,max}$ and average flexibility compared to normative data,[17] and greater anaerobic (lactic) power than those from an equestrian study.[14] We do not have normative data on balance or reaction times for this age group with which to make comparisons.

In this study, lower anaerobic and aerobic fitness were associated with greater risk of falls. Only the association with aerobic fitness was statistically significant but, if our participants are representative of jockeys and track-work riders in general, the association with measures of anaerobic fitness would have been statistically significant for peak and mean power per kg of body mass and for fatigue index had the sample size beenjust one or two times greater (data not shown). This is the first report of a finding that fitness is associated with falls by jockeys and track-work riders, but it is consistent with findings for injuries to other occupational groups including manual material handlers[23] and military personnel.[24, 25]

There was some evidence that higher muscular strength and power were positively associated with falls. This was seen for shoulder pull strength, and for peak alactic power in jockeys. This may be due to riders with greater strength and power being placed on difficult or fractious horses because it is industry practice, where possible, to assign this task to the most capable riders. Possibly consistent with this finding, industrial workers with greater isometric strength have been reported to be at greater risk of back problems.[26] On the other hand, opposite results were found for peak alactic power of track-work riders in our study.This may reflect a true difference between jockeys and track-work riders, but we can not discount the possibility that the associations with muscular strength and power are chance findings due to the small sample size.

Placement of the foot in the stirrup irons was found to be associated with falls for both jockeys and track-work riders. Those riding with the full foot in the stirrup irons had a higher fall incidence than those riding with the ball of the foot in the irons. We also found a small and statistically insignificant increase in risk for those who ride with their toe in the iron. Due to safety concerns, all principal racing authorities in Australia require apprentices to ride with at least their ball of their foot in the irons until they have gained adequate experience(Ring 2010 pers. comm.). We had too few inexperienced riders in our study to investigate this issue.

This study adds to the limited information available on the physiological attributes of jockeys, and is the first study to report comprehensively on the physiological characteristics of track-work riders. A strength of this study was the comprehensive range of tests that was implemented. For the benefit of industry participants and researchers, these results have been made available in a Supplementary Appendix.Additionally, this allowed us to assess the feasibility of applying this battery of tests in large-scale fieldwork with this highly mobile occupational group, and we were able to get some confirmation that doing so was practicable. In a novel contribution, this was the first study to investigate whether these attributes are associated with falls to riders in both licence groups and we found that measurements of fitness and riding style were predictors of falls. So too were the measurements of muscular strength and power, albeit in an unexpected direction.

However, some limitations of this study should be borne in mind. Because our intention was to investigate methods appropriate for large-scale fieldwork, we deliberately restricted tests to those that could be conducted with robustly-constructed and transportable equipment. We did not use more sensitive equipment that may be more accurate. Our sample of 8 jockeys and track-work riders was small, and some of our findings – including the results for muscular strength and power – may be a play of chance. Our sample comprised 44% of the jockey population and 24% of the track-work rider population licensed in Tasmania. Other studies involving jockeys have also reported low response proportions,[3, 27] and this is probably due to the demanding working livesof those in this profession. Race meetings are conducted less regularly in Tasmania than in large metropolitan areas in Australia, and thus the jockeys in this current study may be more representative of the average jockey in Australia than of elite jockeys who ride in races more often. That we had a high proportion of females among track-work riders, and a low proportion of females among jockeys, is nevertheless consistent with the population frequencies. Furthermore, only 35% of track-work riders returned their fall and injury diaries and none of the jockeys returned theirs. It is possible that those who experienced more falls or injuries were more likely to return their diaries, leading to possible bias in the results if they also differed in respect of the factors associated with falls. Lastly, our experience has suggested some refinements to the testing methodology are needed. To obtain better measurements of $\dot{V}O_{2\,max}$, portable gas analysis could be employed during racing and track-work. A more complex stimulus reaction time test, such as a go/no-go or choice reaction time,[28] should be employed because the simple reaction time test we used was not sufficiently sensitive to differentiate between groups and individuals. Furthermore, a riding-relevant balance test or core-stability test with higher specificity is required.Additionally, we had only self-reports of stirrup foot position. Ideally, assessment of this factor would be made by a trained, independent observer.

CONCLUSION

Riding thoroughbred racehorses is a hazardous occupation. This pilot study has confirmed that it is feasible to measure physiological attributes of jockeys and track-work riders that are predictive of the risk of falling. We have investigated risk factors for falls among jockeys using routinely collected race-day data[16] but without the insights that may be possible from actual measurements of the jockeys. What is now required is a large-scale study of the physiological attributes of jockeys, that can provide the evidence base for improvements to apprentice training and remedial riding programmes designed to remedy deficits in physiological performance that lead to falls and possibly to establish minimum standards of performance for jockey licencing.

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COMPETING INTERESTS

None declared.

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AUTHOR CONTRIBUTIONS

All authors contributed to analysis and interpretation of data, review and revision of the manuscript critically for important intellectual content, and provided final approval of the version to be published. Additionally, Peta Hitchens, Leigh Blizzard, and James Fell contributed to conception and design of the study, acquisition of data and drafting of the manuscript. I confirm that this manuscript is an independent contribution, has been read and approved by all co-authors.

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LICENCE FOR PUBLICATION STATEMENT

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***
Note: Page numbers are those displayed in the top left/right corner of the submission pdf.

	Item No	Recommendation	Page No.
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Title page
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5, 6 & 9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-10
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-10
Bias	9	Describe any efforts to address potential sources of bias	Potential bias discussed on page 16
Study size	10	Explain how the study size was arrived at	5 (pilot)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*b*) Describe any methods used to examine subgroups and interactions	9-10
		(*c*) Explain how missing data were addressed	n/a
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	n/a
		(*e*) Describe any sensitivity analyses	n/a
Results			
Participants	13	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5 & 9

		(b) Give reasons for non-participation at each stage	5 & 9
		(c) Consider use of a flow diagram	n/a
Descriptive data	14	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
Outcome data	15	Report numbers of outcome events or summary measures	11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Table 3
Discussion			
Key results	18	Summarise key results with reference to study objectives	13-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17 (feasible to conduct large-scale study)
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18