



# Physical Fitness of Thoroughbred Horse Racing Jockeys

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## Abstract

**Purpose** Thoroughbred racing jockeys compete at maximum physiological capacity in a sport with a high risk of falls and injury. A greater understanding of the physical capacities determining jockey performance may lead to minimum physical performance parameters and corrective interventions to improve jockey fitness and performance and reduce jockey and horse injury. The aim of this study was to develop appropriate physical testing procedures for jockeys and a physical fitness profile for different licence levels.

**Methods** Fifty-eight jockeys ( $n = 24$  females,  $n = 34$  males), representing all apprentice jockeys licenced in New Zealand in 2021 (100%,  $n = 8$  probationers and  $n = 39$  apprentices) and eleven professional jockeys (14%) were assessed to determine baseline physiological and fitness data. Descriptive statistics and boxplots were used to compare aerobic fitness, abdominal (core), upper and lower body strength, muscular power, reaction time, flexibility and a novel ‘saddle’ test targeting lower body strength, balance, and endurance between licencing levels. Effect Size (ES) was used to determine magnitude of differences between groups.

**Results** More experienced jockeys had greater relative lower body strength ( $ES = 0.2–0.7$ ) and better balance ( $ES = 0.5–0.9$ ) compared to the less experienced groups. Jockeys who were in the top 20 of the premiership table (jockey rankings) had faster reaction times ( $ES = 0.7$ ) and greater core extensor strength ( $ES = 0.7$ ) than other cohorts. Most tests showed little differentiation between jockey licence levels, however the ‘saddle test’ showed greater variability in the less experienced race riders. This test may be an effective measure of jockey baseline performance.

**Conclusions** These data could be used to inform minimum jockey licencing requirements and future physical fitness training programmes to increase jockey physiological fitness, thereby minimising risk of falls or injury due to physiological deficits and performance.

**Keywords** Riding · Equestrian · Fitness test · Physical attributes

## Introduction

Thoroughbred race riding requires physical strength, stamina and the ability to make decisions quickly during a physically demanding race [6, 8, 25, 26, 52]. Physical fitness has been positively correlated with horse riding performance in traditional English equestrian disciplines (e.g. dressage,

jumping) which require less rider physiological exertion than race riding [1, 6, 9, 40]. Race day jockey falls result in a high rate of injury to the jockeys themselves [39] and potentially to the horses they ride due to the loss of control. Both jockey experience and physical fitness levels have been identified as risk factors for race day jockey falls [14, 28], with more experienced riders associated with a lower risk of falling, as well as a lower risk of fatal limb fractures in the racehorses they ride compared to jockeys with less experience [15, 42]. Therefore, resisting fatigue throughout a race and a race day are important not only to optimise performance, but for both jockey and horse safety.

Jockeys in New Zealand can be separated into the following categories: amateur, apprentice, jumps and professional. Both male and female jockeys compete in the same races, with female jockeys comprising approximately 50% of the

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lower level and 30% of the higher level jockeys [27, 29]. Apprenticeships in New Zealand are completed in 4 years full time, and apprentices are employed with an approved Thoroughbred trainer who is chiefly responsible for their training, development, well-being and assistance in obtaining race-day rides. The riding competency for an apprentice jockey to progress to race-riding is assessed between the New Zealand Thoroughbred Racing (NZTR, the governing body for Thoroughbred racing) regional riding mentor and the local racecourse stewards. An aspiring apprentice jockey must first obtain a “track riders” licence, where their competency to handle a horse at a training pace (canter) is assessed by the regional NZTR riding mentor. Secondly, they may progress to a ‘probationer’s’ licence where their riding competency is assessed by local racecourse stewards at a number (at the stewards’ discretion) of jump-outs (training runs), as well as passing a medical and base line concussion test. A probationer’s licence allows the aspiring apprentice jockey to compete in trials (mock races, used to prepare horses for competition) and is held for a minimum period of 3 months (maximum 12 months). During this period, they must ride in a minimum of 25 satisfactory trial rides (assessed by both their NZTR regional riding mentor and local stewards) before advancing to an apprentice licence and the ability to ride in an official race day alongside professional jockeys. Therefore, riding competency has historically been the only measure of physical fitness available for New Zealand apprentice jockeys, in contrast to the industry based fitness tests which are a requirement for jockey licencing in the UK. All levels of jockey compete and ride year-round, with senior jockeys and experienced apprentices riding up to 9 horses per race day, twice a week compared to newer or less active jockeys riding in 1–2 horses per race day, once or twice a month [27, 30].

Exercise testing in sport, especially in high performance sports, is an integral part of the training process [11, 48]. Exercise testing applications range from sports selection and identification of potential future champions, to evaluation of dynamics and progress in training [36]. Sport specific tests of elite athletes are recommended to obtain correct, reliable and useful data with which to assess and develop physical training programmes. Although race riding requires a high level of physical fitness, use of exercise testing to select, assess progress and develop training programmes is not prevalent in the racing industry. This could be due to the lack of scientifically valid and reliable tests of racing fitness or performance for jockeys. This lack may be partly due to the difficulty in accounting for the contribution of the horse, thereby limiting the development and use of jockey-specific balance and performance assessment methods. The assessment of a jockeys’ physical characteristics may provide coaches and athletes with a reference physique and physical fitness profile that may aid in the development of physical

fitness training programmes to optimise jockey and horse performance and health.

There have been several studies describing the physical attributes and dietary habits of jockeys [32, 53, 55, 58] and the demands of riding in races, in exercise work and on riding simulators [6, 19, 20, 25, 26, 52, 59]. However, relatively little attention has been given to the physical fitness attributes of jockeys. To date, a small number of studies have assessed the physical fitness of small cohorts of jockeys in specific generalised fitness tests [5, 14, 22]. However, the applicability of these tests in assessing and providing discriminability of jockey performance or riding fitness levels are unclear. Several studies suggest that strength, endurance, balance, reaction time and flexibility are all considered to be important attributes of a successful jockey [14, 31, 56]. However, currently, there is no consensus on which physical factors are the most important in maintaining the optimal jockey position on-horse and predispose to better performance and thus minimise injury risk. The aim of this study was to investigate the validity and reliability of physical testing procedures for jockeys and develop a physical fitness profile for different jockey licence levels. This will provide baseline markers to track jockey progress in future physical exercise programmes and provide benchmarks for jockey physical health and performance.

## Methods

### Participants

Male and female jockeys and apprentices holding a current and valid licence in New Zealand were recruited through New Zealand Thoroughbred Racing (NZTR), the governing body for racing in New Zealand. All participants received a clear explanation of the study, including the risks and benefits of participation and provided written informed consent prior to the study. The nature of this sport is associated with frequent occurrence of injury. To provide a realistic description of the current physical fitness levels, participants with low grade injuries who were still actively race-riding were included in the study, but chose which tests they were able to safely participate. It was ensured that the tests completed did not require contribution from, or use of, the injured area. Ethical approval was provided by the Institutional Human Ethics Committee.

Jockeys were grouped into three licence categories; probationers (a pre-apprenticeship licence, allowing the holder to compete in trials but not races, held for a minimum of 3 and maximum of 12 months), apprentices (young, inexperienced jockeys, serving a 4 year apprenticeship, able to compete in races with a weight allowance) and senior (professional jockeys who have graduated

from a 4 year apprenticeship). The premiership table published by NZTR provided current jockey rankings based on jockey racing performances throughout the season (1 August 2020–31 July 2021), and this was used to identify a group of jockeys in the top 20 (Top20) of the premiership table at the time of testing.

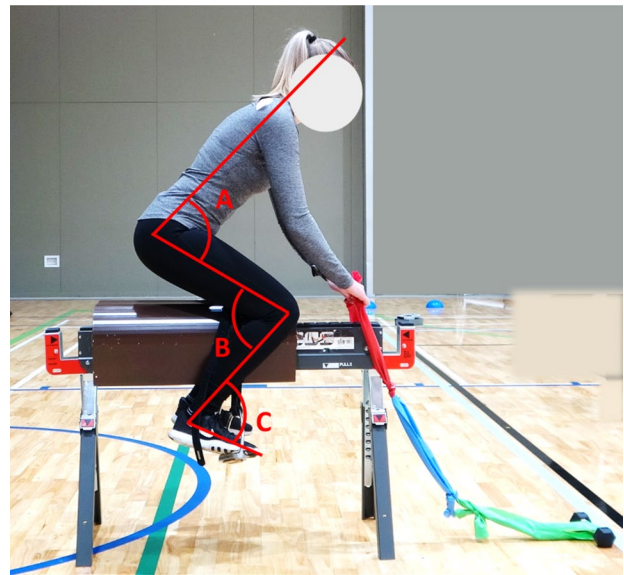
## Procedures

Typically, races are scheduled between Wednesday and Sunday, with premier race meetings held on the weekend (usually Saturday). Therefore, physical tests took place on a Monday (non-racing day), between 12.30 p.m. – 3:30 p.m. (during the hours races would be held on a racing day). Jockeys engaged in morning exercise work would have completed their work between the hours of 5 a.m. – 8 a.m.. During morning exercise work, jockeys exercise at low level physical demand relative to race-riding, with no evidence of fatigue [25]. Therefore, the influence of morning exercise work on physical test parameters was considered minimal.

The physical fitness tests were designed to assess specific aspects of anthropometry and fitness that were relevant to the requirements of Thoroughbred race riding and were based on previous studies of horse riders and performance attributes of athletes [1, 14, 37, 44, 51, 57]. The sport specific balance test was designed specifically as a test of isometric endurance and balance for jockeys maintaining a posture as close as possible to that they would adopt whilst race-riding (Fig. 1). Each participant was tested at one of three different locations (regional jockey hubs). The same equipment was transported to and used at each location. Therefore, the physical tests were additionally selected on their practicality and portability.

Standing height was assessed to the nearest centimetre using a portable stadiometer (Seca 213). Body mass was measured in light clothing (shorts and shirt) using portable digital weighing scales (Tanita InnerScan, Body Composition Monitor, BC-532). Body mass index was calculated as the ratio of the weight to the square of height in meters ( $\text{kg}/\text{m}^2$ ). Size of each foot was measured from the heel (calcaneus) to big toe (large phalange) to the nearest 0.1 cm using a portable foot measurement device (Jaktool, LLC arch height measurement system, 1001–2943, USA) and the result from the left and right foot averaged.

Physical tests are described in Table 1. All tests were supervised and conducted by the same trained assessors. Participants were provided with an outline of the test protocols prior to formal testing and were allowed one attempt to achieve the correct posture (in postural tests) to familiarise themselves with the procedure. Detailed testing procedures are found in Supplementary information 1.



**Fig. 1** Setup of the saddle test used in the study with relative joint angles measured at **A** hip, **B** knee and **C** ankle joints (Image source: author)

## Statistical Analysis

Descriptive statistics and box plots were used to compare means between groups. The Shapiro-Wilk test was used to assess data normality. Differences between groups were determined pairwise Wilcoxon tests for non-parametric data. Cohen's effect size (ES) [3] was calculated to determine differences between the appropriate groups by calculating the difference between the means divided by the pooled standard deviation. Effect size was classified as trivial 0–0.2; small 0.2–0.6; moderate 0.6–1.2; large 1.2–2.0; and very large 2.0 [16].

To identify relationships and similarities of observations between jockey licence level groups and the hip, knee and ankle angles of jockeys in the saddle test, multiple correspondence analysis (MCA) was used. Categories were created for angles above or below the mean value for the entire data set and for completion or non-completion of the 3 min test to determine if there were any underlying structure in the data.

All statistical analyses were conducted using RStudio (version 3.5.1, 2018, R Foundation for Statistical Computing) with the level of significance set at  $P < 0.05$ .

## Results

The anthropometric characteristics for all study participants ( $n = 58$ ) are presented in Table 2. Senior jockeys were older than other cohorts but had similar anthropometric

**Table 1** Description of the physical tests used for fitness testing of jockeys ( $n = 58$ )

Test category	Test name	Brief description	Justification
Aerobic/Endurance	20 m shuttle test (beep test) [24]	Participants run between 2 markers 20 m apart at increasing pace dictated by beeps. Estimate $\dot{V}O_{2\max}$ from level achieved.	Jockeys work close to their physiological limit in a race [6], requiring a good aerobic base fitness. Lower aerobic fitness has been associated with a higher risk of falls [14].
Core [34]	Trunk flexor Trunk extensor Left- and right-side bridge holds Hand grip [4]	Participants maintain specific holds for a maximum of 3 min.	Core stability plays a key role in the maintenance of the racing position [26, 55].
Strength	Mid-thigh pull [17] Maximum relative strength Push ups	Participants squeeze handheld dynamometer (TTM 100 kg, Tokyo) as hard as possible with elbow flexed at $90^\circ$ . Participants pulled as hard as possible using a portable mid-thigh pull stand (attached to a dynamometer [Gloria TTM 300 kg, Tokyo]) starting with legs flexed at $5\text{--}10^\circ$ . Calculated from maximum mid-thigh pull strength divided by body weight (BW), taken as body weight <sup>0.75</sup> . Number of consecutive push ups to a cone.	Higher muscular strength has been associated with increased jockey falls [14]. Jockeys in races adopt a lower crouched posture than jockeys riding track-work, which requires a greater lower leg strength [26].
Power	Vertical jump height [49]	Countermovement vertical jump performed with hands on hips on an electronic timing mat.	Upper body strength has been postulated to be important in maintaining a stable posture on the horse and in pushing the horse to gallop faster [46, 52]. Jockeys have a demand for high intensity lower body power due to the posture adopted during race riding [14, 50].
Sport specific	Vertical jump power Saddle test RPE [2] Reaction time [14, 45]	Average power calculated using the Lewis formula [12]. Maintain jockey position on sawhorse (Fig. 1) with set length stirrups, without moving a 1 kg weight attached to 'reins'. Position held up to a maximum of 3 min. Score perceived difficulty of the saddle test according to Borg's rating of perceived exertion (RPE) 10-point scale. Reaction to 8 illuminated light stimuli (Fitlight® sports Corp., Ontario, Canada) randomly flashed on vertical board.	On-horse posture and stability provide important indicators of rider performance in other horse sports [13]
Flexibility	Sit and reach [14] Hip flexion [4] Hip extension Shoulder flexion Shoulder extension	Participants reach as far as possible along measuring scale (Figure Finder Flex-tester, Novel Products Inc, Rockton, IL, USA) whilst sitting with knees flat to the ground. Lying supine, flex hip with knee flexed to end of range. Lying prone, lift entire leg with knee supported beneath. Lying supine, humerus moves overhead in an anterior and upward direction Lying prone, humerus moves posteriorly	Fast reactions and decision making during a race is important for jockey performance and safety [14, 22]. Flexibility assessment could be considered an important indicator of performance and injury risk when coupled with other factors such as posture [55].

**Table 2** Descriptive characteristics (mean  $\pm$  SD) of a cohort of probationer, apprentice and senior jockeys ( $n=58$ ), of which 11 were in the top 20 of the premiership table (Top 20 jockeys)

Characteristic	Probationer	Apprentice	Senior	Top 20 jockeys	Female	Male	All jockeys
Female ( $n$ )	5	12	7	7	24	–	24
Male ( $n$ )	3	27	4	4	–	34	34
Total ( $n$ )	8	39	11	11	–	–	58
Age (years)	22 $\pm$ 4	25 $\pm$ 4	29 $\pm$ 7	31 $\pm$ 7	26 $\pm$ 7.3	25.1 $\pm$ 26	25 $\pm$ 6
Height (cm)	161 $\pm$ 6.8	162 $\pm$ 6.7	159 $\pm$ 6.7	158 $\pm$ 7.9	157 $\pm$ 4.9	164 $\pm$ 157	161 $\pm$ 7.0
Weight (kg)	53.8 $\pm$ 4.1	52.7 $\pm$ 4.0	52.8 $\pm$ 3.7	53.3 $\pm$ 2.6	52.8 $\pm$ 3.1	53 $\pm$ 52.8	53.0 $\pm$ 3.8
BMI (kg/m <sup>2</sup> )	20.7 $\pm$ 2.5	20.1 $\pm$ 1.5	21.0 $\pm$ 1.9	21.4 $\pm$ 1.3	21.4 $\pm$ 1.6	19.7 $\pm$ 21.4	20.4 $\pm$ 1.7
Foot size (cm)	24.7 $\pm$ 1.3	24.5 $\pm$ 1.3	23.7 $\pm$ 1.2	23.5 $\pm$ 1.3	23.3 $\pm$ 2.4	25.0 $\pm$ 23.3	24.3 $\pm$ 1.3

characteristics. This study represents 100% (47/47) of the total apprentice jockey and 14% (11/79) of the senior jockey population of New Zealand. The top 20 jockeys included seven senior jockeys and four apprentices.

There were no differences between jockey licence types for most of the physical tests, with the exception of the saddle test and mid-thigh pull test when adjusted for body weight (BW) (Table 3). Apprentice jockeys had a greater relative leg and back strength ( $ES=0.6$ ) and a lower left shoulder extension ( $ES=0.8$ ) than probationers. Male jockeys had greater aerobic fitness ( $ES=0.5$ ), grip strength ( $ES=1.3$ ), upper body strength ( $ES=0.7$ ) and vertical jump power ( $ES=0.9$ ) than female jockeys. However, female jockeys had higher core strength than males ( $ES=0.4-0.5$ ).

All senior jockeys maintained the crouch position for the 3 min duration of the saddle test with a large  $ES$  of 0.9 compared to probationers. The distribution of saddle test scores (Fig. 2) was greater for those cohorts less experienced in race-riding ( $P=0.05$ ). Of the jockeys that reported an RPE for the saddle test, senior jockeys ( $n=4$ ) reported a median RPE of 4 (IQR 3.75–4.25), representing ‘somewhat hard’ on the Borg 10-point category ratio scale. Apprentices ( $n=18$ ) reported more variable RPE, with a median of 2.5 (IQR 2–5), representing easy/moderate on the Borg 10-point category ratio scale. Probationers ( $n=4$ ) reported a median RPE of 4 (IQR 2.75–5), similar to jockeys. There was no difference in RPE reported between male and female jockeys ( $P=0.2$ ).

The median and IQR of the hip, knee and ankle angles of participants whilst conducting the saddle test are presented in Fig. 3. There were no correlations between standing height and angles. MCA showed an association with senior jockeys having smaller hip, knee and ankle angles than probationer and apprentice jockeys. There was also an association between smaller knee and ankle and hip angles with completion of the saddle test.

Jockeys in the top 20 of the premiership table ( $n=11$ ) recorded faster reaction times (median 0.43 s, IQR 0.42–0.49) than other jockeys (median 0.49 s, IQR

0.46–0.58,  $P=0.01$ ), with a moderate effect size of 0.7 (Fig. 4). The top 20 jockeys also scored higher in the core trunk extensor test (180 s, IQR 180–180) than other jockeys (180, IQR 134–180,  $P=0.001$ ) with a moderate effect size of 0.7.

## Discussion

Based on the findings of the current study, it appears that most conventional physical tests were not race riding specific enough to differentiate between expert and inexperienced jockeys. This was not surprising as it is reported that jockeys do little training outside of riding [18, 30]. However, relative lower body and back strength was greater for more experienced jockeys, indicating that these may be important factors for improving riding performance, as they can contribute to the ability to maintain riding posture and stability. Additionally, the sport-specific saddle test, testing the isometric balance of the jockeys, provided some differentiation between the licencing levels. Jockeys who were riding as the top 20 jockeys in the country at the time of the study had faster reaction times and greater core strength than jockeys who were not in the top 20. This indicates positive physiological adaptation to the physical demands of the sport from a high level of race riding exposure during the jockeys’ workday [25, 30].

Jockeys experience an intense cardiovascular load during a race, multiple times during a race day, requiring a high level of aerobic fitness [6, 26, 52], and the lower intensity trackwork requires moderate exertion sustained over periods of 2–3 h daily [20, 25]. Professional jockeys in overseas jurisdictions (Europe, Australia and Hong Kong) had a similar cardiorespiratory capacity to values reported for professional football, soccer and tennis players of 46–57 mL/kg/min, recorded in maximal aerobic capacity tests using a cycle ergometer or treadmill [6, 8, 10, 14, 20, 41]. Cardiorespiratory capacity for jockeys in the current study was lower (~44 mL/kg/min) than internationally reported figures,

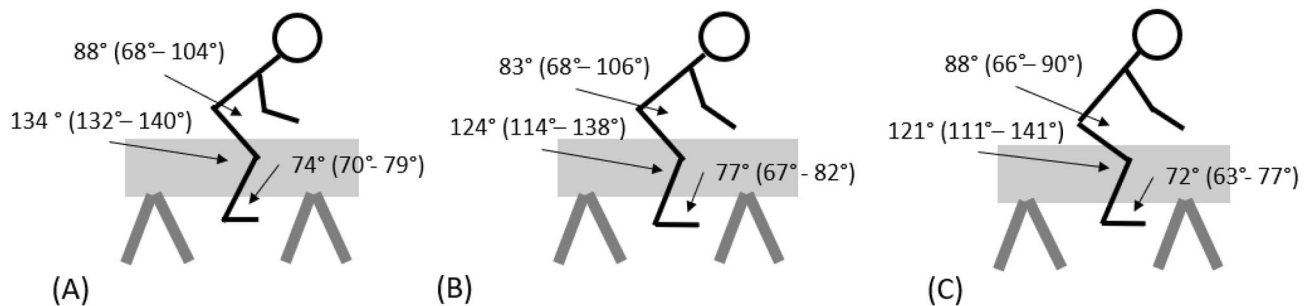
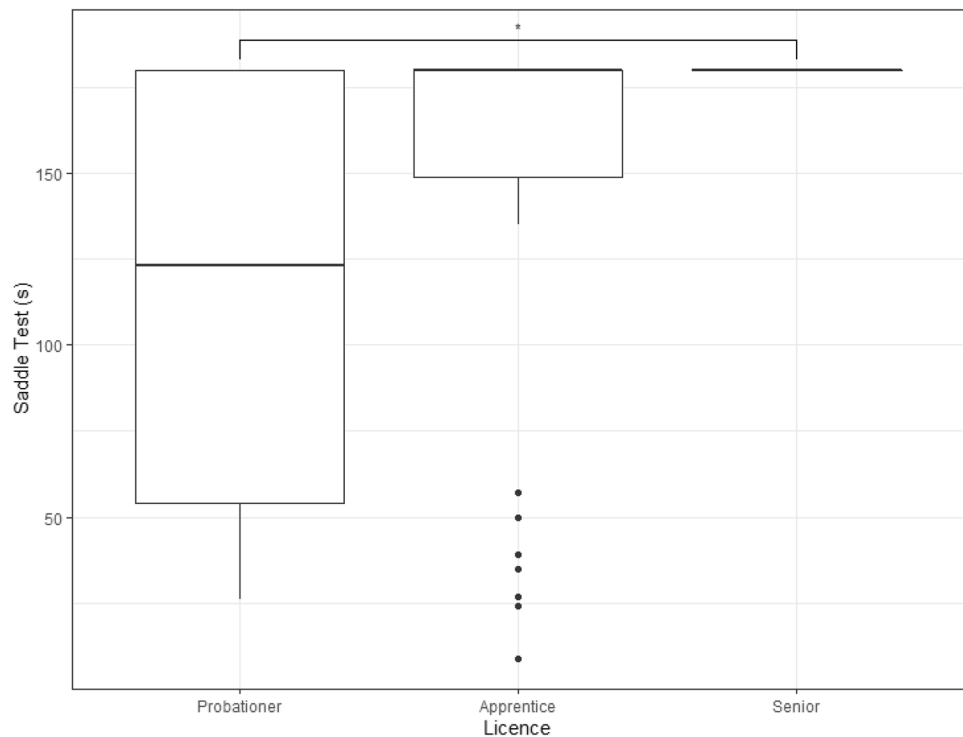
**Table 3** Physical test parameters (mean [SD]) of a cohort of 58 jockeys [probationers ( $n=8$ ), apprentices ( $n=39$ ), and senior ( $n=11$ )]

Study factor	Probationer			Apprentice			Senior			Female		Male		P (M/F)		All jockeys	
	<i>n</i>	ES*	ES*	ES*	ES*	ES*	ES*	ES*	ES*	ES*	ES*	ES*	ES*	ES*	ES*	ES*	ES*
Aerobic/Endurance test																	
Predicted $VO_{2max}$ (mL/kg/min)	40.7	(7.8)	0.1	44.7	(5.7)	-0.4	41.4	(5.3)	41.2	(6.3)	45.0	(5.6)	0.04	43.5	(6.1)		
Core Tests																	
Trunk flexor (s)	173	(13)	-0.3	140	(49)	0.4	162	(36)	167	(24)	136	(52)	0.03	149	(45)		
Trunk extensor (s)	180	(0)	-0.4	156	(34)	0.4	172	(21)	172	(23)	154	(34)	0.02	162	(31)		
Side bridge (s)	92	(39)	-0.4	82	(38)	-0.2	74	(33)	83	(28)	81	(43)	0.6	82	(37)		
	85	(32)	0.0	83	(39)	0.0	84	(31)	91	(31)	77	(38)	0.1	84	(36)		
Strength Tests																	
Grip strength (kg)	36.4	(4.6)	-0.1	37.9	(6.6)	-0.2	35.9	(5.2)	32.5	(4.0)	40.6	(5.0)	<0.001	37.3	(6.1)		
	36.6	(2.5)	0.1	39.9	(6.3)	-0.4	37.0	(4.8)	34.5	(3.5)	41.9	(5.2)	<0.001	38.9	(5.8)		
Mid-thigh pull (kg)	122	(12)	0.7	146	(35)	0.2	162	(54)	137	(31)	154	(43)	0.1	147	(39)		
Maximum relative strength (kg/BW)	6.3	(0.7) <sup>a</sup>	0.7	7.5	(1.8) <sup>b</sup>	0.2	8.2	(2.5) <sup>ab</sup>	7.1	(1.6)	7.8	(2.2)	0.2	7.5	(2)		
Push ups (n)	20	(4)	0.9	33	(15)	-0.2	29	(8)	23	(9)	35	(14)	0.006	30	(14)		
Muscular Power																	
Vertical jump height (cm)	18.8	(16.3)	0.0	26.1	(14.8)	-0.3	19.5	(16.2)	21.2	(11.5)	25.7	(17.5)	0.02	23.8	(15.3)		
Vertical jump power (W)	69.5	(11.5)	0.2	72.0	(10.6)	0.0	72.2	(10.7)	65.1	(7.6)	76.3	(10)	<0.001	71.7	(10.6)		
Sport specific test																	
Saddle test (s)	113	(72) <sup>a</sup>	0.9	149	(57) <sup>ab</sup>	0.5	180	(0) <sup>b</sup>	166	(36)	138	(65)	0.09	150	(57)		
Reaction time (s)	0.518	(0.07)	0.0	0.494	(0.09)	0.2	0.521	(0.08)	0.501	(0.07)	0.503	(0.09)	0.8	0.503	(0.08)		
Flexibility																	
Sit and reach test (cm)	30.8	(5.8)	-0.1	32.5	(8.7)	-0.1	31.7	(5.8)	33.8	(5.8)	31.0	(8.8)	0.3	32.1	(7.8)		
Hip flexion (°)	128	(8)	-0.4	124	(12)	0.0	124	(7)	127	(10)	122	(10)	0.2	125	(10)		
	125	(11)	-0.1	126	(12)	-0.2	123	(10)	126	(11)	124	(12)	0.4	125	(11)		
Hip extension (°)	49	(10)	-0.5	43	(7)	-0.1	42	(9)	45	(9)	43	(7)	0.5	44	(8)		
	45	(11)	-0.2	44	(8)	-0.1	43	(6)	45	(8)	43	(8)	0.6	44	(8)		
Shoulder flexion (°)	176	(5)	-0.3	174	(8)	0.0	174	(6)	175	(7)	173	(7)	0.2	174.0	(7)		
	159	(52)	0.3	176	(8)	-0.1	175	(6)	170	(29)	175	(6)	0.9	173.0	(21)		
Shoulder extension (°)	59	(7) <sup>a</sup>	-0.7	48	(12) <sup>b</sup>	0.2	52	(9) <sup>ab</sup>	53	(11)	48	(12)	0.2	51	(11)		
	53	(5)	-0.1	49	(11)	0.2	52	(8)	52	(10)	49	(9)	0.3	50	(9)		

<sup>a, b</sup>Means with superscripts significantly differ ( $P<0.05$ ) between licence types

\*Effect size (ES) between senior jockeys and probationer or apprentice jockeys

**Fig. 2** Boxplots of saddle test time between jockey licence types (probationers [ $n=8$ ], apprentices [ $n=38$ ] and senior [ $n=11$ ]). \*denotes statistical significance between groups ( $P<0.05$ )



**Fig. 3** Median (IQR) of hip, knee and ankle angles for **A** probationer ( $n=8$ ), **B** apprentice ( $n=39$ ) and **C** senior jockeys ( $n=11$ )

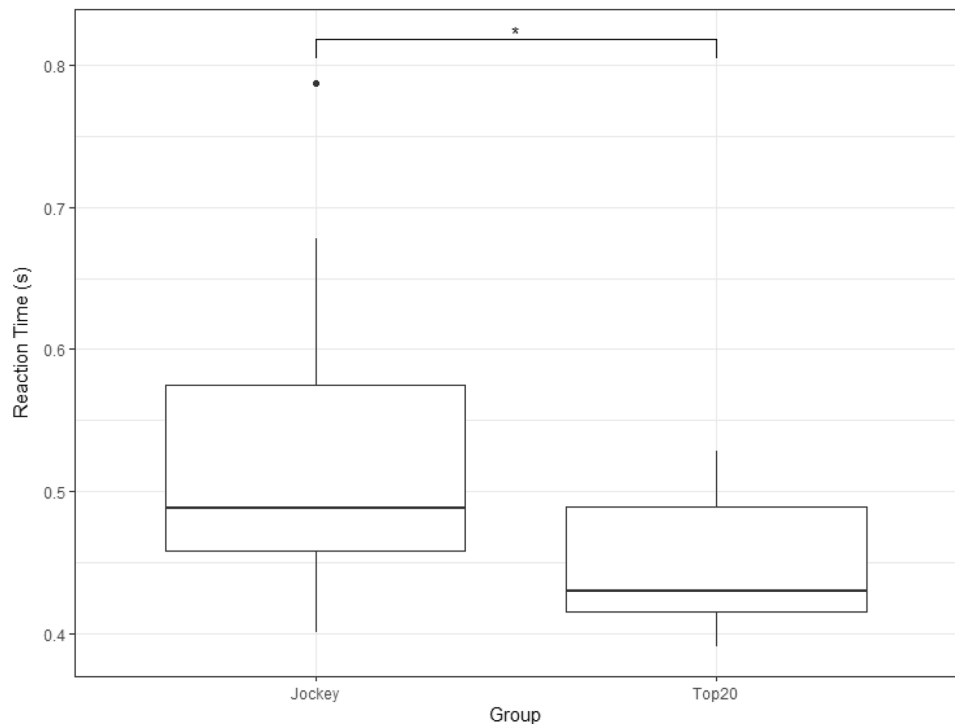
possibly due to the high proportion of females in this cohort of jockeys. Additionally, the use of the 20-m shuttle test rather than cycle ergometry as reported in published studies, may result in the lower than expected estimated values. The lower value recorded for senior jockeys is likely a reflection of the older age of that cohort of jockeys [21].

Core stability is of particular importance to horse racing jockeys due to the key role that these muscles play in the maintenance of the racing position [26, 55]. It was observed in the current study that the top jockeys had a greater level of core extensor strength and endurance than the other jockeys, indicating a greater utilisation of back core musculature in the jockey position. ‘Core stiffness’ in other sports is essential for injury prevention, performance enhancement and requires dedicated training [35]. Interesting, female jockeys also had greater core extensor and flexor strength

than their male counterparts, which could indicate that they are recruiting these muscles in compensation for their relatively lower upper body strength and lower body power. It has been previously shown that abdominal activity in race riding jockeys decreased between the first and last race of the day [26], indicating that reducing fatigue of this muscle group to support the entire core musculature may be of particular importance to jockeys. As similar core fatigue was not observed for jockeys in track-work or trials, the posture and intensity of race-riding is therefore different to that in training rides [25, 26]. Therefore, specific training in addition to track-work and trials is required and targeted core strengthening exercises may be beneficial for the race day training of jockeys.

It has been postulated that jockeys have a demand for high intensity lower body power during race-riding [14, 50],

**Fig. 4** Reaction test time between jockeys in the top 20 of the premiership table (Top20,  $n = 11$ ) and other jockeys (jockey,  $n = 47$ ). \*denotes statistical significance between groups ( $P < 0.05$ )



However, there were no differences in explosive leg power (as measured by the vertical jump test) between groups. Instead, a greater relative leg and back strength was recorded by the more experienced licence levels, indicating increasing strength with experience and riding level. Probationer level riders had not competed in any race riding, though they ride in track-work and trials, whereas apprentices and jockeys race ride more frequently, with the frequency often related to experience [27]. Jockeys in races adopt a lower crouched posture than jockeys riding track-work, which requires a greater lower leg strength [26]. This highlights the strength and endurance required by the lower body to maintain the jockey ‘crouch’ position. Whilst riding racehorses in training appears to result in a similar or greater relative lower body strength than other recreational athletes [47], it may not be sufficient to effectively prepare jockeys to be optimally prepared for race riding. Anecdotally, apprentices are known to comment on the ‘burn’ in their legs after a race ride. Therefore, this study provides preliminary evidence that increasing the strength and endurance in the lower body muscles of prospective jockeys through targeted physical training, may have a large impact on race-riding performance.

There were no differences between jockey experience levels (licence types or top 20 jockeys) in upper body strength or hand grip strength. This may be due to the higher reliance on upper body musculature in the maintenance of the track work position than in races, due to the jockey stabilising themselves with their upper limbs on the horses neck [25, 26]. However, upper body strength has been postulated

to be important in maintaining a stable posture on the horse and in pushing the horse to gallop faster [46, 52]. Indeed, the greater core strength observed in female jockeys, may be compensating for their relatively lower upper body and hand grip strength, indicating that core and upper body strength are instrumental in postural control of the jockey. Hand grip strength for jockeys in the current study was similar to that previously reported for jockeys, track work riders (~41 kg) [14] and elite level equestrian eventers (~40 kg) [7], and is often taken as representative of total body strength and symmetry [38]. Therefore, it should still be considered as a pre-licencing test for apprentices.

The isometric endurance of all muscles involved in maintaining the jockey posture (core, leg and back muscles) in combination with balancing ability were assessed in a novel ‘saddle test’. Comparisons between expert and novice dressage riders have indicated that on-horse posture and stability provide the most important indicators of rider performance [13]. Body size may affect a jockey’s balance and coordination on the horse, especially affecting the body angles needed to maintain an optimum position, however there were no correlations between joint angles and stature of jockey. Interestingly, MCA analysis showed an association between a smaller hip and knee angle (generally held by the senior jockeys) and a higher saddle test score. Accordingly, senior jockeys reported a higher RPE compared to apprentice jockeys in the ‘saddle test’. The heterogeneous reporting of RPE in the apprentices indicates that the tail (low performing outliers) in Fig. 2 may be associated with a small cohort

of apprentices that failed to appreciate the relevance of the testing programme and did not fully commit to this test. Some of the lower scoring apprentices had experienced sustained periods of time away from the apprentice programme indicating injury and recovery, lack of talent, or difficulty in maintaining employment tenure (often associated with weight maintenance issues). The more variable success by the less experienced licence levels in completing the saddle test could be due to adoption of a more 'open' position, with a higher centre of mass and less reliance on leg strength, leading to greater difficulty in balancing in the posture. This 'open' posture is similar to that commonly adopted by track-work riding participants, where they additionally use their upper body and arms to stabilise themselves on the horses neck [26]. However, this additional stabilisation option was not available for the duration of the 'saddle test' (Fig. 1). Collectively, findings indicate that the lower crouch position provides a more stable and efficient riding position. This low crouch posture may require greater recruitment and isometric loading of lower body and back core muscles due to greater flexion at the hip and knee, which could impose greater physical demand for the working muscles, thereby increasing the jockeys' perceived effort. The novel saddle test could be a useful tool in testing the strength, balance and pliability required to achieve a stable riding position. Thus, it could be developed into an effective crude measure of jockey performance, specifically for baseline jockey fitness tests, particularly if the position (hip, knee and ankle angles) of the jockey were controlled. Therefore, it is recommended this test undergo further validation and reliability testing.

The top 20 jockeys in the current study had a faster reaction time than the rest of the jockeys. Reaction time is the ability to detect a stimulus, process it, and then give the appropriate response to it. This provides a measure of the speed of motor response of jockeys, important for the split-second decision making required by jockeys during a race [8]. Fast reactions are essential in race riding as jockeys need to make quick decisions during the race to ensure both their own and their horses' safety, as well as recognising, executing and adopting race strategies by making timely strategic changes to horse placement under dynamic conditions to enable the horse to perform to their best potential. Simple reaction time has also been related to physical fitness in athletes [45], and it appears from this study that assessment of reaction time may provide good discriminability in jockey fitness to perform in competition. Reaction time can be deliberately trained through a wide variety of physical activities (i.e. cognitive training) to influence its development [33, 54], and may be an integral part of race specific fitness associated with jockey success.

Riding in races places considerable physical strain on a jockey's body, specifically pressure on joints and muscles in the lower back, neck, hip, knee and ankle as well as

the major leg and arm muscles [43]. Flexibility assessment could be considered an important indicator of performance and injury risk when coupled with other factors such as posture [55]. Differences in flexibility observed in the present study were minimal and may be due to injuries (old and new) which were prevalent in the apprentice jockey population. Therefore, it appears that flexibility is less representative of performance for jockeys due to confounding factors (such as injury).

Overall, jockeys do little training outside of riding [18, 30], so it was not surprising that there were minimal differences between jockey licence types in a conventional physical fitness testing battery. However, track-work riding does provide some positive physiological adaption which, in turn, supports the requirement for a basic level of physical fitness to safely engage in the sport. The top 20 jockeys had high body and core strength and endurance, the ability to maintain postural control (balance), and fast reactions. This study corroborates previous research in English horse riders that suggest endurance, reaction time, postural control and muscle strength are positively associated with rider performance [1, 23]. Therefore, future jockey specific training programmes should be highly sport specific, containing components to improve reaction time, decision making and lower body and core strength and conditioning. Future tests and physical fitness regimes need to assess the specific muscles used in race riding to effectively assess the competency of jockeys to race ride, and thereafter increase their performance levels. Findings in this study may provide benchmarking levels of fitness for apprentice jockeys to achieve in order to safely enter into the apprentice training programme and engage in race riding.

## Limitations

The tests included in this study were limited by the practicality and portability of their assessment. Assessment days were scheduled during compulsory Apprentice school days, and thus had a set time and place in which all participants could complete all the tests. Mondays are the scheduled Apprentice school days as flat racing in New Zealand occurs Wednesday to Sunday. Thus, fitness assessment on Monday minimised any acute effects of 'making weight' by the jockeys. Senior jockeys were recruited via industry advertisement, resulting in relatively few senior jockeys voluntarily taking part, possibly due to participation being voluntary and their dispersed distribution. Despite this, many of the top ranked jockeys did participate, providing an important contribution and example for the younger jockeys. The distribution of gender does not remain consistent across the ranking of jockeys. This and the small population of eligible participants within New Zealand greatly restricted

examination of the interaction of gender and licence level / experience.

## Conclusions

Conventional physical fitness tests showed little differentiation between jockey licencing levels. There is a need for sports specific physical fitness test in jockeys. The data in this study provides some evidence to enable improvements to apprentice training and establish minimum performance standards for jockey licencing. The differentiations observed between licencing levels in the novel 'saddle test' suggest that its role in assessing deficits in physiological performance that may lead to jockey falls and injury should be investigated further. It can also be developed as a basis in providing clearance for licencing levels. Jockeys who were riding as the top 20 jockeys in the country at the time of the study had faster reaction times and greater core strength than jockeys who were not in the top 20. This highlights several useful measures to be included in future sport specific testing procedures for race riding competency and post-injury/fall assessments.

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**Data availability** The datasets generated during the current study are available from the corresponding author on reasonable request.

## Declarations

**Conflict of interest** The authors have no relevant financial or non-financial interests to disclose.

**Ethical approval** This study was performed in line with the principles of the Declaration of Helsinki. Ethical approval for the study was received from Massey University Human Ethics Committee (SOA 20/27).

**Consent to participate** Informed consent was obtained from all individual participants included in the study.

**Consent to publish** Participants signed informed consent regarding publishing their data and photographs.

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