

1 Article

# 2 Strength and Reaction Time Capabilities of New 3 Zealand Polo Players and Their Association with 4 Polo Playing Handicap

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10 **Abstract:** Polo is an equestrian team sport consisting of four players per team, with level of play  
11 determined by cumulative player handicap (-2 to + 10 goals), with a higher handicap denoting a  
12 better player. There is minimal literature investigating Polo players' physical attributes, hence the  
13 understanding of the physical characteristics that may contribute to an improved handicap are  
14 unknown. This study sought to identify the relationship between pertinent strength measures (left  
15 and right hand grip strength; absolute and relative isometric mid-thigh pull) and reaction time in  
16 Polo handicap in 19 New Zealand Polo players, and ascertain whether handicap could be predicted  
17 by these measures. Correlation coefficients were expressed using R values, accompanying  
18 descriptors and 90% confidence intervals (C.I.). Variance explained was expressed via the R<sup>2</sup>  
19 statistic, and statistical significance set at  $p < 0.05$ . Right hand grip strength, isometric mid-thigh pull  
20 values were found to significantly correlate to and explain variance within Polo player handicap  
21 (all *moderate* to *large* correlations;  $p < 0.05$ ). Whereas left hand grip strength (R: 0.380; 90% C.I. -0.011  
22 to 0.670) and reaction time (0.020; -0.372 to 0.406) were non-significant, *moderate* and *trivial* correlates  
23 and predictors of handicap respectively. Practically, these findings highlight the differing roles  
24 between rein and mallet hands of Polo players and emphasise the importance of a strong and stable  
25 platform when riding and striking the ball. Lack of association with reaction time may be explained  
26 in part by higher handicapped Polo players employing a more proactive approach to the game.

27 **Keywords:** grip strength; reaction time; isometric strength; Polo; equestrian

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## 29 1. Introduction

30 Polo is one of the oldest equestrian sports in the world and requires the synchronisation of both  
31 equine and human athletes in a dynamic and high-paced environment [1]. Previous literature has  
32 begun to characterise Polo gameplay through global positioning systems (GPS) [2], quantitative  
33 performance analysis [3], and equine internal workloads via heart rate [4,5], and biochemical  
34 responses [6]. These investigations have allowed insight into the science behind Polo and discuss how  
35 applied research may be utilised within the sport. One factor each of these previous studies has  
36 acknowledged, is the subjective handicap rating system used to provide Polo players a quantitative  
37 measure of their ability (between -2 and +10) [7]. This system is based on a variety of features  
38 including horsemanship, playing skills, technique and the quality of horses being utilised [7]. Many  
39 of these factors contributing to handicap rely on the physical capabilities of the players themselves.  
40 Horse riding requires physical strength through both the upper and lower limbs, general  
41 cardiovascular endurance, balance, reaction time and flexibility [8,9], with these elements further  
42 complicated by the grips, sudden accelerations / decelerations, and reaction times required when the  
43 dynamic and unpredictable demands of Polo gameplay are introduced. The need to identify, train,  
44 and evaluate the physical attributes required for effective and safe Polo performance is crucial [10],

45 as players may be exposed to speeds exceeding 60km/h and distances upwards of 5km per chukka  
46 [1,11] which potentiates a variety of risks and potential for injury [1].

47 The aim of this study is to quantify the sport-specific physical characteristics of Polo players, and  
48 furthermore, to assess the relationship these characteristics have to player handicap. Findings will  
49 provide evidence to inform Polo athlete training programmes and also advise how physical attributes  
50 may contribute to improving player handicap. It is hypothesised that left and right grip strength, and  
51 lower limb strength, will possess high correlations to player handicap. This is due to the large forces  
52 required to manipulate a horse at high speeds and control the mallet through high velocity contacts.  
53 It is also hypothesised that reaction time will show little correlation to handicap, as a proactive tactical  
54 awareness becomes better developed as experience in the sport increases.

## 55 2. Materials and Methods

### 56 *Experimental approach*

57 Player handicap was selected as the independent variable, as this is a measure of players' Polo ability  
58 that is awarded by the local Polo governing body (e.g. the New Zealand Polo Association) and  
59 reviewed annually; therefore, it could not be manipulated by the researchers. The dependent  
60 variables of interest were selected as strength assessments related to horse riding skill or body  
61 position (hand grip; isometric mid-thigh pull (IMTP)) and mimicked the dynamic requirements of  
62 Polo (reaction time) [8,9].

### 63 *Subjects*

64 Nineteen participants (12 male; 7 female) were originally recruited for this investigation (Handicap:  
65  $0 \pm 2$  goals; Age:  $36.2 \pm 14.1$ y; Weight:  $78.9 \pm 19.4$ kg). Participants' height was not recorded due to the  
66 variability in heel height of players' Polo boots; it would have been unsafe for testing to be performed  
67 unshod. Ethical approval for this investigation was awarded by the institution's Human Ethics  
68 Research Group. Participants provided written informed consent prior to undertaking the testing  
69 battery and retained the right to withdraw themselves and their data from the study at any time.

### 70 *Procedures*

71 Left and right-hand grip strength was assessed via a hand grip dynamometer (Smedley's, Tokyo),  
72 calibrated up to 100kg. Grip strength procedures need to mimic the specific demands of the sport to  
73 improve the validity of the recording [12]. As such, participants were asked to grip the dynamometer  
74 firmly and raise their hand above their head with the palm facing forward. They were to then squeeze  
75 as hard as possible and adduct the shoulder whilst pronating the forearm. The final position was with  
76 their arm by their side with the palm facing medially. This protocol was used as it best mimics the  
77 dynamics of a Polo swing. Participants self-selected their starting hand but alternated between trials.

78 Isometric mid-thigh pull (IMTP) was assessed using a customised testing rig, consisting of two Pasco  
79 force plates (Roseville, California) and perpendicular vertical poles drilled at 1cm increments to allow  
80 appropriate grip adjustment and positioning of the bar to the participants' mid-thigh. Similar  
81 protocols have shown reliable measures both within (ICC = 0.97) and between (ICC = 0.89) sessions  
82 [13]. Peak IMTP net forces were recorded in Newtons (N), and Newtons per kilogram (N/kg) for  
83 relative forces.

84 Reaction time was assessed via Fitlight reaction lights (Ontario, Canada) set at 30sec sample duration,  
85 with a 0.1 sec delay between lights. The number of lights a participant correctly waved their hands  
86 over in a 30 sec period was recorded. Lights were mounted on two tables positioned in a right angle  
87 and arranged in a fan-like shape around the participant; lights were not placed behind the

88 participants as when mounted on a horse a player cannot leave the confines of the saddle, and to play  
89 behind the saddle is considered dangerous.

90 Participants were permitted three attempts for each test following a demonstration by a researcher,  
91 participants' best efforts were used for analysis.

### 92 *Statistical Analyses*

93 Data were assessed for normality via the Shapiro Wilks test and found to be normally distributed  
94 ( $p > 0.05$ ), meaning parametric tests could be employed. Pearson correlation coefficients were used to  
95 assess the relationship between Polo handicap and measures of strength and reaction time, with  
96 statistical significance set *a priori* at  $p \leq 0.05$ . Ninety percent confidence intervals (C.I.) are used to  
97 describe the uncertainty in the data and magnitudes of relationships were described using the  
98 following intervals: *Trivial* 0 – 0.2, *Small* 0.1 – 0.3, *Moderate* 0.3 – 0.5, *Large* 0.5 – 0.7, *Very Large* 0.7 – 0.9  
99 and *Nearly Perfect*  $> 0.9$  [14]. Variance explained was expressed via the  $R^2$  statistic.

100 Linear regression was used to determine the predictive ability of Polo handicap upon strength  
101 variables and reaction time, with relationships described using the formula  $y = a + bx$ ; where  $y$  is the  
102 dependent variable score,  $a$  is the intercept on the  $y$  axis,  $b$  is the slope of the regression line and  $x$  is  
103 the Polo handicap. For clarity, correlation coefficients,  $p$  values, and  $R^2$  values are stated to three  
104 decimal places. All data analysis was conducted in SPSS (IBM SPSS Statistics version 24, IBM,  
105 location); confidence intervals for correlation coefficients were calculated using a customised  
106 spreadsheet [15].

### 107 **3. Results**

108 Group means identified handgrip strength was greater in the right hand ( $50.9\text{kg} \pm 16.6$ ) when  
109 compared to the left ( $46.3\text{kg} \pm 15$ ). As depicted in Table 1, both left and right handgrip strengths  
110 displayed Moderate to Large correlations to player handicap, with significance achieved by the right  
111 hand only ( $p = 0.019$ ). Significant relationships to player handicap were also demonstrated by IMTP  
112 ( $p = 0.004$ ) and IMTP-R ( $p = 0.035$ ), which displayed correlations to player handicap of 0.609 and 0.484,  
113 respectively. Reaction time was shown to have a non-significant relationship ( $p = 0.889$ ) to player  
114 handicap, with a group mean of  $23.3 \pm 2.7$ .

115 All variables that displayed significant relationships to handicap (right handgrip strength, IMTP and  
116 IMTP-R) also demonstrated significant  $R^2$  values, suggesting that these metrics may be predictive of  
117 Polo handicap. Regression equations for each variable can be found in Table 1; individual data plots  
118 for each variable that displayed moderate to large relationships with player handicap, with  
119 accompanying regression lines are depicted in Figure 1, panels A-D.

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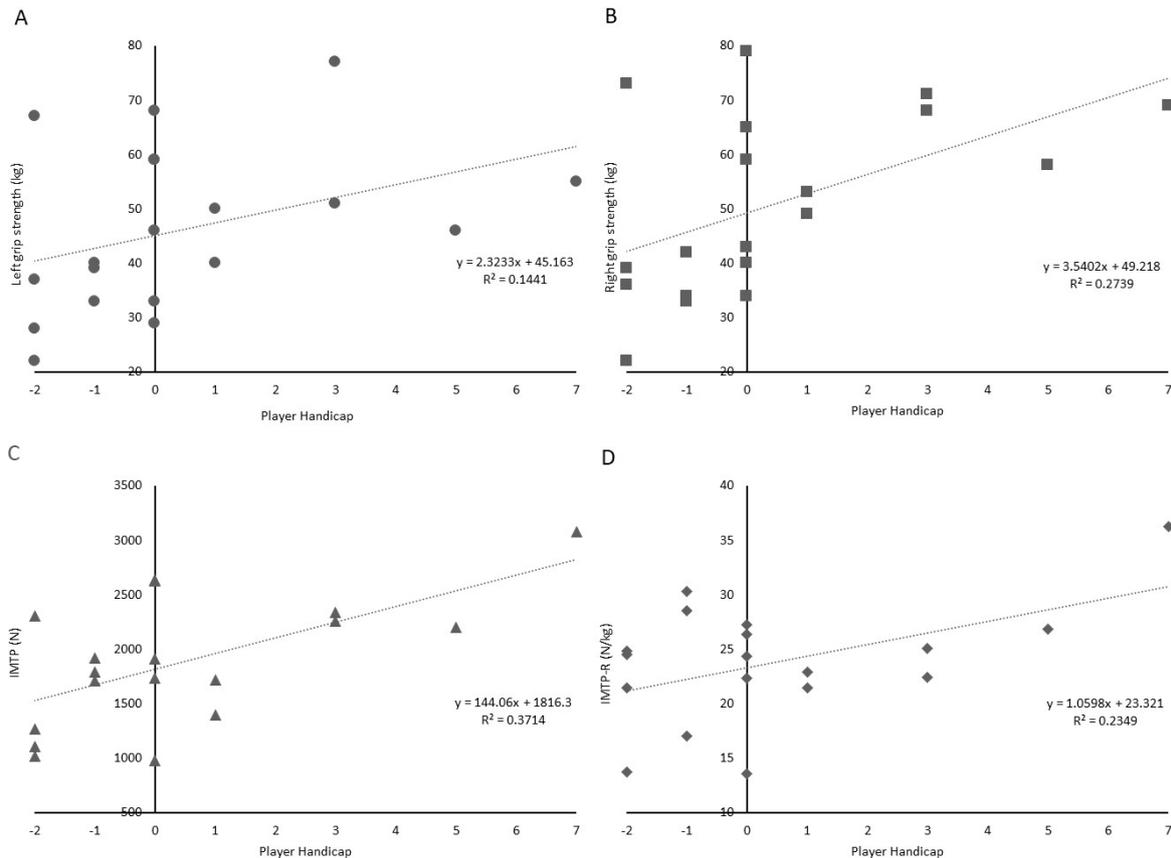
121 3.2.

122 Table 1: Correlation coefficients between Polo handicap and strength and reaction time (RT). Accompanying 90% Confidence intervals (C.I.), *p* values and magnitude  
 123 descriptors are also shown. Variance explained ( $R^2$ ) and the linear regression equations are also presented for each variable, as per Polo handicap. HG: Handgrip;  
 124 IMTP: Isometric mid-thigh pull; IMTP-R: Isometric mid-thigh pull relative to bodyweight; RT: Reaction time; Significant values ( $p < 0.05$ ) are denoted by an asterisk  
 125 \*.

Variable	Correlation	90% C.I.		<i>p</i> value	Descriptor	$R^2$ value	Regression equation
HG Left	0.380	-0.011	to 0.670	0.102	<i>Moderate</i>	0.144	$y = 2.387x + 44.362$
HG Right	0.523	0.168	to 0.758	0.019*	<i>Large</i>	0.274*	$y = 3.613x + 48.305$
IMTP	0.609	0.275	to 0.812	0.004*	<i>Large</i>	0.371*	$y = 148.030x + 1766.396$
IMTP-R	0.484	0.103	to 0.741	0.035*	<i>Moderate</i>	0.235*	$y = 1.065x + 23.258$
RT	0.020	-0.372	to 0.406	0.889	<i>Trivial</i>	0.001	$y = -0.037x + 23.463$

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**Figure 1.** Individual data points and accompanying linear regression lines for left (Panel A) and right (Panel B) hand grip strength, IMTP (Panel C) and IMTP-R (Panel D).

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#### 4. Discussion

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The purpose of this study was to characterise strength and reaction time attributes of Polo players and assess the relationship between these factors and player handicap. This study shows that right-hand grip strength, IMTP, and IMTP-R have significant relationships to player handicap. However, reaction time neither correlates to nor is predictive of player handicap, therefore supporting the hypothesis of this paper. Left-hand grip strength presented a non-significant *moderate* relationship with player handicap, which was contrary to the initial hypothesis.

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The ability to grip and manipulate objects is an important aspect of many sporting endeavours, with athletes often requiring a combination of general grip strength and the ability to produce intricate movements to perform most effectively [16]. A range of handgrip strength values are present across sporting codes [12], with dressage horse riders displaying some of the lowest hand grip values (<30kg) [17] and rowers displaying some of the highest (>70kg) [18]. In the current study, handgrip strength was higher than previous equine-based investigations [11,17,19], although the methods of collecting handgrip strength differed based on the event specific requirements of the various equestrian pursuits examined. Differences in methodology have also been shown to influence the validity of maximal measures in some instances and therefore may account for some of the variation identified [12]. It is suggested that handgrip demands differ between equestrian events, and with the added intensity, speed and manoeuvrability required in Polo, a stronger grip may in fact be more advantageous. With the added need to manipulate the mallet with the right-hand, strength becomes important to repeatedly control impacts on the ball and produce consistent shots. Weaker correlations and decreased grip strength were observed in the left hand. This may be explained by the riding style required for Polo (K. Brooks & J.P. Clarkin, personal communication, March 24, 2019), where finesse and intricate controlled movements are used to manoeuvre the horse via the left-hand on the reins, and not necessarily through strong and forceful movements as initially hypothesised. The left to right

155 asymmetry may also be described by the right-hand dominance which is witnessed in 80-90% of  
156 demographic studies [12,20,21]. Whilst using one hand to swing the mallet, and the other to  
157 manipulate the horse, the need to remain stable in the saddle is also of critical importance.

158 Stability in the saddle is determined by the interaction of various factors, namely the horse, type  
159 of saddle, rider and the type of movements being performed [22]. Stability is maintained by the rider's  
160 ability to follow the movements of the horse and by using both legs to provide the base for this  
161 movement [22,23]. IMTP-R and IMTP displayed *moderate to large* relationships with player handicap  
162 and significant  $R^2$  values of 0.235 and 0.371, respectively, highlighting the predictive qualities of these  
163 measures. There is a clear need for a strong base of support and the ability to produce high levels of  
164 force on the stirrups, through both legs whilst Polo players are riding at speed, playing shots out of  
165 their saddle and absorbing contacts from different angles (ride-off). Previous literature has performed  
166 static muscle testing of the lower limb [24], with no significant differences between riders and control  
167 groups identified. There is a paucity of literature surrounding lower limb strength in horse riders,  
168 therefore the novel findings of this relationship warrant further investigation within a Polo context  
169 to better understand how this can be assessed dynamically, to mirror the oscillatory pattern of riding.

170 The ability to predict gameplay and be proactive in sport is a skill that comes with experience  
171 and knowledge of the game [25,26]. Polo is no exception to this rule, as reaction time was shown to  
172 have a *trivial* non-significant relationship to handicap. The need to be proactive and predict plays is  
173 a skill that does not necessarily require fast reaction times, rather an ability to read the game and  
174 respond more efficiently. Through time in the saddle, players gain valuable insight into how the game  
175 is played which allows them to make better-informed decisions about when and where they need to  
176 be on the pitch, and how to manipulate their horses to accomplish this effectively. These skills are  
177 contributors to 'horsemanship' and 'playing skills', two of the categories considered when player  
178 handicap is attributed [7]. It is important to note, that the physical characteristics measured within  
179 this study are not directly measured to influence or attain player handicap ratings. These variables  
180 do however contribute to the players ability to perform the subjectively measured aspects related to  
181 Polo play.

182  
183 **Practical applications**

184 Without consistent and objective handicap profiling procedures, it is difficult to make conclusive  
185 statements about how players may be able to utilise these findings to improve their handicap.  
186 However, results of this study suggest practitioners working with Polo players, or other equestrian  
187 pursuits, should focus on the development of grip strength, as well as the riders' ability to stabilise  
188 and transfer force through their lower limb as this provides a stronger platform on the stirrup when  
189 playing on-ball. Time spent developing players' ability to read the game and make proactive moves  
190 may be a more effective use of time than training reactive components. Future research should further  
191 investigate the bilateral differences between left and right hands of Polo players, and the motor  
192 nuance required to perform most effectively. Lower limb strength and endurance capacities should  
193 also be investigated within Polo and could be used in conjunction with player heart rates to clarify  
194 central or peripheral limitations [27]. Further information pertaining to the internal physical demands  
195 and external workloads of Polo would further aid in training programmes for Polo players.

196

197 **Author Contributions:** For research articles with several authors, a short paragraph specifying their individual  
198 contributions must be provided. The following statements should be used. Conceptualization, R.S. and R.B.;  
199 methodology, R.S; R.B; validation R.S; R.B.; formal analysis, R.S; R.B.; investigation, R.S; R.B; resources, R.S; R.B  
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206

207 **References**

- 208 1. Costa-Paz, M.; Aponte-Tinao, L.; Muscolo, D.L. Injuries to polo riders: a prospective evaluation. *Br. J.*  
 209 *Sports Med.* **2008**, *33*, 329–331.
- 210 2. Best, R.; Standing, R. Feasibility of a Global Positioning System to assess the spatiotemporal  
 211 characteristics of Polo performance. *J. Equine Vet. Sci.* **2019**.
- 212 3. Best, R.; Standing, R. Performance Characteristics of a Winning Polo Team. *New Zeal. J. Sport Exerc.*  
 213 *Sci.* **2019**, *2*, 1–11.
- 214 4. Marlin, D.J.; Allen, J.C.R. Cardiovascular demands of competition on low-goal (non-elite) polo ponies.  
 215 *Equine Vet. J.* **1999**.
- 216 5. Wright, R.; Peters, D. A heart rate analysis of the cardiovascular demands of elite level competitive  
 217 polo. *Int. J. Perform. Anal. Sport* **2008**, *8*, 76–81.
- 218 6. Zobba, R.; Ardu, M.; Niccolini, S.; Cubeddu, F.; Dimauro, C.; Bonelli, P.; Dedola, C.; Visco, S.; Pinna  
 219 Parpaglia, M.L. Physical, Hematological, and Biochemical Responses to Acute Intense Exercise in Polo Horses.  
 220 *J. Equine Vet. Sci.* **2011**, *31*, 542–548.
- 221 7. Hurlingham Polo Association *Outdoor Rules and Regulations*; Hurlingham Polo Association:  
 222 Faringdon, 2018;
- 223 8. Mitani, Y.; Doi, K.; Yano, T.; Sakamaki, E.; Mukai, K.; Shinomiya, Y.; Kimura, T. Effect of Exercise  
 224 Using a Horse-Riding Simulator on Physical Ability of Frail Seniors. *J. Phys. Ther. Sci.* **2008**, *20*, 177–183.
- 225 9. Hitchens, P.; Blizzard, L.; Jones, G.; Day, L.; Fell, J. Are physiological attributes of jockeys predictors  
 226 of falls? a pilot study. *BMJ Open* **2014**, *1*, 1–7.
- 227 10. Noleto, P.G.; Cubas, J.P.C.; Barbosa, F.C.; Guimarães, E.C.; Mundim, A. V. Biochemical profile of polo  
 228 horses in training phase and those players of official competition: Biochemical profile of polo horses. *Comp. Clin.*  
 229 *Path.* **2016**, *25*, 911–915.
- 230 11. Warrington, G.; Dolan, E.; McGoldrick, A.; McEvoy, J.; MacManus, C.; Griffin, M.; Lyons, D. Chronic  
 231 weight control impacts on physiological function and bone health in elite jockeys. *J. Sports Sci.* **2009**, *27*, 543–550.
- 232 12. Cronin, J.; Lawton, T.; Harris, N.; Kilding, A.; McMaster, D.T. A brief review of handgrip strength and  
 233 sport performance. *J. Strength Cond. Res.* **2017**, *31*, 3187–3217.
- 234 13. De Witt, J.K.; English, K.L.; Crowell, J.B.; Kalogera, K.L.; Guilliams, M.E.; Nieschwitz, B.E.; Hanson,  
 235 A.M.; Ploutz-Snyder, L.L. Isometric Midthigh Pull Reliability and Relationship to Deadlift One Repetition  
 236 Maximum. *J. strength Cond. Res.* **2018**, *32*, 528–533.
- 237 14. Hopkins, W.G.; Marshall, S.W.; Batterham, A.M.; Hanin, J. Progressive statistics for studies in sports  
 238 medicine and exercise science. *Med. Sci. Sports Exerc.* **2009**.
- 239 15. Hopkins, W.G. A spreadsheet for deriving a confidence interval, mechanistic inference and clinical  
 240 inference from a p value. *Sportscience* **2007**, *11*, 16–20.
- 241 16. Moran, C.A. Anatomy of the hand. *Phys. Ther.* **1989**, *69*, 1007–1013.
- 242 17. Hobbs, S.J.; Baxter, J.; Broom, L.; Rossell, L.-A.; Sinclair, J.; Clayton, H.M. Posture, Flexibility and Grip  
 243 Strength in Horse Riders. *J. Hum. Kinet.* **2014**, *42*, 113–125.
- 244 18. Secher, N.H. Isometric rowing strength of experienced and inexperienced oarsmen. *Med. Sci. Sports*  
 245 *Exerc.* **1975**, *7*, 280–283.
- 246 19. Meyers, M.C. Effect of equitation training on health and physical fitness of college females. *Eur. J.*  
 247 *Appl. Physiol.* **2006**, *98*, 177–184.
- 248 20. Johnston, D.W.; Nicholls, M.E.R.; Shah, M.; Shields, M.A. Nature's experiment? Handedness and early  
 249 childhood development. *Demography* **2009**, *46*, 281–301.
- 250 21. Llaurens, V.; Raymond, M.; Faurie, C. Why are some people left-handed? An evolutionary  
 251 perspective. *Biol. Sci.* 2009.
- 252 22. Peham, C.; Kotschwar, A.B.; Borkenhagen, B.; Kuhnke, S.; Molsner, J.; Baltacis, A. A comparison of  
 253 forces acting on the horse's back and the stability of the rider's seat in different positions at the trot. *Vet. J.* **2010**,  
 254 *184*, 56–59.
- 255 23. Greve, L.; Dyson, S. The horse-saddle-rider interaction. *Vet. J.* **2013**, *195*, 275–281.
- 256 24. Westerling, D. Applied Physiology A Study of Physical Demands in Riding. *Scand. J. Clin. Lab. Investig.*  
 257 **1983**, *50*, 373–382.
- 258 25. Aglioti, S.M.; Cesari, P.; Romani, M.; Urgesi, C. Action anticipation and motor resonance in elite  
 259 basketball players. *Nat. Neurosci.* **2008**, *11*, 1109–1116.
- 260 26. Cañal-Bruland, R.; Schmidt, M. Response bias in judging deceptive movements. *Acta Psychol. (Amst).*  
 261 **2009**, *130*, 235–240.
- 262 27. McLaren, S.J.; Graham, M.; Spears, I.R.; Weston, M. The sensitivity of differential ratings of perceived  
 263 exertion as measures of internal load. *Int. J. Sports Physiol. Perform.* **2016**