1  *Article*

2  # The Spatiotemporal Characteristics of 0 – 24 Goal
3  # Polo

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10  **Simple Summary:** Polo is an equestrian sport that requires two teams of four players to score goals at
11  opposing ends of a 150m x 275m pitch. Each player is rated on a handicap system which quantifies
12  their abilities and permits their inclusion in different levels of Polo play; the cumulative handicap of
13  four players sets the level of play. Using GPS technology, we investigated how levels of Polo differ
14  regarding distance covered, speeds achieved, and high intensity activities performed. As cumulative
15  Polo handicap increased, so too did the distances and average speeds attained, decelerations
16  performed, and impacts encountered during each period of play. These findings suggest that as each
17  player improves and increases their handicap, they need to ensure the ponies they play have sufficient
18  aerobic, anaerobic and speed capacities to perform effectively at that level. This information provides
19  valuable insight to Polo players, grooms and equine vets, as to how they can best prepare their ponies
20  for game-day, and how they may be able to maintain their longevity in the sport.

21  **Abstract:** Global positioning systems (GPS) have recently been shown to reliably quantify the
22  spatiotemporal characteristics of Polo, with the physiological demands of Polo play at low and high
23  goal levels also investigated. This study aimed to describe the spatiotemporal demands of Polo across
24  0 – 24 goal levels. A player worn GPS unit was used to quantify distance, speed and high intensity
25  activities performed. Data was divided into chukkas and five equine-based speed zones, grouped per
26  cumulative player handicap and assessed using standardised mean differences. Average distance and
27  speed per chukka increased in accordance with cumulative player handicap, with the magnitude of
28  differences being *Trivial – Large* and *Trivial – Very Large,* respectively. Differences between time spent
29  in speed zones 4 and 5 show a linear increase in magnitude, when comparing 0 goal Polo to all other
30  levels of play (*Small – Very Large;* 6 – 24 goals, respectively). High intensity activities predominantly
31  shared this trend, displaying *Trivial – Large* differences between levels. These findings highlight the
32  increasingly demanding cardiovascular, anaerobic and speed-based needs of Polo ponies as playing
33  level increases. Strategies such as high intensity interval training, maximal speed work and aerobic
34  conditioning may be warranted to facilitate this development and improve pony welfare and
35  performance.

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37  **Keywords:** Polo; GPS; Pony welfare, Horse
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39  ## 1. Introduction

40  The use of global positioning systems (GPS) in sport and animal research is increasingly prevalent
41  and can provide valuable data pertaining to activity type, distance covered, speeds attained and
42  location [1-4]. Despite reported widespread use in equine settings [4-6], the use of GPS to provide
43  tactical or training value in equestrian sport appears limited or underreported. This may be due to a

44  perceived inability to interpret the data obtained [5-7] hence, most published GPS use in equestrian
45  settings consists of methodological reports, typically pertaining to reliability [7-11].
46  In order to advance the application of GPS data in equestrian sports, consistent GPS use in training and
47  competitive scenarios is to be encouraged [6,12]. A greater understanding of the external workloads
48  (speed, distance, accelerations, decelerations) placed upon Polo ponies, would not only inform training
49  and competition management, but would also be of benefit in ponies returning from injury [12] or
50  transitioning from one equestrian discipline to another, as individualisation of training volume and
51  intensity can be easily assessed and prescribed.
52  Polo presents an ideal model to apply GPS, as Polo ponies are required to perform high intensity
53  movements and tolerate impacts in a manner that is unique to Polo, and players are required by Polo
54  regulations to interact with a relatively large number of ponies per game in comparison to other
55  equestrian pursuits [13]. Furthermore, Polo is played on the largest pitch in professional sport (275m x
56  145m) and is seeing an increase in ponies transitioning from racing to Polo [14], suggesting an
57  increase in game speed or a tactical use of fast ponies may be a contemporary issue that has the potential
58  to affect game outcome. Polo players are assigned a handicap (-2 to 10 goals), which provides a
59  quantitative measure of players' ability based on horsemanship, playing skill (individual and team) and
60  the quality of Polo ponies used [13]. The level of Polo play is depicted by the cumulative handicap of
61  all four players on a team (i.e. 10 goal) and can be made up of various combinations of players and skill
62  levels.
63  This research aimed to assess the spatiotemporal demands of Polo, across a range of handicap levels, to
64  accurately describe the performance requirements placed upon Polo ponies, with a view to informing
65  training practices and identifying points of distinction between levels of play. It is hypothesized that as
66  cumulative player handicap (i.e. level of play) increases, average speed and distance covered per
67  chukka (period of play) will also increase.
68
69  **2. Materials and Methods**

70  *2.1 Sample Population*

71  All data were gathered during the 2018-2019 New Zealand Polo Season, on the north island of
72  New Zealand. Data were obtained from a total of 338 chukkas of Polo. All players had a current New
73  Zealand Polo Association handicap (range -2 to +7 goals). The cumulative handicap for each team (4
74  players) was used to define the level of play (goals) for the tournament (e.g. 0 + 5 + 4 + 7 = 16 goals). All
75  games were contested under Hurlingham Polo Association rules [13] and were played over four
76  chukkas, with the exception of 16 and 24-goal games, which were contested over six chukkas. The
77  investigation was carried out following the rules of the Declaration of Helsinki and in accordance with
78  the International Guiding Principles for Biomedical Research Involving Animals as issued by the
79  Council for the International Organizations of Medical Sciences. Approval from the Waikato Institute
80  of Technology ethics committee was obtained in October 2018 prior to undertaking this research
81  (Approval code: WTFE2601102018).

82  *2.2 GPS Data Collection*

83  The present investigation utilised VX Sport 350 GPS units (VX Sport, Wellington, New Zealand),
84  sampling at 10 Hz, with a speed range of 0 - 60 km/h, in equestrian mode. The speed range permits for
85  derivation of speed zones (see 2.3 Data Processing and Analysis) but does not set an absolute upper
86  limit upon data captured. These devices have previously been reported as reliable independent of unit
87  position (CV <10% and ICC>0.70 [15]), for use in Polo [7].
88  GPS units were turned on 30 minutes prior to the start of each game to allow sufficient time for satellites
89  to be located and a secure connection to multiple satellites established. As players use multiple ponies
90  per game, possibly per chukka, with limited time between chukkas it is neither feasible nor
91  representative of typical Polo play to mount a GPS unit per horse, nor record data per horse, hence the
92  use of a player worn unit. As players use multiple ponies per game, possibly per chukka, with limited
93  time between chukkas it is neither feasible nor representative of typical Polo play to mount a GPS unit

94 per pony, nor record data per pony, hence the use of a player worn unit. Each player was fitted with
95 one GPS unit in a pouch on the player's belt; this position has previously been shown to produce reliable
96 results of speed and distance in Polo [7], with the same unit assigned to the same player for each data
97 collection to further enhance reliability. The belt pouch was secured with insulation tape to minimise
98 potential oscillation of the unit during data collection and reduce the risk of type 1 error. Upon game
99 completion units were collected by researchers and turned off, ending the data collection session.

100 *2.3 Data Processing and Analysis*

101 Data was extracted using specialist software (VX Sport, Wellington, New Zealand) and was
102 trimmed to remove the initial satellite lock period. The game period was divided into chukkas as per
103 notational analyses that accompanied each game. Speed zones were assigned *a priori* based upon an
104 estimated maximum speed of 60km/h which is within the tolerable limits of the manufacturer's
105 equestrian mode. Using in-built software thresholds, the following speed zones were constructed: Zone
106 1: 0 – 19.2km/h; Zone 2: 19.2 – 23.4km/h; Zone 3: 23.4 – 28.2km/h; Zone 4: 28.2 – 47.4km/h; Zone 5: 47.4
107 – 60km/h.
108 Distance covered (m) and time (min:sec) in each speed zone per chukka were selected as primary
109 dependent variables, with the number of sprints (a positive or negative acceleration >3m/s/s), impacts
110 and acceleration and deceleration counts, collectively termed high intensity activities, provided as
111 secondary dependent variables that further describe the load placed upon Polo ponies. Data are
112 presented per chukka to allow comparison between levels of play.
113 Data was exported to Microsoft Excel and variables analysed using a customised spreadsheet to
114 calculate standardised mean differences (Hedge's *g*) ± 90% confidence intervals (C.I.), between
115 handicap levels (0, 6, 10, 16 and 24 goals). Standardised mean differences were described using the
116 following magnitudes: *Trivial* 0-0.2, *Small* 0.2-0.6, *Moderate* 0.6-1.2, *Large* 1.2-2.0, *Very Large* >2.0 [16]. An
117 effect was deemed meaningful is the accompanying C.I. did not overlap zero.

## 3. Results

119 Prior to providing a detailed quantification of the spatiotemporal characteristics of each chukka
120 per level of play, the following descriptive statistics are provided for chukka time across 0 - 24 goal
121 levels: The median chukka duration from the sample (n = 338) was 11:09 ± 0:10, with absolute minimum
122 and maximum values of 6:33 and 19:27, respectively.

*3.1. Distance characteristics*

124 Distance characteristics for each level of play are shown in Figure 1, with a predominant increase
125 in median distance covered per chukka seen as cumulative player handicap increases. *Large* increases
126 in mean distance per chukka are observed when 24 goal Polo is compared to all other levels of play,
127 with average 10 goal chukka distance showing a *small* increase in comparison to that covered per
128 chukka at 0 and 6 goal levels. All other comparisons either showed *trivial* differences in average distance
129 covered per chukka or had C.I. that overlapped zero.

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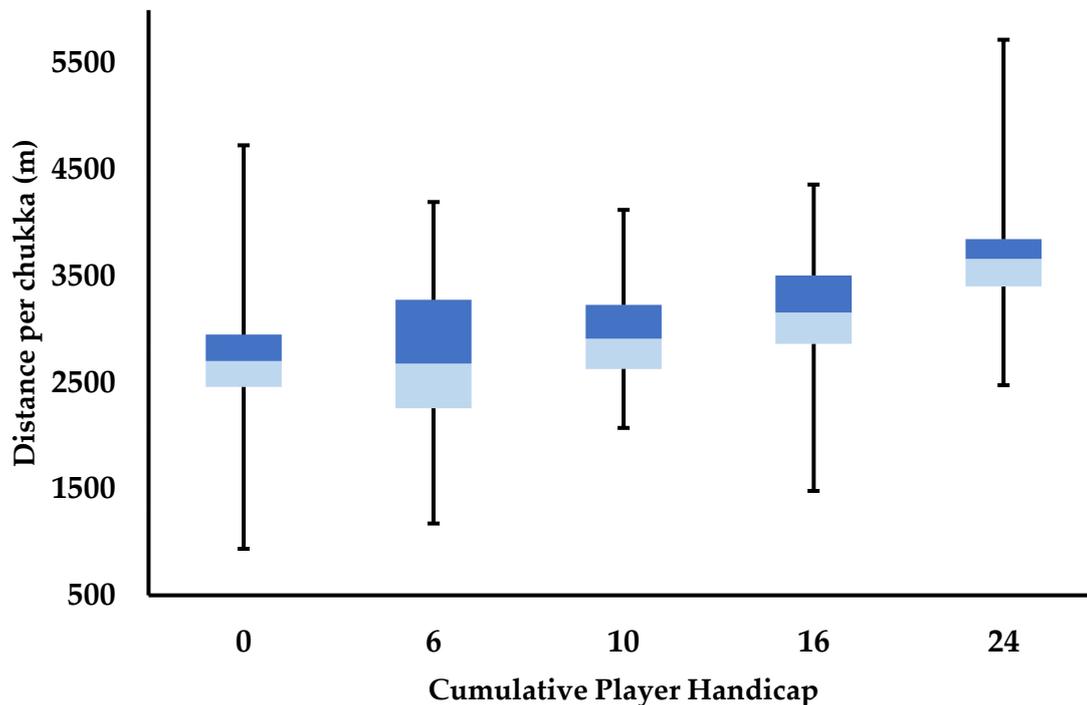


**Figure 1.** Box-plot of the median distance (m) per chukka at each level of play. Lower and upper box boundaries 25th and 75th percentiles, respectively, line inside box median, lower and upper error lines minimum and maximum, respectively.

**Table 1.** Distance (m) covered in each speed zone, per chukka at each level of play. Data are presented as means ± 90% confidence intervals.

| Level of Play | Speed Zone 1 | Speed Zone 2 | Speed Zone 3 | Speed Zone 4 | Speed Zone 5 |
|---|---|---|---|---|---|
| 0 goal | 377.2 ± 27.5 | 1036.9 ± 72.8 | 981.2 ± 114.9 | 287.7 ± 56.6 | 15.1 ± 8.4 |
| 6 goal | 410.9 ± 35.2 | 927.7 ± 55.5 | 914.9 ± 77.2 | 397.0 ± 62.1 | 41.4 ± 17.1 |
| 10 goal | 381.4 ± 19.5 | 1044.6 ± 36.5 | 1003.3 ± 43.5 | 461.6 ± 43.0 | 46.4 ± 11.1 |
| 16 goal | 604.9 ± 34.0 | 690.7 ± 45.0 | 744.9 ± 49.2 | 717.8 ± 43.1 | 88.6 ± 12.9 |
| 24 goal | 460.3 ± 34.4 | 1101.5 ± 92.2 | 1251.8 ± 108.4 | 796.4 ± 94.3 | 150.8 ± 32.6 |

Distance covered in each speed zone per chukka at each level of play is shown above in Table 1, with all effect sizes, C.I. and descriptors for all comparisons found in Table S1. As the level of play increases, there is a trend towards an increase in distance covered in higher intensity speed zones. This is most apparent in speed zones 4 and 5, as 24 goal Polo displays a *very large* increase in distance covered in speed zones 4 and 5 compared to 0 goal play. This increased high-speed distance demand decreases in magnitude when 24 goal play is compared to 6, 10 (*large*) and 16 goals (*moderate*). Differences in lower speed zone (zones 1-3) values are predominantly *small* to *moderate* across all levels of play, however *large* differences between distance covered are seen when 16 and 24 goal play are compared for speed zones 2 and 3. These findings support the general distance characteristics outlined above (Figure 1), suggesting that not only does average chukka distance tend to increase with level of play, but the speed at which this distance is covered also increases propotionally.

*3.2. Speed characteristics*

Average speed per chukka increases in accordance with increasing cumulative player handicap (Figure 2), with the magnitude of differences observed between levels of play also increasing. *Large* differences in average speed per chukka are seen between 0 and 24 goal play, with average speed

152    between 0 and 10, 0 and 16 and 6 and 24 goals differing *moderately.* All other comparisons present *small*
153    differences in average speed per chukka, except for 0 and 6 goal play which only differ from each other
154    *trivially*.

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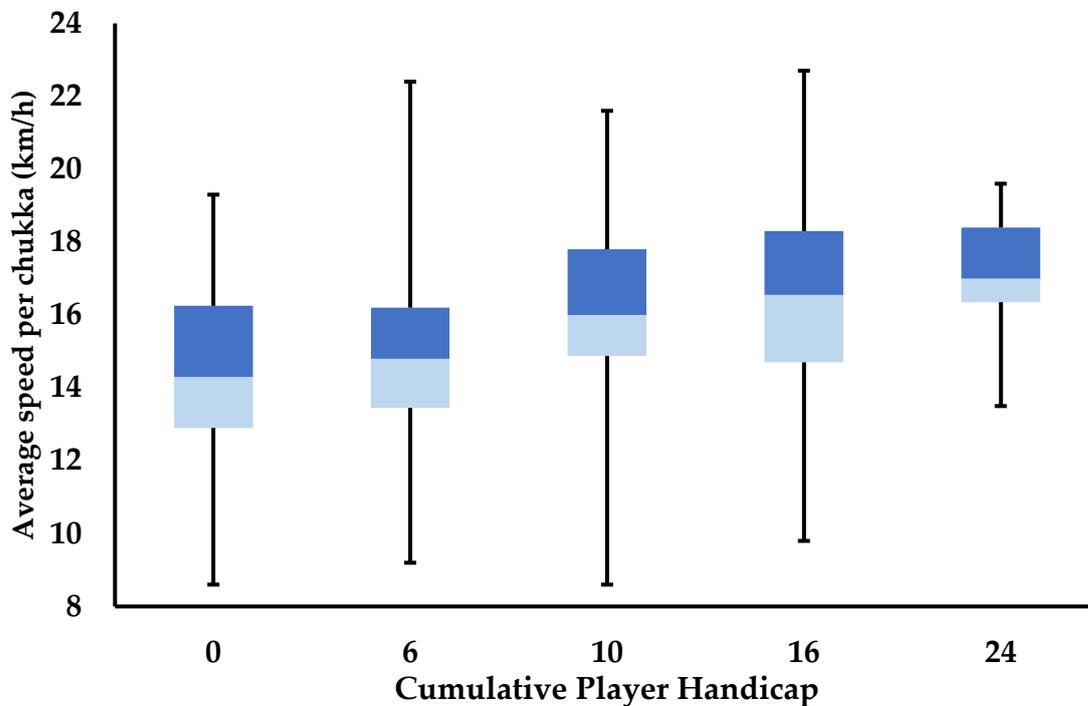


156    **Figure 2.** Box-plot of the median average speed (km/h) per chukka at each level of play. Lower and
157    upper box boundaries 25th and 75th percentiles, respectively, line inside box median, lower and
158    upper error lines minimum and maximum, respectively.

159    Time spent in each speed zone per chukka at each level of play is shown in Table 2, with all effect sizes,
160    C.I. and descriptors found in Table S2. Broadly speaking differences between cumulative player
161    handicaps increase in number and magnitude as cumulative player handicap and speed zone number
162    increases. Differences in time spent in Zone 1 are predominantly *trivial* or have C.I. overlapping zero,
163    however *small* reductions in Zone 1 time are seen when 10 goal play is compared to 0, 16 and 24 goal
164    play. In Zone 2, 0 goal play differs only *trivially* to that of 10 and 24 goals, with 10 and 24 goals also
165    differing *trivially.* All other Zone 2 comparisons differ by a *small* to *moderate* extent, bar *large* differences
166    between 10 (3:25 ± 0:07) and 16 goal (2:11 ± 0:09) levels. There is a *large* difference in time spent in Zone
167    3 between 16 (1:35 ± 0:05) and 24 goals (2:34 ± 0:13) and these levels differ *moderately* in comparison to 0
168    and 10 goal play. 6 goal Polo shows *small* and *moderate* reductions in time spent in speed zone 3, when
169    compared to 10 and 24 goal play, respectively; but ponies are subject to a *small* increase in speed zone 3
170    time compared to 16 goal Polo.
171    Differences between time spent in speed zones 4 and 5 show a linear increase in magnitude, when
172    comparing 0 goal Polo to all other levels of play (*Small – Very Large*; 6 – 24 goals, respectively), with a
173    similar trend seen when 6 and 10 goal play are compared to 16 and 24 goal levels (*Small – Large* effects);
174    confidence intervals for 6 and 10 goal play overlap zero in speed zone 4, and they differ *trivially* to one
175    another in time spent in speed zone 5. Confidence intervals also overlap zero when time in speed zone
176    4 is compared between 16 and 24 goal play, yet *moderate* differences are also seen when comparing time
177    spent in speed zone 5 between these levels. Collectively, these findings emphasize the findings outlined
178    in Figure 1, showing that differences between levels of play typically increase in magnitude, with
179    increased average playing velocity.

180　　　**Table 2.** Time (minutes: seconds) spent in each speed zone, per chukka at each level of play. Data
181　　　　　　　　　　are presented as means ± 90% confidence intervals.

| Level of Play | Speed Zone 1 | Speed Zone 2 | Speed Zone 3 | Speed Zone 4 | Speed Zone 5 |
|---|---|---|---|---|---|
| 0 goal | 5:28 ± 0:27 | 3:23 ± 0:14 | 2:02 ± 0:14 | 0:25 ± 0:05 | 0:01 ± 0:00 |
| 6 goal | 5:22 ± 0:27 | 3:03 ± 0:10 | 1:52 ± 0:09 | 0:35 ± 0:05 | 0:02 ± 0:01 |
| 10 goal | 4:51 ± 0:17 | 3:25 ± 0:07 | 2:04 ± 0:05 | 0:41 ± 0:03 | 0:03 ± 0:00 |
| 16 goal | 5:37 ± 0:14 | 2:11 ± 0:09 | 1:35 ± 0:05 | 1:09 ± 0:04 | 0:06 ± 0:00 |
| 24 goal | 5:44 ± 0:22 | 3:33 ± 0:17 | 2:34 ± 0:13 | 1:10 ± 0:08 | 0:10 ± 0:02 |

182　*3.3. High Intensity Activities*

183　　　All effect sizes, confidence intervals and descriptors for high intensity activities can be found in
184　Table S3. There is a tendency for values of all high intensity activities to increase as level of play
185　increases (Table 3). There is also apparent 'stability' of values when 0 goal play is compared to 6 and 10
186　goal levels, with all comparisons showing *trivial* differences, or confidence intervals that overlap zero.
187　The only exception being a pony would perform a *small* increase in decelerations between 0 and 10 goal
188　levels. However, when 0, 6 and 10 goal values are compared to 16 and 24 goal play, *small* to *moderate*
189　differences in sprint counts are observed. This increases to a *large* difference in sprint count when 6 and
190　24 goal levels are compared, with a *small* difference in sprint values also seen between 16 and 24 goal
191　values.
192　Differences in accelerations only occur in 50% of comparisons; 16 goal play requires *moderately* more
193　accelerations than 0, 6, 10 and 24 goal Polo, with 24 goal Polo only demonstrating a *small* increase in
194　acceleration count compared to 10 goal play. Whereas, *small* to *moderate* differences in decelerations are
195　seen between all level comparisons, except for 0 and 6 goal levels (48.8 ± 3.3 and 48.7 ± 3.7, respectively;
196　*trivial*), and when 16 and 24 goals are compared (60.5 ± 2.0 and 65.4 ± 5.3, respectively; C.I. overlaps
197　zero). *Moderately* fewer impacts are sustained in 0 and 10 goal play compared to the 24 goal level (1.2 ±
198　0.3), this difference decreases in accordance with handicap as when 0 and 10 are compared to 16 goal
199　(1.2 ± 0.2) play the difference is *small*. Confidence limits overlapped zero between all levels of play and
200　6 goals, likewise for 0 and 10 goal impact counts.

201　　　**Table 3.** High Intensity activities per chukka at each level of play. Data are presented as means ±
202　　　　　　　　　　90% confidence intervals.

| | 0 Goal | 6 Goal | 10 Goal | 16 Goal | 24 Goal |
|---|---|---|---|---|---|
| Sprints | 32.9 ± 2.0 | 30.3 ± 2.0 | 34.2 ± 1.2 | 36.4 ± 0.9 | 39.9 ± 2.5 |
| Accelerations | 55.6 ± 4.7 | 52.6 ± 4.2 | 51.5 ± 1.9 | 66.9 ± 2.0 | 57.0 ± 3.8 |
| Decelerations | 48.8 ± 3.3 | 48.7 ± 3.7 | 53.3 ± 2.0 | 60.5 ± 2.0 | 65.4 ± 5.3 |
| Impacts | 0.4 ± 0.2 | 0.8 ± 0.4 | 0.6 ± 0.2 | 1.2 ± 0.2 | 1.2 ± 0.3 |

203

204　**4. Discussion**

205　　　The aim of this research was to assess the spatiotemporal demands of Polo and to accurately
206　describe and compare the performance requirements placed upon Polo ponies across varying levels of
207　Polo play. It was hypothesized that as cumulative player handicap increased, average speed attained,
208　and distance covered per chukka would also increase. The findings of this investigation support this
209　initial hypothesis, with overall trends displaying a rise in distance and speed metrics as level of play
210　increased. Further to this, speed zones 4 and 5 show a linear increase in magnitude when compared
211　across level of play; a trend also shared by decelerations and impacts. These findings provide valuable
212　insight into the horse management and tactical demands of Polo, as they afford a greater understanding
213　of potential horse welfare considerations and may also mitigate potential injuries to ponies or Polo
214　players. These findings provide valuable insight into the pony management and tactical demands of
215　Polo, as they afford a greater understanding of potential pony welfare considerations and may also
216　mitigate potential injuries to ponies or Polo players.

217   The use of the cumulative team handicap to categorise Polo encourages creativity and variety in
218   approaches to best satisfy this constraint, whilst maximising a team's effectiveness. For example, a 0
219   goal team may be made up of three players with a -2 handicap, and one 6 goal player; or equally it may
220   comprise two 1 goal players, a 0 goal player and one -2 goal player. As cumulative player handicap
221   increases to ≥10 goals, it prompts the inclusion of higher handicapped individuals in order to be
222   competitive. Based on the HPA handicap guidelines [13], a higher player handicap suggests increases
223   in level of ball control, riding ability and the inclusion of more capable ponies across a player's string.
224   These factors facilitate the flow of the game, permitting a faster, more expansive style of Polo, as
225   evidenced by higher average speeds (Figure 2) and a greater proportion of distance and time spent at
226   higher velocities (Tables 1 and 2, respectively) per chukka. Increased handicap will likely also have a
227   strategic influence on gameplay and as such may increase the number of high intensity activities
228   performed per chukka (Table 3). Collectively, the combination of distance covered at high velocities
229   and increased high intensity activity counts suggest that as cumulative player handicap improves, there
230   is a concomitant physiological cost upon the players' ponies. Previous quantification of the
231   cardiovascular demands of low goal Polo (≤6 goals) has reported that Polo ponies are subject to
232   moderate to high cardiovascular stress [17], with 56 ± 8% of playing time spent at heart rates ≥75% heart
233   rate maximum. This high cardiovascular demand has been corroborated by haematological measures
234   in high goal Polo ponies, who demonstrated acutely high markers associated with anaerobic
235   metabolism, post-game [18,19].
236   Gondin *et al.*, [20] concluded that positional attributes may elicit varying energy system contributions
237   in Polo ponies, as defenders displayed elevated blood lactate concentrations and glycolysis markers
238   post-game, indicative of a greater anaerobic contribution during game play. This increased anaerobic
239   contribution may be explained by an increase in high intensity activities as handicap increases as per
240   this investigation, however we have previously shown that defensive players tend to be more highly
241   handicapped, and have a greater shot success rate [21], supporting the notion that high goal players
242   require a string that can meet the tactical and physiological demands of high goal Polo. From a training
243   perspective, this suggests that as players improve their handicap and play in higher goal Polo matches,
244   there needs to be accompanying improvements in pony fitness and anaerobic capacity. However, there
245   is a documented tendency towards aerobic development in Polo training programmes [22], which may
246   alter muscle fibre types to become more oxidative in nature even within the competition phase of the
247   Polo season [22]. Based upon the somewhat linear relationship between cumulative player handicap,
248   high intensity demands (Table 3) and time spent in speed zones 4 and 5 (Table 2), we would recommend
249   the incorporation of high intensity interval training, a strategy that has been shown to be effective in
250   thoroughbred race ponies [23], in Polo training programmes, although aerobic training should not be
251   neglected as chukka lengths in the present study ranged from 6:33 to 19:27 (min:sec).
252   By understanding the requirements of the level of Polo being played and the physical capabilities of a
253   player's string, pony management strategies can be further individualised to maximise the effectiveness
254   of each pony and ultimately improve their contribution to the team's performance whilst ensuring pony
255   and player safety [24,25]. Practice chukkas may be an effective way of achieving this [7,19,20], and may
256   be more protective than longitudinal high intensity interval training. Whilst high intensity interval
257   training may develop anaerobic characteristics, it has been shown to induce premature aging of
258   superficial digital flexor tendon [26]. Alternatively, opting for pony management strategies such as
259   opting to 'half-chukka' or 'cycling through' one's string may be appropriate at 16 and 24 goal levels,
260   and support attainment of high speeds and distances as per the tactical demands of the level of play,
261   without compromising athletic pony longevity.
262   Speed zone (Tables 1 and 2) and high intensity activity data (Table 3) was analysed to provide a more
263   thorough breakdown of the differences observed between levels of play. As the level of play increased,
264   the time spent in, and distance covered, in speed zones 4 and 5 increased also. This suggests that higher
265   velocity play, comprised of more frequent decelerations and impacts, is a requisite proportional to
266   cumulative player handicap; at the individual level this may be a manifestation of improvements in
267   riding and technical abilities and repeated positive interactions with one's string [27,28]. This is an
268   important finding from a horse welfare perspective too, as high intensity efforts are common causes of

269  musculoskeletal injuries and tendon injuries and are the most commonly reported injuries in Polo
270  ponies [25]. This is an important finding from a pony welfare perspective too, as high intensity efforts
271  are common causes of musculoskeletal injuries and tendon injuries and are the most commonly
272  reported injuries in Polo ponies [25]. Whilst up to 91% of Polo players actively check ponies' tendons
273  prior to exercise [25] and bandaging tendons is compulsory to play Polo under Rule 4c of the HPA rules
274  [13], without appropriate training and conditioning increases in pony workload caused by exposure to
275  high intensity activities and velocities may put the pony at an increased risk of injury. Decelerations
276  likely present the greatest risk of injury due to eccentric loading through multiple joints [29], and
277  potential torques generated if these decelerations are accompanied by turns [29,30]. Impacts may also
278  increase the energetic cost of playing Polo on ponies, but through accompanying notational analysis we
279  feel that despite a linear relationship with cumulative player handicap, the present values may
280  underreport impact occurrence. This may be due to the technical nuance of a ride-off (impact), with a
281  more frequent technique being a sustained application of pressure when contesting the 'line', as
282  opposed to a collision-based contact. It is understood that these movements and thus injury risks are
283  an inherent part of Polo. The longitudinal use of appropriate monitoring and performance analysis by
284  GPS as outlined within this paper may be best used in complement with the established risk
285  management strategies outlined above to increase the health, longevity and playing performance of
286  Polo ponies.
287

## 5. Conclusions

289  The aim of this research was to assess the spatiotemporal demands of Polo and to accurately
290  describe and compare the performance requirements placed upon Polo ponies across varying levels of
291  Polo play. Key findings of this investigation were that as cumulative player handicap increased, so too
292  did distance covered per chukka, with a greater proportion of time spent at higher velocities and a
293  greater number of high intensity activities also performed. With the increases in average speeds and
294  distances covered as level of play increases, the cardiovascular and anaerobic needs of Polo ponies must
295  match the demands of the level of Polo they are playing. Strategies to facilitate this development may
296  include the incorporation of high intensity interval training, maximal speed work and aerobic
297  conditioning. GPS presents a tool that can effectively quantify the spatiotemporal demands of Polo, and
298  is capable of detecting changes in activities that are indicative of the level of Polo played. This paper
299  has identified trends and values at a team level, however future research may seek to investigate how
300  these metrics vary at an individual level to identify the strengths and weaknesses within a player's
301  string, and how best to train or manage these ponies. Further work is also required to understand
302  whether player position interacts with measures of equine Polo performance in a causative manner.

303  **Supplementary Materials:** Table S1: Effect sizes ± 90 Confidence Intervals for mean distance (m) per chukka,
304  compared at each level of play. Table S2: Effect sizes ± 90 % Confidence Intervals for mean time (min:s) in speed
305  zone per chukka, compared at each level of play. Table S3: Effect sizes ± 90 % Confidence Intervals for mean
306  high intensity activities per chukka, compared at each level of play

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