Double and Triple Fully Airborne Phases in the Gaits of Racing Speed Thoroughbreds

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INTRODUCTION

Current literature suggests that during the gallop, there is normally one airborne phase during a single stride,[1,2] beginning when the lead foreleg leaves the ground and ending when the non-lead rear leg bears weight. During a normal transverse gallop stride pattern, the following step sequence occurs. Sequence numbers with corresponding occurrences include:

1. Left rear leg (LR) bears weight. This leg would be considered the non-lead rear leg of a horse on its right lead.
2. A few hundredths of a second before the left rear leg stops bearing weight, the right rear leg (RR) bears weight. In this instance, the right rear leg is called the "lead rear leg," and the horse is said to be on its "right lead."
3. A few hundredths of a second before the right rear leg stops bearing weight, the non-lead left foreleg (LF) bears weight.
4. A few hundredths of a second before the left foreleg stops bearing weight, the lead right foreleg (RF) bears weight.
5. The right foreleg (lead foreleg) stops bearing weight and the horse is fully airborne until the non-lead left rear leg (LR) again bears weight, thus starting another stride cycle.

This sequence could be shown as LR, RR, LF, RF. A horse on its left lead would have the sequence: RR, LR, RF, LF.

Among single airborne phase stride patterns, there are two common exceptions to the above stride pattern. One exception occurs when a horse switches leads from the right to the left, or vice versa. The other exception is the rotary gallop, often seen in a horse coming out of the starting gate. The rotary gallop is generally seen in the counter-clock wise direction of LR, RR, RF, LF, and, unlike the switching of leads, the rotary gallop is often repeated for more than one stride.

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This study documents the frequency of occurrence of additional airborne phases within a single stride between the lead rear leg and non-lead foreleg and between the forelegs (these air phases respectively referred to as "double-air-P2" and "double-air-P3").

We refer to horses that used more than one airborne phase within a single stride as "double-air" horses. We refer to horses that used 3 airborne phases within a single stride as "triple-air" horses. Figure 1 presents step diagrams describing the "single-air," "double-air-P2," "double-air-P3," and "triple-air" running patterns.

The extension variables studied in this paper (P1, P2, and P3) are a measure of how stretched out a horse is. We measured this extension between the pairs of legs shown in Figures 2 through 4. Figure 2 shows extension between the rear legs. We call this extension P1. We have never seen an airborne phase between these legs. Figure 3 shows extension between the lead rear and the non-lead foreleg. We refer to this extension as P2. If there is an airborne phase between these legs (as exists in this panel), we say the horse is double-air-P2. Figure 4 shows extension between forelegs. We refer to this extension as P3. If there is an airborne phase between these legs (as exists in this panel), we say the horse is double-air-P3.

A technical definition of double-air would be that exactly as one leg stops bearing weight, the next leg bears weight. In this case, there would be little or no overlap between those legs, and the horse would be said to be 100% extended (or totally stretched out) between those legs. If a period of time exists between the time the first leg stops bearing weight and the next leg bears weight, the horse is considered to be more than 100% extended. It is so stretched out that it cannot bring the next leg down before it lifts the previous leg.

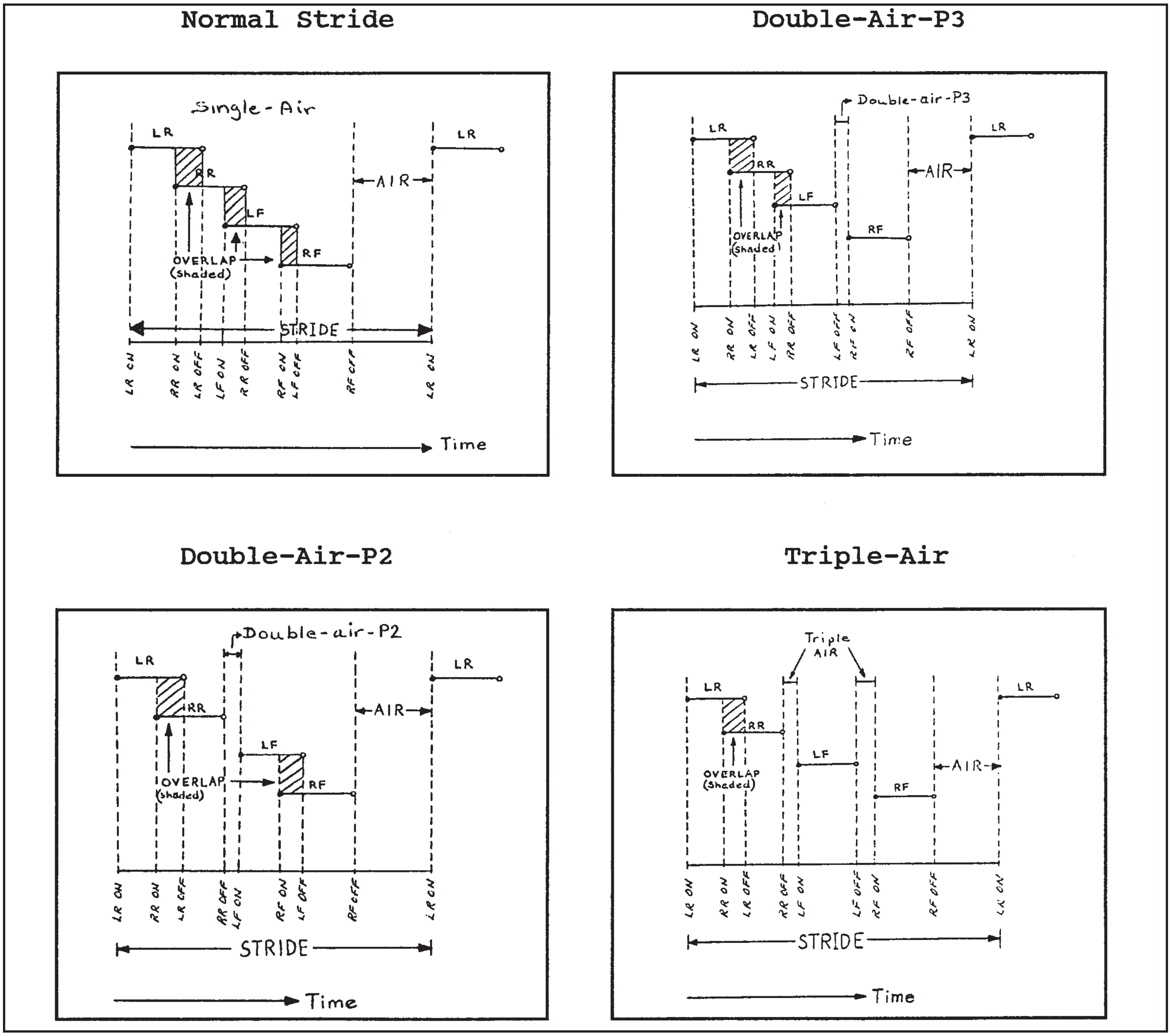

Fig 1: Step Diagrams: The solid dot indicates the start of ground contact and stance phase of the limb, while the open circle represents the end of ground contact for that step. Overlap is denoted by the diagonally shaded area. Airborne phases are noted in each panel.

MATERIALS AND METHODS

Approximately 2.5 strides of more than 6500 different Thoroughbred racehorses were filmed with Lo-Cam 16-mm cameras (Redlake Corporation, Campbell, Calif) at a frame rate of 300 frames per second. Digitizing was conducted on more than 12,000 filmings (each horse filmed an average of 1.9 times) using motion analyzer projection equipment (Vanguard Instrument Corporation, Melville, NY; Lafayette Instrument Corporation, Lafayette, Ind; L-W Athena International Corporation, Simi Valley, Calif). Computer analysis was done with a Prime 2450 minicomputer (Prime, Natick, Mass) and SAS statistical software (SAS Institute, Cary, NC). For the purposes of this study we used only the 5724 filmings, representing 3008 unique horses, which were on dry dirt surfaces and in which the horses were in an unimpeded transverse gallop (no lead changes or rotary gallops), at speeds from 44 to 66 feet per second (13.4-20.1 m/second or 15-10 seconds/furlong), and which had been in training for at least 60 days. All filmings used were made with professional jockeys who

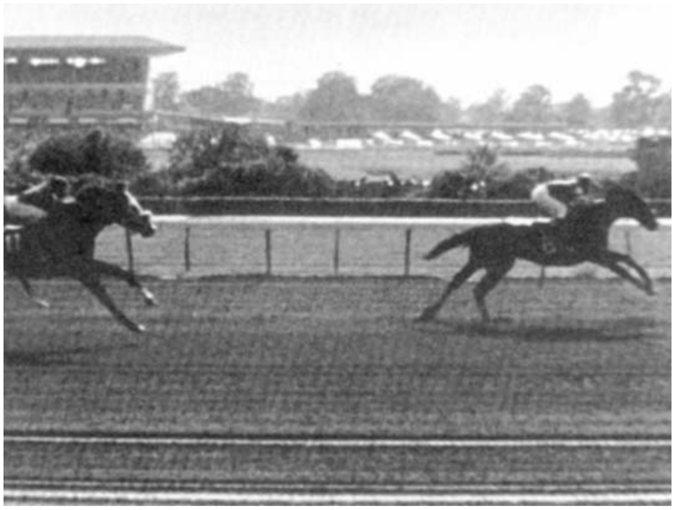

Fig 2: Extension between the rear legs.

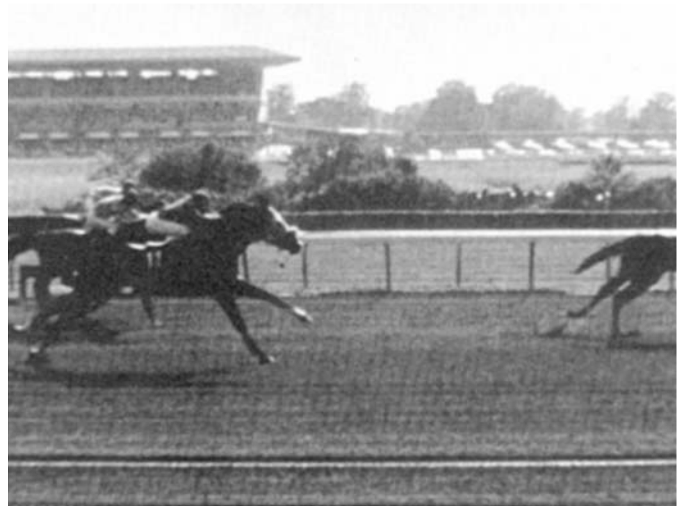

Fig 3: Extension between the lead rear and non-lead foreleg.

were in normal riding positions and did not use their whip during the filming. The riders and trainers were working independently of the authors, with no a *priori*-dictated behavior with respect to this study.

Most filmings (n = 4681: 2699 colts, 1982 fillies) were from early spring 2-year-old auctions. These horses were filmed during the final 16th mile of their work. Each camera filmed from 2.5 to 3 strides of each horse, depending on the facilities at each racetrack (which dictated how far back from the horses the cameras could be set up, and thus, their field of view). For about half of the filmings, the cameras were positioned to film a continuum of strides, such that as the horse left the field of view of the first camera, it entered the field of view of the second camera.

The remainder of the filmings (n = 1043: 614 colts, 429 fillies) were of race age horses (some were 2-year-olds actually in races in August or later, but most were at least into their 3-year-old year, often filmed in real races). These horses were generally filmed during the final one-sixteenth mile of their work but sometimes were filmed elsewhere in their work or during races after they had gone approximately three-sixteenths to one half mile. Typically, during a Breeders' Cup race or major stakes event, cameras were positioned at the "clocker's stand" at the halfway point on the backside of the racetrack. During these major events, the point in the race filmed depended on the starting gate placement relative to the clocker's stand position used for filming.

Eighty percent of horses used their right lead. No more than 3 consecutive strides were used to calculate the gait variables studied. Temporal measurements were used to describe each horse's gait characteristics in terms including extension, stride length, stride frequency, overlap times between limbs, and contact and non-contact times for the limbs.

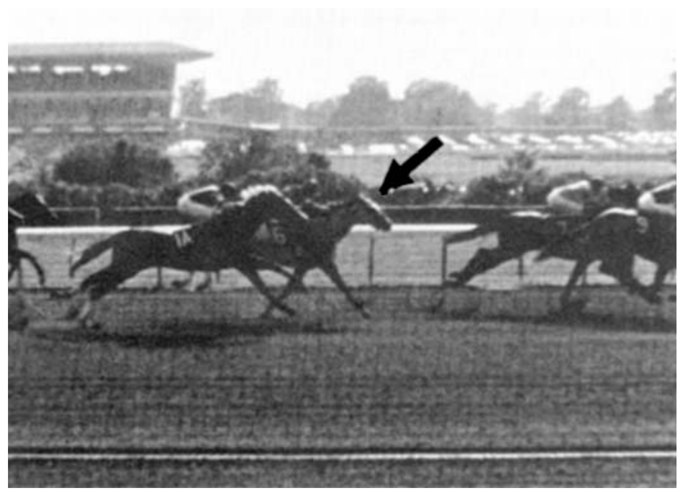

Fig 4: Extension between the forelegs (Horse No. 6).

There were 2 clockers spaced approximately 330 feet apart, with the cameras and camera operators set up between them. Using "Equi-talk" FM wireless communication sets (EQB, Inc, Unionville, Penn), the first clocker called the "on," at which time both clockers started their stopwatches. The second clocker called the "off," at which time both clockers stopped their watches. The 2 times on the clockers' watches were then averaged and, upon discretion, were compared with the times taken directly from the film. Previous unpublished studies of this timing technique conducted by EOB showed this technique to be accurate. It also solved the problem of being forbidden by racetrack authorities to place electronic timing devices (which the authors used in other studies) on the actual racetracks.

Only a few people (digitizers) digitized the filmings used for this study. They had years of training and horse experience. For practically all horses, the digitizers acted "blind." That is, they did not know the sex, pedigree, value, or ability of the horses they were digitizing. The digitizers identified each horse only by a hip number or a filming identification number.

The unknowns in the data included soundness, conditioning levels, drugs administered, tack and rider weight, and ability. All practically available information, including sex, age, conformation, pedigree, financial value, and known drug use were recorded.

RESULTS AND DISCUSSION

Incidence of Multiple-airborne Phases Within a Single Stride

Using the 100% cutoff for double-air, more than 50% of horses used some form of the double-air running style at velocities exceeding 55 feet per second (16.8 m/second or 12 seconds/furlong) (Fig 5). Visually and intuitively, the 100% cutoff for double-air is not convincing because one cannot see the airborne phase. A more visually intuitive criteria for double-air is that at least 1/300th of a second (one camera frame) must exist between the time the first leg stopped bearing weight and the subsequent leg bore weight. Typically, the amount of extension with this criteria exceeds 104%. This minimum double-air criteria (104%) appears in the titles of many of the graphs and tables which follow in this report.

Using 104% extension as the minimum criteria for double-air, more than 25% of horses used some form of the double-air running style at velocities exceeding 55 feet per second (16.8 m/second or 12 seconds/furlong; Fig 6). Horses began to exhibit 104% P2 extension at 51 feet per second (15.5 m/second or 12.9 seconds/furlong; Fig 7). Horses began to exhibit 104% P3 extension at 45 feet per second (13.7 m/second or 14.7 seconds/furlong; Fig 8). Using 104% extension as the minimum criteria for double-air, 1.9% of horses used the triple-air running style at speeds up to 60 feet per second (18.3 m/second or 11 seconds/furlong). At speeds exceeding 60 feet second (18.3 m/second or 11 seconds/furlong), 17% of horses exhibited the triple-air running style (Fig 9).

Table 1 lists the incidence of double and triple airborne phases within a single stride. The definition of "double-air" used in Table 1 was that at least one full camera frame (1/300th of a second) elapsed between the time the first leg stopped bearing weight and the subsequent leg bore weight.

VELOCITY DEPENDENCE OF GAIT EXTENSION VARIABLES

Regression analysis was used to examine how P1, P2, and P3 relate to velocity to more clearly understand the velocity dependence of the double-air running style. This analysis showed that double-air was the natural result of the increase of P2 and P3 with increasing velocity. Table 2 presents regression equations and their R^2 values.

Linear regression equations relating velocity to extension variables for thousands of horses showed low R^2 values because of the high degree of individual variation from horse to horse. To eliminate this high degree of variation from one horse to the next, we calculated the averages of the extension variables within 22 1-foot-per-second velocity increments from 44 to 66 feet per second (13.4-20.1 m/second or 15-10 seconds/furlong). Taking averages within groups is a standard way to perform regression analysis when there is a high degree of variation from one subject to the next, yet a strong underlying trend exists. For example, weight variation from one person to the next, among persons 15 to 35 years old, would be very high, yet weight generally increases with age. Thus, you might take the average weight within each single year age category and then regress these averages to understand age's influence on weight.

Table 2 shows that P1 had the weakest relationship relative to velocity. P2 had R^2 more than 0.98 for 2 year-olds and more than 0.94 for older horses relative to velocity. P3 had R^2 of 0.94 for 2-year-old colts and 0.89 for 2-year-old fillies. Among older horses, P3 was not as significantly related to velocity, although its clear increase with increasing velocity could be seen in the averages.

For 2-year-olds, P1 varied from about 70% at 44 feet per second (13.4 m/second or 15 seconds/furlong) to 66% at 66 feet per second (20.1 m/second or 10 seconds/furlong). A similarly narrow range of changes occurred for P1 among older horses. Among 2-year-old colts and fillies, P2 and P3 regression lines intersected at 100% extension at about 61 feet per second (18.6 m/second or 10.8 seconds/furlong). Thus, at these speeds, the horses' legs truly began to resemble the spokes of a wheel described by Pratt,[1] whereby exactly as one leg stops bearing weight, the next leg bears weight (Fig 10).

Regression analysis showed that P1 decreased with increasing velocity within the population studied. This finding does not mean that individual horses necessarily decrease P1 with velocity. It means that, on average, this trend was true of the large population of normal Thoroughbred racehorses studied. P2 and P3 increased with increasing velocity. The slopes of the regression equations for P1, P2, and P3 relative to velocity were very different from one another (Fig 10). Figure 10 shows that P1 extension decreased with increasing velocity, whereas P2 and P3 increased. At 45 feet per second (13.7 m/second or 14.7 seconds/furlong), P2 and P3 were very dissimilar, whereas at speeds more than 60 feet per second (18.3 m/second or 11 seconds/furlong), they were very similar.

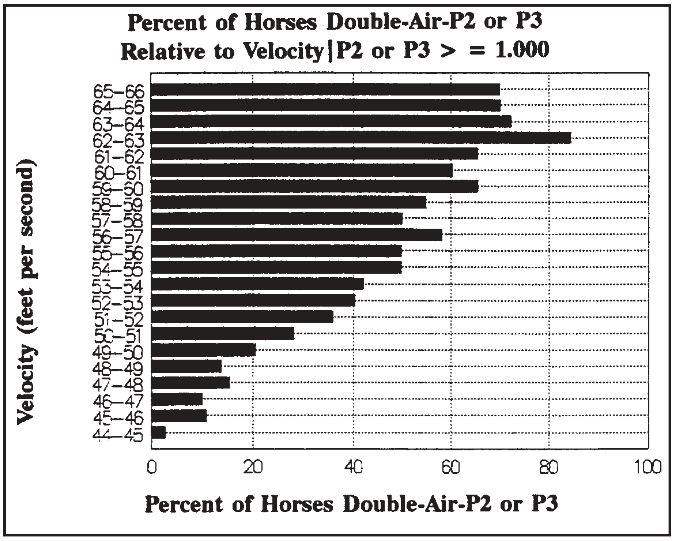

Fig 5: Percentage of horses using some form of the double-air running style with 100% P2 or P3 extension as the minimum requirement for double-air.

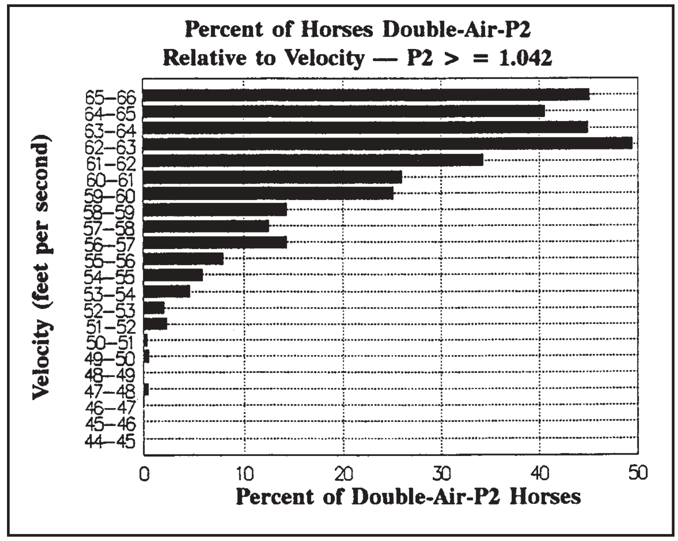

Fig 7: Percentage of horses using the double-air-P2 running style with 104% P2 extension as the minimum requirement for double-air-P2.

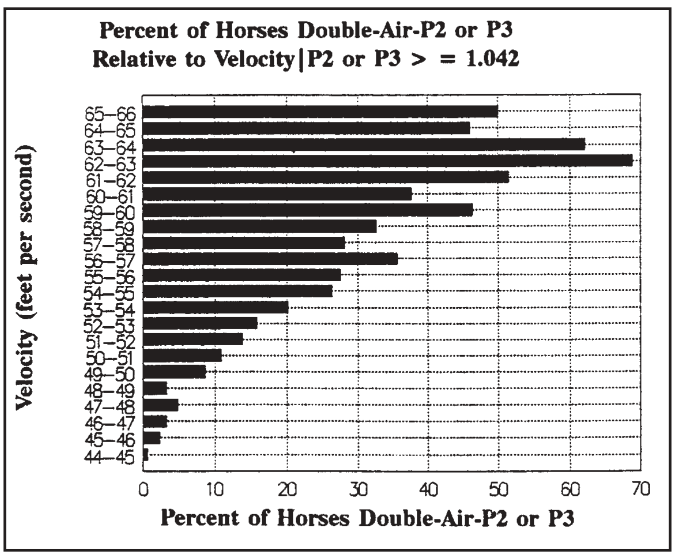

Fig 6: Percentage of horses using some form of the double-air running style with 104% P2 or P3 extension as the minimum requirement for double-air.

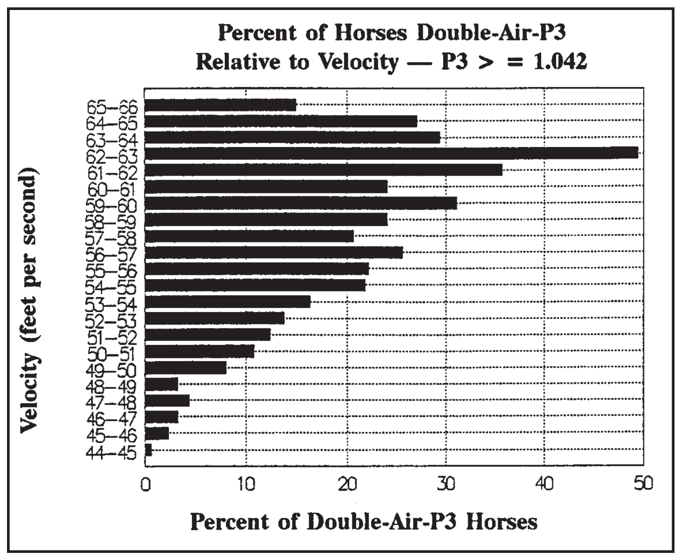

Fig 8: Percentage of horses using the double-air-P3 running style with 104% P3 extension as the minimum requirement for double-air-P3.

AGE- AND SEX-RELATED DEPENDENCIES AMONG GAIT EXTENSION VARIABLES

While establishing the velocity dependence of P2 and P3, we examined age- and sex-related differences among extension variables. Figure 11 plots P2 versus velocity for 2-year-old colts and fillies to show an example of sex-related differences in a key gait variable. The regression equations presented in Table 2 clearly indicate strong age-related differences in key gait variables. EQB's research paper, "Temporal Gait Variables of Thoroughbred Racehorses At or Near Racing Speeds," explains age- and sex-related differences among gait variables for this same group of horses in greater detail. For this study, we analyzed most horses in 4 main groups differentiated by age and sex. Those groups were: 2-year-old colts, 2-year-old fillies, older colts, and older fillies.

Table 1 Incidence of multiple airborne phases with double-air at least 104% within a single transverse gallop stride of Thoroughbred racehorses

Velocity group	N	No. D-A-P2	% D-A-P2	No. D-A-P3	% D-A-P3	No. Triple	% Triple
Two-year-old colts at early spring auctions							
45-48	385	1	0.26	10	2.86	0	0.00
48-51	377	2	0.53	28	7.69	1	0.27
51-54	622	26	4.18	83	17.04	3	0.48
54-57	758	96	12.66	143	28.10	26	3.43
57-60	334	62	18.56	75	35.03	20	5.99
60-63	103	37	35.92	31	49.51	17	16.50
63-66	10	6	60.00	4	80.00	2	20.00
Totals	2589	230	8.88	374	14.45	69	2.67
Two-year-old fillies at early spring auctions							
45-48	284	0	0.00	12	4.23	0	0.00
48-51	258	0	0.00	19	7.36	0	0.00
51-54	464	13	2.80	64	13.79	3	0.65
54-57	548	39	7.12	123	22.45	11	2.01
57-60	258	41	15.89	65	25.19	19	7.36
60-63	88	30	34.09	27	30.68	18	20.45
63-66	11	7	63.64	5	45.45	4	36.36
Totals:	1911	130	6.80	315	16.48	55	2.88
Race-age colts (August two-year-olds and older)							
45-48	18	0	0.00	1	5.56	0	0.00
48-51	53	0	0.00	7	13.21	0	0.00
51-54	127	1	0.79	22	17.32	1	0.79
54-57	215	10	4.65	73	33.95	7	3.26
57-60	95	9	9.47	25	26.32	5	5.26
60-63	62	25	40.32	20	32.26	14	22.58
63-66	39	19	48.72	12	30.77	8	20.51
Totals:	609	64	10.51	160	26.27	35	5.75
Race-age fillies (August two-year-olds and older)							
45-48	10	0	0.00	0	0.00	0	0.00
48-51	27	0	0.00	1	3.70	0	0.00
51-54	86	0	0.00	18	20.93	0	0.00
54-57	126	8	6.35	42	33.33	0	0.00
57-60	75	7	9.33	17	22.67	3	4.00
60-63	48	10	20.83	22	45.83	6	12.50
63-66	55	18	32.73	9	16.36	3	5.45
Totals:	427	43	10.07	109	25.53	12	2.81

RELATIONSHIP BETWEEN DOUBLE-AIR AND EARNINGS AND NUMBER OF STARTS

Chi-square analysis was used to identify the relationships between double-air and eventual earnings and number of races run by the end of these horses' 3-year-old year. Cochran-Mantel-Haenszel's case-control odds ratios were used to describe the advantage or disadvantage of the double-air running style versus the single-air running style relative to starts and earnings.

Relating double-air to the number of races run, we asked: Compared with single-air horses, were double-air horses more likely to race 0 to 5 times or were they more likely to race more than 5 times? Relating double-air to earnings, we asked: Compared with single-air horses, were double-air horses more likely to be low earners (defined as earning <\$1000 per start) or high earners (defined as earnings per start of at least \$10,000 and total earnings through the 3-year-old year of at least \$50,000)? To place these earnings criteria into perspective, half of all Thoroughbred racehorses in the United States earn <\$2000 per year. A horse that earns >\$25,000 per year (or \$50,000 in 2 years, as in our definition of a high earner) is well within the top 10% of earners in the United States.

The results of the χ^2 tests were similar when run for all ages combined and for 2-year-olds only. For these tests, double-air horses had P2 or P3 extension exceeding 104%, and double-air horses had P2 or P3 that was at least one

Table 2 Regression results describing extension variables with velocity as the independent variable

Dependent variable	Constant	Velocity coefficient	Standard error	R^2
Two-year-old colts (18 degrees of freedom)				
P1	0.77872	–0.00179	± 0.010226	.53
P2	–0.99369	+0.032787	± 0.031452	.98
P3	0.52707	+0.007798	± 0.012209	.94
PCTXLAP*	0.58447	–0.008822	± 0.015553	.91
Two-year-old fillies (17 degrees of freedom)				
P1	0.73162	–0.0009	± 0.00626	.41
P2	–1.12395	+0.034602	± 0.020355	.99
P3	0.53372	+0.007591	± 0.015539	.89
PCTXLAP	0.63921	–0.00909	± 0.014515	.93
Race-age colts (19 degrees of freedom)				
P1	0.89980	–0.00354	± 0.020644	.54
P2	–1.19782	+0.034645	± 0.057433	.94
P3	0.73403	+0.00387	± 0.039024	.28
PCTXLAP	0.57046	–0.0076	± 0.018792	.87
Race-age fillies (19 degrees of freedom)				
P1	0.86349	–0.00297	± 0.021689	.44
P2	–1.19915	+0.03409	± 0.04445	.96
P3	0.68421	+0.00463	± 0.02802	.53
PCTXLAP	0.57728	–0.00855	± 0.018039	.88

**PCTXLAP is an abbreviation for the total percentage of overlap during a single stride.*

These regression equations were calculated using averages of the dependent variables (P1, P2, P3, and PCTXLAP) from within 22 1-foot-per-second velocity groups, from 44 to 67 feet per second (13.4-20.1 m/second or 15-10 seconds/furlong).

Degrees of freedom varied because some velocity groups (at extreme low or extreme high) contained too little data and were eliminated from regression. No velocity groups were selectively removed from the "middle" of the velocity gradient.

standard deviation high relative to velocity. These results are shown in Table 3. Among horses filmed at similar velocities, double-air-P3 horses were more likely to earn more and race more than single-air horses. Double-air-P2, by itself, was not significantly related to earnings and number of starts.

RELATIVELY HIGH EXTENSION VERSUS RELATIVELY LOW EXTENSION

To place these multiple airborne phases in the context of the overall relationship of extension to velocity, we compared "low" extension horses to "high" extension horses that were not necessarily double-air. We defined low extension for P1, P2, and P3 as being at least 1.5 standard deviations lower than the mean for that extension variable relative to velocity. High extension was defined as being at least 1.5 standard deviations higher than the mean relative to velocity. To facilitate this analysis, we calculated regression equations for P1, P2, and P3 versus velocity for the 4 main groups of horses studied (2-year-old colts, 2-year-old fillies, older colts, and older fillies). We then used the root mean square error (RMSE) from these equations as the standard deviation. Chi-square results are shown in Table 4.

Horses with high P3 extension (not necessarily double-air-P3), relative to velocity, were more likely to be high earners than horses with relatively low P3 extension. Horses with high P2 extension (not necessarily double-air-P2), relative to velocity, were less likely to be high earners compared with horses with relatively low P2 extension.

High extension, relative to velocity, does not imply a long stride length or a low stride frequency. In fact, when horses were grouped into similar velocities, neither stride length nor stride frequency was significantly different for double-air horses when compared with single-air horses, or for high extension horses compared with low extension horses.

EFFECT OF DOUBLE-AIR RUNNING STYLE ON OTHER GAIT VARIABLES

Double-air-P2 and double-air-P3 horses had gait variables significantly different from single-air horses and from each other. The double-air running style affected more than extension variables. Other variables affected included:

- Average Stance Time (AVGSTN): Average of 4 stance times (one for each leg) from a complete stride.

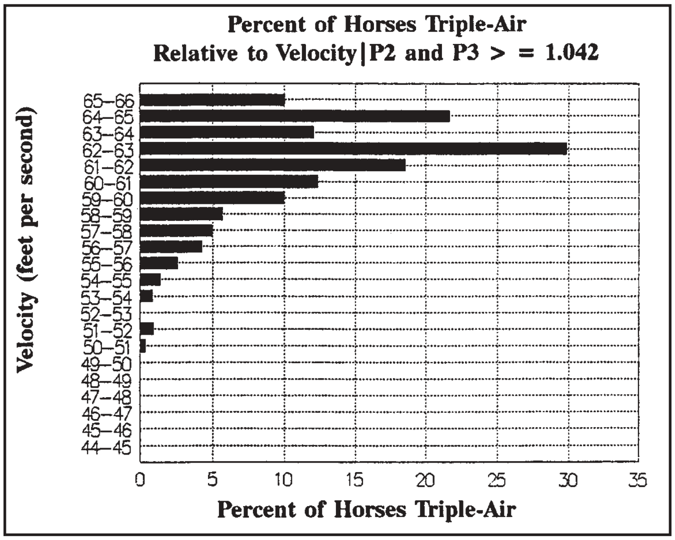

Fig 9: Percentage of horses using the trip-air running style with 104% P2 and P3 extension as the minimum requirement for triple-air.

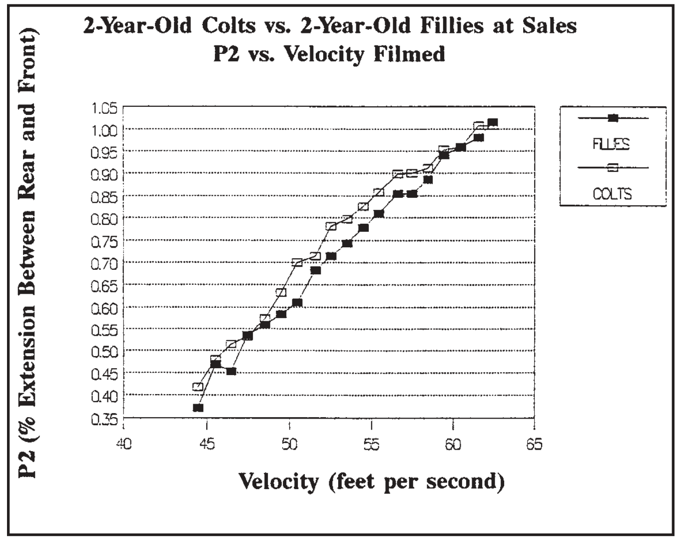

Fig 11: P2 extension versus velocity for 2-year-old colts and 2-year-old fillies.

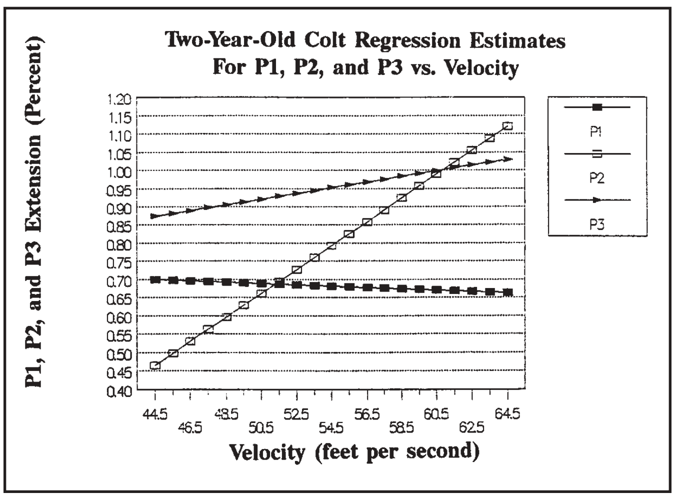

Fig 10: Regression lines for P1, P2, and P3 vs. velocity among 2-year-old colts.

- Average Swing Time (TSWG): The average time spent by each leg during each complete stride while the leg is not bearing weight.
- Air Time (TAIR): Total time during a complete stride that no legs bear weight.
- Ground Time (TGND): Total time during a complete stride that at least one leg bears weight.
- Inspiration (INSP): Time period beginning when the lead foreleg stops bearing weight and ending when the non-lead foreleg bears weight. A horses's inhalation of air occurs during this time and is mechanically linked to this phase of the horse's stride.
- Expiration (EXP): Time period beginning when the non-lead foreleg begins bearing weight and ending when the lead foreleg last bears weight. A horse's expiration of air occurs during this time and is mechanically linked to this phase of the horse's stride.
- Percentage of Overlap (PCTXLAP): Percentage of time within a complete stride that any 2 legs simultaneously bear weight.

DIFFERENCES BETWEEN DOUBLE-AIR-P2 AND SINGLE-AIR HORSES

The following variables were significantly lower for double-air-P2 horses compared with single-air horses running at similar velocities: TAIR, P1 (at velocities up to 60 feet/second), PCTXLAP, AVGSTN, and EXP.

The following variables were significantly higher for double-air-P2 horses compared with single-air horses running at similar velocities: TSWG (at velocities above 54 feet/second), P2, P3, and INSP.

DIFFERENCES BETWEEN DOUBLE-AIR-P3 AND SINGLE-AIR HORSES

The following variables were significantly lower for double-air-P3 horses compared with single-air horses running at similar velocities: TGND, PCTXLAP, AVGSTN, and EXP.

The following variables were significantly higher for double-air-P3 horses compared with single-air horses running at similar velocities: TSWG, TAIR, P1, P2, P3, and INSP.

DIFFERENCES BETWEEN DOUBLE-AIR-P2 AND DOUBLE-AIR-P3 HORSES

At opposite poles for double-air-P2 and double-air-P3:

- TAIR (lower for double-air-P2)

Table 3 Chi-square results and Cochran-Mantel-Haenszel's case-control odds ratios for double-air horses versus single-air horses

	Colts ratio	Colts *P* value	Fillies ratio	Fillies *P* value
D-A-P3 vs earnings	2.89	.0001	3.20	.0001
D-A-P3 vs count	1.80	.0001	1.20	NS
D-A vs earnings	2.02	.0001	2.35	.0001
D-A vs count	1.63	.0001	1.31	.038
T-A vs earnings	3.65	.004	1.5	NS
T-A vs count	2.81	.009	1.84	NS

NS, Not significant.

No significant relationships were identified between double-air-P2 and earnings or starts.

High double-air-P3 horses were about 3 times more likely to be high earners compared with single-air horses. They were about 1.5 times more likely than single-air horses to race more than 5 times.

Triple-air colts were about 3.5 times more likely to be high earners and 2.8 times more likely to race more than 5 times compared with single-air horses.

Table 4 Chi-square results and Cochran-Mantel-Haenszel's case-control odds ratios for high extension horses versus low extension horses*

	Colts ratio	Colts *P* value	Fillies ratio	Fillies *P* value
High P1 vs earnings	8.07	.0001	9.22	.0001
High P2 vs earnings	.216	.0001	.105	.0001
High P3 vs earnings	NS	NS	2.58	.0300

NS, not significant.

**1.5 standard deviations away from mean is criterion for "high" and "low."*

No significant relationships between count and high extension were significant using the $P \leq .01$ level.

No significant relationships were identified between the number of starts and high extension.

Chi-square tests showed that, relative to velocity, high P1 horses were 8 to 9 times more likely to be high earners than low P1 horses. High P2 horses (not necessarily double-air) were one-fifth to one-tenth as likely to be high earners.

Although double-air P2 was not significantly related to earnings and number of starts, high P2, relative to velocity, was strongly related to lower earnings.

- P1 (lower for double-air-P2)
- TGND (higher for double-air-P2)

Two sensible questions about the double-air running style are: Why are multiple-airborne phases not previously well documented, and why are they not accounted for in much of existing research? There are several reasons, including the following:

- Most of these airborne phases lasted only a fraction of a second (about 1/300th of a second). To consistently capture such activity on film, one must be filming at speeds of at least 300 frames per second. Most published gait studies do not use a frame rate this high.
- The majority of double-air occurred at racing speed velocities exceeding 55 feet per second (16.8 m/second or 12 seconds/furlong). Some of the most extreme cases of double-air occurred at speeds exceeding 60 feet per second (18.3 m/second or 11 seconds/furlong). Many published gait studies involve horses going slower than 50 feet per second (15.2 m/second or 13.2 seconds/furlong).
- Some obvious, extreme cases of double-air occurred in only a fraction of the population. One must film hundreds of horses going fast to recognize the pattern of double-air

CONCLUSION

Multiple airborne phases (referred to as "double-air" and "triple-air") within a single stride exist and are common for Thoroughbreds at racing speeds on dirt racetracks

P2 (extension between lead rear and non-lead forelegs) and P3 (extension between the forelegs) were shown to be velocity-dependent, in the process of showing that the double-air running style was velocity-dependent. The faster horses ran, the more likely they were to exhibit the double-air running style.

Results relating the double-air running style to performance were presented mainly because they seemed counterintuitive. In what has previously been described as the "normal" gait for horses in the four-beat gallop, weight is gradually shifted from the lead rear lead onto the non-lead foreleg, and then gradually from the non-lead foreleg onto the lead foreleg. This research has shown that gradual shifting of weight from one leg to the next does not always occur within a normal stride. Double-air-P2 causes instantaneous loading of forces onto a horse's non-lead foreleg. Double-air-P3 causes instantaneous loading of forces onto a horse's lead foreleg. Triple-air causes the instantaneous loading of forces onto each of the forelegs in succession. The authors suspected that these instantaneous forces would far exceed those experienced by single-air horses, thus increasing the likelihood of injury to the forelegs, as might be evidenced by fewer career races and lower career earnings; however, double-air horses did not race less or earn less than single-air horses, and double-air-P3 horses, in fact, earned more and raced more than single-air horses.

These results suggest that the double-air running style is not necessarily more dangerous than the single-air running style.

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