Chapter 15: The Horse Connection

I was sitting at the desk in the front office in Amherst, looking out of the window at the cars whizzing by on the road and the people walking in front of our office with the quizzical expression that our company name generally evoked. Ann and I were discussing some of the on-going projects when the phone rang. I answered it and the man said, "I've heard about your motion analysis system and I want to know if you can meet me to discuss a project on racehorses."

By now, I was used to people and companies asking about our abilities to quantify movement for all types of applications. Most of them had been with humans, excluding the cats and the study on Daisy the monkey, and the majority had been associated with sporting applications. However, our company motto was "If it moves, we can measure it," so I was willing to listen to his proposal.

"What type of business do you have?" I asked.

"I have several business interests here in the greater Miami, Florida area, but I also own 50 horses which live on my farm near Orlando, Florida," was his answer. "My name is Irving Pollock and I would like you to fly to Miami so I can

Major Motion Pictures - Gait Analysis Coming into Focus as Performance Predictor and Diagnostic tool
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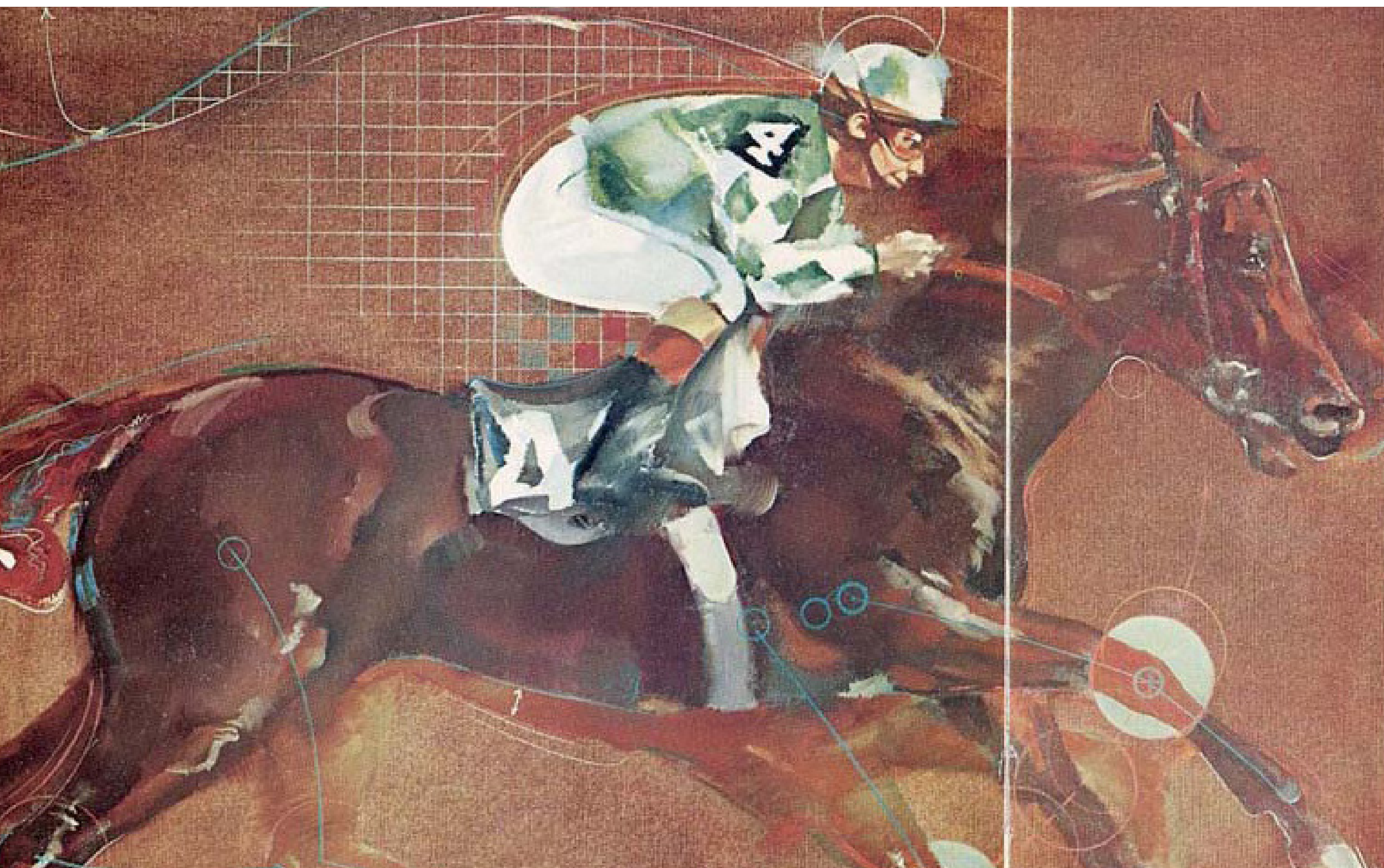

Ike and Tina at the Newport Hotel
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discuss some of my ideas and see if your motion system can help me."

"Ok," I answered, and we agreed upon a date.

After I had hung up the phone, Ann and I looked at each other and shrugged our shoulders in unison. We had studied many topics in our short biomechanical career so why not horses. In fact, in one of our early biomechanics lectures as students, Ann had leaned towards me and whispered that this would be a great technique for analyzing horses. Now might be the time to find out.

I left the following Tuesday and flew to Miami, Florida. As I left the baggage claim area, I saw a man holding a big white card with my name on it. He led me to a large black limousine and held the door for me as he took my suitcase. I sat in the rear seat next to another man also dressed in black with sunglasses. I had recently seen the Hollywood blockbuster movie, "The Godfather", and I had a few pangs of worry. The man in the back seat introduced himself as Mr. Irving Pollock and inquired whether I would like a drink. "No, thank you," was my answer as I continued to consider the Godfather movie.

Actually, it was a quiet comfortable ride from the airport to the Fontainebleau Hotel on the beach front in Miami. This was the era when everyone wanted to visit Florida for its sunny, sandy beaches and relaxed life style. I had been to Miami many times in the past, so I was very happy to have this opportunity to return.

At the hotel, Mr. Pollock invited me into the hotel lobby which was beautiful, welcoming, and opulent. Mr. Pollock was gray-haired, dapper, and cheerfully charming. He possessed an air of relaxed confidence and seemed genuinely pleased to share his hotel with me. We walked through a maze of public rooms onto a veranda which provided a beautiful view of the ocean, gardens, and palm trees waving their fronds gently in the breeze. As we sat on white cushioned couches, Mr. Pollock told me about his various business interests which included the Fontainebleau and the Newport Hotels in Miami as well as his private hobby of horse racing. He owned about 50 horses which were raised and trained at his farm near Orlando, Florida.

After a relaxing conversation on the hotel's veranda, we rode in his limousine for dinner at his Newport Hotel which was located in North Miami. The hotel's restaurant was beautiful and was a perfect setting for a truly delicious meal. After dinner, we attended a performance in one of the hotel's public rooms. The entertainers were Ike and Tina Turner. These two musical performers became famous over the years and I was overwhelmed by the energy and passion displayed by Tina. If Mr. Pollock could select equine talent with the same skill as these musical performers, then he was going to be very successful!

After dinner, Mr. Pollock invited me to his home. We drove through the gate, through the lush gardens, and around the circular driveway stopping beneath a large portico. We climbed out of the limo and walked the few steps to the elaborate front door which was opened by a diminutive Chinese fellow who gave us a slight bow. We followed our Chinese guide through the house as Mr. Pollock described the house and its furnishings. The house was quite large, I estimate at least 20,000 square feet. There were many spacious rooms and the view from each of them featured the lovely gardens of greenery, hibiscus bushes, roses, and semitropical plants. It was an exquisite home which generated an air of comfort and luxury.

Mr. Pollock asked me how I liked his home.

"It is quite extraordinary," I answered.

"It should be," he replied. "It was once owned by Al Capone, and he lived here most of his successful years."

After the tour, Mr. Pollock showed me to my room which was not only beautiful but enormous. It had a lavish bathroom and a patio which wrapped around the corner of the room. The patio was furnished with chaise lounges, chairs, and small tables situated among plants and small trees. The bedroom was nearly as large as my house in Belchertown! Mr. Pollock asked me if this was satisfactory and I assured him that the room was beautiful and more than I had expected. We arranged to meet for breakfast the next morning and closed the door as he left.

The Chinese fellow tapped on my door in the morning to take me to the breakfast area which was fortunate for me. Without a guide, I would still be wandering around that enormous house. As with everything associated with Mr. Pollock, breakfast was magnificent and delicious.

It was a working breakfast as Mr. Pollock had several of his equine staff there as well. While we ate, Mr. Pollock introduced me to these equine staff members. There were two trainers and the farm manager. We discussed biomechanical analysis in general and I explained how we evaluated people and products. Then I described how biomechanics could be applied to all four-legged creatures as well, including horses.

The biomechanics of racehorses, or, as it is more appropriately know, equine biomechanics, applies biomechanical analysis techniques to horses. Newtonian laws of motion are the basis of analyzing horses in the same manner as those applied to human athletes or any other body in motion. The primary difference when analyzing horses and humans are the number of joints involved. The same techniques are used, including digitization of the movement and similar computer programming, to analyze the gait of horses running.

The first equine biomechanics should probably be credited to Eadweard Muybridge's work for Mr. Leland Stanford in 1877–1878. Muybridge was an English photographer known for his pioneering work in photographic studies of motion and in motion-picture projection. He is equally famous for his pioneering work on animal locomotion, which used multiple cameras to capture motion, as well as his "zoopraxiscope", which was a device for projecting motion pictures that pre-dated the flexible perforated film strip.

Eadweard Muybridge had immigrated to the United States at the age of 25, arriving in San Francisco in 1855, a few years after California became a state and while the city was still the "capital of the Gold Rush." He started a career as a publisher's agent for the London Printing and Publishing Company. By 1860, Muybridge was a successful bookseller.

He left San Francisco on a trip to England to purchase more antiquarian books to sell in his shop. On the trip, a violent runaway stagecoach crash resulted in severe head in-

Eadweard Muybridge
http://arielnet.com/ref/go/1207

Zoopraxiscope used by Muybridge
http://arielnet.com/ref/go/2711

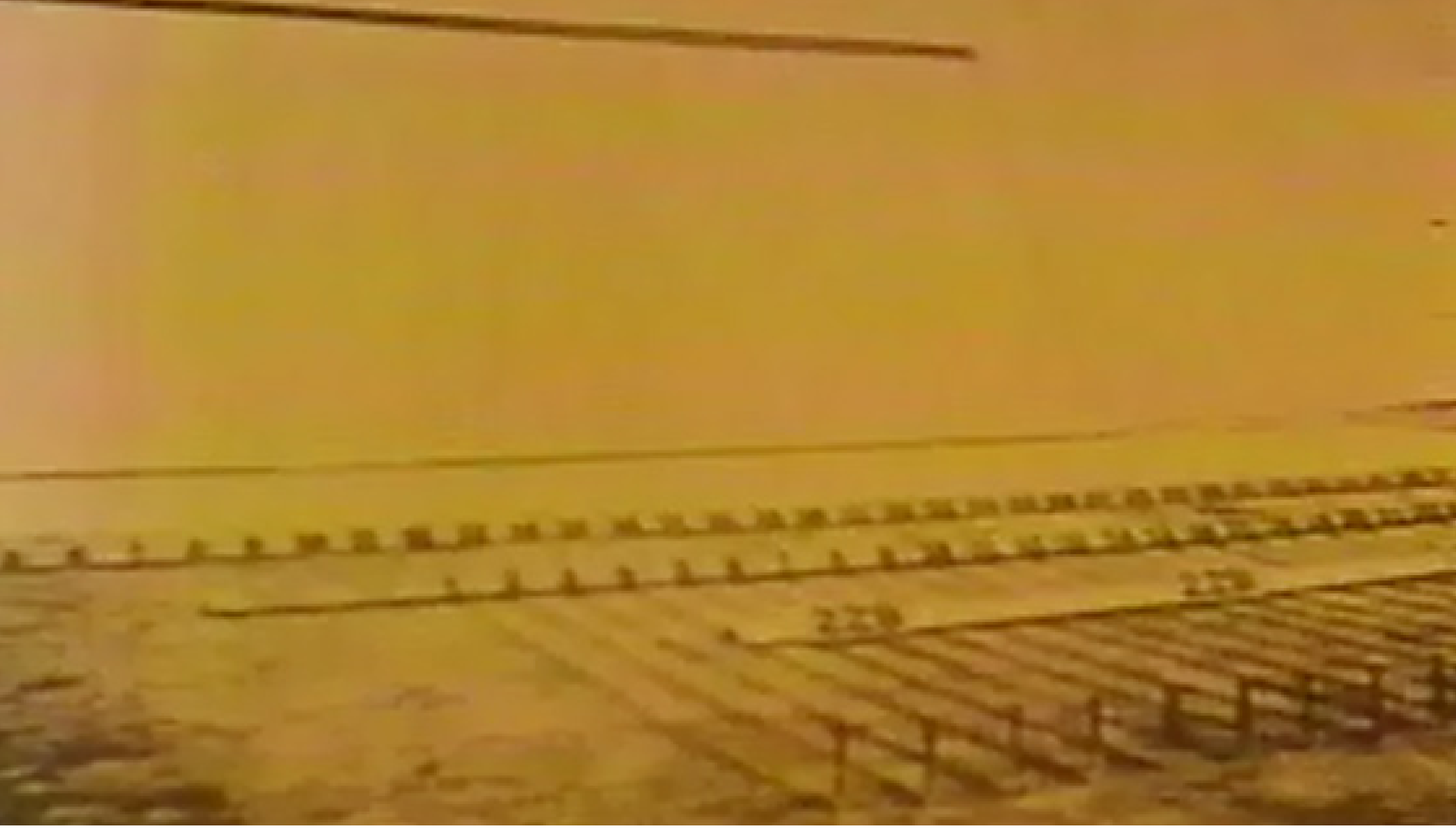
juries to Muybridge. He spent time in the both the United States and England during his approximately five years of treatment and recovery. In England, he began a new profession in the new field of photography.

Although Muybridge had left San Francisco in 1860 as a merchant, he returned in 1867 as a professional photographer. He possessed highly proficient technical skills and an artist's eye. His photographic reputation was established with his pictures of Yosemite Valley wilderness and he quickly achieved notice for his landscape and architectural subjects. He traveled to Alaska to photograph Tlingit Native Americans, lighthouses of the American west coast, and the Modoc War between Native Americans and the U.S. Army in northern California and southern Oregon. He made a sequence of images of the construction of the San Francisco Mint from 1870 to 1872. In 1878, Muybridge made a 13-part photographic panorama covering 360 degrees of San Francisco which was presented to the wife of Leland Stanford.

In 1872, Muybridge was hired by Leland Stanford who was a businessman and racehorse owner. Leland Stanford had decided to challenge a common belief in the late 19th century that when a horse trots at least one foot was on the ground during the stride. The debate also included the actions of a horse's feet during the gallop. Stanford believed that all feet left the ground at one point in the gallop.

Muybridge settled the debate with a single photographic negative showing Stanford's Standardbred horse, Occident, being airborne during the trot. By 1878, encouraged by Stanford, Muybridge expanded the process by using multiple cameras to photograph a galloping horse.

The technique used by Muybridge to determine how and when the horse's feet were in contact with the track was to place numerous cameras in a line along the edge of the track.



Original photo of the camera placement used by Muybridge
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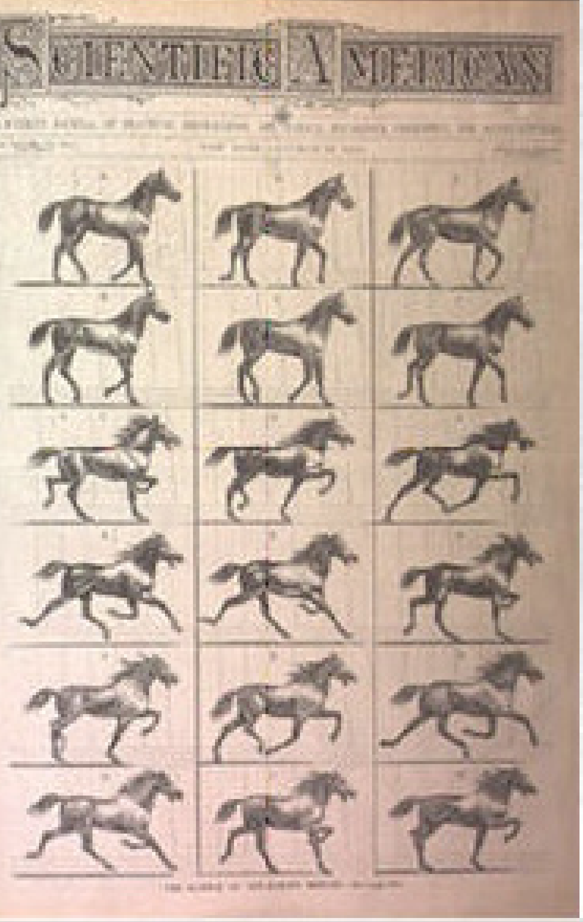
The shutter for each camera was triggered by a thread. As the horse galloped down the track, the hoof hit each thread which activated the camera to photograph that moment. Thus, each camera recorded a single image of the motion during the entire stride as the horse galloped. Muybridge copied each image in the form of silhouettes onto a disc to be viewed on the machine that he had invented which he called a "zoopraxiscope". This device was later regarded as an early movie projector and the process as an intermediate state toward motion pictures or cinematography. It was easily seen that during the gallop, as had been with the trot, all of the horse's feet were momentarily in the air.

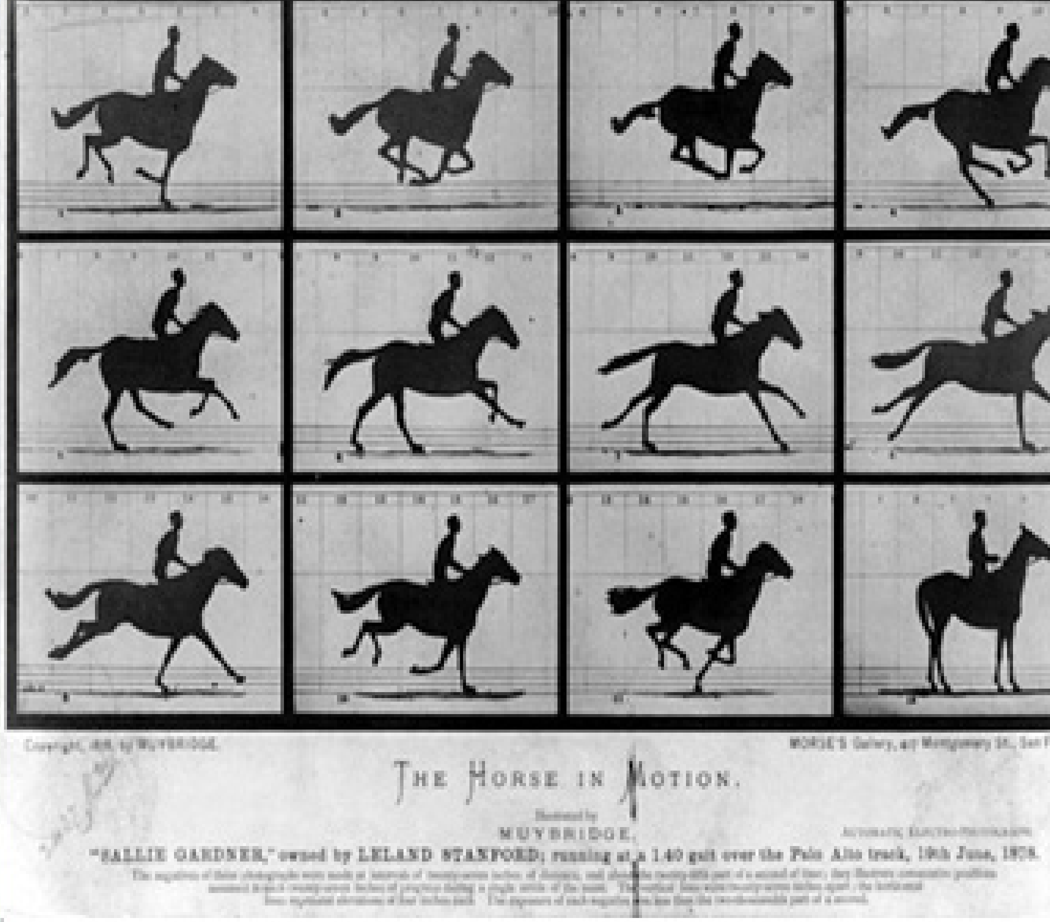
Muybridge's contribution to biomechanics went beyond his work with horses. In Pennsylvania, between 1883 and 1886, Muybridge made more than 100,000 images of diverse activities. He worked obsessively in Philadelphia under the auspices of the University of Pennsylvania which sponsored his research. He used banks of cameras to photograph people in a studio and animals from the Philadelphia Zoo to study their movement. The human models, either entirely nude or very lightly clothed, were photographed against a measured grid background in a variety of action sequences which included walking up or down stairs, hammering on an anvil, carrying buckets of water, or throwing water over one another. Muybridge produced sequences showing various activities in farming, industrial work, construction, household tasks, military maneuvers, and everyday activities. He also photographed athletic activities such as baseball, cricket, football, boxing, wrestling, fencing, rowing, discus throwing, and a ballet dancer.

Muybridge was influenced by the French photographer Étienne-Jules Marey. Before returning to the U.S. to further his own work in the same area, Muybridge had visited Marey's studio in France and viewed stop-motion studies. Marey's work in scientific achievements in the realms of cardiology and aerodynamics, as well as pioneering work in photography and chronophotography, are indisputable.

Muybridge's success brought him national and international fame. Scientific American and other magazines published articles about his work. In addition, his breakthroughs unwittingly began the motion picture industry.

Muybridge's ultimate gift to equine biomechanics was the use of multiple camera exposures to capture the movement. Although Muybridge's created spectacular images, both still and moving, they lacked the scientific applications which could be applied to bodies in motion. Creation of scientifically accurate quantification requires the use of photographic images captured in sequential order at a known camera speed. Multiple camera sequences allow for the application





of Newtonian laws to the identified joint actions. Equine biomechanics has evolved significantly since Muybridge's days and currently impacts several fields in equine management, including injury prevention and treatment, performance enhancement, and several equine sports.

The competitive racing of horses is one of the world's most ancient sports. Its origins seem to have arisen from among the prehistoric nomadic tribesmen of Central Asia who first domesticated the horse about 4500 BC. Archaeological records indicate that horse racing occurred in ancient Babylon, Syria, and Egypt as well. For thousands of years, horse racing flourished as the sport of kings and the nobility. By the time humans began to keep written records, horse racing was an organized sport in all major civilizations from Central Asia to the Mediterranean. Both chariot and mounted horse racing were events in the ancient Greek Olympics in 638 BC and the sport became a public obsession in the Roman Empire.

The origins of modern racing lay in the 12th century when English knights returned from the Crusades with swift Arabian horses. The British settlers brought horses and horse racing with them to the New World and the first race track was laid out on Long Island as early as 1665. Although the sport became a popular local pastime, the development of organized racing in America did not materialize until after

Muybridge frame-by-frame sequence of the gait of a galloping horse
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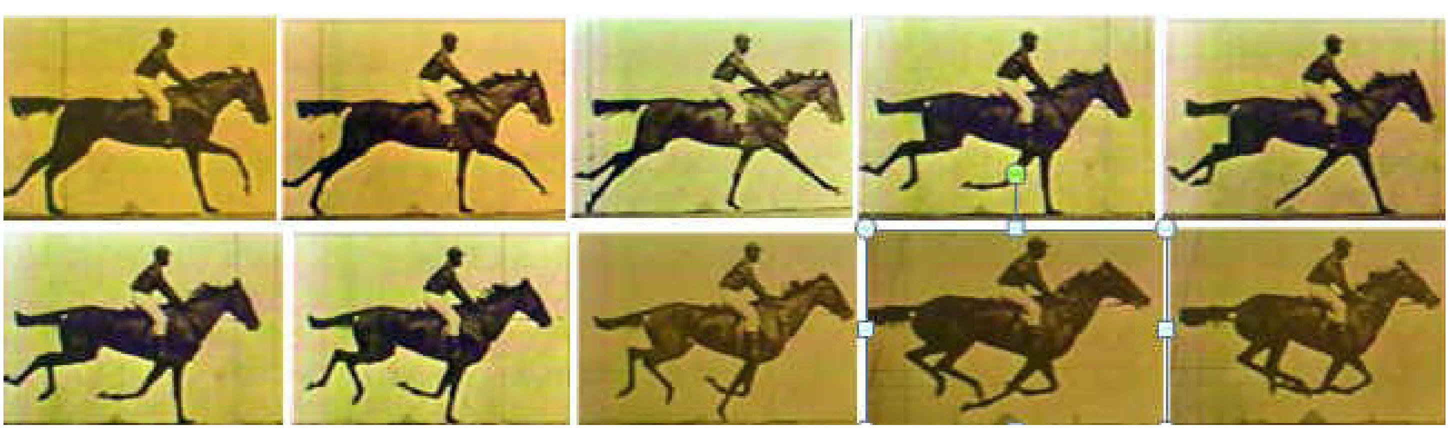

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Anatomy of a Motion

Computer programmer Gideon Ariel's digitalizing screen shows athletes how to shatter world records

By Paul Bernstein

YOU PROBABLY THOUGHT YOU HAD EVERYTHING you would ever need to get in shape—your polypropylene knit sweat-suit, your glow-in-the-dark, perforated, nylon-and-mesh running shoes with the ankle stabilizers and podiatrist-approved insoles, your battery-powered, anti-dog safety stick with special compartment for keys and ID, your predigested aloe vera drink and your high potency vitamins with bioflavinoids all amino-acid chelated, whatever that means.

And then along comes Gideon Ariel to tell you it's not enough. What's worse, he has the computer print-outs to prove it.

Gideon Ariel is a computer whiz and former Olympic discus thrower who can tell you how much farther you could hit a golf ball if you dropped your left shoulder two inches. He can tell a high school swimming champ not to waste five years training for the Olympics because his body build would never allow him to swim fast enough. He told Olympic shot-putter Terry Albritton to change the position of his front leg; a month later, Albritton broke the world record. Discus thrower Mac Wilkins, also following Ariel's advice, broke a world record, too—by six feet. Ariel started giving pointers to the U.S. Olympic women's volleyball team two years ago when they were 45th in the world. Now they are in the top three, and they have moved in next door to his southern California research center fulltime.

How does Ariel know so much? Give the credit to the computer program he worked out over some 10,000 hours. He can take a high-speed film of a race horse, a baseball pitcher or a long-distance runner, transfer it frame-by-frame to a computer screen, turn the image around to look at it from above, below or anywhere in between, and calculate the physical forces at work on any joint or limb. Besides giving advice to athletes, he has been using his computer to turn out one new exercise toy after another. The latest is a running shoe with a computer chip in the heel. Once a week, you take out the chip, stick it in your home computer, and get a full report on how far you ran, how fast, how efficiently, how many calories you burned, how much force you exerted on your knees, ankles and back and how much progress you have made since last week. Then you get on another of his inventions, a computerized weight machine Wilson Sporting Goods has agreed to market. Instead of depending on some over-muscled, over-sexed college kid to tell you how much weight you need on the Nautilus machine, you will be able to slip your personal diskette into the weight machine and get a personalized prescription automatically—exactly the force best suited to you, based on your physical characteristics, your goals and your exercise history.

If you think Ariel's computer is just the thing to improve your golf swing, you're probably right—if you happen to have a spare $5,300 lying around. It may sound like a lot, but Ariel suggests that, playing for $500 a hole the next time out, you could easily recoup the investment.

IT'S NOT EASY TO FIND GIDEON ARIEL. YOU HAVE to get off the freeway at an Orange County shopping mall and drive past the McDonalds and the Thriftys and the Alpha Betas until even the tract houses start to disappear. You find yourself in the middle of the kind of open land you thought no longer existed in southern

1982 PASSAGES 35

Article in "Northwest-Orient Passages"
http://arielnet.com/ref/go/1212

the Civil War. The American Stud Book, which is an official list of all the Thoroughbred horses within the United States whose parents are known, was begun in 1868. The rapid growth of the sport without any central governing authority resulted in the domination of many tracks by criminal elements. In 1894, the nation's most prominent track and stable owners met in New York to form an American Jockey Club. Shortly thereafter, racing was ruled with an iron hand and much of the corruption was eliminated.

Although horse racing is one of the oldest of all sports, its basic concept has undergone virtually no change over the centuries. It developed from a primitive contest of speed or stamina between two horses into a spectacle involving large fields of runners, sophisticated electronic monitoring equipment, and immense sums of money. Its essential feature has always been the same, however. The horse that finishes first is the winner. In our modern era, horse racing developed from a diversion of the leisure class into a huge public-entertainment business.

The style of racing, the distances, and the type of events vary significantly by country. There are three major types of racing: flat racing, steeplechase (racing over jumps), and harness racing, where horses trot or pace while pulling a driver in a sulky. A major part of horse racing's economic importance lies in the gambling associated with it. In 2008, gambling on horse racing generated a world-wide market worth around $115 billion U.S. dollars.

In the early 1900s, however, racing in the United States was almost wiped out by the anti-gambling sentiment that led almost all states to ban bookmaking. By 1908, the number of tracks had plummeted to twenty-five. That same year, however, the introduction of parimutuel betting for the Kentucky Derby signaled a turnaround for the sport. More tracks opened as many state legislatures agreed to legalize parimutuel betting in exchange for a share of the money wagered.

At the end of World War I, prosperity and great horses like Man o' War brought spectators flocking to race tracks. The sport prospered until World War II, but declined in popularity during the 1950s and 1960s. Resurgence of the sport in the 1970s was triggered by the immense popularity of great horses such as Secretariat, Seattle Slew, and Affirmed, each winners of the American Triple Crown: The Kentucky Derby, the Preakness, and the Belmont Stakes.

For hundreds of years, people have asked, "What is it that makes one horse run faster than another?" This question is at the heart of biomechanics as applied to Thoroughbreds. Equine biomechanics applied to Thoroughbred performances focuses mainly on the mechanical systems. Important gait differences occur in time intervals impossible to see with the naked eye or even with slow motion video. The eye can observe differences in style, particularly with slow motion video, but it is impossible to see forces, velocities, and joint displacements without performing mechanical calculations. Using high-speed video to record thoroughbred horses at racing speeds has provided an opportunity for detailed gait analysis. The gait analysis can examine such factors as stride length, leg angles, joint positions of the shoulder and neck. In addition, hoof movement patterns and alignment of the body are important considerations.

Equine biomechanics also examines the relative positions of the limbs at each phase of the stride and the timing of each hoof placement. The track material is another consideration which can affect the horse's performance either positively or negatively. American Thoroughbred horses race on soft sandy tracks compared with many of the tracks in other countries which utilize grass.

Track material can help to minimize the forces transmitted to their joints in an effort to prevent or reduce injuries. Just as human runners have more shock absorption when running on dirt paths with proper shoes compared with running on concrete roads without shoes, horses must contend with shock as well. For horses, it is possible to change the track material but less easy to provide more shock-absorbing footwear.

The weather is another factor since some horses thrive while others dislike running in the rain or on muddy tracks. Regardless of the weather's influence, however, sinking into sand affects the net velocity of the horse. Some energy is lost in this shock-absorbing strategy. The important question is, "How much energy is lost?" The answer to this type of question can be addressed by calculating biomechanical parameters.

Another consideration that can be applied to horses is how their joint speeds correlate to their linear speed on the track or, as yearlings, in the meadow. How a young horse moves, when startled, can easily be accessed through biomechanical procedures and more accurately predict future performance since the angular rotations at the hip are exact measurements without regard to heritage. Determination of whether the angular velocity at the hip joint changes dramatically from the morning training time and the afternoon racing time can provide interesting comparative evaluations.

The biomechanical techniques applied to determining horses' joint speeds as they correlate to their actual speed on the track are the same as previously utilized on human racing events. I had been asked to calculate the speeds of human sprinters who had performed in prior Olympic com-

Ann and I at the CAPPY Awards

petitions. The obvious question followed which was "How did the previous Olympian compare with the present day Olympic runner?" Comparisons were frequently made of previous Olympic competitions or of world records. In order to compare two sprinters, for example, several problems were encountered including: (1) it is impossible to exactly replicate the situation and (2) the competitors may be too old or have passed away. However, we made our best estimate with the data provided.

One question posed had been to compare two of the best sprinters of that time, Ben Johnson and Carl Lewis, to the great Jessie Owens. Try to imagine how these three great sprinters would run around the track against each other. Of course, it could only happen in a dream or a vivid imagination. What we could accomplish biomechanically was to digitize Jessie Owens and compare his running technique against the two modern sprinters. Jesse Owens won 4 gold medals and broke the world record in the 100-meters dash in 10.20 seconds in the 1936 Berlin Olympic Games. His 100-meter dash record stood for 20 years and was broken by Willie Williams in 1956 in 10.1 seconds. The question was how Jessie Owens' results compared to sprinters who ran the same distance in 9.90 seconds and faster. Since modern sprinters ran on artificial tracks, used starting blocks, and had access to special sprint shoes with spikes to gain better contact with the running surface, was it possible to eliminate those factors and compare the runners outside of their actual competitive environment?

Bud Greenspan, the famous producer of the series on the "Olympics Games", was a friend of mine. One of Mr. Greenspan's most beautiful and moving productions was "Jesse Owens Returns to Berlin" (1968). Mr. Greenspan gave me access to the original film of Jessie Owens' Berlin Olympic performance. In my data collection, I had various Olympics and International competitions, including sprinting performances of Ben Johnson and Carl Lewis.

When a sprinter runs, the movement results from the displacement of his/her rotational leg and hips segments. In addition to the hip displacements, the movement of the ankle joint is added to that of the displacement at the knee and the hip joints. When these angular displacements are calculated in their coordinated actions, the total stride length is created. Of course, the net distance is always slightly less since some motion is wasted at the surface contact, while another motion is absorbed due to the flexibility of the shock absorbing joints. Another factor is air which will resist the movement forward. The amount of time that the runner is out of contact with the ground and the height that the center of gravity is displaced will, also, affect the result.

However, the most important joints about which forces are generated to propel the body forward are those at the ankle, knee and hip. By calculating the angular velocities at these joints, it is possible to calculate the absolute velocity and compare athletes that ran at different times and under different conditions. For example, one athlete might run a hundred meters in 10.0 seconds, but another athlete running into the wind might run the same distance in 10.20 seconds. In other words, the distance covered would be the same, but external circumstances might be the factor producing the time differences. If the calculation of their speed was measured by determining the angular velocities at the joints, a comparison of the absolute speed of two people running at times, places, and under dissimilar conditions could be made.

Using the films provided by Mr. Greenspan, we applied biomechanical analysis to several of the sprints Jesse Owens ran in the Berlin Olympic competitions. Based on our calculations of his joint center kinematics (which yielded positions, velocities, and accelerations), Jessie Owens was as fast as Ben Johnson and Carl Lewis. However, these modern-day sprinters won the same 100-meter race, at faster speeds, most likely due to the environmental conditions under which they competed. Carl Lewis won the Gold medal in the 1984

Olympics in 9.99 seconds. However, Carl Lewis performed on an artificial surface with special sprint shoes. Comparing the kinematic parameters for these athletes suggests that they would have been competitively equal.

I was pleased and honored when Bud Greenspan selected me to receive The CAPPY Award named in honor of his late wife. I received this special life achievement at the Jewish Sports Hall of Fame in 1991.

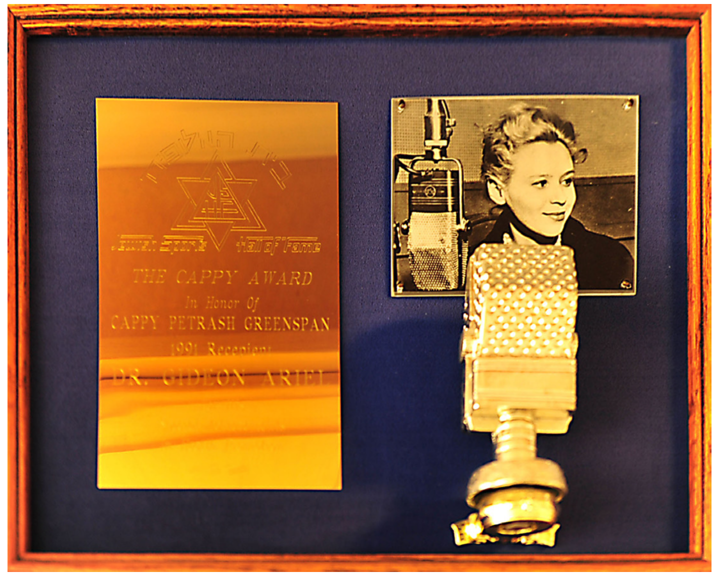
I had the privilege of meeting the great Jessie Owens at one of the World Championships in track and field. I was in awe of him and his accomplishments on the track and in life. He introduced himself to me and told me how much he appreciated my study that was published in Track and Field Quarterly Review Journal. It was an added honor for me that he appreciated my work. Jesse was a great athlete and a wonderful person.

I explained to Mr. Pollock and his staff at our breakfast meeting that the same analytical techniques could be applied to racehorses. Biomechanical analyses could determine the joint speed that correlated with their actual speed on the track. We know that horses race on soft sand to minimize the forces which are transmitted to their joints. The reason for racing on softer surfaces is to minimize the injuries caused by the repetitive pounding caused by running. In other words, the harder the surface, the more forces transmitted into the joints. However, the effect of sinking in the sand results in a reduction of the velocity of the horse. Energy is lost by this shock-absorbing mechanism, so the trade-off is a slower running speed but reduced damage to the joints.

All of these ideas were discussed during our delicious breakfast in Mr. Pollock's house. After several hours, we had talked about nearly every aspect of biomechanical analysis and its application to humans and horses. Mr. Pollock suggested that we drive to the track to see some of his horses.

Another question frequently asked is why the velocity at the hip joint changes dramatically from the morning training session to the afternoon race. In one of our subsequent filming sessions, we measured a reduction of 40 percent in the joint angular velocity in one horse between the morning breeze and the afternoon race. Although we detected this change, we were in no position to identify the cause. One possibility would be a pharmaceutical effect, injury, or deliberate speed reduction by the jockey. The biomechanical analysis could reveal the differences, but not the causative factor.

We drove to the race track near Mr. Pollock's home in Miami, Florida and walked around the barns. I was introduced to a number of trainers and saw some of his beautiful horses which were housed there for the current racing season. After this firsthand experience, we returned to Mr. Pollock's home to discuss the next step.



The CAPPY Award
1991 Recipient Dr. Gideon Ariel

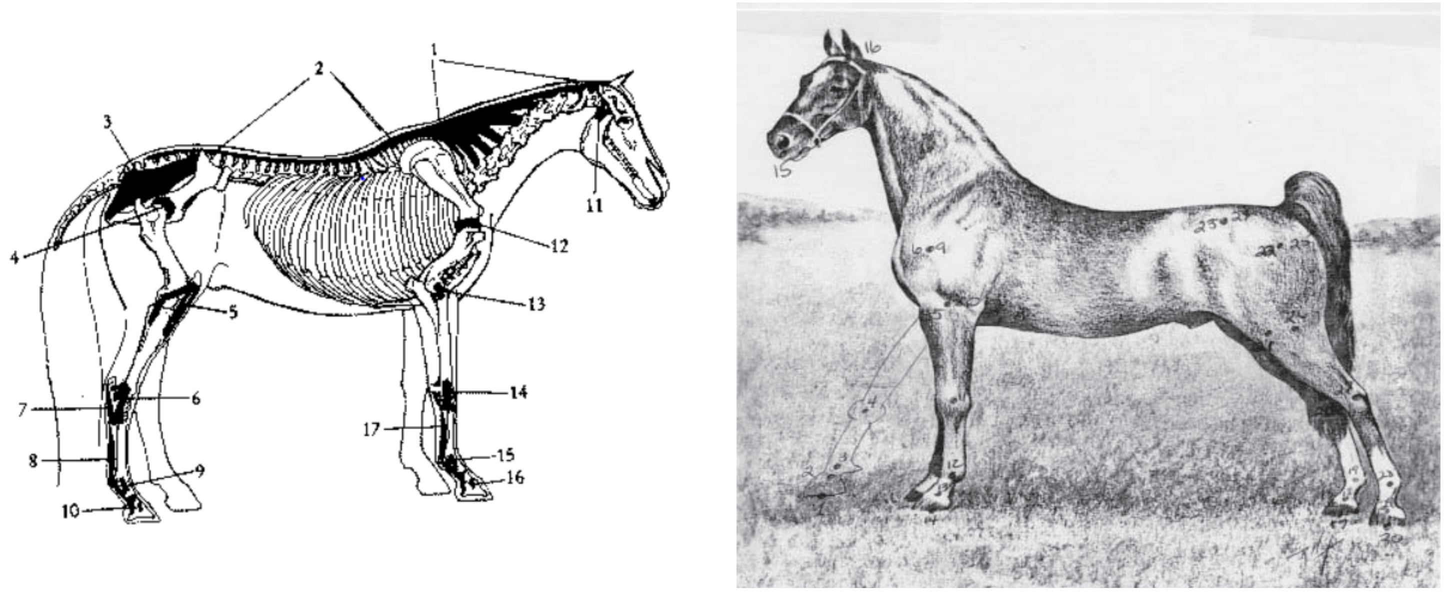
In general, Mr. Pollock wanted to know if we could analyze his horses and provide information as to which of his horses had more potential. He also wanted some information on the horses of some of his competitors. We discussed many topics including training suggestions and shoes in addition to the normal running analysis. At one point, Mr. Pollock offered to include a percentage of the prize money. I declined the offer since we would receive ample payment for each analysis.

I returned to Amherst where Ann and I prepared a proposal for Mr. Pollock. The project we envisioned which would provide the information that he requested was initially for twelve horses. In this pilot study, we restricted our focus to the parameters which would contribute to the speed of the horse. The parameters we selected were:

1. Ground contact time
2. Time in the air when all feet were not in contact with the ground
3. Stride length
4. Ratio of stride length and time in the air

Since this was only a pilot study, we anticipated that other factors would be revealed during the analysis which were equally or even more significant. We sent our proposal to Mr. Pollock who agreed with it. Now we, as well as the horses, were "off and running".

One of the first things we had discovered was that there was little research related to horse racing. In general, the information was still in the dark ages since most knowledge was based on hearsay, guesswork, and tradition. However,



Joint centers traced for the Thoroughbred

all objects on earth must obey the same laws of motion. The forces created by and acting upon horses depend on the same physical characteristics as all other bodies on Earth. Our primary objective for this pilot project was to identify those parameters that would optimize selection of new horses, training of both young and currently active racers, and to determine the most effective manner to maximize the forces produced in racing performances.

Ann and I flew to Florida with the photographic and biomechanical gear that we needed. In retrospect, we were lucky that we were traveling in 1980 because the modern-day travel problems because of security concerns would have made the trip more like one of Jason's epic voyages to retrieve the Golden Fleece.

Once we arrived at the race track, we began organizing the cameras and other items necessary for the biomechanical analysis. For this cinematographic phase, we had to film both the horse as well as the special apparatus referred to as "test points". The test points are needed to calibrate the visual field through which the horse ran. We explained to Mr. Pollock that the test points would allow us to know precisely the measurement and angles as well as converting the tiny horse shown on the computer screen into the correct three dimensions of an actual Thoroughbred as it raced down the track.

Another essential factor was that everything had to be filmed simultaneously from three separate camera angles. This procedure was required for the subsequent computer processing of the data to calculate the three-dimensional coordinates of the horse. This step was relatively simple when filming humans since six running stride lengths would cover approximately twenty meters. However, several strides by a horse requires a longer distance. Three cameras placed at various locations covering twenty meters would capture less than three strides of a horse. The logistics of camera placement were much more complicated for these "athletes" but, eventually, we set the cameras correctly.

At that time, we used Photosonic high-speed cameras placed at appropriately calculated locations. Although we used the most modern cameras available, their fastest speed was only 500 frames per second. The cameras incorporated a pin registration to advance the film and had a variable shutter speed to eliminate blur at that filming rate. These were the days of film cameras, rather than the digital ones available today, so we also had to wait for the film to be developed. Digital cameras, which are available in today's modern world, were figments of our imagination and fantasies of the future. Thus, we had to rely on experience and luck when we filmed the desired action and could only know days later if we had been successful.

We coordinated the filming process for each horse with the trainer and his staff. We would first film the test points and move them off of the track. Then we would tell the trainer to signal the selected horse to race down the section of the track following another horse. It turned out that racehorses are more easily encouraged to run at full speed when they see another horse galloping ahead of them. We filmed each horse from three views as it ran at a full gallop and kept records of the name of the horse and some distinguishing characteristics such as the color of the jockey's shirt for subsequent coordination of film sequences.

After we had filmed all of the horses, we discussed with Mr. Pollock and his staff what the next steps would be in the biomechanical calculations. We determined some of their questions and flew back to Amherst to try to find the answers. As we left, we assured Mr. Pollock that we would work as quickly as possible to provide a report for him.

The biomechanical procedures required an extensive time commitment. Analyzing all of the horses from three cameras was more time consuming than for humans. Horses have more joints than people have, and the strides are much longer than human runners so the time commitment for these twelve analyses was enormous. A schematic representation of the horse and the designated joint centers are shown in the diagram above.

We applied our standard analytic techniques for processing the films and executing the numerous biomechanical calculations. We prepared extra graphs and tables with the stick figure representations, since non-scientists frequently perceive information more comprehensively from visual rather than numerical presentations.

After the work was completed and the report prepared, I flew to Miami to present the findings to Mr. Pollock. I explained that we had selected twelve horses for analysis as a pilot study so that we could identify those parameters which appeared to contribute significantly to the speed of the horse.

The first parameter we evaluated was the "ground contact time". This parameter measured the time that each foot was in contact with the track. The shorter the contact, the greater the magnitude of the force with which the horse pushed against the ground. For example, if a particular horse produced a contact time of 94 milliseconds, that horse would run faster than one which had a 100 millisecond contact time. Assuming that all other factors remain the same, horses with shorter contact time would be faster.

The second factor concerned the duration of the "airborne phase" which occurs when all four feet are off the ground. The horse can propel its body forward only when the feet are in contact with the ground. No forward thrust can occur during the flight phase since the horse has nothing to push against. The horse cannot propel itself forward until returning to earth at the speed of the earth's gravitational pull. Since all horses are subject to the same gravitational effects, a horse which spends less time in the air and more time pushing against the ground will obviously run faster.

To optimize the "ground contact time" parameter, the horse should have a long stride with a short airborne phase. A long "airborne phase" is caused by the horse pushing upward rather than forward which results in a longer time in the air. To increase speed, it is important to minimize the up and down fluctuations of the center of gravity of the horse. The optimal air phase time was determined to be one of short duration. Horses which can maintain the center of gravity on approximately a level plane, that is, with little wobble or bounce up and down, are faster than horses which do not have this pattern.

Another phenomenon we detected was a movement behavior which we labeled "rear leg delay". After pushing off with the rear legs, which propelled the horse into the air, the faster horses appeared to be more energetic in bringing the rear legs forward in preparation for the next stride. The slower horses appeared to relax and merely waited for the rear legs to swing forward. It seemed that the slower horses relied on the energy from the impact of the front legs to naturally bring the rear legs forward in a manner similar to human arms swinging when walking. Our calculations revealed that the sooner the horse contracted the rear legs after the completion of the push-off, the more efficient the movement and the faster the horse ran.

Another factor we observed was that the longer the horse allowed the rear legs to stretch, the greater the angle of impact and, therefore, the greater the force of the forelimbs impacting the ground upon contact. This has the undesired effect of slowing the horse's forward speed, since the force of this impact functions as a brake. The longer the delay in rear leg activation and the more acute the impact angle, the greater this braking force. Therefore, it is an advantage for the horse to activate the rear legs as rapidly as possible.

A critical component of fast speed was the "front foot placement". Our analysis found that the speed was faster when the horse landed with the angle of the forelimb nearly perpendicular. At this angle, little stopping or braking force from the ground slowed the horse's forward motion. The greater the deviation of the impact angle from perpendicular, the greater the deterrent force to the movement forward.

Our analysis found that, in the better horses, the body angle remained nearly parallel to the ground. Slower horses demonstrated a rhythmic change in the angle up and down as the horse rocked in the plane of motion in a manner like a teeter-totter. This rotation caused the head to bobble up and down as well as increased the energy expenditure. This was analogous to the technique that we had discovered with the best track hurdlers in the world. The runner who could jump over the hurdle without displacing the center of gravity usually won the race.

Carrying our large report, replete with graphs, pictures, and extensive details, I met Mr. Pollock and his trainer. The purpose of the pilot study had been to demonstrate our techniques and capabilities and to provide as much information to him as we could. We each sought the same knowledge, but we were fledglings in identifying exactly what we needed to know. The ultimate goals were:

Hialeah Race track in Miami

1. To identify the characteristics produced by horses during racing
2. To optimize these parameters
3. To properly select young animals for racing
4. To devise effective training techniques to optimize performance

Based on our pilot study, however, a continuation of the present research would focus on specific measurements and statistical determinations of the various parameters for the horses studied. These results would be compared to performances by other horses. We suggested some specific routines and training techniques to try on some of his horses and proposed a model for testing future animals.

Needless to say, our pilot study was extremely impressive and well-received by Mr. Pollock and his staff. They realized that this was a fantastic method with enormous potential for substantial profit. The ability to train his horses for better endurance, quicker speeds, and more sensitive detection of injuries was very promising. Mr. Pollock was quite enthusiastic and promised to contact us as soon as he could arrange for additional analysis.

I returned to Amherst and our CBA staff focused on our two on-going studies. It was about three weeks later that Mr. Pollock called our office. He requested that we evaluate one very special horse and compare it with some of his own horses. He would arrange travel to the appropriate tracks where the horses would be racing, as well as secure permission for us to film on the track premises. We agreed to the proposed terms and Ann and I flew to Miami to film the first set of horses.

As soon as Ann and I arrived in Miami, Mr. Pollock explained that he wanted us to see his horse farm. We readily agreed and off we went. He owned a large farm of beautiful gently rolling green hills and in all of the fenced areas were horses. It was amazing to see a big pasture filled with young horses, their mothers, as well as other horses munching on grass oblivious to the humans standing at the fence. Mr. Pollock and his training staff led the tour through the barn, paddocks, training circles, and to the track. It was a beehive of activity with the many different stages of care and training that was more than uninformed horse observers would know existed. Ann and I were fascinated.

After the tour, we sat to discuss the project details. Because we were at the farm, we inquired about the preparation of each of the "horse athletes". Since we had extensive knowledge about training and nutrition for humans, we were curious about how these four-legged athletes were trained.

The answers to our questions were beyond our ability to fathom.

We discovered that the techniques and practices were deeply rooted in old traditions. They had been feeding the same food, at the same time, to horses in what seemed to us to have been popular with Alexander the Great in 300 BC. The training procedures apparently dated to the 1700s in England. We were beyond astonished by what they were doing and, more shockingly, that the trainers were rigidly opposed to changing anything. "This is the way that it has always been done," was the mantra of horse training.

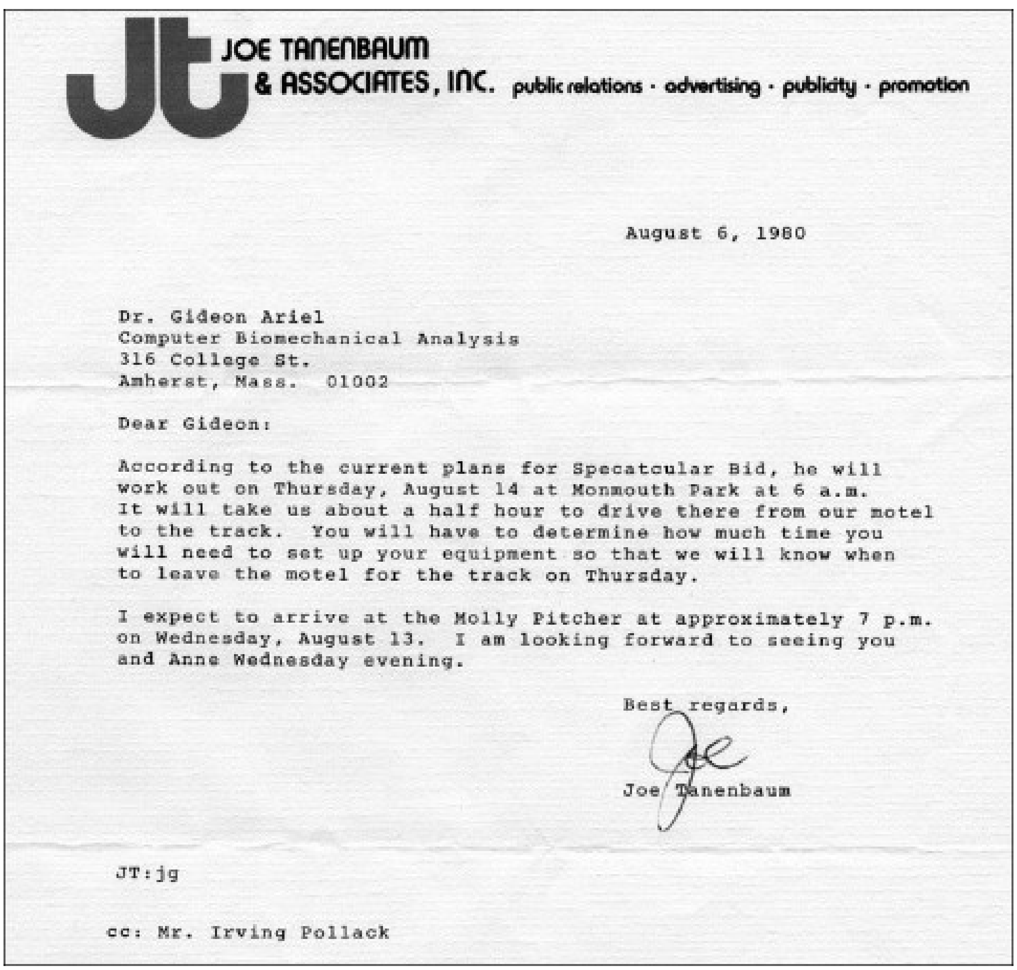
We told Mr. Pollock that we had some ideas and would come to him with suggestions. In addition, we wanted Mr. Pollock to meet Dr. Arie Selinger. Our friend and colleague, Aryeh ("Arie") Selinger, was widely regarded as one of the greatest volleyball coaches of all time. He happened, at that moment in time, to be residing at our second home in Coto de Caza as the head coach of the U.S. women's volleyball team.

For our purposes, it was Arie's expertise in physiology from his college and graduate studies that provided the factual knowledge basis for training his volleyball players to reach their maximum potentials. There was no reason to doubt that he would be able to provide valuable insight into training practices for horses.

We explained these concepts to Mr. Pollock as we drove back to Miami. He was very receptive to any information that we could provide that would improve his horses and their performances. I believe that the achievement of his horses was a challenge more than anything else. He had enough money, his business was incredibly successful, but he needed "windmills at which to tilt" as a modern Don Quixote and perhaps we were his latter-day Sancho Panzas. Regardless of his underlying motive, he was extremely receptive to our ideas and was hopeful that we would improve the racing performances of his horses.

After we had returned to Miami, we set about preparing to film at the race tracks where Mr. Pollock stabled his

Preparations for data collection on thoroughbred horses



JOE TANENBAUM & ASSOCIATES, INC. public relations · advertising · publicity · promotion

August 6, 1980

Dr. Gideon Ariel
Computer Biomechanical Analysis
316 College St.
Amherst, Mass. 01002

Dear Gideon:

According to the current plans for Specatcular Bid, he will work out on Thursday, August 14 at Monmouth Park at 6 a.m. It will take us about a half hour to drive there from our motel to the track. You will have to determine how much time you will need to set up your equipment so that we will know when to leave the motel for the track on Thursday.

I expect to arrive at the Molly Pitcher at approximately 7 p.m. on Wednesday, August 13. I am looking forward to seeing you and Anne Wednesday evening.

Best regards,

Joe

Joe Tanenbaum

JT:jg

cc: Mr. Irving Pollack

Monmouth Park Race Track

horses. There were three race tracks for us to collect data in Florida: Hialeah Park, Calder, and Gulfstream.

We needed permission to collect data within areas which were normally inaccessible to the public. In addition, we had to have a sufficiently large area for setting the cameras, since we needed to film several running strides. To record the stride of a horse running at its maximum speed required approximately 45 to 60 feet in order to capture the entire movement pattern. We also needed the same area to be viewed from at least two camera views in order to create the three-dimensional results. One of the results of the pilot project was that we needed a much larger area for the horse to run than we had previously realized. Mr. Pollock was able to secure the permissions necessary to accommodate our filming needs for both the Florida and New Jersey tracks.

We received correspondence from Mr. Grant Gravitt, the president of Tel-Air Interstate, who was the director of Public Relations at Monmouth Park Racing track. This letter covered our needs for filming Spectacular Bid in New Jersey.

Dear Mr. Haight:

This will identify Gideon Ariel and Ann Penny of my staff who will be shooting still photographs of Spectacular Bid. I would appreciate your issuing press credentials to them. Joe Tanenbaum has obtained permission from Bud Delp for the pictures to be taken.

In addition to four of his own horses, Mr. Pollock also wanted us to quantify another horse which was owned by his friend Mr. Harry Meyerhoff, owner of Hawksworth Farm. At that time, Mr. Meyerhoff's pride and joy was a magnificent steel gray horse named Spectacular Bid and the people who knew horses were confident that he was the best horse of the time. In order to film Spectacular Bid, we would have to film at Monmouth Park which was a race track in New Jersey. We filmed Spectacular Bid at Monmouth Park on Aug. 16, 1980.

After collecting data from several sprinting sessions as well as actual race performances with these remarkable horses, Ann and I returned to Amherst to process the films. It took longer than the pilot study had taken because there were more complicated questions to answer with these particular horses. Ann insisted that she was nearly cross-eyed and completely crazy because the sequences were extremely lengthy and the horses had so many joint centers. I knew what she meant since each analysis consumed at least three to four times the time necessary to process a human runner. Finally, however, we completed the biomechanical analyses.

I flew to Florida to present our research results to Mr. Pollock and his training staff. Since they were familiar with the biomechanical procedures, I proceeded directly to the results. We had divided the horses into three general categories:

1. The best horse—Spectacular Bid
2. A grass runner (which happened to be injured at the time)—Clayton Delaney
3. Horses owned by Mr. Pollock—Midnight Mystique, Arkansas Bev, and Gentil Knight.

We had prepared an extensive, detailed report for Mr. Pollock. However, only a summary of the more salient points is presented here.

The results of this horse study were presented in three different formats. The first was a stick figure representation of the motion of each of the horses in an orientation such that the horse is running from left to right across the page. An example of the motion of one of the horses displayed in this mode is shown in the figure on page 333. The lines connect the body joints and, thus, represent the bone structure of the horse rather than an outline of the body of the horse. The head is represented by a single line from nose to ears and is not connected to the body. The number of lines on the figure of the horse is, thus, reduced in an effort to enhance clarity especially when multiple images are presented in the same figure.

The formats for presentation to Mr. Pollock included: plotting graphs of joint center movements, graphs or "X–Y" plots of the biomechanical data, and gait analysis. The footfall pattern and the data measured in the 3-D analysis were utilized in a gait analysis, which determined the number of parameters.

The data was reported by the absolute magnitude and by percentage of a full stride, the latter being useful for comparing animals running at different velocities. A "gait analysis" is a good summary of the locomotion pattern of a horse since it most directly relates to the horse's efficiency in propelling itself along the track. To better understand what factors make one horse more efficient or faster than another required an examination of the more complex relationships between the various body joints and limbs especially in the patterns and magnitudes of accelerations produced by the muscular action.

Spectacular Bid had a longer stride duration and a longer stride length which resulted in the highest average velocity of the group. Despite his having the longer stride duration and stride length, there were indications that he was prevented from running at his maximum speed. Of the two track horses owned by Mr. Pollock, Midnight Mystique demonstrated the highest average velocity followed by Arkansas Bev. Midnight Mystique achieved a high velocity, although with significantly shorter stride duration and having a shorter stride length than Arkansas Bev. Since Mystique was a smaller horse than Bev, the shorter stride length was not unexpected. It appeared, however, that Bev was not running at full speed. This fact was later confirmed by the trainer. If a similar stride duration could be achieved, Bev could have an average velocity significantly greater than Mystique and closer to that of Spectacular Bid.

Clayton Delaney was unique among the horses since he ran on the grass while the others ran on turf. Therefore, a direct comparison of velocity was probably invalid. Clayton Delaney exhibited the shortest stride length and a stride duration similar to that of Bev's. Again this may be attributed to the grass track. However, it was subsequently learned that Delaney was experiencing shoulder problems and this was most likely the prime factor behind the short stride and low velocity.

In a comparison of the "stance" (ground contact) phase and "swing" (airborne) phase for individual limbs for the various horses, Midnight Mystique exhibited the shortest stance phase (in both time and percentage) of any of the horses. The limiting factor in the animal's ability to produce a high impulse was the individual limb structure and muscular strength. It appeared that Mystique more closely approached this physiological limit compared to the other horses in the group. Thus, considering the potential of the various horses, Mystique appeared to be running near his maximum speed.

If the other horses possessed the ability to similarly shorten their stance phase through an increase in impulse, i.e. exerting more force, the data indicated their potential to increase their speed by at least 10%. In that case, Bev would run considerably faster than Mystique, and Delaney only slightly slower than Mystique. Spectacular Bid would still be in a class by himself, a full 10% faster than Bev.

Another factor of concern in stride efficiency is "overreach". This is the distance beyond the point of foreleg lift that the same side (ipsilateral) hind leg strikes. Obviously, it is directly related to the speed of the horse. However, by comparing the percentage of "overreach length" and duration to total stride length and duration, relative efficiencies in this area can be compared. A long overreach indicates good hind leg extension which in turn indicates a good use of the large muscle groups in the area of the back and rump. Spectacular

Composite multiple stick figures of horse running
http://arielnet.com/ref/go/4015

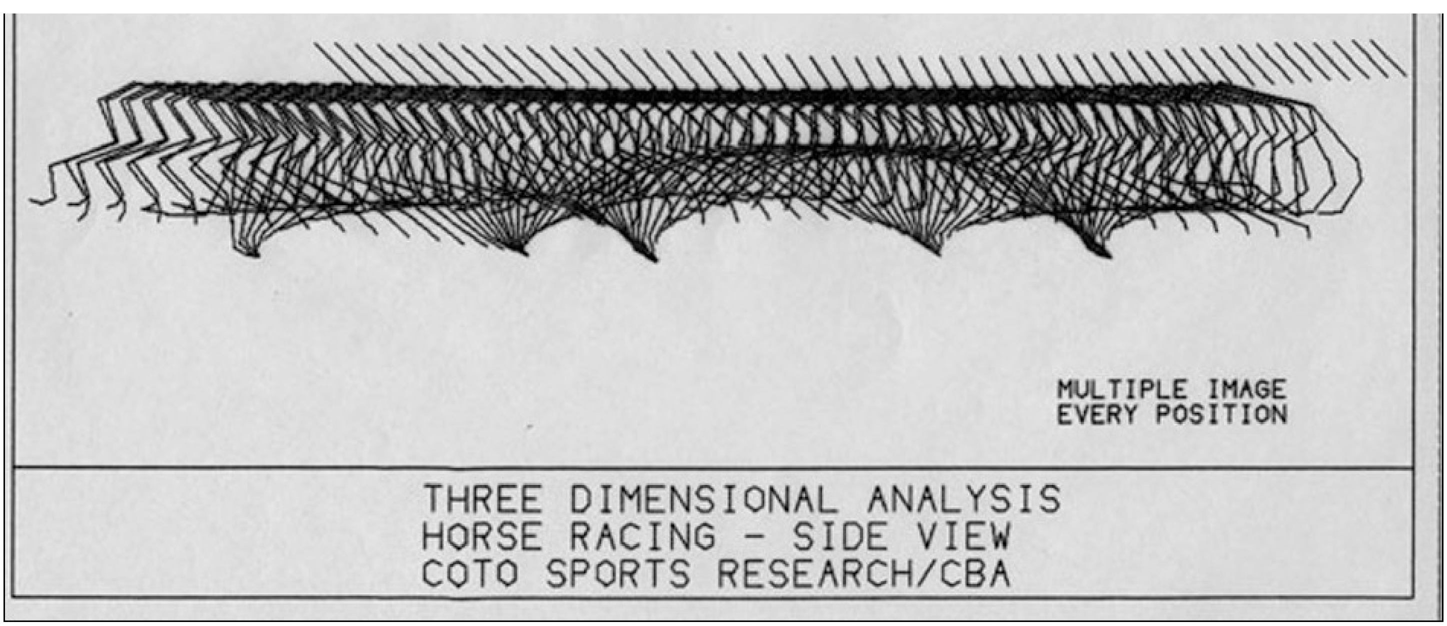


Table 1

COMPUTERIZED BIOMECHANICAL ANALYSIS, INC. - GAIT ANALYSIS OF:

***MARIONLY 1ST RUN AFTER 200 METERS 5/4/81
*** 5/ 4/81
QUADRUPEDAL LOCOMOTION
GAIT TYPE IS GALLOP

STRIDE LENGTH = 514 CM
STRIDE DURATION = .390 SEC
AVERAGE VELOCITY = 1318. CM/SEC

LEG	STANCE	SWING	%
LH	.045	.345	11.5
RH	.050	.340	12.8
LF	.060	.330	15.4
RF	.050	.340	12.8

STEP LENGTH: FORE = 81. CM (15.7%)
HIND = 58. CM (11.2%)
STEP DURATION: FORE = .055 SEC (14.1%)
HIND = .050 SEC (12.8%)

OVERREACH LENGTH: RIGHT = 230. CM (44.7%)
LEFT = 253. CM (49.2%)
OVERREACH DURATION: RIGHT = .200 SEC (51.3%)
LEFT = .195 SEC (50.0%)

DIAGONAL LENGTH: RIGHT = 342. CM (66.5%)
LEFT = 203. CM (39.6%)
DIAGONAL DISSOCIATION: RIGHT = .190 SEC (48.7%)
LEFT = .085 SEC (21.8%)

SUSPENSION = .150 SEC (38.5%)

--END OF ANALYSIS--
R

Pollock Studies - Analysis Of Thoroughbred Racing
http://arielnet.com/ref/go/4041

Bid again showed his superiority with both the longest overreach and the highest percentage of the overreach to the total stride when compared to the other horses.

A final concern in comparing the gait of the various horses was the "suspension phase" which is that time when the horse has no ground contact. It is probably advantageous to minimize this time since, while the horse is airborne, it cannot exert propulsive force. Also, excessive time in suspension may indicate misdirected force, i.e. too much vertical and insufficient horizontal.

However, certain positive aspects of efficient locomotion tend to lengthen suspension. The first is good "hind leg extension" which is the movement of the hind legs forward during the suspension in preparation for the next stride. The second is that increased impulse, i.e. higher force between the hoof and ground, results in a shorter time on the ground and a longer time in the air.

Spectacular Bid demonstrated the longest suspension, both in magnitude and percentage, which was probably due to his excellent hind leg extension. Clayton Delaney showed the shortest suspension but had poor hind leg extension and the smallest percentage of overreach. Arkansas Bev showed perhaps the most efficient suspension phase combining good overreach with a short time in the air. With greater impulse and at a higher speed, however, this time might well lengthen and, thus, it was difficult to draw any direct conclusion for Arkansas Bev in comparison to Spectacular Bid. Midnight Mystique already demonstrated a high impulse (short stance phase), and, thus, any efficiency increase would have to come through an increase in hind leg extension and a corresponding increase in suspension.

The discussion of gait analysis, thus far, had addressed only the horizontal component of the motion of the feet. Brief consideration should be given to the vertical motion of the feet during the execution of a typical stride since this would provide additional information on how each of the horses used the various limbs during locomotion. The general pattern for each hoof was the same:

1. Ground contact followed by a rapid lifting of the hoof
2. Forward motion of the hoof during which the height of the hoof may vary
3. Rapid lowering of the hoof
4. Ground contact

Within this general pattern, several distinct variations were noted. Midnight Mystique demonstrated a high degree of symmetry in the motion of the fore legs and the hind legs. Also, the peak height for each foot was nearly identical. Arkansas Bev showed good symmetry between the fore legs. However, her left hind hoof demonstrated a slow, steady descending pattern while the right hind hoof performed a hitch followed by a more rapid descent. Spectacular Bid demonstrated a similar hind hoof pattern with an even more exaggerated hitch, while his front hoofs showed a higher degree of asymmetry. In fact, his right front hoof reached a peak height of 51 cm while his left front hoof reached a peak height of only half that value. This may have indicated a strong footedness in his gait. It may, perhaps, have revealed that he was favoring the left foreleg for some unknown reason (possibly pain or discomfort). Clayton Delaney showed a lower magnitude of vertical hoof motion which may be due to the grass track. Symmetry was high for the fore legs and less so for the hind legs.

In addition to the motion of the hooves, it was useful to consider the motion of other major body points during the stride. The motion of the body points for all the horses followed the same general pattern with the head (nose and ears) showing the most vertical motion through the stride and the withers showing the least. Midnight Mystique and Clayton Delaney demonstrated considerably more vertical motion in the back and rump than did Arkansas Bev. Reducing the up-and-down motion of these heavy body parts minimized the motion of the center of gravity and, thus, conserved energy and increased efficiency.

The data collected and analyzed in this study demonstrated that differences in locomotion patterns between horses could be measured in a valid and consistent way using our quantitative methods. Furthermore, measured differences can be related to the goal of maximizing the speed of the horse and the overall efficiency of motion. In a specific sense, this study showed that several unknown horses, Midnight Mystique, Arkansas Bev, and Clayton Delaney, could be compared to the "ideal horse", Spectacular Bid, in a practical and straightforward manner. This comparison demonstrated that one of the horses, Arkansas Bev, showed the most potential for being able to approach the performance of the ideal horse and that another horse, Midnight Mystique, was near the limit of his potential.

In the process of performing this study, much knowledge was acquired as to the best methods to be used for equine analysis as well as the type of data format that is most useful in comparing horses and evaluating performance. In that sense, it quite successfully fulfilled its role as a pilot study.

At this point, I recommended that these methods be placed into production in the form of a continuing program of monitoring the development of individual horses and of selecting horses with good potential to receive additional training. In addition, I suggested to Mr. Pollock that different training regimens be specified for horses which possessed similar potentials. Then the horse could be evaluated to measure the progress and the efficacy of the different regimens. The end result of such a program would be to maximize the returns in a horse breeding and training program through superior selection and achievement of maximum potential. Mr. Pollock and his head trainer thought that this was a good suggestion. We decided to work with Arie Selinger, in addition to Mr. Pollock's staff, to outline some prospective training protocols.

One interesting episode occurred during our project with Mr. Pollock. The situation was created because of the personalities of horses. We learned that some racehorses were gifted athletes because they can run faster than the other horses. However, even these star athletes maintain their herd instinct and prefer to associate with other horses rather than live solitary lives regardless of the luxuries of privacy available to them. Apparently, horses are like teenagers; they need to hang out with others that look and think like they do.

For this reason, even the most valuable horse needs a "friend" which is most commonly another horse. There are alternatives available including donkeys, goats, dogs, and, occasionally, chickens. Mr. Pollock's "million-dollar horse", Gentil Knight, had a friend pony. In this case, it was not actually a pony, but rather an inexpensive horse compared to her more expensive friend. In this case, the pony was a filly named Arkansas Bev and she and Gentil Knight were inseparable.

On the morning we were to film Gentil Knight, we arrived at the track at 5 a.m. The plan was to film the horses as they executed their morning workout session. We had requested the trainer to have the session include a maximum speed sprint at the location of our cameras. He told us that race horses run their fastest when they have to run with, or try to catch up to and pass, another horse. Therefore, he suggested that we let Arkansas Bev run ahead of Gentil Knight. Then Gentil Knight's jockey would urge him to run faster in order to overtake Arkansas Bev. We had no quarrel with this strategy, since our expertise was biomechanics of locomotion and the trainer's knowledge was in knowing how to get horses to run faster. During our data collection, however, we recorded both horses as they raced past the camera locations.

We completed our data collection and Ann returned to Amherst to process everything. She had a large amount of data to work on and it was going to require a dedicated and intense work schedule. These were the old slow days when 35mm film development times and expensive overnight delivery charges were normal business problems to overcome. As soon as Ann completed digitizing and analyzing some of the horses, she sent the results to me in Florida. Some of the first results were for Spectacular Bid, Gentil Knight and his companion, Arkansas Bev. As soon as the results arrived in Miami, I immediately presented the findings to Mr. Pollock.

I presented the most recently acquired data to Mr. Pollock.

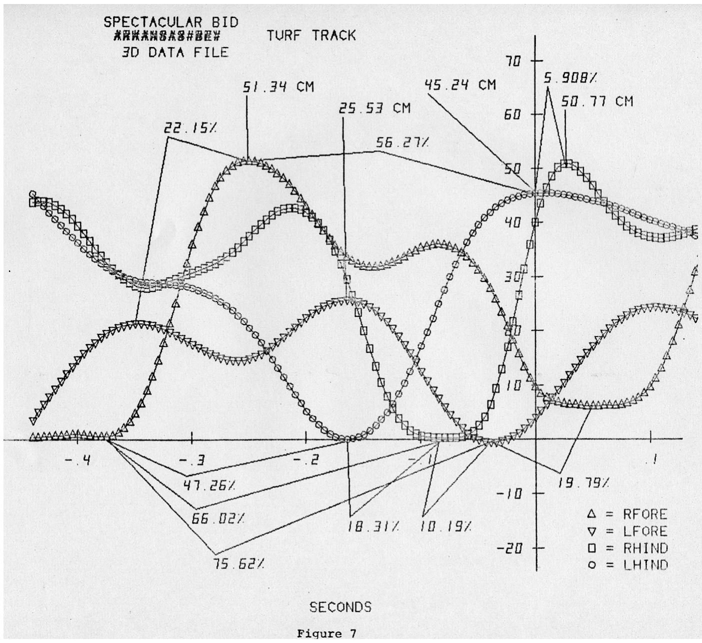
Of course, the most impressive results were those of Spectacular Bid. I described to him the various characteristics that made this horse as impressive as his name.

After I had explained some of the results for Spectacular Bib, I noticed that Arkansas Bev had incredible angular velocity at her hip and knee. In fact, she demonstrated a gait pattern that was equivalent to Spectacular Bids! Gentil Knight's results were much less impressive. When I presented it to Mr. Pollock, he did not believe it. He insisted that Ann had made a mistake or some miscalculation.

I called Ann and told her: "Ann, you made a mistake with the pony, Arkansas Bev." I could hear a special kind of skepticism and frustration as she answered: "I did not make a mistake. You know how precise I am with details."

"I believe you," I told her. "But Mr. Pollock doesn't know how exact you are, so he is rejecting our results. In order to convince him, we will have to repeat the analysis."

"Please don't make me do them again. There are 32 joints per horse, 75 frames per view, and three camera views. It takes so many hours to digitize each view and it's unbeliev-



Some graphical results for Spectacular Bid
http://arielnet.com/ref/go/4017

ably difficult to see some of the joints because the light was dim, since we filmed so early in the morning," she pleaded.

I had absolute confidence in Ann because I knew how meticulous she was in everything and especially when it came to the biomechanical processes. However, Mr. Pollock was paying the bills and we wanted to convince him to continue horse projects with us. Ann relented and agreed to reprocess the analysis for the pony, Arkansas Bev, as well as for Gentil Knight and Spectacular Bid.

After several more days, she sent the repeated calculations for the three horses. The results were nearly identical to the first set of findings. Excluding Spectacular Bid, Arkansas Bev was the best of all the horses we analyzed at that time. Mr. Pollock examined the results very thoroughly as I pointed out the extensive points of comparison among all of the horses. He was disappointed that the horse that had cost him the most money was much less impressive than the inexpensive companion horse.

After pondering the results for hours, Mr. Pollock reached a decision. He decided to take a risk and enter Arkansas Bev in a race, despite the fact that she had no experience except for some practice sprints with Gentil Knight. He found an appropriate race and when she was on the track, the odds against her were 70 to 1. Mr. Pollock also decided to bet on her but he made his wager in Las Vegas. "I want to be anonymous in my bet since I would be embarrassed to bet here in Florida where my friends could make fun of me!"

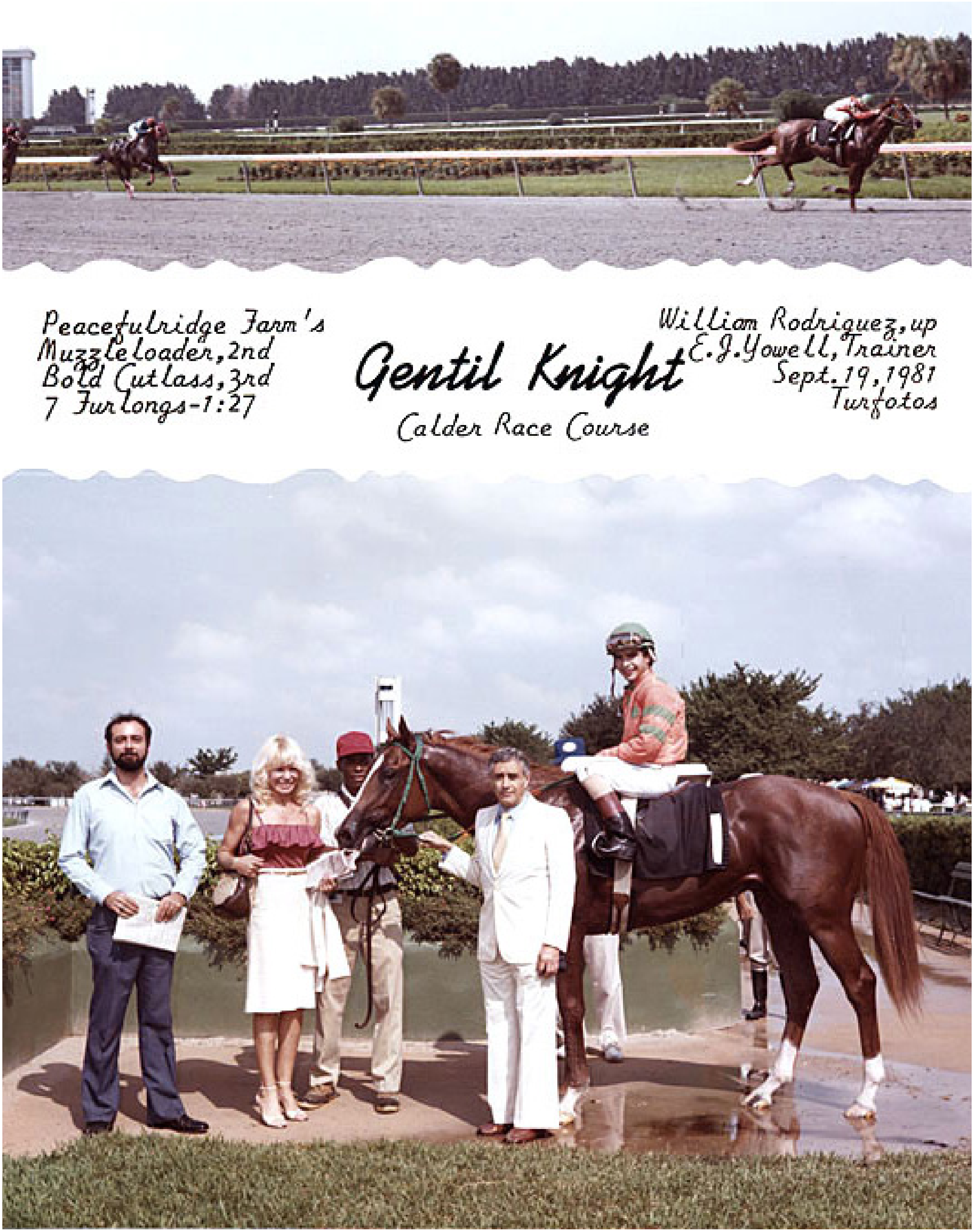
With the odds against her at 70 to 1, Mr. Pollock bet $10,000 on Arkansas Bev. I think I held my breath during the entire race because the horse had only her inherently natural skills rather than scientific knowledge about her biomechanical advantages. But, I should have had more confidence in our biomechanical calculations since Arkansas Bev won by five body lengths and Mr. Pollock won $700,000. I immediately called Ann and we shouted with joy about Arkansas Bev's victory. We felt vindicated about our biomechanical process. Another reason we were happy was we were pulling for the underdog who had no chance of winning. It was an especially happy event for us to see this little horse, and additionally a filly, win with such impressive results.

One thing I noticed, perhaps because my background involved humans running on artificial track surfaces, was that horses lost time because they sank into the sand on every stride. Historically, equine race tracks are one of three types: dirt, turf, or synthetic. Dirt tracks are the most popular for spectators wagering on a race as conditions are easiest to gauge when trying to choose a winner. Turf or grass is kinder on a horse's legs since there is much shock absorption. Synthetic tracks have been used for years but have only come to the United States fairly recently.

Dirt tracks are easy to maintain and are the most economical option for any track. They can be softened with the use of ground pine or other mulches and provide a good, clean running surface. While horses tend to slide a little more on dirt, it is preferred over grass because horses can maintain or increase speed unhindered by the softer landing that grass provides. The downside to dirt lies in its inability to provide good shock absorption. Dirt is very hard on a horse's legs because there is little to no shock absorption at all. It can be compared to a human trying to run down the road on their hands at 40 mph. Horses have thin legs holding up a thousand-pound body and are very fine boned from the forearm down to the hoof. Fractures can occur easily even on the softer ground.

Another result we detected during our studies was the different responses of running on a dry dirt track compared with racing on a wet, muddy surface. Horses seemed to prefer one over the other. I suggested to Mr. Pollock that we experiment with a Polyurethane shoe placed over the hoof joint. The idea was to increase the size of the hoof in the same way that fins increase the size of a swimmer's foot. It was legal and, as far as we could determine, no one had thought about it. We made the shoe at a special manufacturer and used it on several horses. They all improved their time by at least one second on an 8-furlong track regardless of surface conditions.

Mr. Irving Pollock with Gentil Knight


Peacefulridge Farm's
Muzzleloader, 2nd
Bold Cutlass, 3rd
7 Furlongs-1:27
Gentil Knight
Calder Race Course
William Rodriguez, up
E.J. Yowell, Trainer
Sept. 19, 1981
Turfotos

From Hilary Clayton's article
http://arielnet.com/ref/go/1214

We also arranged for Arie Selinger to meet us at Mr. Pollock's horse farm, located in the central part of the state of Florida. The gentle hills were green with grass and trees, and there was the usual heat and humidity. Mr. Pollock and the trainers gave Arie a tour of the barns, training facilities, and exercise yards.

We sat together to discuss some of the training strategies that we thought would be useful in developing stronger and faster horses, preventing injuries, and increasing the longevity of each animal. Because Arie, Ann, and I came from different backgrounds, we could suggest a variety of training proposals.

To improve the strength development, we suggested having the horses run in both directions around the track. This would allow for a more balanced muscular development since both right and left sides would have equal training. Without this balanced exercise, one side of the horse would be stronger than the other side and the imbalance would eventually lead to injury.

Another suggestion was to use water exercises. Having the horse swim would be extremely beneficial because:

1. There would be less stress on the joints and bones because the gravitational pounding on the ground would be eliminated.
2. The horses could increase their cardiovascular strength without having to run on the ground.
3. Swimming constituted an inefficient method of exercise much like having track runners practice in soft sand
4. Training injuries could be reduced and rehabilitation was usually quicker.

Because Arie had coached athletes around the world, had received his advanced academic education in physiology, and was currently the head coach for the U.S. Olympic Women's Volleyball Team, he was well-versed in training athletes, even the four-legged ones. In addition to the water exercises previously discussed, he also recommended different daily strategies for development of endurance as well as balanced strength increases. These techniques were also recommended so that the horses would be continually stimulated mentally as well as physically.

In addition to their physical training, Arie was interested in the food and timing of meals. His recommendations included adequate protein intake during the developmental times and while recovering from injury. On the day of the race, he advocated a technique which was known at the time as "carbo-packing". This meant excess carbohydrates, with reduced protein, on race day.

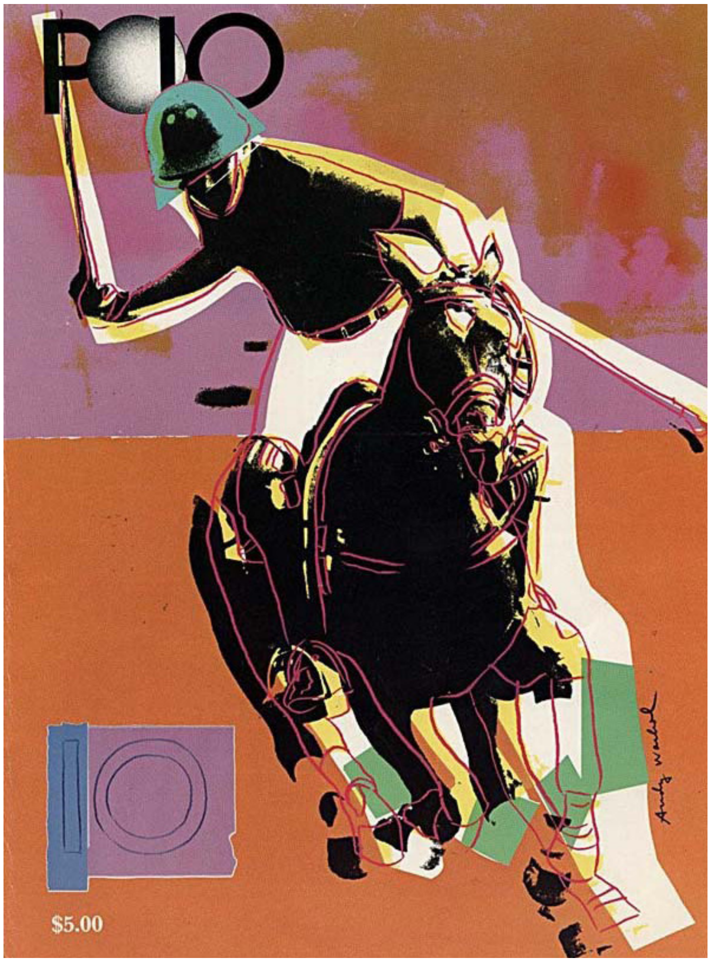
What he learned about the normal timing of meals on the day of the race was that the horses were fed early in the morning and only after the race were they fed again. Arie insisted that the horse be given a high carbohydrate snack prior to the race. Otherwise, they were like a racing car running on "empty" during the time when they most needed high-powered fuel. Imagine our shock when he was told that the horse could not eat before a race because they would explode!

Arie asked, "What do you mean 'explode'?"

The trainers insisted that the horse's stomach would explode all over the track during the race. None of them had actually seen such an event take place but all agreed that it was a known and irrefutable fact.

We discussed the situation with Mr. Pollock and determined that there was one horse that he was willing to try the dietary technique we advocated. After following the meal pattern for several months, the horse was entered in a race. Despite ingesting his "snack" a mere two hours before the race, he did not explode and finished in a better time than had been predicted.

However, most of the suggestions we proposed were met with skepticism and, I am sure, were totally ignored after we left. To say that horse racing was locked in antiquated tradition is an understatement. It operated like the medieval guild system with a master at the top and apprentices on the bottom. The individuals were closed-minded, inflexible, and secure in their place in the societal structure. Perhaps in today's more modern, forwarding thinking and technological world, things have changed within horse racing. I hope for the sake of the horses that this is true.



Frame by frame, the high-speed film is projected on an electronic screen and each reference point is touched with an electronic pen connected to a computer. With lines, the computer connects the points to create stick figures. Although all three men were mounted when the film was made, w subsequently removed the horses from the computer image in order to reduce confusion.

THE HIGH-TECH SWING

POLO Magazine sets out to unlock the mystery of 10-goal strokes using state-of-the-art technology. A mystery no more, we offer fresh promise to all who want to improve.

By Ami Shinitzky

Thankful be he who is blessed with God's gifts to athletes — remarkable coordination, quick reflexes and the ability to perform well without really knowing why. Still, when you can enhance God's gifts with scientific insights, the results can be even more astounding. For those of us whose athletic talents are less distinguished, however, the same scientific insights can play a much greater role. In fact, much of the credit for the improved performance in various athletic endeavors over the last decades is directly due to science — whether through better understanding of the biomechanics of sports or of exercise physiology. By contrast, over the same period, racehorses have not shown the same level of improvement because the sport has traditionally paid little attention to what modern

The High-Tech Swing, article published in Polo Magazine
http://arielnet.com/ref/go/1215

We continued to work with Mr. Pollock and analyzed many horses. At his direction, we evaluated other racing horses as well as young horses which were offered for sale. Eventually, our activities at the race track and our success were noticed. Some of the other horse owners were less than appreciative of our work and the obvious results with Mr. Pollock's horses. One day Ann and I returned to our hotel room to discover that all our cameras had been smashed. We read a note left on the bed, which read: "Your knees are next!"

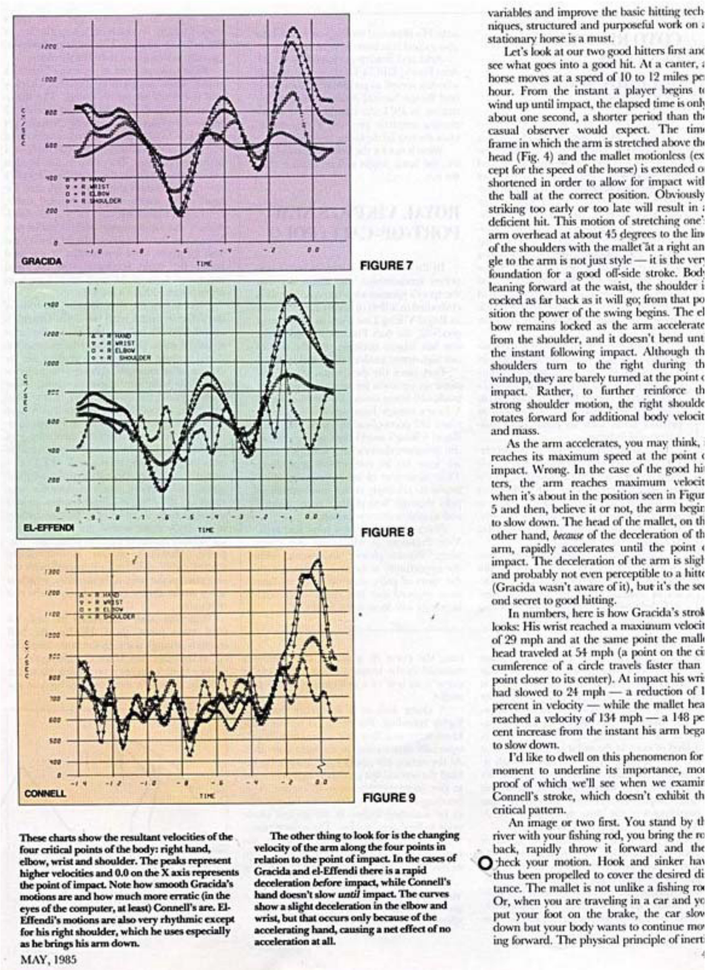
Regardless of the warning or whether it was a realistic threat, we decided that analyzing horses was too time consuming for our small business. We had worked with Mr. Pollock so that he could evaluate the efficacy of biomechanical analysis and the training regimens which we had successfully implemented. We were sorry to conclude our relationship with Mr. Pollock since it had been interesting and lucrative. However, we had put many of our other projects on hold and needed to return to those customer projects.

Several other groups were interested in analyzing horses and purchased our biomechanical analysis system of hardware and software. Most of these institutions were universities that used our system for veterinary research.

Another group that utilized our biomechanical analysis was Hilary Clayton and her students. In preparation for the 1992 Olympic Games in Barcelona, she used the APAS system to analyze the gait of the horses which were to participate in the Olympic Games. We corresponded with Hilary and instructed her how to set the cameras to collect data for our analysis system.

In the Olympics, a multitude of cameras was focused on Barcelona where they captured Olympic athletes in motion for sports fans worldwide. The vast majority of the cameras were for television broadcasting, but there were also several cameras whirring away at the equestrian events with an entirely different purpose.

These video cameras recorded specific parts of the performances of elite equine athletes for gait analysis. With her studies, Ms. Clayton envisioned help in answering one of the main questions in gait analysis research: "does a horse pos-



variables and improve the basic hitting tech niques, structured and purposeful work on stationary horse is a must.

Let's look at our two good hitters first an see what goes into a good hit. At a canter, horse moves at a speed of 10 to 12 miles pe hour. From the instant a player begins t wind up until impact, the elapsed time is onl about one second, a shorter period than th casual observer would expect. The tim frame in which the arm is stretched above th head (Fig. 4) and the mallet motionless (ex cept for the speed of the horse) is extended o shortened in order to allow for impact wit the ball at the correct position. Obviously striking too early or too late will result in deficient hit. This motion of stretching one' arm overhead at about 45 degrees to the lin of the shoulders with the mallet at a right an gle to the arm is not just style — it is the ver foundation for a good off-side stroke. Bod leaning forward at the waist, the shoulder i cocked as far back as it will go; from that po sition the power of the swing begins. The el bow remains locked as the arm accelerate from the shoulder, and it doesn't bend unt the instant following impact. Although th shoulders turn to the right during th windup, they are barely turned at the point impact. Rather, to further reinforce th strong shoulder motion, the right should rotates forward for additional body velocit and mass.

As the arm accelerates, you may think, reaches its maximum speed at the point impact. Wrong. In the case of the good hi ters, the arm reaches maximum velocit when it's about in the position seen in Figur 5 and then, believe it or not, the arm begi to slow down. The head of the mallet, on th other hand, *because* of the deceleration of th arm, rapidly accelerates until the point impact. The deceleration of the arm is sligh and probably not even perceptible to a hitt (Gracida wasn't aware of it), but it's the se ond secret to good hitting.

In numbers, here is how Gracida's stro looks: His wrist reached a maximum velocit of 29 mph and at the same point the mall head traveled at 54 mph (a point on the ci cumference of a circle travels faster than point closer to its center). At impact his wri had slowed to 24 mph — a reduction of percent in velocity — while the mallet hea reached a velocity of 134 mph — a 148 pe cent increase from the instant his arm beg to slow down.

I'd like to dwell on this phenomenon for moment to underline its importance, mo proof of which we'll see when we exami Connell's stroke, which doesn't exhibit th critical pattern.

An image or two first. You stand by t river with your fishing rod, you bring the r back, rapidly throw it forward and th check your motion. Hook and sinker ha thus been propelled to cover the desired di tance. The mallet is not unlike a fishing ro Or, when you are traveling in a car and y put your foot on the brake, the car slo down but your body wants to continue mo ing forward. The physical principle of inert

These charts show the resultant velocities of the four critical points of the body: right hand, elbow, wrist and shoulder. The peaks represent higher velocities and 0.0 on the X axis represents the point of impact. Note how smooth Gracida's motions are and how much more erratic (in the eyes of the computer, at least) Connell's are. El-Effendi's motions are also very rhythmic except for his right shoulder, which he uses especially as he brings his arm down.

The other thing to look for is the changing velocity of the arm along the four points in relation to the point of impact. In the cases of Gracida and el-Effendi there is a rapid deceleration *before* impact, while Connell's hand doesn't slow *until* impact. The curves show a slight deceleration in the elbow and wrist, but that occurs only because of the accelerating hand, causing a net effect of no acceleration at all.

MAY, 1985

Analysis of the polo swing
http://arielnet.com/ref/go/2797

sess certain gait characteristics that are essential for superior performance?"

Together with several scientists from Spain, Clayton videotaped the most difficult of dressage movements: the "piaffe", a stylized trot in place, and the "passage", a very slow trot with an exaggerated elevation of the limbs. Olympic contenders must execute two "passage-piaffe-passage" sequences in the center of the arena and their performances of these movements accounts for 25% of their total marks. Three cameras were set along the edge of the arena to capture a minimum of six steps of passage preceding and following the piaffe, the piaffe itself, and the transitions between them.

Ms. Clayton also positioned three video cameras at the show jumping event to record world-class horses as they approached and cleared a specific obstacle. The motion included the final approach stride, take off, airborne phase, landing and the first stride as the horse ran to the next obstacle in the course (the recovery stride).

Ms. Clayton reported that winning jumpers at the 1992 Olympics differed in their recovery strides after negotiating a fence compared to their competitors. Successful horses had briefer time intervals between hind limb impacts and shorter time intervals between leading forelimb contact with the ground and the initiation of the next stride. Fewer penalties were garnered by horses whose hind limbs were planted closer together during takeoff and whose forelimbs landed nearer each other.

There are still some questions to answer before gait analysis can be used routinely to select the youngsters that may become stakes winners, futurity stars, or Olympic contenders, as well as identifying young horses that are structurally disadvantaged or poorly coordinated. It is generally accepted that an individual's inherited movement patterns can be enhanced by practice (your piano teacher didn't say "practice makes perfect" a million times for no reason). Those drills cause subtle refinements in your neuromuscular coordination to translate notes on a page to accurate movements of your fingers. Whether the same need for practice applies to horses has yet to be scientifically verified.

Researchers are scratching the surface to understand how much equine gait characteristics change over time due to training and/or maturity and which characteristics are reliable predictors of ability in a given sport. To complicate matters, the final performance is more than just the sum of the horse's innate talent and any improvements through training. It involves the ability of the rider or trainer, the nature of the working surface, the overall health of the horse, and that elusive, unquantifiable quality, heart.

Nevertheless, as both a performance predictor and diagnostic aid, gait analysis holds great promise. Whether comparing limb to limb, before and after, your horse to a superstar, your horse to a composite "ideal", or your horse to the norm, its advantages are clear: gait analysis is noninvasive (no wires or sensors attached to the subject; skin markers optional) and flexible (cameras are portable and can be set up just about anywhere from the clinical setting to the competition arena).

The biomechanical analysis that Ms. Clayton performed on the various equine events held promise for use in several areas. She suggested that horses in rehabilitation may benefit from gait analysis. Just as physical therapists for human patients could utilize biomechanics analysis to evaluate a patient, a clinician could compare a horse's movement before and after treatment to help evaluate its effectiveness.

At one end of the gait analysis spectrum are the talented horses that perform in a superior manner. Their abilities to move more economically or efficiently than their less gifted peers may be what separates them from their peers during competitions. A superstar appears only rarely, but when they do, the contrast can be spectacular as in the classic cases of Secretariat or Spectacular Bid. The advantage of biomechanical analysis is that without invasive procedures or examination of bloodline records, good horses can be identified.

From a quantification point of view, Ms. Clayton suggested that the question of, “is this horse lame?” should be rephrased as, “how lame is this horse?” A permanent record of a film or tape can be replayed repeatedly. The films would form a baseline for comparison or stored as an archive. This stored data can be analyzed and presented in innumerable ways to give a clearer picture of what is happening currently, compared to previous movement patterns, or relative to other horses.

We were also involved in analysis of polo swings and contributed to the design of the polo stick. Our polo project was also in Florida. The question we were asked involved the polo stick or “mallet”. Our results were surprising since we discovered that the rider actually hits the ground behind the ball rather than the ball itself. This was the same phenomenon that we had observed with ice hockey. Essentially, these two sports create situations where they “load” the stick with energy which is released when the stick “snaps” forward. A similar situation occurs when snapping the fingers. The middle finger is “pushed” firmly against the thumb until the thumb slides and “snaps”. Therefore, we found that finger snapping, ice hockey hits, and polo strikes use the same loading technique.

To summarize, the same system that we used to maximize the performance of race horses were applied to Olympic horse athletes to achieve their gold medals. Prior to these projects with horses, our experiences had been with two legged athletes with the notable exception of Daisy the monkey. With these experiences working with exceptionally talented racehorses and equally skilled Olympic horses, we had again demonstrated our company motto: “If it moves, we can measure it.”