

# The Relationship Between Anteroposterior Pelvic Tilt and Trail Leg Recovery: An Accelerometer Study



## Medical Science

**KEYWORDS:** Sprint Speed, Accelerometer, Pelvic Tilt

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### ABSTRACT

*It is the role of the coach/trainer to choose (recruit) athletes with the most potential as a sprinter. One such measure of potential is leg speed, more aptly leg turnover. Through the use of an accelerometer, this investigation explored the role of pelvic tilt and its relationship to trail leg recovery, which in turn governs stride turnover. Ten male NCAA varsity track and field athletes performed a trail leg recovery three times at each pelvic tilt position, 55 degrees and 70 degrees. Using a t-test to compare the difference between the mean time for trail leg recovery at 55 degrees (Normal tilt) and the time required for trail leg recovery at 70 degrees, it was found that trail leg recovery speed was faster in a pelvis position of 70 degrees of tilt. These findings were found to be statistically significant at the 0.01 confidence level.*

### INTRODUCTION

It is the role of the coach/trainer to choose (recruit) the athlete with the most ideal characteristics and potential as a sprinter. One such measure of potential is leg speed, more aptly leg turnover. Leg turnover is the ability to facilitate a rapid succession of strides. The most substantial phase of striding that affects the speed of "turn over" is that of trail leg recovery. This investigation explored the role of pelvic tilt and its relationship to trail leg recovery, which in turn governs stride turnover, which is a major determining factor of sprint speed.

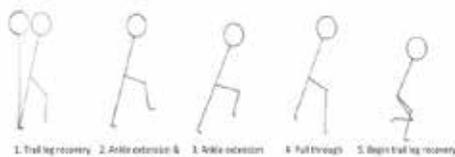
### Statement of the Problem

The purpose of this study was to determine the effect of increased antero-posterior pelvic tilt (>60°) upon trail leg recovery speed.

### REVIEW OF RELATED LITERATURE

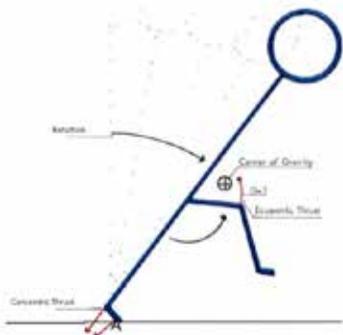
Tom Ecker, in this book *Track and Field: Through Dynamics* points out that success in sprinting is dependent upon two factors: stride length and stride frequency (Ecker, 1976). The running stride consists of a series of leaps, each of which is made up of four segments or phases. (Figure 1)

Figure 1 Stride Phases



The first phase of trail leg recovery accomplishes this by bringing about a change in angular momentum ( $I\omega$ ). This angular momentum causes an eccentric thrust which sets the body into a rotation about the contact foot which extends causing a concentric thrust, bringing about linear motion (acceleration). (Figure 2)

Figure 2 Stride Angular Momentum



The second and third phases consist of ankle extension and reaching with the foreleg, which cause the actual propulsion or drive forward. The pull through which is the fourth phase, acts as a fulcrum enabling the body to rotate around it as the axis point. It is the stride frequency, or more explicitly, the ability to recover the trail leg quickly into a position that will facilitate the subsequent stride reach and pull through that this investigation shall explore.

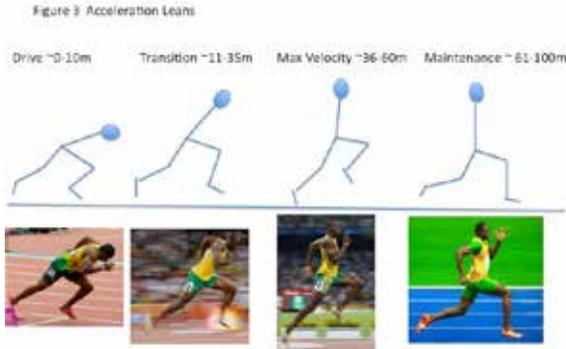
The muscles that act upon the femur to produce thigh flexion, i.e., trail leg recovery are: adductor magnus, pecteneus, adductor brevis, adductor longus, rectus femoris, sartorius, tensor fascia latae, psoas major, and the iliacus (Tortora and Anagnostakos, 1975). Howel (1965) in this research and subsequent work with speed in animals notes that in reference to limb function and the mechanical influences working upon them, that the limb is in reality a compound lever whose action is too complicated in practice for manual mathematical determination of the results. He continues by noting that even in the case of a single limb joint, although it is easy to compute the effect that a particular muscle of given power will have, it is painstakingly difficult to determine the group action of these muscles at high speed (Howel, 1965). But it is feasible to get some understanding of the principles involved.

Considered as a single lever or unjointed crutch, the variable factors, concerned, reduced to their simplest terms, comprise the actual strength of force as well as the point where it is applied, length of the limb, and its weight, particularly of its distal part. Howel (1965) found that if the power or force was applied more distally, (from the axis) the action of the lever will be slower but of greater strength, (Newton's II Law). Likewise, by raising the insertion (the power arm) or actually shortening the muscle, the resulting action will be of increased speed, but of decreased strength. As such, by increasing the limb length the stride will increase but the power will decrease. Howel in his studies notes that the exact position of muscle insertions upon the leg of a cursorial animal varies in accordance with other cursorial specializations. But that relatively higher insertions reduce strength but raise the center of gravity, reduce the moment of inertia, and quicken the action (Howel, 1965).

While one may not readily be available to surgically alter the insertions of the muscles effecting thigh flexion, the power arm (force arm) may be altered with the knowledge and proper implementation of kinesiological applications, and pelvifemoral measures.

For many years, coaches and trainers have been looking for athletes, sprinters in particular that fit the mold of the typical sprint somatotype. There have been a number of studies com-

pleted on the ideal sprinter body contour. These studies found that there was a high degree of correlation between a body contour of this type (increased pelvic tilt) in terms of two things, vertical jump (a measure of leg power) and, speed (the ability to sprint). It has been theorized that this body contour puts the body into a more ideal position and thus more adaptable to the sprinting motion, which utilizes a slight forward lean (Miller, 1979). During the phases of acceleration, the body is leaning forward. Once maximum acceleration is reached, the body is straight up and down (vertical) (Ecker, 1976). (see Figure 3)

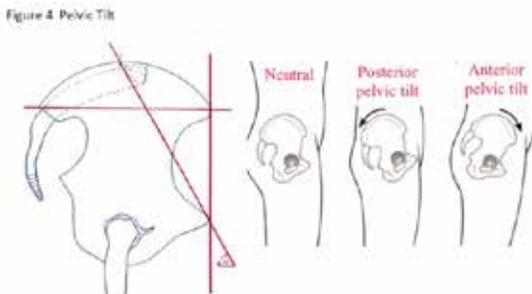


Steve Miller, NCAA Championship track coach notes that when the "pelvis is tilted forward, the body is in more of a natural alignment for the running position itself, it seems to indicate that either it is easier to begin acceleration or acceleration is easier to maintain, and this assists in acceleration itself" (Miller, 1979).

One common measure of body contour is pelvic tilt. The subsequent sections of this investigation will show that pelvic tilt is a valid indicator of potential trail leg recovery speed.

The normal anteroposterior tilt of the pelvis on the hip joints ranges from fifty to sixty degrees, although most authors quote the latter. Lowman, Colestock, and Cooper (1937) in their book *Corrective Physical Education for Groups* cite Testut's measures of anteroposterior tilt of fifty-four degrees for males and fifty-eight degrees for females.

To determine the degree of pelvic tilt, one of several methods may be used; the first of which compares the position of the anterosuperior spine of the ilium with the symphysis pubis. In normal pelvic alignment, these two landmarks fall on the same vertical plane. If the anterosuperior spine of the ilium falls in a plane anterior to the line of the symphysis pubis, the athlete has a condition described as forward (anterior) pelvic tilt, whereas the reverse would be described as backward (posterior) pelvic tilt (Arnheim, Auxter, and Crowe, 1977). The second measure of determining tilt, consists of locating a line from the posterior superior spine of the fifth lumbar or top of the sacrum to the upper border of the symphysis. The relation of this line to horizontal (a straight line drawn between the hip joints) gives the degree of tilt (Lowman, Colestock, and Cooper, 1937). (see Figure 4)

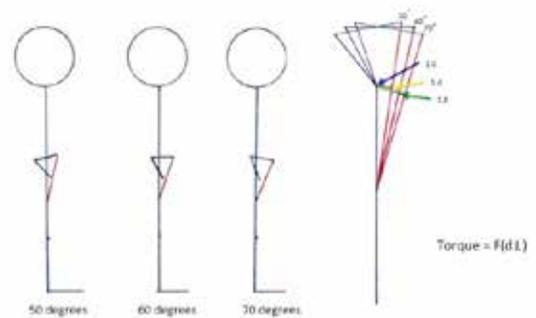


As Howel pointed out, it is difficult to accurately determine the roles of individual muscles without the aid of computer analysis.

It is acceptable, however, to consider the joint as a single lever with the muscle group action as a single propulsive force. The type of lever that will be presented here to symbolize the hip joint is a third class simple lever (Type III). The Type III lever, as Krause and Barham note in their book *Mechanical Foundations of Human Motion*, is a speed-favoring lever, and as such is capable of reaching high velocities from a relatively low level of force applied (Krause and Barham, 1975).

By utilizing sound physical laws of motion such as Newton's II, vector resolution and componential analysis to calculate the torques and forces applied to the type II lever, ideal pelvic tilt can be calculated to ensure energy conservation and maintain maximal acceleration of the leg. Figure 5 illustrates the different pelvic tilt angles of 70 degrees, 60 degrees (normal), and of 50 degrees, and their approximate lines of muscle application. Figure 6 illustrates the resolution of torque and the corresponding force arms for each degree of pelvic tilt 70, 60, and 50 degrees. By applying the formula  $T = F(d)$ , where the magnitude of the torque is defined as the applied force multiplied by the perpendicular distance of the force from the center of rotation. The distance of the force from the center of rotation, distance (d) is sometimes called the lever arm or force arm causing the angular motion, and is measured from the axis at right angles to the direction of the force applied (Krause and Barham, 1975).

Figure 5: Pelvic Tilt Angles and Force Arm Distances



As Figure 5 illustrates, the greater the pelvic tilt, the longer the force arm. If a force of 5 lbs. is applied to each lever, the resulting torque for each of the pelvic angles would be 5 lbs. for 50 degrees, (5 x 1.0), 7 lbs. for 60 degrees (5 x 1.4), 9 lbs. for a pelvic tilt of 70 degrees (5 x 1.8). What this means in terms of athletic application is that an athlete with a pelvic tilt of 70 degrees would have to impart only 55 percent of the force needed by an athlete with a pelvic tilt of 50 degrees, to result in the same amount of torque. Thus an athlete is able to expend less energy to accomplish the same torque, as well as having the potential to apply almost twice the torque, resulting in an increase in acceleration of the limb.

**PROCEDURES**

**Selection of Subjects**

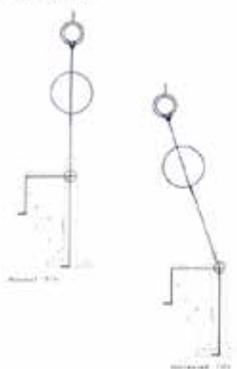
The subjects used in this study consisted of ten male NCAA varsity track and field athletes who were attending California Polytechnic State University. Their ages ranged from eighteen to twenty-six, and their sprinting experience varied. The group represented a heterogeneous collection of heights, weights, ages, and musculature.

**Testing Procedures**

Prior to testing, all subjects were oriented to the purpose and procedures to be followed in the study. Each subject was familiarized with the Orthotron and the thigh flexion attachments, which were adjusted so that the axis of the Orthotron swing arm and the hip joint of the subject were aligned. The Orthotron served only as a swing arm. No resistance was applied.

Each subject was instructed to step down on a predetermined starting point so that the entire foot was flat on the floor. The subject was then instructed to bring his thigh to a position parallel with the floor as rapidly as possible. (see Figure 6)

Figure 6 Orthotron testing positions



Each subject was instructed to perform his trail leg recovery three times in each position, the first position with the pelvis in 55 degrees of anteroposterior tilt, and the second position with the pelvis in 70 degrees of tilt. The third trial for each position was photographed and recorded for comparison.

An accelerometer was attached to a small aluminum plate and held firmly to the subjects' thigh with a Velcro strap. The subject's thigh was attached to the Orthotron swing arm with a padded thigh flexion attachment strap. The accelerometer was connected by a coaxial cable to a Tektronix T912 10 MHz storage oscilloscope upon which the acceleration of the limb produced an acceleration curve that was recorded for comparison.

The viewing screen of the oscilloscope was divided into sectional grids from which, once the speed through each grid was selected, the impulse time could be accurately read. The speed was set at 50 milliseconds each division. The voltage per division was set at 0.2 volts/division.

The triggering system was set at the internal source setting and at the normal mode. With this setting, the acceleration curve was recorded the instant any movement was initiated by the subject. The deceleration peak was initiated by a stop mechanism designed specifically for this investigation by the author. The pelvic tilt angle was measured with the aid of Johnson tilt-o-meter, also designed by the author.

**ANALYSIS AND INTERPRETATION OF THE DATA**

**Statistical Analysis**

A validity test was run prior to mass subject testing to determine whether a change in position (from 55 degrees to 70 degrees) would bring about a significant change in trail leg recovery time. A single subject conducted a series of ten measures at each position. If the mean score difference between 55 degrees and 70 degrees was greater than one standard deviation, then it was assumed that the difference between the means was brought about by the change of position, and the test was valid.

The mean score for the 55-degree trials was found to be 5.94 grids with a standard deviation of 0.15. Whereas the mean score for the 70-degree trials was found to be 5.68 grids with a standard deviation of 0.16. Thus, with a difference between the means of 0.26, it was determined that the change of position from 55 to 70 degrees of tilt was the cause for the change in the time of trail leg recovery.

Statistical computations consisted of applying the t-test for two dependent means where the variances are assumed to be equal.

The difference between the means was found to be significant at the 0.01 level of significance. Table 1 presents a tabular analysis of the statistical results.

**Table 1 t-Test**

Subject	(x) 55 °	(y) 70 °	(x-y)= (d) difference	(d) <sup>2</sup> difference
1	5.60	5.80	.20	0.4000
2	6.30	5.64	-0.66	0.4356
3	5.64	5.60	-0.04	0.0016
4	6.44	6.00	-0.44	0.1936
5	5.90	6.00	0.10	0.0100
6	5.80	6.20	0.40	0.1600
7	6.40	6.19	-0.21	0.0441
8	5.60	5.50	-0.10	0.0100
9	6.20	6.15	-0.05	0.0025
10	6.15	6.24	0.09	0.0081
N=10	Σ x = 60.03	Σ y = 59.32	Σ d =0.71	Σ d <sup>2</sup> =0.9055
	$\bar{X}$ =6.003	$\bar{Y}$ = 5.932	$\bar{d}$ =0.71	
	$\sigma_x$ = 0.334	$\sigma_y$ = 0.276		
	$\sigma_x^2$ = 0.1117	$\sigma_y^2$ = 0.0766		

**SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS**

**Summary**

The purpose of this study was to determine whether an increased anteroposterior pelvic tilt (70 degrees) would facilitate a decrease in trail leg recovery time. It was hypothesized that by increasing the anteroposterior pelvic tilt from the normal of 55 to 60 degrees would bring about an increase in the length of the force arm, and thus bring about an increase in trail leg recovery speed.

A review of the literature revealed that sprint speed is dependent upon two factors: stride length and stride frequency. It was the stride frequency, or more explicitly, the ability to recover the trail leg quickly into a position that would facilitate the subsequent stride reach and pull through that was explored by this investigation.

To facilitate this investigation several new devices were designed and constructed by the author, among which were the Johnson Tilt-o-meter and the Orthotron stop device. Also the use of an accelerometer on a human subject may be a breakthrough, for no literature reviewed employed this instrument for biomechanical research on athletes. This is primarily due to its high cost, being in the tens of thousands of dollars. Because of its size and weight, its applications in the area of bioengineering and biomechanics are endless.

Using a t-test to compare the difference between the mean time for trail leg recovery at 55 degrees (Normal tilt) and the time required for trail leg recovery at 70 degrees, it was found that trail leg recovery speed was faster in a pelvis position of 70 degrees of tilt. These findings were found to be statistically significant at the 0.01 confidence level.

In the writer's opinion what these findings mean is that a person with a forward pelvic tilt (>55°) is better suited for an event that requires a quick trail leg recovery and/or explosive speed, such as sprinting and hurdling.

**Recommendations for Further Study**

- A larger sample should be tested.
- More trials should be given and recorded for each position.
- Velocity curves should be investigated and computed by taking the integral of the acceleration curves.
- An investigation into the shape of the acceleration curves and event types should be performed, i.e., peak velocity and position.

### Recommendations to Coaches and Athletes

By determining the position in which an athlete is best able to achieve maximal acceleration and reach peak velocity, the coach is better able to determine the type of event which the athlete is best suited for, i.e., a high peak acceleration at 70 degrees of tilt, and a low peak acceleration at 55 degrees may suggest that the athlete is better suited for an event in which the pelvis is in a position of 70 degrees of anteroposterior tilt, like sprinting or hurdling, whereas the reverse may be true of a distance or (non-sprint) runner.

### Epilogue

The accelerometer was originally developed to support the test and evaluation (T&E) community. This group, with their aerospace and military specifications and budgets, drove the market for 50-60 years. In 2015, multi-axial accelerometers and gyroscopes are found in cellphones, auto airbags and even children's toys. What was once a \$100,000 laboratory grade test instrument is now a < \$1.00 circuit board element found in our everyday electronics. Today the ease with which one can capture human movement with today's iPhone (with its three embedded triaxial accelerometers), or by the application of postage stamp size sensors offer enormous opportunity for previously arduous and complicated investigation, unlocking the potential for a much greater understanding of human movement and the elements that lead to peak performance.

This study *The Relationship Between Anteroposterior Pelvic Tilt and Trail Leg Recovery: An Accelerometer Study*, was initially produced as an unpublished undergraduate thesis in 1980 and is published here to add to the historical record regarding accelerometer use as a tool for biomechanical analysis in humans.

• Time is given in grids  $1.0 = (1.0) \times (50 \text{ ms})$

Ho:  $\mu_{55} = \mu_{70}$

Ha:  $\mu_{55} \neq \mu_{70}$

df=9

tcalc= 9.531\*

tcrit=2.82

=.01

\*The mean time of the 55 degree trials was significantly slower than the time of the trials with the pelvis at 70 degrees at  $\alpha = .01$

## REFERENCE

- Arnheim, D. D., Auxter, D., and Crowe, W. C. (1977) *Principles and Methods of Adapted Physical Education and Recreation*. Saint Louis: The C.V. Mosby Company. | Ecker, T. (1976) *Track and Field Techniques Through Dynamics*. Los Altos, California: Tafnews Press. | Howel, A. B. (1965) *Speed in Animals: Their Specialization For Running and Leaping*. New York: Hafner Publishing Co. | Krause, J. V. and Barham, J. N. (1975) *The Mechanical Foundations of Human Motion*. Saint Louis: The C. V. Mosby Company. | Lowman, C. L., Colestock, C., and Cooper, H. (1937) *Corrective Physical Education for Groups*. New York: A. S. Barnes and Company. | Miller, S. (1979) Personal Interview, Head Track and Field Coach, California Polytechnic State University, San Luis Obispo, California., November 20, 1979. | Tortora, G. J. and Anagnostakos, N. P. (1975) *Principles of Anatomy and Physiology*. San Francisco, California: Canfield Press, pp. 192-223. |