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A Biomechanical Analysis of Steeplechase Barrier Clearance Techniques: Hurdle and Step-On

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A BIOMECHANICAL ANALYSIS OF STEEPLECHASE BARRIER CLEARANCE TECHNIQUES: HURDLE AND STEP-ON

by

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A BIOMECHANICAL ANALYSIS OF STEEPLECHASE BARRIER CLEARANCE TECHNIQUES: HURDLE AND STEP-ON

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The problem investigated was to compare the kinematic variables associated with the conventional hurdle technique and the step-on technique used in barrier clearance in the steeplechase. Twenty NCAA Division 1 male track and field athletes were filmed during competition in the steeplechase event of the Mid-American Conference Track and Field Championships, May, 1995.

Five ANOVAs and descriptive statistics were used to compare the step-on technique and the hurdle technique. Descriptive statistics provided information for the dependent variables. Statistically significant differences ($p < .05$) were found for trajectory angle, initial horizontal velocity and final horizontal velocity. The step-on technique was found to be superior to the hurdle technique in all cases. Suggestions were made for applying these findings in pragmatic settings.

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This thesis is dedicated to the loving memory of my mother, Lynn D. Paschke, who passed away before she could see its completion or the completion of my graduate studies. Her faith and love for me knew no limits. Her impact on my life has been immeasurable.

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David G. Paschke

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CHAPTER I

INTRODUCTION

The steeplechase is often an neglected event due to its origins stemming from both track & field and cross country (Adams, 1979; Hartwick, 1981; Hessel, 1981; Wiger, 1979). Hartwick (1981) and Hessel (1981) noted that, in addition to its origin, other problems that contribute to the underdevelopment of the steeplechase event include: (a) the lack of proper track facilities equipped to conduct a steeplechase, (b) the lack of opportunities for steeplechasers to compete, and (c) the apparent lack of athletic and coaching interest in the event at the high school and collegiate levels. Hessel (1981) suggested that "...the steeplechasers in the U.S.A. lack technique and confidence regarding barrier strategy. This poor technique is often a result of coaches and athletes not putting emphasis on proper hurdling technique (p.41)." Although many authors have contributed research related to proper and efficient hurdle technique, most research has centered on the shorter sprint hurdle events.

However, the 3,000 meter distance and the encountering of 35 barriers, including 7 water barriers, adds an element of fatigue to the steeplechase not usually associated with the other hurdling events (Benson, 1993). To maximize efficiency most steeplechasers use a combination of two techniques in clearing the barriers. If the barrier is not a water barrier a conventional hurdle technique is most often used. The athlete vaults the barrier in a style similar to one used by an intermediate hurdler thus the barrier is cleared without contact. If the barrier is a water barrier, the athlete will employ a technique whereby they land on top of the barrier and push off from that point to gain extra momentum and leverage in order to clear as much of the water pit as possible.

Statement of the Problem

The problem of this study was to compare the kinematic variables associated with the conventional hurdle technique and the step-on technique used in barrier clearance in the steeplechase. Specifically, the study compared phases of the two techniques with their corresponding changes in kinematic variables.

Need for the Study

Few biomechanical studies have been conducted investigating the differences between the hurdle technique and the step-on technique used for barrier clearance in the steeplechase track & field event. The results of this study should provide information to assist track and field coaches in the teaching and the understanding of steeplechase barrier clearance techniques.

Delimitations

The study was delimited to the following:

1. NCAA Division I athletes participating in the steeplechase event in the 1995 Mid American Conference Track & Field Championships served as subjects.

2. The study included only those athletes who used a conventional hurdle barrier clearance technique or a step-on barrier clearance technique, or a combination of both techniques.

3. A two dimensional cinemagraphical analysis was used to analyze the data.

4. The data analysis was executed by using Peak Technology 5.2 software (Englewood, CO).

5. The motion analyzed was restricted to that which occurred at the time of take-off before barrier clearance until time of landing plus 0.085 s after landing.

6. The dependent variables were kinematic quantities, displacement, time, and velocity.

Limitations

The study was limited to the following:

1. The environmental conditions that existed on the day of filming could not be controlled.

2. The subjects were members of invited track & field teams for the competitions and as such are considered an opportunistic sample.

3. The movements and positioning of the athletes were not controlled as they cleared the barriers because of the competition setting. This resulted in only the athlete closest to the camera being a suitable subject for analysis.

Hypotheses

It was hypothesized that when the step-on technique was used there would be a greater elevation in the athletes' center of gravity, an increase in vertical displacement, a greater time-lag per barrier, and a shorter approach phase than when the hurdle technique was used.

Definition of Terms

The following terms are used throughout the research:

1. Acceleration is the rate at which the velocity changes with respect to time (Hay, 1993).

2. Push-off refers to the point at which the foot is no longer in contact with the barrier.

3. Touchdown refers to the moment the foot re-establishes contact with the track.

4. Toe-off refers to the point following foot strike where the toe is not in contact with the ground.

5. Center of gravity (COG) is the point of application of gravity's force on a mass (Kreighbaum & Barthels, 1990).

CHAPTER II

REVIEW OF LITERATURE

Introduction

The steeplechase originated in 1850, but it wasn't until 1900 that it was contested as an Olympic event (Adams, 1979; Hartwick, 1981; Wiger, 1979). Since then few biomechanical studies have considered the technical aspects of the steeplechase (Hessel, 1981). This may in part be due to many people thinking that the event is primarily a middle distance or distance event (Adams, 1979; Bowerman, 1985). However, others place a greater importance on proper run training and hurdle technique development (Alford, 1979; Benson, 1993; Hartwick, 1981; Hislop, 1985). Alford (1979) stated that:

When one considers that the athlete, often hampered by the maneuvers of other runners and fighting to resist fatigue, has to clear 28 hurdles in the course of a 3,000 meter race, there should be no need to remind him of the importance of acquiring a really sound hurdling technique (p. 2480).

Steeplechase Technique

In considering technique development, it is widely regarded that the steeplechase athlete should consider the form of the 400 meter hurdler as a basis for hurdling technique (Alford, 1979; Alford, 1980; Baeta, 1992; Benson, 1993). However, the same mechanics that would apply to the 400 meter hurdler do not have a direct parallel in the steeplechase athlete. The steeplechase athlete, for example, is moving at a slower rate of speed and for at least part of the race is hurdling in a crowd. Both of these factors will change how an athlete will negotiate a steeplechase barrier and are inherent to the steeplechase event only.

Approach Phase

The objective of this phase is to prepare the body for barrier clearance if the hurdle technique is employed or to prepare the body for contact with the barrier if the step-on technique is employed. The trunk will have a slightly more forward lean than in a normal running stride and the lead leg will be moved more quickly and higher (Alford, 1979).

Barrier Phase

The barrier phase occurs only when the step-on technique is employed. Dyson (1977) described the technique of the athlete as follows:

> In taking the water jump the skilled performer speeds up several strides before take-off and gauges this spot without chopping or changing stride. For it is essential to accelerate beyond average racing speed in order to negotiate this wide (12ft, 3.66m) obstacle. He then springs on to the rail, meeting it just above the hollow of the front foot. Now, by maintaining a crouch position over a bent leg, he reduces the body's moment of inertia about the supporting foot, thus pivoting quickly and easily forward. The leg thrust (primarily horizontal) is powerfully yet smoothly coordinated. The trunk straightens, the rear leg is kept trailing momentarily and the arms are raised laterally for balance correction. The landing (about 2ft (0.6m) from the water's edge) is made on one foot and the first stride is taken on to dry land (pp. 160-161).
>
> The pivot and the push off are performed to gain the necessary velocity and trajectory in order to clear the water pit (Fix & Smith, 1984).

Clearance Phase

Many authors stated that the technique used in the clearance phase should be very similar to that used by a 400 meter intermediate hurdler (Adams, 1979; Alford, 1979; Baeta, 1992; Benson, 1993; Griak, 1982). Alford (1980) stated that the "essential thing...is to get the leading leg up and across the hurdle rail as far in advance of the other leg as possible (p. 2481)."

Basic Technique Considerations

Dapena and McDonald (1991) stated that "hurdlers face two main problems: (a) they lose forward speed during the take-off of the hurdle stride, and (b) they have difficulty recovering the lost speed after they land (p. 3710)." Therefore, speed losses can be minimized by reducing time spent during take-off and/or by improving the recovery of speed after landing. Speed losses during the take-off period can be kept low if the athlete keeps a low path of travel while going over the hurdle. An active landing, one that places the body in a specific position, will help the athlete recover lost forward speed after hurdle clearance. These same theories apply to all types of hurdling (110 meter, 400 meter, steeplechase).

Related Literature

Scientific study of the steeplechase has not been wide spread. Most authors, in considering steeplechase technique, refer the athlete to the technique used in the 400 meter intermediate hurdle event. In turn, the authors of text concerning the 400 meter intermediate hurdle event refer to technique used by the 100 meter high hurdle athletes. Each of these, the 400 meter intermediate hurdles and the 110 meter high hurdles, will be discussed separately.

The 400 Meter Intermediate Hurdles

The 400 meter intermediate hurdle event presents an unique challenge to an athlete. It is considered a sprint event by virtue of its distance, requires great technical prowess due to running the barriers, and spatial awareness relative to positioning of the body for barrier clearance and hurdling on curves. The main concerns of an athlete competing in this event are those of maintaining a regular number of strides between hurdles and accounting for "...the effect of centrifugal force which tends to pull the runner outwards (Mitchell, 1982)." The steeplechase athlete doesn't have to pay great attention to either of these due to the distance between the barriers and the slower speed of the race (centrifugal forces are not as great).

The 400 meter intermediate hurdler also may not have to raise their COG to clear a barrier. This helps to keep vertical velocity close to that found in normal sprinting and reduces horizontal velocity very little. This helps to keep time spent over the hurdle (in air) to a minimum. This minimal change in COG also eliminates the need for the pronounced forward lean of the trunk as found in the 110 meter high hurdler (Ecker, 1985).

The 110 Meter High Hurdles

The 110 meter hurdle race is considered a sprint event and hence the athletes competing in this event frequently have a sprinting background. "The biomechanics of hurdle clearance must be seen in the context of the whole event's demand for compromise of an individual athlete's normal sprinting action (Dick, 1982, p. 34)."

Increasing a runner's speed is of great importance. Changes in speed can only be achieved by increasing stride length or stride frequency. A change in a hurdler's stride length (at the 110 meter distance) would occur between hurdles and would have a negative result. Stride frequency, according to Ecker (1985), "...is an inborn characteristic which cannot be improved appreciably in the mature athlete (p. 91)." It has also been stated that a perfect stride in hurdling is very difficult unless the athlete is the perfect size for the distance to be covered (Smith, 1979). Stride pattern changes in the inter-hurdle strides of an advanced athlete may put him in an awkward position for negotiating the hurdle. Therefore, Ecker (1985) stated that "...improved clearance technique is the most important factor in the improvement of hurdle times (p. 92)."

Summary

This chapter should be used as a guideline to aid the reader and researcher in understanding the kinematics that occur during steeplechase barrier clearance. It is important to note that most authors placed a greater importance on the cardiovascular training of steeplechase athletes than on technique development. Those authors that examined technique development most often referred to standard hurdle technique as the basis for proper technique development.

CHAPTER III

METHODS AND PROCEDURES

Introduction

The 3,000 meter steeplechase event in track and field incorporates the skills of hurdling and jumping, but is most often considered, by virtue of its distance, a middle-distance running event. The purpose of this research was to compare the mechanics associated with the hurdle clearance technique and the step-on technique used in the steeplechase. This chapter is organized into the following categories: (a) subjects, (b) instrumentation, (c) filming procedures, (d) data acquisition, (e) research design, and (f) analysis of data.

Subjects

The 20 subjects participating in this study were NCAA Division I male track and field athletes. The athletes were filmed during competition in the steeplechase event of the Mid American Conference Track and Field Championships, May 20, 1995.

Instrumentation

The following instruments were utilized in the filming and data collection procedures for this study:

1. A Panasonic AG450, SVHS, video camera (Panasonic Industrial Co., Seacaucus, NJ) was used to film the water barrier.

2. A Panasonic WV-D5100HS video camera (Panasonic Industrial Co., Seacaucus, NJ) was used to film the land barrier.

3. A Tenex DX-2, 486, computer (Tenex, Mishawaka, IN) was used to run the software needed to digitize the video tape and calculate the kinematic variables.

4. Video and Analog Motion Measurement System (PEAK), version 5.2, (Peak Performance Technologies, Inc., Englewood, CO) was interfaced to the Tenex and was used to digitize the video tapes and calculate the kinematic variables.

Filming Procedures

The athletes were filmed during competition in the steeplechase event of the Mid American Conference Track and Field Championships, May 20, 1995. The meet was held at

Western Michigan University's 400 meter outdoor track on a Martin surface (Hunt Valley, MD).

The cameras were set at 60 frames per second at a distance of 40 ft. Cameras were positioned parallel to the steeplechase barriers and perpendicular to the path of the athletes. A meter stick was filmed before the start of the race to serve as a scaling factor in the digitizing process. Fugi SVHS ST-120 (Fuji Photo Film Co., Tokyo, Japan) was used to record the motion in both cameras.

Data Acquisition

The following anatomical surface features assisted the researchers in defining 14 body segments: (a) distal end of foot, (b) medial malleolus, (c) center of knee joint, (d) head of greater trochanter of femur, (e) distal end of hand, (f) styloid process, (g) center of elbow joint, (h) acromion process, (i) top of sternal notch, (j) tragus of ear, (k) top of head, and (l) crotch. Both the left and right sides of the body were digitized.

The film analysis, digitizing process, was started 0.085 s before contact of the takeoff foot with the ground, prior to the barrier clearance. Digitizing ended 0.085 s after push-off of the lead foot, following barrier clearance. All pictures/frames between the starting point and the ending point of the analysis were digitized. This process was repeated for all analyses. The digitizing processes provided X and Y coordinates used by the PEAK System to calculate displacement, velocity, and COG data.

Research Design

Phases of Motion

Each technique was broken into phases for analysis. The phases for the hurdle technique are listed below:

1. The approach phase (A1) began 0.085 s before touchdown of the takeoff foot and ended when the take-off foot made contact with the ground.

2. The take-off braking phase (TB1) began when the take-off foot contacted the ground and ended when the COG was directly above the base of support.

3. The take-off push-off phase (TP1) began when the COG was directly above the base of support and ended when the take-off foot lost contact with the ground.

4. The flight phase (F1) began when the take-off foot lost contact with the ground and ended when the lead foot made contact with the ground on the other side of the barrier.

5. The landing braking phase (LB1) began with contact of the lead foot with the ground and ended when the COG was directly over the base of support (foot).

6. The landing push-off phase (LP1) began when the COG was directly over the base of support and ended when the push-off foot lost contact with the ground.

7. The acceleration phase (AX1) began at push-off of the lead foot and ended 0.085 s later.

The phases for the step-on technique were as follows:

1. The approach phase (A2) began 0.085 s before touchdown of the takeoff foot and ended when the take-off foot made contact with the ground.

2. The take-off braking phase (TB2) began when the take-off foot contacted the ground and ended when the COG was directly above the base of support.

3. The take-off push-off phase (TP2) began when the COG was directly above the base of support and ended when the take-off foot lost contact with the ground.

4. The pre-barrier flight phase (BF2.1) began when the take-off foot lost contact with the ground and ended when the lead foot made contact with the barrier.

5. The barrier braking phase (BB2) began with contact of the lead foot with the barrier and ended when the COG was directly over the base of support.

6. The barrier push-off phase (BP2) began when the COG was directly over the base of support and ended when the lead foot lost contact with the barrier.

7. The post-barrier flight phase (BF2.2) began when the lead foot lost contact with the barrier at push-off and ended when the opposite foot made contact with the ground.

8. The landing braking phase (LB2) began with contact of the opposite foot with the ground and ended when the COG was directly over the base of support (foot).

9. The landing push-off phase (LP2) began when the COG was directly over the base of support and ended when the push-off foot lost contact with the ground.

10. The acceleration phase (AX2) began at push-off of the foot and ended 0.085 s later.

Categorical Variables

The research design included two categorical variables, technique and flight time. The research investigated two techniques used to clear the steeplechase barriers; the hurdle technique and the step-on technique. Subjects were grouped according to flight time over the barriers. Two groups were established for each barrier technique, fast and slow. Inclusion in a group was based on the average linear velocity during the A1 and A2 phases for the hurdle and step-on techniques, respectively.

Dependent Variables

Kinematic variables were measured to aid in determining the differences between the hurdle technique and the step-on technique. Each of these variables was measured for each athlete. Following is a list of the variables measured and an explanation as to how each was calculated.

1. Initial horizontal velocity for the COG was calculated by measuring the distance covered by the COG from 0.085 s before take-off until the beginning of the take-off phase and then dividing by the time taken to cover that distance (Hay, 1993). This variable was measured in phases A1 and A2.

2. Final horizontal velocity for the COG was calculated by measuring the distance covered by the COG from the beginning of the acceleration phase until 0.085 s later. This sum was then divided by the time taken to cover that distance (Hay, 1993). This variable was measured in phases AX1 and AX2.

3. COG vertical displacement was calculated by subtracting the minimum Y value from the maximum Y value using the parameter vertical displacement of COG.

4. Support time for both techniques was calculated by counting the number of frames between touchdown and toe-off of the takeoff foot, then multiplying by 0.017 s.

5. Nonsupport time (time-lag) for the hurdle technique was calculated by counting the number of frames between toe-off of the takeoff foot and touchdown of the opposite foot and multiplying by 0.017 s.

6. Support time for the step-on technique at takeoff was calculated by counting the number of frames between touchdown and toe-off of the takeoff foot, then multiplying by 0.017 s.

7. Support time for the step-on technique while on the barrier was calculated by counting the number of frames from initial contact with the barrier to toe-off from the barrier, then multiplying by 0.017 s.

8. Angle of trajectory was determined by calculating the arc tangent of the angle formed by a horizontal line through the COG at toe-off of the takeoff phase with the path of the COG between toe-off and the next frame.

9. Trunk inclination was found by calculating the angle formed between the sternal notch and crotch with a vertical line through the crotch.

Analysis of Data

The kinematics were described by means and standard deviations. Each subject was randomly assigned and subsequently represented by a number at the time of digitizing. The descriptive statistics were calculated for each of the dependent variables. ANOVAs' were used to evaluate trajectory angle, velocities, and trunk inclination, between the two techniques. Subjects were grouped according to approach velocity. The means of the variables for the two techniques were tested for significantly statistical differences at a .05 level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The problem of this study was to compare kinematic variables used in two barrier clearance techniques in the steeplechase track and field event. Specifically, the conventional hurdle technique and the step-on technique were analyzed. Data were collected for the entire race. However, the data analyzed were only that which occurred during Laps 2 and 5 for the hurdle technique and during Lap 5 for the step-on technique. This provided a sufficient time frame for the initial pack of runners to spread out during the race so that a subject's performance in barrier clearance would be minimally influenced by the proximity of another athlete. All race participants data were collected and analyzed during these laps except those unidentifiable on the film.

All subjects were participating in the steeplechase event of the 1995 MAC Conference Track and Field Championships. As filming was performed during one, continuous running event, the two groupings of subjects were related in that the same subjects performed both techniques. However, a subject was not necessarily in the same speed group for both techniques. Therefore, the data was analyzed using techniques for independent groups

Results

ANOVA

Five ANOVAs were performed. The dependent variables for the ANOVAs were initial horizontal velocity, final horizontal velocity, COG vertical displacement, COG horizontal displacement, and trajectory angle. The ANOVA was comprised of one research variable and one grouping variable. The research variable was technique with two levels, the step-on technique and the hurdle technique. The grouping variable was speed with two levels, fast and slow.

Initial Horizontal Velocity

This ANOVA consisted of two main effects: (1) technique, the step-on technique and the hurdle technique; and (2) speed, fast and slow. The dependent variable was initial velocity. Refer to Table 1 for ANOVA results. A significant difference was found between the techniques, step-on (M = 5.61) and hurdle (M = 5.35), $F(1, 33) = 12.63$, $p = .00$. A significant difference was also found for the groups, fast (M = 5.76), and slow (M = 5.20), $F(1, 33) = 55.26$, $p = .00$. No significant interaction effect between speed and technique was found, $F(1, 33) = 1.00$, $p = .32$.

Table 1

ANOVA Summary Table for Initial Horizontal Velocity

Source	SS	df	MS	F	p
Technique (T)	0.70	1	0.70	12.63	.00
Group (G)	3.06	1	3.06	55.26	.00
T X G	0.01	1	0.01	1.00	.32
Error	1.83	33	0.06		

Final Horizontal Velocity

This ANOVA consisted of two main effects: (1) technique, the step-on technique and the hurdle technique; and (2) speed, fast and slow. The dependent variable was final velocity. Refer to Table 2 for ANOVA results. A significant difference was found between techniques, step-on (M = 5.23 m), and the hurdle technique (M = 4.13 m), $F(1, 33) = 20.48$. A significant difference existed between the fast group (M = 5.07 m) and the slow group (M = 4.36 m) group, $F(1, 33) = 9.42$, $p = .00$. No significant interaction effect between speed and technique was found, $F(1, 33) = 1.6$, $p > .05$.

Table 2

ANOVA Summary Table for Final Horizontal Velocity

Source	SS	df	MS	F	p
Technique (T)	11.6	1	11.6	20.48	.00
Group (G)	5.34	1	5.34	9.42	.00
T X G	1.19	1	1.19	2.10	.16
Error	18.69	33	0.57		

COG Vertical Displacement

This ANOVA consisted of two main effects: (1) technique, the step-on technique and the hurdle technique; and (2) speed, fast and slow. The dependent variable was COG vertical displacement. Refer to Table 3 for ANOVA results. A significant difference was found between the techniques, step-on (M = .51 m), and hurdle (M = .73 m), $F(1, 33) = 16.40$, $p = .00$. No significant difference was found for the groups, fast (M = .61 m) and slow (M = .61 m), $F(1, 33) = 0.01$, $p = .93$. No significant interaction effect between speed and technique was found, $F(1, 33) = 1.04$, $p = .31$.

Table 3

ANOVA Summary Table for COG Vertical Displacement

Source	SS	df	MS	F	p
Technique (T)	0.44	1	0.44	16.40	.00
Group (G)	0.00	1	0.00	0.01	.93
T X G	0.03	1	0.03	1.04	.31
Error	0.88	33	0.03		

COG Horizontal Displacement

This ANOVA consisted of two main effects: (1) technique, the step-on technique and the hurdle technique; and (2) speed, fast and slow. The dependent variable was COG vertical displacement. Refer to Table 3 for ANOVA results. A significant difference was found between the techniques, step-on (M = .51 m), and hurdle (M = .73 m), $F(1, 33)$ = 16.40, p = .00. No significant difference was found for the groups, fast (M = .61 m) and slow (M = .61 m), $F(1, 33)$ =

0.01, $p = .93$. No significant interaction effect between speed and technique was found, $F(1, 33) = 1.04$, $p = .31$.

Table 4

ANOVA Summary Table for COG Horizontal Displacement

Source	SS	df	MS	F	p
Technique (T)	5.53	1	5.53	31.97	.00
Group (G)	0.01	1	0.01	0.04	.84
T X G	0.06	1	0.06	0.33	.57
Error	5.71	33	0.17		

Trajectory Angle

This ANOVA consisted of two main effects: (1) technique, the step-on technique and the hurdle technique; and (2) speed, fast and slow. The dependent variable was trajectory angle. Refer to Table 5 for ANOVA results. A significant difference was found between the techniques, step-on ($M = 21.73°$), and hurdle ($M = 31.7°$), $F(1, 33) = 19.38$, $p = .00$. A significant difference was also found between the fast group ($M = 24.96°$) and the slow group ($M =$

27.72°) group, $F(1, 33) = 1.90$, $p = 0.18$. No significant interaction effect between speed and technique was found, $F(1, 33) = 0.25$, $p = .62$.

Table 5

ANOVA Summary Table for Trajectory Angle

Source	SS	df	MS	F	p
Technique (T)	929.93	1	929.93	19.38	.00
Group (G)	91.35	1	91.35	1.90	.18
T X G	12.04	1	12.04	0.25	.62
Error	1583.65	33	48.0		

Descriptive Statistics

Temporal and Vertical Displacement

Vertical Displacement

It was hypothesized that there would be an increase in vertical displacement when an athlete performed the step-on technique versus the hurdle technique. This hypothesis was supported. However, an increase in vertical displacement was not observed when comparisons were made between fast and slow groupings.

Table 6

Temporal Data

Land		Water	
Phase	Time	Phase	Time
A1	0.14 0.05	A2	0.09 0.02
TB1	0.08 0.04	TB2	0.09 0.03
TP1	0.09 0.02	TP2	0.10 0.03
		BF2.1	0.14 0.03
F1	0.51 0.04	BB2	0.14 0.02
		BP2	0.21 0.07
		BF2.2	0.32 0.05
		LB2	0.06 0.02
LP1	0.12 0.03	LP2	0.19 0.05
AX1	0.09 0.02	AX2	0.13 0.08
Total Time	1.03	Total Time	1.47

Each technique was broken into phases for analysis. The phases for the techniques are listed below:

Approach Phase

The approach phase, A1 and A2, began 0.085 s before touchdown of the takeoff foot and ended when the take-off foot made contact with the ground. Mean times were 0.14 s and 0.09 s, for the hurdle and step-on techniques, respectively.

Take-off Braking Phase

The take-off braking phase, TB1 and TB2, began when the take-off foot contacted the ground and ended when the COG was directly above the base of support. Mean times were 0.08 s and 0.09 s, for the hurdle and step-on techniques, respectively.

Take-off Push-off Phase

The take-off push-off phase, TP1 and TP2, began when the COG was directly above the base of support and ended when the take-off foot lost contact with the ground. Mean times were 0.09 s and 0.10 s, for the hurdle and step-on techniques, respectively.

Pre-barrier Flight Phase

The pre-barrier flight phase, BF2.1, began when the take-off foot lost contact with the ground and ended when the lead foot made contact with the barrier. This phase occured only during the step-on technique with a mean time of 0.14 s.

Flight Phase

The flight phase, F1, began when the take-off foot lost contact with the ground and ended when the lead foot made contact with the ground on the other side of the barrier. Mean time for this phase, which occured only during the hurdle technique, was 0.51 s.

Barrier Braking Phase

The barrier braking phase, BB2, began with contact of the lead foot with the barrier and ended when the COG was directly over the base of support. This phase, occuring only during the step-on technique, had a mean time of 0.14 s.

Barrier Push-off Phase

The barrier push-off phase, BP2, began when the COG was directly over the base of support and ended when the lead foot lost contact with the barrier. This phase occured only during the step-on technique with a mean time of 0.21 s.

Post-barrier Flight Phase

The post-barrier flight phase, BF2.2, began when the lead foot lost contact with the barrier at push-off and ended when the opposite foot made contact with the ground. This phase occured only during the step-on technique with a mean time of 0.32 s.

Landing Braking Phase

The landing braking phase, LB1 and LB2, began with contact of the lead foot with the ground and ended when the COG was directly over the base of support (foot). This phase occurred only during the step-on technique, with a mean time of 0.06 s.

Landing Push-off Phase

The landing push-off phase, LP1 and LP2, began when the COG was directly over the base of support and ended when the push-off foot lost contact with the ground. Mean times were 0.12 s and 0.19 s, for the hurdle and step-on techniques, respectively.

Acceleration Phase

The acceleration phase, AX1 and AX2, began at push-off of the lead foot and ended 0.085 s later. Mean times were 0.09 s and 0.13 s, for the hurdle and step-on techniques, respectively.

Discussion

The purpose of this research was to compare the mechanics associated with the hurdle clearance technique and the step-on technique used in the steeplechase. Each technique was broken into phases for analysis. The phases for the hurdle technique were: (1) the approach phase (A1), (2) the take-off braking phase (TB1), (3) the take-off push-off phase (TP1), (4)the flight phase (F1), (5) the landing braking phase (LB1). (6) the landing push-off phase (LP1), and (7) the acceleration phase (AX1).

The phases for the step-on technique were:

(1) the approach phase (A2), (2) the take-off braking phase (TB2), (3) the take-off push-off phase (TP2), (4) the pre-barrier flight phase (BF2.1), (5) the barrier braking phase (BB2), (6) the barrier push-off phase (BP2), (7) the post-barrier flight phase (BF2.2), (8) the landing braking phase (LB2), (9) the landing push-off phase (LP2), and (10) the acceleration phase (AX2).

Kinematic variables were measured to aid in determining the differences between the hurdle technique and the step-on technique. Each of these variables was measured for each athlete.

The discussion of results will follow the order in which the results were presented. Where appropriate, the results will be compared to results found in the literature. Finally, the results will be analyzed to see if they support the research hypotheses.

ANOVA

Initial Horizontal Velocity

A significant difference was found in the initial horizontal velocities between the step-on technique and the hurdle technique. This is in agreement with Dyson (1977) who stated that it is essential for an athlete to accelerate the last few strides before take-off in order to negotiate the water jump obstacle. Although not directly hypothesized by the researcher it corresponds with the overall hypothesis that the step-on technique would show greater increases than the hurdle technique would have in kinematic measurements.

Trajectory Angle

The trajectory angle was found to be significantly higher when the subjects used the hurdle technique than when the step-on technique was used. This result is inconsistent with the research hypothesis. The researcher believed that there would be a lower trajectory angle for the step-on technique because the subject did not have to cover as much horizontal distance in order to clear the height of the barrier. That statement was similar to what Mann (1985) believed, that a successful sprinter needs only enough vertical movement to complete swinging the nonsupporting leg through and to prepare the leg for ground contact. Thus, that hypothesis was not supported.

An interesting result occurred when the ANOVA was looked at in regards to the speed grouping. The trajectory angle was found to be greater in the athletes in the slow group as compared to the athletes in the fast group. This corresponds to a statement made by Dapena and McDonald (1991) that one of the main problems that hurdlers face is a loss of forward speed during take-off of the hurdle stride. This loss of speed during the take-off period can be kept low if the athlete keeps a low path of travel while going over the hurdle. There was not a significant interaction effect between speed and technique.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The problem of this study was to compare kinematic differences and similarities that exist between two barrier clearance techniques in the steeplechase track and field event. Specifically, the conventional hurdle technique and the step-on technique were analyzed. It was hypothesized that when an athlete used the step-on technique changes in their center of gravity, vertical displacement, time-lag per barrier and approach phase would be found.

The 20 subjects participating in this study were NCAA Division I male track and field athletes. The athletes were filmed during competition in the steeplechase event of the Mid American Conference Track and Field Championships, May 20, 1995.

ANOVAs were performed on these dependent variables : (1) initial horizontal velocity, (2) final horizontal velocity, (3) center of gravity vertical displacement, (4) support time, (5) non-support time (time-lag), (6) trajectory angle, and (10) trunk angle.

ANOVAs' were used to evaluate trajectory angle, velocities, and trunk inclination, between the two techniques. Subjects were grouped according to approach velocity.

Findings

An alpha level of 0.05 was used to determine significance in the present study. The ANOVAs comparing the hurdle technique and step-on technique indicated the following:

1. There was a significantly lower trajectory angle when using the step-on technique.
2. There was a significantly faster initial horizontal velocity when using the step-on technique.
3. There was a significantly faster final velocity for the step-on technique.

Conclusions

It was the belief of the researcher that differences would exist in the kinematics of subjects when performing the step-on barrier clearance technique and the hurdle barrier clearance technique. Statistically significant differences existed for the initial horizontal velocity, final horizontal velocity, center-of-gravity vertical displacement, center-of-gravity horizontal displacement, and trajectory angle. However, the statistical significance does not mean that there is a practical difference. For instance, the differences of the means for initial horizontal velocity and center-of-gravity vertical di-placement were small, 0.26 m/s and 0.22 m/s, respectively. Furthermore, the descriptive statistics revealed small differences between techniques.

Recommendations

Many dependent variables related to the comparison of the barrier clearance techniques were analyzed and discussed for the first time in the present study. This approach afforded an opportunity to study possible relationships among these variables. Future studies in this area could benefit from using this comparative approach. In addition, future studies of the steeplechase might find it informative to do the following:

1. Collect data in a non-competitive setting where one athlete can be filmed at a time.

2. Females should be studied in a similar project to compare results to those found in males.

3. Three cameras should be used to capture the motion. Specifically, a camera placed so the athletes are filmed head-on so that possible variances in lead-leg technique might be observed.

APPENDIX A

Human Subjects Insituitional Review Board Approval Form

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-3899
616 387-8293

WESTERN MICHIGAN UNIVERSITY

Date: May 5, 1995

To: David Paschke

From: Richard Wright, Interim Chair

Re: HSIRB Project Number 94-10-17

This letter will serve as confirmation that your research project entitled "A biomechanical analysis of steeplechase techniques: Conventional and hurdle" has been **approved** under the **full** category of review by the Human Subjects Institutional Review Board. This includes approval for the following change made in your memos dated April 21 and May 2, 1995:

1. Collection of data at the MAC Track & Field Championships at Kanley Track, May 20, 1995.

The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you must seek specific approval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date. In addition if there are any unanticipated adverse or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: May 5, 1996

xc: Dawson, HPER

APPENDIX B

Consent Form

WESTERN MICHIGAN UNIVERSITY

Department of Health, Physical Education, and Recreation

Principal Investigator: Dr. Mary Dawson

Research Associate: David Paschke

I,_____________________ (print name), consent to serve as a subject in the research project entitled: "A biomechanical analysis of steeplechase techniques: conventional and hurdle." The purpose of this study is to examine the kinematic variables of (a) time, (b) velocity, and (c) center of gravity as they relate to two different techniques used to clear a steeplechase barrier. I understand that this study is David Paschke's thesis project.

I understand that if I agree, I will be asked to participate in one, one-hour video data collection session. I will be asked to meet David Paschke for this session at the Biomechanics/ Exercise Physiology laboratory located on the first floor of the Student Recreation Center at Western Michigan University, Kalamazoo, MI. The session will involve high speed video data collection while I perform either a conventional barrier clearance technique, a hurdle barrier clearance technique, or both techniques.

I understand that it is not possible to identify all potential risks to the participant in a research project. If an accidental injury occurs, appropriate emergency measures will be taken; however, no compensation or treatment will be made available to me except as otherwise specified in this consent form.

I understand that all information collected from me is confidential. That means my name will not appear on any project papers, project forms, or video tapes for which data is being recorded. The forms and the video tape will all be coded, and David Paschke will keep a separate master list with the names of participants and the corresponding code numbers. Once the data are collected and analyzed, the master list will be destroyed. All other forms and video tape will be retained for three years in a locked file in the principal investigator's laboratory.

I understand that I may refuse to participate or quit at ant time during the study without prejudice or penalty. If I have any questions or concerns about this study, I may contact David Paschke at 616/387-3767, or Dr. Mary Dawson at 616/387-2669. I may also contact the Chair of Human Subjects Institutional Review Board or the Vice President for Research at 616/387-8293 with any concerns that I may have. My signature below indicates that I understand the purpose and requirements of the study and that I agree to participate.

_____________________________ ______________

Signature Date

BIBLIOGRAPHY

Adams, W. C. (1979). Steeplechasing. Track and Field Quarterly Review, 3, 50-52.

Adrian, M. J., & Cooper, J. M. (1989). The mechanics of human movement. Indianapolis: Benchmark Press.

Alford, J. (1979). Steeplechase. Track and Field Quarterly Review, 3, 57-59.

Alford, J. (1980). Developing technique in the steeplechase. Track Technique, 2480-2482.

Baeta, A. (1992). Track and Field Quarterly Review, 2, 48-51.

Balakhynichev, V. (1984). 110-meter hurdling styles. In F. Wilt (Ed.), Soviet Theory, Technique and Training for Running and Hurdling (pp. 83-84). Ames, Iowa: Championship Books.

Benson, T. (1993). Steeplechasing: The art of interrupted running. Track and Field Quarterly Review, 2, 27-29.

Bowerman, B. (1985). Steeplechase training. Track and Field Quarterly Review, 3, 15-17.

Bowerman, W. J., & Freeman, W. H. (1990). High-performance training for track and field (2nd ed.). Champaign, IL: Leisure Press.

Dapena, J., & McDonald, C. (1991). Hurdle clearance technique. Track & Field News, 3710-3712.

Dick, F. W. (1982). Biomechanics of high hurdle clearance. Track and Field Quarterly Review, 2, 34-35.

Dillman, C. J. (1975). Kinematic analyses of running. Exercise and Sport Sciences Reviews.

Doherty, K. (1985). Track & Field Omnibook (4th ed.). Los ALtos, CA: Tafnews Press.

Dyson, G. H. (1962). The mechanics of athletics. London: Hodder and Stoughton.

Ebberts, R. (1986). Development of the steeplechaser. Track Technique, 3082-3085.

Ecker, T. (1985). Basic track and field biomechanics. Los Altos, CA: Tafnew Press.

Fisher, B. (1985). The steeplechase. Track and Field Quarterly Review, 4, 39-40.

Fix, D., & Smith, N. (1984). Analysis chart for steeplechase waterjumping. Track and Field Quarterly Review, 3, 23-25.

Gambetta, V. (1979). Steeplechasing: Plastic cross-country. Track and Field Quarterly Review, 3, 49.

Gartland, J., & Henson, P. (1984). A comparison of the hurdle steeplechase water barrier techniquw with the conventional water barrier technique. Track and Field Quarterly Review, 3, 26-28.

Griak, R. (). Steeplechase: Points to remember. Track and Field Quarterly Review, 41.

Hartwick, B. (1981). The 3,000m steeplechase. Track and Field Quarterly Review, 3, 43-56.

Hay, J. G. (1993). The biomechanics of sports techniques (4th ed.). Englewood Cliffs, NJ: Prentice Hall.

Hessel, D. G. (1981). The steeplechase: A unique event. Track and Field Quarterly Review, 3, 41-42.

Hislop, C. (1985). Steeplechase technique. Track and Field Quarterly Review, 3, 18-22.

Jarver, J. (1981). In J. Jarver (Ed.), The Hurdles (pp. 9-13). Los Altos, CA: Tafnews Press.

La Fortune, M. (1988). Biomechanical analysis of 110 m hurdles. Track Technique, 105, pp. 355-3356, 3365.

Lewis, H. (1981). An analysis of hurdling. Track Technique Annual, 81-83.

Mann, R. (1985). Biomechanical analysis of the elite sprinter and hurdler. In N. K. Buts, T. T. Gushiken, & B. Zarins (Eds.). The elite athlete (pp. 43-80). Jamaica, NY: Spectrum.

McDonald C., & Dapena, J. (1991). Angular momentum in the men's 110-m and women's 100-m hurdles races. Medicine and Science in Sports and Exercise, 23(12), 1392-1402.

McDonald C., & Dapena, J. (1991). Linear kinematics of the men's 110-m and women's 100-m hurdles races. Medicine and Science in Sports and Exercise, 23(12), 1382-1391.

McFarlane, B. (1976). Correct hurdling technique. Track Technique, 2014-2016.

McFarlane, B. (1981). Evaluation of hurdling. In J. Jarver (Ed.), The Hurdles (pp. 22-24). Los ALtos, CA: Tafnews.

Mitchell, L. (1981). Basic hurdling technique. In J. Jarver (Ed.), The Hurdles (pp. 102-103). Los ALtos, CA: Tafnews.

Nytro, A. The steeplechase. 101-107.

Rushton, J. (1980). Developing the steeplechaser. Track Technique, 2543-2544.

Saunders, T. (1969). Steeplechase technique and training. Track Technique, 1102-1103.

Schroter, G. (1981). Basic hurdling technique. In J. Jarver (Ed.), The Hurdles (pp. 18-21). Los ALtos, CA: Tafnews.

Singh, J. (1978). Direction of jumping action tendency through foreleg movement in hurdles. Track and Field Quarterly Review, 4, 24-27.

Singh, J. (1978). Hurdler's take off: Application of Newton's Third Law. Track and Field Quarterly Review, 4, 22-23.

Smith, C. (1977). Some thoughts on steeplechasing. Track Technique, 2227-2228.

Smith, I. (1979). Teaching correct lead leg hurdling. Track Technique, 2386-2387.

Tsarouchas, L., Papadopoulos, C., Kalamaras, K., & Giavroglou, G. (1993). Approach phase for the clearance of the 110m high hurdles run. Track and Field Quarterly Review, 1, 40-45.

Vaiksaar, V. (1981). Some aspects of high hurdling. In J. Jarver (Ed.), The Hurdles (pp. 80-82). Los Altos, CA: Tafnews Press.

Ward, T., & India, D. M. (1982). Temperal and kinematic facts on 110m hurdling: High level performers. Track and Field Quarterly Review, 2, 30-31.

Warhurst, R. (1985). Training for distance running and the steeplechase. Track & Field Quarterly Review, 3, 13-14.

Watts, D. (1975). Hints on steeplechasing. Track Technique, 1902-1903.

Wiger, E. (1979). The 3,000m steeplechase. Track and Field Quarterly Review, 3, 53-56.