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ScienceDirect
Journal of Sport and Health Science 4 (2015) 353–356
www.jshs.org.cn

Original article

The relationship between steeplechase hurdle economy, mechanics, and performance

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Received 1 November 2014; revised 3 February 2015; accepted 26 March 2015
Available online 12 June 2015

Abstract

Background: Research surrounding the steeplechase is scarce, with most research focusing primarily on how biomechanical factors relate to maintaining running speed while crossing barriers. One area that has not been well explored is the relationship between biomechanical factors and hurdling economy. The purpose of this study was to investigate how performance times and biomechanical variables relate to hurdling economy during the steeplechase.
Methods: This was accomplished by measuring running economy of collegiate and professional steeplechasers while running with and without hurdles. Biomechanical measures of approach velocity, takeoff distance, clearance height, and lead knee extension while hurdling, as well as steeplechase performance times were correlated to a ratio of running economy with and without hurdles.
Results: While oxygen uptake was 2.6% greater for the laps requiring five barriers, there was no correlation between steeplechase performance time and the ratio of running economy during the hurdle and non-hurdle laps. Results also indicated no correlation between the aforementioned biomechanical variables and ratio of running economy during the hurdle and non-hurdle laps.
Conclusion: Increasing approach velocity did not negatively affect running economy. Increased approach velocity is a benefit for maintenance of race pace, but does not hurt economy of movement.

Keywords: Endurance; Racing; Running; Track and field

1. Introduction

In the quest to run faster, jump higher, and throw further, track and field events are continually being researched. One such event, the steeplechase, is filled with questions to be answered dealing with maintenance of horizontal velocity while negotiating obstacles and minimizing metabolic cost. Although it has been contested for over 150 years, it was not until 2005 that the women's steeplechase was introduced to the World Championships. In 2008 it was first contested in the Olympic Games. With the introduction of the women's steeplechase to world contests, interest in the race has increased[1,2] with organizations from junior national meets to major international championships including the event.

The steeplechase is 3000 m long with four barriers and one water pit per lap. The water pit is a barrier followed by a 3.66-m long water pit, typically about 0.7 m at the deepest point (Fig. 1). A steeplechaser encounters a total of 28 barriers and seven water pit jumps during the race. The barrier heights are set at 0.914 m for men and 0.762 m for women (Fig. 2). There are no lane assignments, therefore steeplechasers often have to navigate the obstacles (barriers and water pit jump) surrounded by their competitors. With approximately 80 m between barriers there is no set stride pattern as seen in the hurdle races of shorter distances; therefore adjustments to running stride are made before each barrier. Just like running technique influences running economy,[3] hurdle and water jump technique should influence the economy of steeplechase running. As coaches and athletes begin to understand the techniques needed to improve hurdling economy during the steeplechase, athletes will achieve greater running speeds between and over obstacles.

To improve race performance, steeplechase runners must examine their distance running economy as well as their hurdling economy. Economy of distance running has been extensively researched,[3–9] and many biomechanical factors related to steeplechase hurdling have been examined,[2,10–12] however, economy of hurdling in the steeplechase has not been studied.

Better running economy leads to better distance running performance. In highly trained runners with similar ability and

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Peer review under responsibility of Shanghai University of Sport.

http://dx.doi.org/10.1016/j.jshs.2015.03.009
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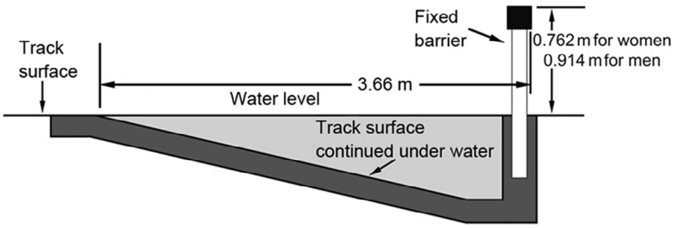

Fig. 1. Steeplechase water pit.

VO_{2max}, running economy accounted for a significant amount of variation in 10,000 m race performances.[5] Running economy is measured by oxygen uptake at a given submaximal speed.[13] Trained runners are more economical at their specific race pace than at other paces.[6] Much time in the steeplechase is spent between barriers, therefore, good distance running economy will benefit the athlete.

In addition to high distance running economy, successful steeplechasers need an economical hurdling and water jump technique. There are two ways to clear the non-water pit barriers in a steeplechase race. The first is the hurdle technique in which the athlete keeps the lead leg knee slightly flexed and pulls the trail leg through after the lead leg clears the barrier. The second is the step-on technique where the athletes put one foot on top of the barrier, thus taking off and landing on the same foot. From a biomechanical viewpoint the hurdle technique is more effective for maintaining velocity.[2,12]

Faster overall speeds come from having a steady pace in distance running; therefore, one of the most important considerations in successful steeplechase hurdling is maintenance of horizontal velocity. Biomechanical measures that have previously been used to describe steeplechase hurdling include horizontal velocity into, over, and exiting the hurdle and water jump; takeoff distance; landing distance; crouch height; clearance height; push-off angle; hip, trunk and knee angles during flight; and takeoff and landing step lengths. An understanding of how these biomechanical characteristics relate to maintaining running speed while crossing the barriers already exist for men and women.[1] However, the relationship between these characteristics and the economy of steeplechase hurdling is unknown.

This study investigated the difference in oxygen uptake while running with five hurdles every 400 m and no hurdles every 400 m. We also measured approach velocity, clearance height, takeoff distance, and lead knee extension since they all contribute to the maintenance of horizontal velocity.[1] Measuring these biomechanical factors while also measuring running economy (oxygen uptake at a given submaximal speed) will allow a comparison of steeplechasers technique as it relates to running economy. We expected that athletes with a smaller economy ratio would have a greater approach velocity, lower clearance height, greater takeoff distance, and greater lead knee extension.

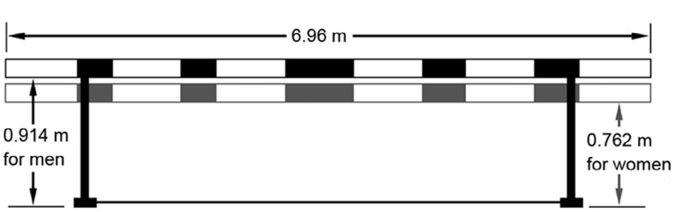

Fig. 2. Steeplechase barrier.

2. Materials and methods

2.1. Participants

Ten female steeplechasers participated in this study (age: 25 ± 5 years; height: 1.70 ± 0.05 cm; mass: 58.6 ± 4.5 kg; season best 3000 m steeplechase time: 677 ± 29 s). Each participant was either a Division 1 NCAA or professional steeplechase athlete. Participants were contacted in person or by phone and asked to participate in the study. All procedures were approved by the appropriate institutional review board. Written informed consent was obtained from subjects prior to participation in the study.

2.2. Protocol

The participants' height, weight, age, personal best, and season best steeplechase time were recorded prior to beginning testing. All running took place at the Brigham Young University outdoor track. While wearing a portable metabolic system (K4 telemetry system; COSMED, Concord, CA, USA), participants completed their typical warm-up followed by one 800 m interval (two laps around the outdoor track). Only rest days or recovery runs were completed in the 3 days prior to testing. Participants then ran four 800 m intervals (from a standing start) with 3 min rest between intervals. Two of the intervals were over steeplechase barriers and two were without barriers. Intervals alternated between running with and without the barriers. Steeplechase barriers were set at 0.762 m (30 in). There were five barriers per 400 m lap spaced evenly around the track (providing a total of 10 barriers) in each hurdling interval. Only barriers without the water pit were chosen to isolate the effect of hurdling while running at steeplechase pace. Participants ran all intervals at their individual season best steeplechase race pace. Order of intervals was counter balanced as each subject served as his own control. Five subjects started with a non-hurdle interval and five started with a hurdle interval. Oxygen uptake was measured using the COSMED K4 telemetry system. It has been shown to be an accurate and reliable system of measuring oxygen uptake.[14] Since hurdling was included during the intervals, our measure of oxygen uptake is combined running/hurdling economy during the intervals with hurdling. Throughout the text, running economy will be defined as the economy of running with or without hurdling included depending upon the condition. Running economy was determined by the participants' oxygen uptake divided by their running speed in meters per second expressed as mL/kg/min. Running speed was confirmed with a stopwatch. All interval times were within 1.5% of the average interval time for each subject.

Two of the barriers were on the straight sections of the track. A video camera running at 120 Hz (Exilim FH-25; Casio, Tokyo, Japan) was placed to film the athlete's hurdling the barriers from a sagittal view at each of these barriers. A two-dimensional analysis was completed using Vicon Motus 9.2 (Vicon Corp., Colorado Springs, CO, USA). Measures of