Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 147 (2016) 544 – 549

Procedia Engineering

www.elsevier.com/locate/procedia

11th conference of the International Sports Engineering Association, ISEA 2016

Outdoor tests for the validation of an inertial system able to detect illegal steps in race-walking

Giuseppe Di Gironimo[a,*], Teodorico Caporaso[a], Giuseppe Amodeo[b], Domenico Maria Del Giudice[a], Antonio Lanzotti[a], Stephan Odenwald[b]

[a]*University of Naples Federico II – Fraunhofer JL IDEAS, DII, P.le Tecchio 80, Naples 80125, Italy*
[b]*Chemnitz University of Technology, Reichenhainer Str. 70, Chemnitz 09126, Germany*

Abstract

Aim of this study was to validate an inertial system able to detect the loss of ground contact (LOGC) in race-walking through outdoor tests in real training conditions. An inertial sensor was placed at L5/S1 of the vertebral column of a Italian national team athlete to acquire timing measurements of the LOGC. Data were encoded by a well-defined protocol. After a preliminary laboratory study, the athlete performed outdoor-field-tests at different velocities. A specific e-bike with a high-speed camera allowed to acquire a video and to validate sensor measurements. Results indicate that the inertial system can improve the accuracy in detecting the visible LOGC.

Peer-review under responsibility of the organizing committee of ISEA 2016

Keywords: **Race walking; loss of contact; inertial sensor; video analysis;outdoor test**

1. Introduction

Race-walking is a long-distance discipline, included in the athletics program of the Olympic Games since 1908. As defined by the rule 230 of Competition Rules 2014-15 of International Association of Athletics Federations (IAAF), "*Race Walking is a progression of steps so taken that the walker makes contact with the ground, so that no visible (to the human eye) loss of contact occurs. The advancing leg must be straightened (i.e. not bent at the knee) from the moment of first contact with the ground until the vertical upright position*" [1]. Not complying with the first part of this rule (no visible loss of contact) represents the most common violation at elite-level in this discipline, named loss of ground contact (LOGC). The LOGC is defined as the time between two temporal gait events, "toe off", i.e. the last toe-contact with the ground, and the following "heel strike", i.e. the first instant of heel contact with the ground, within a sequence step as shown in Fig.1.

During competitions, the control of the rule is committed to several judges present at the racing track. They can show to the race walker a yellow paddle (i.e. a caution) or they can give a red card (i.e. proposal for disqualification). The athlete is disqualified when three red cards are given from three judges. In the last World Championships in Beijing, approximately 60% of red cards were caused to a LOGC, in particular, with a peak of over 80% in the men's 20km race [2]. Many efforts have been made to evaluate the LOGC during the elite-racewalkers' training or competition. A video-analysis study on sixteen international-level athletes, including ten men and six women, during training sessions, has shown a range for LOGC values from 30ms up to 45ms (i.e. average speed from 12.0 km/h to 15.0 km/h) [3]. During the 25th World Race Walking Cup, in Saransk, Russia on May 2012, the LOGC was evaluated for medallists (both men and women) of the 20 km race-walk, and of the men's 50km race-walk. The LOGC value was equal to 50ms for the male in the 20 km race, to 30ms for the female in 20km race and to 40ms for male ones in 50km race; the average speed of 15.2, 13.2 and 13.9 km/h, respectively [4].

* Corresponding author. Tel.: "+39 0817682461" ; fax: +39 0817682470.
E-mail address: giuseppe.digironimo@unina.it

Peer-review under responsibility of the organizing committee of ISEA 2016
doi:10.1016/j.proeng.2016.06.236

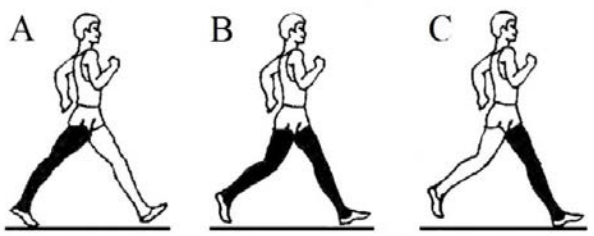

Fig. 1 –Temporal gait events: A) the toe-off and C) the heel-strike; B) shows a LOGC

It is worth noting that judges can rely only on subjective observations (i.e. by human eyes) and no technology is used to support their decisions. The short duration of gait events makes a proper identification of LOGC very difficult. Previous researches explain how people can perceive a movement in different ways [5, 6]. Experimental tests on professional athletes of a first-person shooter have found that for refresh rates over 30fps (i.e. about every 33ms) the visual perception of the human eye does not show significant improvements [5]. On the other hand, the examination of limits of the visual resolution in natural scene viewing [6] has shown that the detecting image for human eye did not occur for fixations below 100ms. In [7] researchers have studied the assessment of three judges about the race-walking technique. Each judge made 100 evaluations of step sequences in according to IAAF recommendation to give a red card only when the athlete continues to break the rules of race-walking, not only for a step. A long observation area of 30 m (i.e. about 30 steps) was defined. Actions of racewalkers were simultaneously filmed with a standard video camera at 200fps. The study indicates a difficulty in recognizing LOGC shorter than 50 ms.

Therefore, basing the control of the rule on a subjective human observation represents a critical point in race-walking discipline, especially thinking that an incorrect application can lead to the disqualification of the athlete. The aim of the present study is to validate an inertial system capable to detect the LOGC in accord with limits of the human eye.

2. Background

In a preliminary study [8] referring to device architecture, an inertial sensor was chosen, whose the conceptual design was conducted through the Kansei Engineering after the analysis of properties and characteristics of the device, required by race-walking experts (i.e. athletes, trainers and judges). During preliminary tests at the Laboratory of Advanced Measures on Ergonomics and Shapes of the University of Naples Federico II, inertial, dynamic and kinematic measures were collected. An elite race walker, member of Italian national team, to acquire timing measurements of LOGC, used an inertial sensor (i.e. the model type G-Sensor2, BTS) with a sampling frequency of 200Hz. The response of the sensor, which it was placed at L5/S1 of the vertebral column of the athlete, was encoded, processed and optimized by means of a well-defined protocol that concerns the filtering and the correlation between the acceleration and gait events. The validation of the sensor was made by eight integrated force platforms (i.e. model type P-600, BTS, sampling rate 680Hz). The study consisted of fifteen sessions; twenty-two valid steps were collected. The analysis considered 25Hz as the limit of the human eye. The dynamic system identified twenty-two LOGC, three of them evaluated as illegal. The inertial system identified 100% of the LOGC and the system reported an accuracy of 73% in the evaluation of steps.

3. Material and Methods

3.1. Experimental set-up

An athlete of Italian national team performed outdoor race-walking tests. The specific purpose of the experiment was to analyse LOGC events for long sequences of steps on paved road (in training conditions) at different walking speeds. LOGC values were firstly deduced from the kinematic study of the human centre of mass (CoM) by using an inertial system (i.e. the model type G-Sensor2, BTS) set at sampling frequency of 200Hz, ±8g for the tri-axis accelerometer, ±300gps for the tri-axis gyroscope sensor, and ±6 Gauss for the tri-axis magnetic sensor [9, 10]. The sensor was located at the bottom of athlete vertebral column in correspondence of the L5–S1 inter-vertebral space.

Acquired data were transmitted via Bluetooth to a laptop mounted on an electrical bicycle that accompanied the athlete during the test. It was provided with a motor system including a torque sensor that permits to obtain instant seamless power without noise, to follow the athlete at constant speed.

The e-bicycle was also equipped with a high-speed camera (i.e. the model type GoPro Black Hero4, Woodman Lab.) operating at 240fps with a resolution of 848x480 in 16:9, fixed on rear dropout and controlled remotely via wireless connection with a mobile device (i.e. the tablet, Samsung Galaxy Note 2014 Edition) positioned on the handlebars. The high-speed camera video of the athlete's performance allowed evaluating a precise visual assessment of the LOGC. Finally, a webcam (i.e. the model type HD C310, Logitech International S.A, resolution of 320x240 at 30 Hz) was connected with the laptop and fixed on