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Original article

Can coordination variability identify performance factors and skill level in competitive sport? The case of race walking

Dario Cazzola [a], Gaspare Pavei [b], Ezio Preatoni [a,*]

[a] *Department for Health, University of Bath, Bath BA27AY, UK*

[b] *Department of Pathophysiology and Transplantation, University of Milan, Milan 20133, Italy*

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Abstract

Background: Marginal changes in the execution of competitive sports movements can represent a significant change for performance success. However, such differences may emerge only at certain execution intensities and are not easily detectable through conventional biomechanical techniques. This study aimed to investigate if and how competition standard and progression speed affect race walking kinematics from both a conventional and a coordination variability perspective.

Methods: Fifteen experienced athletes divided into three groups (elite, international, and national) were studied while race walking on a treadmill at two different speeds (12.0 and 15.5 km/h). Basic gait parameters, the angular displacement of the pelvis and lower limbs, and the variability in continuous relative phase between six different joint couplings were analyzed.

Results: Most of the spatio-temporal, kinematic, and coordination variability measures proved sensitive to the change in speed. Conversely, non-linear dynamics measures highlighted differences between athletes of different competition standard when conventional analytical tools were not able to discriminate between different skill levels. Continuous relative phase variability was higher for national level athletes than international and elite in two couplings (pelvis obliquity—hip flex/extension and pelvis rotation—ankle dorsi/plantarflexion) and gait phases (early stance for the first coupling, propulsive phase for the second) that are deemed fundamental for correct technique and performance.

Conclusion: Measures of coordination variability showed to be a more sensitive tool for the fine detection of skill-dependent factors in competitive race walking, and showed good potential for being integrated in the assessment and monitoring of sports motor abilities.

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Keywords: Biomechanics; Gait; Joint coupling; Motor control; Sports technique; Training

1. Introduction

Race walking is a peculiar form of locomotion that requires athletes to walk as fast as possible following two main rules: keep the knee of the supporting leg locked "from the moment of first contact with the ground until the vertical upright position"; and generate a progression of steps with no visible flight phase.[1] Previous studies have attempted to characterize race walking performance, focusing on spatio-temporal characteristics, joints kinematic, ground reaction forces, and kinetic factors, but a fine description of how technique could affect and be affected by race walking pace and skill level of the performer is still lacking.[2]

A number of authors have shown that race walkers are typically able to adhere to the "locked knee" rule,[3–8] but when progression speed becomes greater than about 11.5 km/h (with this threshold depending on gender) athletes may struggle to comply with the "no flight phase" requirement.[4–6,9–11] Race walking often appears as an awkward form of locomotion, due to the combination of unnatural knee position and increased angular displacement of the pelvis in the three planes of motion. However, both knee and pelvis movements are used by the race walker to achieve progression speeds at which humans would naturally turn from walking into running.[10,12] The analysis of joint kinematics and kinetics has highlighted that greater pelvic mobility is functional in maintaining correct technique. The pelvis assists in the absorption of load at heel strike (HS), contributes to the generation of a wider step length, and limits the excursion of the center of mass.[9,13,14] Ankle plantarflexion, coupled with hip extension, are instead the main determinants of power generation.[15–17]

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* Corresponding author.

E-mail address: e.preatoni@bath.ac.uk (E. Preatoni).

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The currently available literature offers analyses of race walking carried out on different types of cohorts (recreational and professional, male and female) at different speeds, but no one has found biomechanical attributes that may clearly distinguish groups as a factor of competition standards, or has studied the within-group adaptations to changes of race walking pace.[2] Indeed, it could be expected that higher movement intensities elicit distinct behaviors between cohorts of different skill, physical condition and/or experience. Addressing these issues is valuable because it could provide practitioners with important information to direct coaching and the monitoring of technical abilities. A number of studies have shown that when groups of high-level athletes are compared, the biomechanical changes due to training, injury, or skill level can be very small, and that dynamical systems techniques can represent a more powerful tool than conventional biomechanical analyses to detect skill- or injury-dependent changes in movement execution.[18–21] Such techniques become particularly useful when the coordinative synergies between elements of the system are key factors for performance. Given the role played by pelvis and lower limb coordination in race walking technique, it appears important to look at measures of coordination between the multiple elements involved in the accomplishment of the task.

Therefore, the aim of this study was to assess the effect of competition standard and speed on race walking technique, and to evaluate the sensitivity of coordination variability measures to these two factors in comparison with conventional biomechanics measures. The hypothesis was that coordinative measures could detect differences across groups and conditions where the other approach could not. Also, it was hypothesized that coordination variability is greater for higher-level athletes in key phases of the gait cycle, and that it increases with faster race walking pace.

2. Materials and methods

2.1. Study design

A cross-sectional study was carried out to assess the effect of gait speed and competition standard (independent factors) on lower limb kinematics and coordination (dependent measures) in race walking.

2.2. Participants

Fifteen male race walkers (age range: 18–38 years; height: 1.78 ± 0.05 m; mass: 64.7 ± 5.3 kg) participated in this study. Participants were assigned to one of three groups according to their performance best (PB) in the 10-km event: elite (E, $n = 4$, average PB: 40 min 25.8 s ± 1 min 5.5 s); international (I, $n = 6$, average PB: 43 min 27.6 s ± 43.5 s), national (N, $n = 5$, average PB: 48 min 54.2 s ± 56.5 s). All participants were competitive athletes and were experienced in walking on a treadmill. The study was approved by the Ethics Committee of the University of Milan, and an informed consent was signed by participants before the experimental session.

2.3. Experimental protocol

Prior to testing each participant performed a self-selected warm-up of about 10 min, typically including a mix of race walking at low pace, stretching and joint mobility exercises. Participants were then asked to race walk on a motorized treadmill (Woodway Ergo LG, Weil am Rhein, Germany) in bouts of 90 s at incremental speeds (incremental step of 0.5 km/h), from 10.0 km/h to the maximum speed sustainable by each individual athlete. The participants were told to start the trial at the next incremental speed only when they felt fully recovered and at least 2-min recovery was allowed between trials. The range of average maximum speed covered by the athletes varied from 15.5 km/h for national to 18.0 km/h for international.

Data collection started 30 s after the beginning of the trial, and lasted for 60 s, to ensure that at least 40 full gait cycles could be collected for each speed. A six-camera motion-capture system (Vicon MX; Oxford Metrics, Oxford, UK) recorded race walkers' kinematics at a sampling rate of 300 Hz. A set of 23 markers was used to define a lower limb biomechanical model[22] including seven anatomical segments and seven joints (Fig. 1). Local coordinate systems (LCS) were constructed for the pelvis, thigh, shank, and foot to calculate pelvis orientation and lower limb joint angles. The pelvis segment was defined by the right PSIS, left PSIS, and L4 markers; the thigh segment was tracked by four markers placed on greater trochanter, lateral and medial condyle, and a technical marker on the back

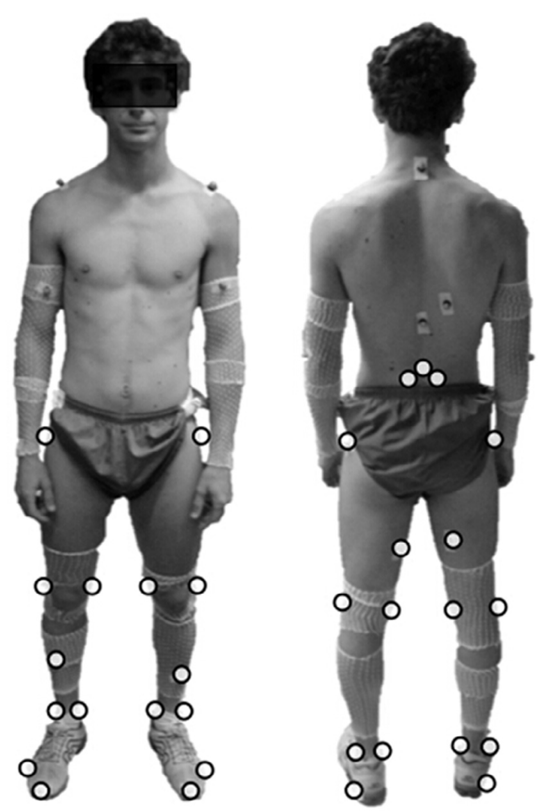

Fig. 1. Frontal plane views of the biomechanical model used for the analysis, where marker positions have been highlighted through white circles.

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