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Original article

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

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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.

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 RW 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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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

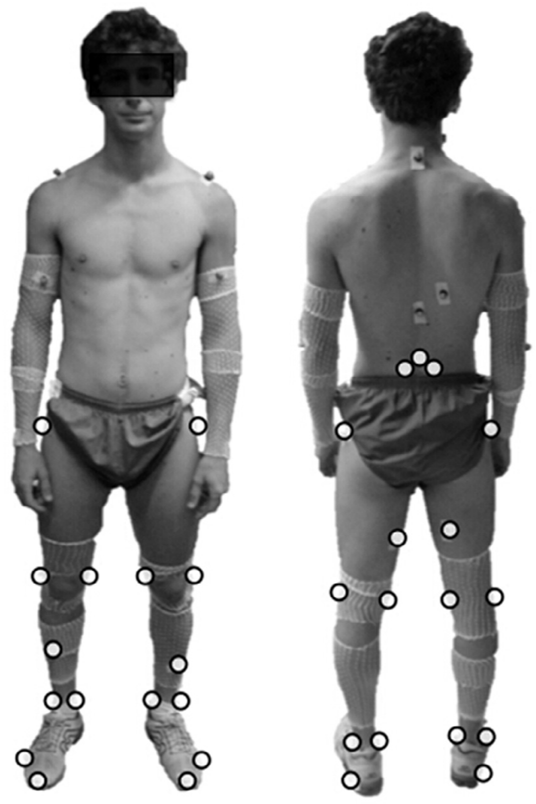

Fig. 1. Frontal plane views of the biomechanical model used for the analysis, where marker positions have been highlighted through white circles.

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of the thigh; the shank segment was tracked using four markers placed on the lateral condyle, lateral and medial malleoli, and a technical marker on the front of the shank; the foot segment was tracked using four markers placed on lateral and medial malleolus, toe, and heel.

2.4. Data processing

The three-dimensional coordinates of body landmarks were saved and then processed through bespoke routines implemented in Labview (version 2010; National Instrument, Austin, TX, USA). Data were low pass filtered with a 4th order, zero-lag Butterworth filter with a cutoff frequency of 16 Hz.[23] The main gait events, HS, and toe-off (TO), were identified from the kinematics of foot markers, following the validated method proposed by Maiwald et al.[24] A further event, the vertical upright position (VUP), was defined as the instant when the lateral malleolus of the stance leg was vertically aligned with the greater trochanter. VUP is of particular importance here because of race walking's defining rules.[1] For this research, only the right limb and pelvis kinematic patterns were analyzed, and the gait cycles were defined on the basis of subsequent right HSs. Three main functional phases were included in the analysis: early stance, from first HS to vertical upright position; mid-stance and push-off (propulsive phase), from vertical upright position to TO; and swing, from TO to HS. Contact time and flight time were defined, respectively, as the interval between HS and TO of the right foot, and between TO of the right foot and HS of the contralateral foot. Among the many speeds collected as part of a larger investigation on race walking biomechanics, 12.0 km/h and 15.5 km/h conditions were selected and used for the aims of this investigation. The slower speed represents a relatively slow training pace at which all the participants should feel in control of their movements and race walk without breaking any event-defining laws. Indeed, progression speeds between 12.0 km/h and 13.0 km/h have been indicated as the possible threshold at which a flight phase and/or incorrect technique start appearing.[5,7,9–11] The faster pace was the highest speed achieved by the participants collectively, and is approximately the average speed of the current world record in the 20 km event.

A number of discrete measures were considered to give a description of race walking kinematics according to a more conventional approach: step length and frequency; contact and flight time; and, the range of movement (ROM) of pelvic angular displacement in the frontal (pelvic obliquity) and horizontal (pelvic rotation) planes, and of hip, knee, and ankle angles in the sagittal plane. These measures were selected both due to their roles as key aspects of race walking technique,[2,8,9,14,15,20,25] and for being among the most reliable measures in gait analysis.[26,27]

Pelvis orientation and lower limb joint angles were used to study coordination variability through a dynamical systems approach.[21,23,28] Continuous relative phase (CRP) and its variability (deviation phase, DP) across the 40 strides recorded for each individual and race walking speed were estimated. CRP is a higher order measure of the coordinative relationship between two oscillating elements (i.e., body segments or joints), whereby their normalized phase plots are first created, and the difference between their phase plane angles is then calculated. CRP indicates how in-phase or out-of-phase the two oscillators behave across the movement cycle, and its variability is calculated as the standard deviation with respect to the mean CRP (Fig. 2).[23,28]

Multiple joint couplings were included in the analysis, focusing on the ones that other authors have indicated as most relevant for accomplishing the requirements of the task and for

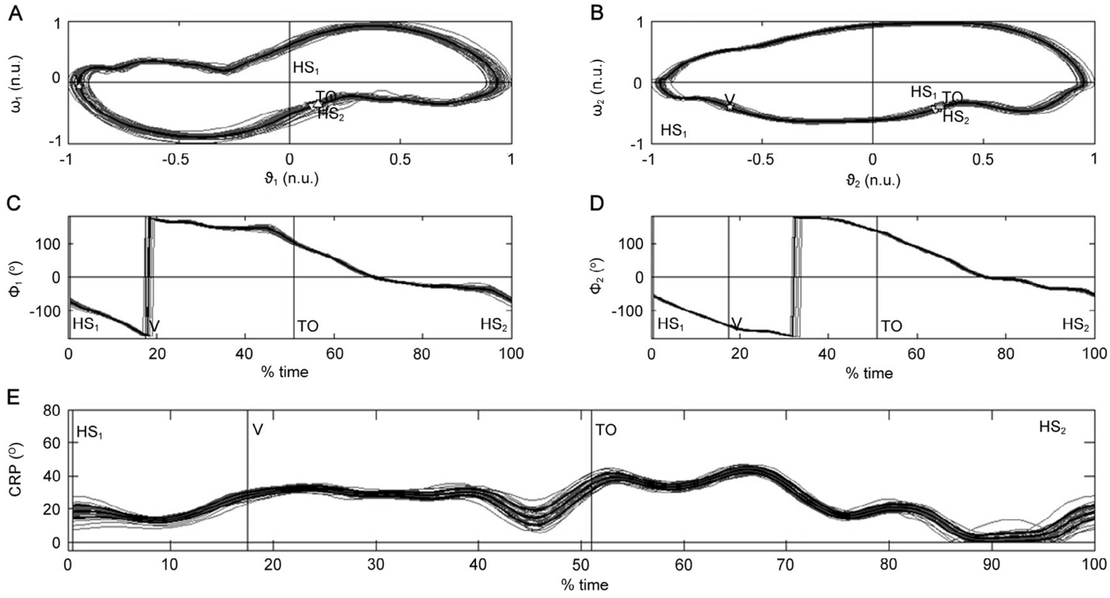

Fig. 2. Example of CRP calculation.[28] The normalized phase plots (angular velocity *vs.* angular displacement) of elements 1 (A) and 2 (B) are used to calculate phase angles (C and D). Phase angles are then subtracted to calculate continuous relative phase of the 1 *vs.* 2 coupling. Coordination variability (deviation phase) is the standard deviation of CRP curves (E). HS = heel strike; V = vertical upright position; TO = toe-off; CRP = continuous relative phase.

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enhancing performance:[8,9,13,14,17,25] hip sagittal angle *vs.* ankle sagittal angle; pelvic obliquity *vs.* hip sagittal angle; pelvic rotation *vs.* hip sagittal angle; pelvic obliquity *vs.* ankle sagittal angle; pelvic rotation *vs.* ankle sagittal angle; and pelvic obliquity *vs.* pelvic rotation. Coordination parameters were estimated for the three functional phases and for the gait cycle as a whole.

2.5. Statistics

Average measures from individual data were used to depict competition level and gait speed characteristics. Descriptive statistics were reported as mean ± SD. Two-way (mixed design) ANOVA and Bonferroni *post hoc* comparisons were used to assess the effect ($p < 0.05$) of competition standard (between-group factor) and race walking speed (within-group factor) on the kinematic and coordinative variables considered (dependent measures). Effect sizes (η^2) and observed power (OP) were included in the analysis. All statistical procedures were carried out in SPSS (version 22; IBM Corp, Armonk, NY, USA).

3. Results

3.1. Conventional variables

All the spatio-temporal and angular parameters, with the exception of the ankle ROM in the sagittal plane, highlighted significant main effects for race walking speed, but did not evidence any difference between competition standards (Table 1). Observation of the continuous patterns over the gait cycle (e.g., Fig. 3) did not show any evident difference between the three competition standards, either. No interaction effect was observed for any measure.

Increased step length ($p < 0.001$, $\eta^2 = 0.974$, OP = 1.000), step frequency ($p < 0.001$, $\eta^2 = 0.956$, OP = 1.000), and flight time ($p < 0.001$, $\eta^2 = 0.957$, OP = 1.000) were observed in 15.5 km/h compared with 12.0 km/h. Step length was 11% (national) to 17% (elite) greater at the faster pace, step frequency increased by a range of 12% (elite) to 17% (national), and flight time became between 3% (national and international) and 4% (elite) longer. With the increase in speed, contact time shortened by between 0.07 (national and international) and 0.09 s (elite) ($p < 0.001$, $\eta^2 = 0.958$, OP = 1.000). Pelvis ROM

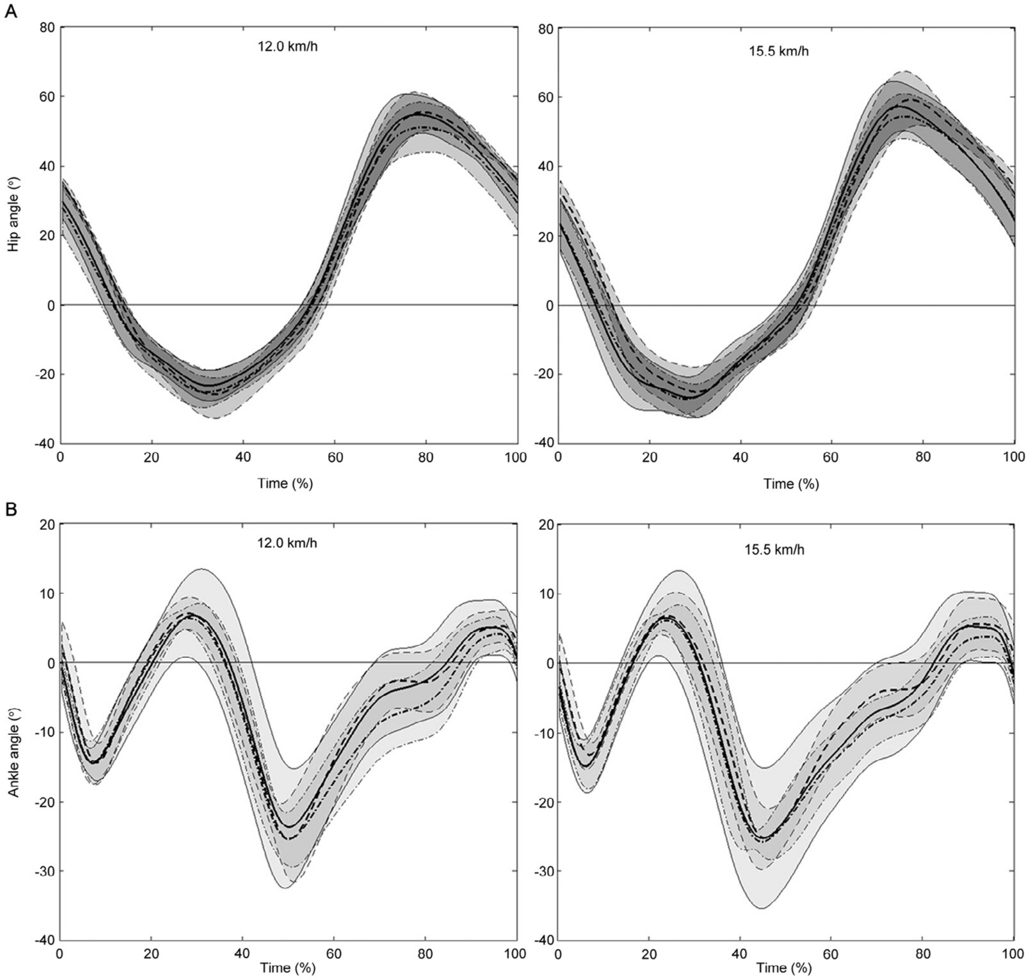

Fig. 3. Average (mean ± SD) curves for the hip (A) and ankle (B) sagittal angles in the slow (12.0 km/h) and fast (15.5 km/h) pace conditions. Time is normalized to the gait cycle and expressed in percentage. Solid lines for elite; dash-dot lines for international; dashed lines for national.

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Table 1
Spatio-temporal and angular measures (mean ± SD).

Variable	Gait speed (km/h)	
	12.0	15.5
Spatio-temporal gait characteristics		
Step length (m)[a]		
E	1.10 ± 0.03	1.29 ± 0.04
I	1.10 ± 0.03	1.27 ± 0.02
N	1.13 ± 0.04	1.25 ± 0.03
Step frequency (Hz)[a]		
E	2.99 ± 0.07	3.35 ± 0.08
I	3.03 ± 0.06	3.39 ± 0.09
N	2.95 ± 0.09	3.37 ± 0.08
Contact time (s)[a]		
E	0.35 ± 0.01	0.26 ± 0.01
I	0.33 ± 0.04	0.26 ± 0.03
N	0.34 ± 0.03	0.27 ± 0.01
Flight time (s)[a]		
E	0.00 ± 0.01	0.04 ± 0.01
I	0.01 ± 0.02	0.04 ± 0.01
N	−0.00 ± 0.01	0.03 ± 0.01
Angles ROM		
Pelvic obliquity (°)[a]		
E	51 ± 6	35 ± 4
I	45 ± 7	31 ± 3
N	50 ± 3	33 ± 3
Pelvic rotation (°)[a]		
E	57 ± 5	49 ± 6
I	60 ± 6	48 ± 5
N	61 ± 3	53 ± 7
Hip sagittal (°)[a]		
E	78 ± 2	84 ± 4
I	77 ± 5	82 ± 3
N	82 ± 7	85 ± 8
Knee sagittal (°)[a]		
E	111 ± 8	120 ± 7
I	104 ± 13	109 ± 13
N	102 ± 7	105 ± 8
Ankle sagittal (°)		
E	32 ± 3	34 ± 4
I	34 ± 2	34 ± 2
N	33 ± 5	33 ± 2

[a] Significant main effect between race walking speeds ($p < 0.05$).
Abbreviations: E = elite; I = international; N = national level.

in the frontal ($p < 0.001$, $\eta^2 = 0.901$, OP = 1.000) and horizontal ($p = 0.001$, $\eta^2 = 0.901$, OP = 1.000) planes was also reduced, whereas hip ($p = 0.040$, $\eta^2 = 0.511$, OP = 0.901) and knee ($p = 0.045$, $\eta^2 = 0.295$, OP = 0.539) ROM in the sagittal plane increased (Table 1).

3.2. Coordination variability

Coordination variability measures showed significant main effects for RW speed in a number of angular couplings, in different phases of the cycle (Fig. 4). In the faster pace pelvic obliquity *vs.* hip, pelvic obliquity *vs.* ankle, and pelvic obliquity *vs.* pelvic rotation couplings generated higher deviation phase values over the whole cycle, the VUP–TO and the swing phases (p values always lower than 0.026, η^2 greater than 0.348, OP greater than 0.643). Larger values of deviation phase for the pelvic rotation *vs.* hip coupling in the VUP–TO phase were observed at the higher speed ($p = 0.030$, $\eta^2 = 0.336$, OP = 0.619).

Differences between competition standards (Fig. 4) emerged for the pelvic obliquity *vs.* hip coupling in early stance (HS–VUP) ($p = 0.008$, $\eta^2 = 0.553$, OP = 0.866), and in the pelvic rotation *vs.* ankle coupling during the VUP–TO phase ($p = 0.048$, $\eta^2 = 0.398$, OP = 0.595). In both cases the national group reported higher coordination variability than international and elite, with the increase spanning between 13.3% (elite *vs.* national, pelvic rotation *vs.* hip) and 32.1% (international *vs.* national, pelvic rotation *vs.* hip). Also for coordination variability measures, no interaction effect between the two factors was found.

4. Discussion

The aim of this research was to evaluate the effectiveness of coordination variability measures in the characterization of race walking biomechanics for different competition standards and progression speeds. Results showed that both conventional and coordinative variables could detect the changes induced by race walking pace, but only coordination variability measures could differentiate between experienced athletes of different rank under these experimental conditions. Moreover, the coordinative changes due to competition standard involved the joints and phases of the movement that are considered key aspects for correct technique and performance. These findings suggest that coordinative variability measures may be a more sensitive tool for the fine detection of skill-dependent factors in sports performance.

The national level athletes generated higher levels of variability than the other two groups both in the early stance phase, for the pelvic obliquity–hip coupling, and in the second stage of stance, for the pelvic rotation–ankle coupling. Pelvis and hip motion have been indicated as a fundamental mechanism for the race walker to counterweight the fully extended knee over the period from the approach to the ground to the vertical upright position of the support leg.[8,9,14] Differently to normal walking, where knee flexion plays an important role in load acceptance after HS, race walking defining rules oblige the athletes to keep their knee locked and rely on other strategies to accomplish the same task. While no change in the kinematic patterns of any single joint was detected, the competition standard factor seemed to affect the variability of the phase relationship between pelvis motion in the frontal plane and hip flex/extension. Some authors[21,23] have indicated an increase in CRP variability as a possible functional feature of the neuro-musculo-skeletal system, whereby less repetitive patterns could allow for a better redistribution of load on anatomical structures and reduce the risk of injury. Similarly, Preatoni et al.[20] found lower levels of regularity in the hip angle time series of more skilled race walkers *vs.* less skilled ones, and hypothesized that increased variability could reveal an improved ability to adapt to the unnatural knee position. The outcomes from the current study seem to go in the opposite direction, and could thus indicate that (1) higher standard athletes may be at risk of more repetitive mechanical stresses acting on their joints, or that (2) a more proficient technique requires coordination variability to stay within certain boundaries.

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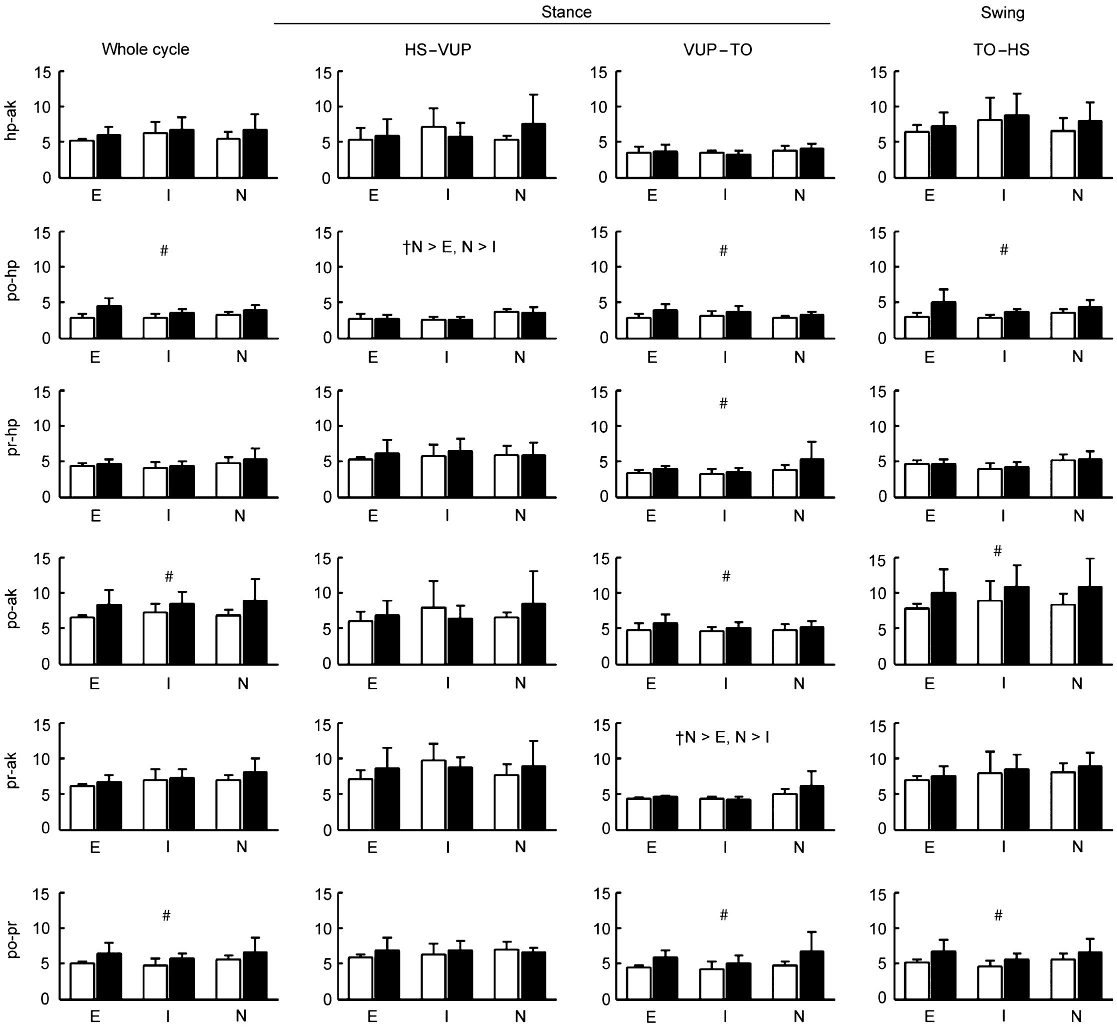

Fig. 4. Coordination variability (mean ± SD) over the whole gait cycle and the subsequent functional phase (left to right columns). #Significant main effect between race walking speeds ($p < 0.05$); †Significant main effect between competition standards ($p < 0.05$). Outcomes of ANOVA and *post hoc* tests are reported below each subplot. White bars refer to 12.0 km/h, black to 15.5 km/h speed. HS = heel strike; VUP = vertical upright position; TO = toe-off; hp = hip; ak = ankle; po = pelvic obliquity; pr = pelvic rotation. E = elite level; I = international level; N = national level.

During the push-off phase, the combination of increased pelvis rotation and larger ankle plantar-flexion has been defined as "functional lengthening" and has been indicated as a key aspect of technique to increase step length and improve performance.[14] It is therefore very interesting that the coordinative relationship of this coupling provided a further difference between the lower standard race walkers and the more skilled ones. As in the previous case, the National rank group had higher levels of coordination variability than the International and Elite groups, which would seem to support the consideration that variability may be a detrimental coordinative feature, as opposed to a functional form of flexibility of the neuromuscular system, as has been suggested elsewhere.[21] However, caution should be advocated in drawing such a conclusion, and three main observations should be put forward.

(1) Variability should not be taken as necessarily good or bad, and from a dynamical systems perspective it rather reveals a range of coordinative solutions that could accomplish the given task. Too narrow, or too broad ranges may become detrimental for performance, and may therefore differentiate between skilled (or healthy) and suboptimal executions.[21,28] The thresholds identifying optimal ranges are likely to be task-, environment-, and cohort-dependent and are still an issue to be investigated through prospective experimental rather than cross sectional study designs.[21,23] Also, not only the overall magnitude of variability should be considered, but also its inherent features in terms of randomness or determinism,[20] as these may play a fundamental role in the characterization of skills.[21]

(2) The levels of coordinative variability may be affected by the experimental conditions in which the tests were carried out. Indeed, the use of a treadmill was needed to collect a sufficient number of cycles to give a correct representation of the phenomenon and of the measures under analysis.[25] However, the imposition of a specific constant progression speed might require less flexibility in movement execution

because of a reduced need to adapt to possible perturbations and/or changing environmental conditions.[29–32] It may be that under such circumstances a narrower range of joint coupling variation is more effective to carry out the task, whereas race walking at a self-imposed speed in an open skill scenario may require a wider variety of coordinative patterns, as found by Preatoni et al.[20] in a similarly skilled group of participants.

(3) CRP variability was calculated over three intervals that were considered functional phases of the gait cycle: approach to the ground and load acceptance (from HS to vertical upright position); propulsive phase (from vertical upright position to TO); and swing (from TO to HS). Overall this subdivision has allowed the identification of skill-dependent changes in coordination strategies and related them to fundamental features of race walking technique. However, such a subdivision may not be fine enough to separate the periods in which variability is not essential, from the ones where increased variability could grant enough flexibility in the system. For example, it may happen that at higher speeds and around transition phases (e.g., about HS or TO) more skilled individuals have higher levels of coordination variability, but that this feature does not emerge when the magnitude of variability is averaged over longer periods (Fig. 5). More refined statistical approaches to compare groups of continuous variables, such as the one proposed by Pataky et al.[33] should be explored in the future to avoid the need to define intervals *a priori*, and increase the chance to detect different behaviors independent of their duration.

Increasing the race walking speed from 12.0 km/h to 15.5 km/h determined a change in most of the considered variables. The flight time confirmed that participants managed to maintain strict adherence to the continuous contact rule at the slower pace, whereas at higher speed longer periods of no contact with the ground started to appear. The duration of the flight phase was similar to the one detected by other authors for similar race walking intensities and competitive standards,[4] but still at an order of magnitude that would not allow judges to detect it by visual observation.[9,11,34]

As expected, the change of pace determined an increase of step length and frequency, but quite surprisingly was accompanied by a reduction in the range of motion of the pelvis. This aspect seems to suggest that faster progression was achieved with greater angular displacement at the hip and knee level. Also, it may be speculated that at this speed the role of the pelvis in limiting the vertical excursion of the center of mass and maximizing step length[9,14] becomes less fundamental, and likely replaced by a more "running style" technique where stronger pushes and flight phases start to further separate race walking from the inverted pendulum paradigm.[10,12] More investigations with a broader spectrum of speeds and the support of ground reaction force measures will be needed to confirm such an interpretation.

Four out of the six observed couplings showed greater coordinative variability with increased speed. The propulsive phase during stance and the swing phase were the phases affected by the change in task intensity. It therefore appears that higher performance demands not only affect the single joints contributing to the movement outcome, but also influence the coordinative relationships between the multiple elements of the system. Larger coordination variability at the faster pace was recorded across the board, for every competition standard. This change could be interpreted as either a functional requirement to accomplish the task more effectively and healthily, or as increased instability of neuro-musculo-skeletal synergies due to the higher biomechanical demands. Indeed, it could be speculated that the more intense push on the ground and the higher angular momenta needed to achieve a faster pace may induce

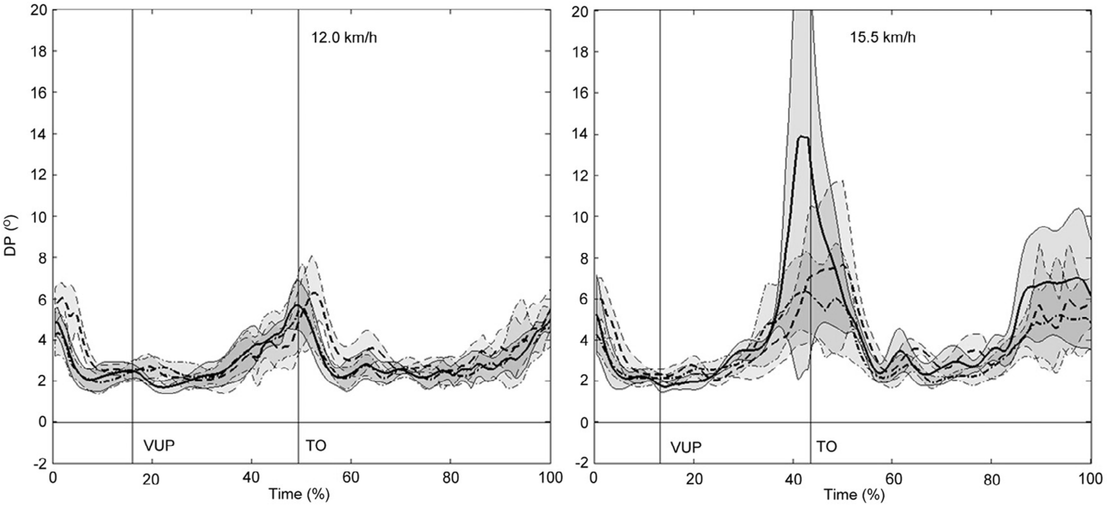

Fig. 5. Average (mean ± SD) CRP variability (deviation phase) for the pelvis obliquity–hip flex/extension coupling in the slow (12.0 km/h) and fast (15.5 km/h) pace conditions. Time is normalized to the gait cycle and expressed in percentage. Solid lines for elite; dash-dot lines for International; dashed lines for national. Vertical upright position (VUP) and toe-off (TO) events are shown as an approximate average across the three groups for clarity of representation. CRP = continuous relative phase.

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lack of control on kinematic patterns or, conversely, that a less rigid control of joint couplings may favor a better distribution of stresses on joints and a smoother action. However, similarly to what was previously pointed out, it is difficult to draw conclusions in either direction given the current experimental design. A further limiting factor for the analysis is the reduced number of participants in each of the three groups. The restricted sample size is inherent in experiments focusing on athletes of a certain standard, but can reduce the statistical power of the analysis.

5. Conclusion

This study analyzed competitive sports performance from both a conventional biomechanics and a dynamical system perspective. In the analysis of race walking gait, both approaches proved sensitive to a change in progression speed, but measures of coordination variability proved to be more sensitive than conventional kinematic quantities in differentiating between groups of athletes that possess mastery of the task, but compete at different levels. Future studies should focus on prospective experimental designs to monitor individual changes due to improved skills and try to give a finer assessment of the meaning of variability and of whether boundaries for functional *vs.* detrimental variability exist. This would represent important information for coaches and practitioners, as understanding what the subtle discriminants of skilled and healthy performance are could assist in monitoring athletes and tailoring more specific and effective training programs. Currently, motion capture evaluations requiring multiple trials and complex data analyses are typically confined to a laboratory setting. However, the potential of dynamical system approaches such as CRP could find its practical application in wearable technologies, which are constantly improving in terms of quality of measures and are becoming more and more popular across practitioners and scientists.

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Authors' contributions

DC conceived the study, participated in its design, collected the data, contributed to statistical analysis, and helped to draft and revise the manuscript; GP participated in the study design, collected the data, and helped to draft and revise the manuscript; EP conceived the study, participated in its design, carried out data processing, contributed to statistical analysis, and drafted and revised the manuscript.

All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

None of the authors has competing financial, professional or personal interests that might have influenced the performance or presentation of the work described in this manuscript.

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