A BIOMECHANICAL COMPARISON BETWEEN RACEWALKING AND NORMAL WALKING STANCE PHASE

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The purpose of this study was to understand the peculiarities of lower limbs kinematics and kinetics during racewalking stance, by comparing it with normal walking gait. Four young but skilled athletes were analysed through a motion analysis system and a force platform. Results were expressed in terms of average kinetics and kinematics curves. Many differences emerged between the two walking modes, most of which can be reconducted to the rules that govern this sport. These observations might be useful, both for trainers and practitioners, to gain more insight in racewalking technique and proficiency, but they are just a first step toward an effective application “on the field”. In fact, an individual analysis might discover the athlete’s distinctive biomechanical characteristics and consequently might help in setting better training methodologies.

KEY WORDS: race walking, motion analysis, kinetics, kinematics.

INTRODUCTION: The sport of racewalking (RW) is included in every track & field main event. According to the International Amateur Athletic Federation (IAAF) two rules must be strictly respected to perform a correct action: first, the advancing foot must make contact with the ground before the rear foot leaves it, so that double support period is established during each gait cycle and the movement can be defined as “walking”; second, the supporting leg must be maintained straight in a vertical upright position (i.e. with the knee fully extended).
Despite the particular requirements of the racewalker to follow, and this makes this motor task very interesting from a biomechanical point of view, few research has been carried out (Murray et al., 1983; Cairns et al., 1986). These surveys, though very interesting and appropriate, are rather old and used simple instrumentation in comparison with current technology. This work aimed at analysing the kinematic and kinetic variables of lower limbs in a population of young but skilled racewalkers, and at understanding their common strategies and average features. Results were compared with normal gait (NW) patterns of the same athletes, thus allowing the description of differences and analogies.

METHOD: Two male and two female young racewalkers of national class were the subjects of this study. Their age, height and body mass were (mean±standard deviation): 18.3±2.5 years, 1.79±0.11 m, 60.06±6.33 Kg. Their personal best over the 10 Km, reported from the previous agonistic season, ranged between 42’08” and 54’20”, with a mean value of 47’49”. All the subjects used to undergo at least 6 training sessions a week. They didn’t show any remarkable lower limb injury or dysfunction at the time of the experiments.
After some preliminary tests with Davis (Davis et al., 1991) and Saflo (Frigo et al., 1998) protocols, the latter was chosen and subjects were prepared by gluing 19 retroreflective hemispherical markers (15 mm diameter) on selected body landmarks. The Saflo protocol allows for the measurement of the total body kinematics, focusing on the lower limbs in particular. The absence of markers both on critical points (e.g. the great trochanters) and on bars, lets the athlete move naturally and limits the noise that vibration from racewalkers’ action might induce. After a standard 20 minutes warm up routine, each subject was asked to racewalk across a 15 m walkway. The laboratory was big enough to let the subjects perform their action continuously and to maintain an adequate, approximately constant speed while being tested.
An 8-cameras optoelectronic motion analysis system (ELITE2002, BTS, Milan, Italy) was used to capture the 3-D coordinates of markers; its sampling rate was fixed at 100 Hz. Before each experimental session, accuracy was assessed while calibrating the system: a maximum mean error of 1.5 mm concerning the length of a 60 cm rigid bar was tolerated.

Ground reaction force (GRF) was measured by a force platform (AMTI OR6-7-1000, Watertown, USA) at a sampling frequency of 500 Hz. The subjects had previously been instructed not to alter or adjust their progression by looking at the plate; therefore, only the trials in which they randomly put their left or right foot on it were recorded. Anthropometric measures and specially designed algorithms (D'Amico and Ferrigno, 1990; Pedotti and Frigo, 1992) were used to estimate and filter the 3D coordinates of internal joint centres and joint angles. Net joint moments at the three main joints (M_{hip}, M_{knee}, M_{ankle}) of the lower limb were computed using the Newton-Euler free body dynamic equilibrium equations. The regression equations proposed by Zatsiorskji and Seluyanov (1983) were used to estimate each body segment mass, inertial moments, and gravity centers position. Hip and knee extension and plantar flexion moments were defined as positive. Net joint powers (P_{hip}, P_{knee}, P_{ankle}) were calculated by multiplying net joint moments and joint angular velocities. As many as 17 suitable racewalking trials, performed at a self-selected training pace and supervisioned by the trainer, were collected for each athlete's left and right side. 6 normal walking gaits (NW) performed at natural cadence (3 left and 3 right) were acquired as well, to allow comparison. Individual median curves of GRF, angles (A_{joint}), moments and powers, concerning hip, knee and ankle on the sagittal plane, were calculated by normalizing single trials over the stance phase (SP); cubic spline interpolation was applied to the original data points to obtain 100 samples independently from the actual movement duration. The 8 individual average patterns for each variable, 4 from athletes' left side and 4 from the right one, were used to estimate the median curves and the 17°-83° percentile range of the whole population. GRF curves had been previously normalised by body weight and M and P ones by body weight and height. The median curve was preferred to the mean one because the data set was not always distributed normally. 17°-83° percentiles were preferred to interquartile range to maintain a ±standard deviation-like depiction of variability.

RESULTS AND DISCUSSION: The mean stance duration resulted 0.63±0.03 s for NW and 0.36±0.04 s for RW. Mean velocities of progression were, respectively: 1.57±0.09 m/s and 2.85±0.40 m/s.

Figure 1 shows GRF, angles, moments and powers, plotted as percentage of stance time.

During racewalking the ankle reached a greater dorsiflection angle at heel strike and plantarflection angle at toe-off than during normal gait. This phenomenon, coupled with a lower flexion of the knee at toe-off and with greater rotation of the pelvis in the horizontal plane (Cairns et al., 1986), might depend on the effort to gain a more effective "functional lengthening" (i.e. increased stride length - Murray et al, 1983). Due to the constraints of the International Federation rules, the athlete has to keep the supporting leg in a straight position. This demand made the knee angles differ significantly between RW and NW. The knee flexion in the first phase of stance during normal walking disappeared, and an hyperextension angle (here defined for angles <0 degrees) was maintained for almost 50% of the SP (25 to 75%). As A_{hip} in the sagittal plane was substantially comparable in both gait modes, the knee in the straight position would have caused a sensitive excursion of the center of mass in the vertical direction. Cairns (Cairns et al., 1986) suggested that the alternating wave of knee extension and flexion of NW is compensated, in RW, by the large increase in the lateral drop of the pelvis away from the stance leg.

The vertical component of ground reaction force was significantly higher during racewalking than during normal gait, except for the last 25% of the stance. Furthermore, in RW, a central plateau replaced the typical walking curve with 2 peaks and a midstance valley. This suggests that racewalkers are able to reduce the vertical oscillation of the CoM, thus achieving a less expensive action. The transition from posterior (breaking) to anterior (propulsive) GRF was anticipated in RW compared to NW. Values turned from negative to positive at 54% and 60% of SP, respectively, in agreement with Cairns' findings (Cairns et al., 1986). Even with respect to this variable, subjects seemed to have a more efficient strategy while racewalking, as they described an equally distributed negative and positive area.

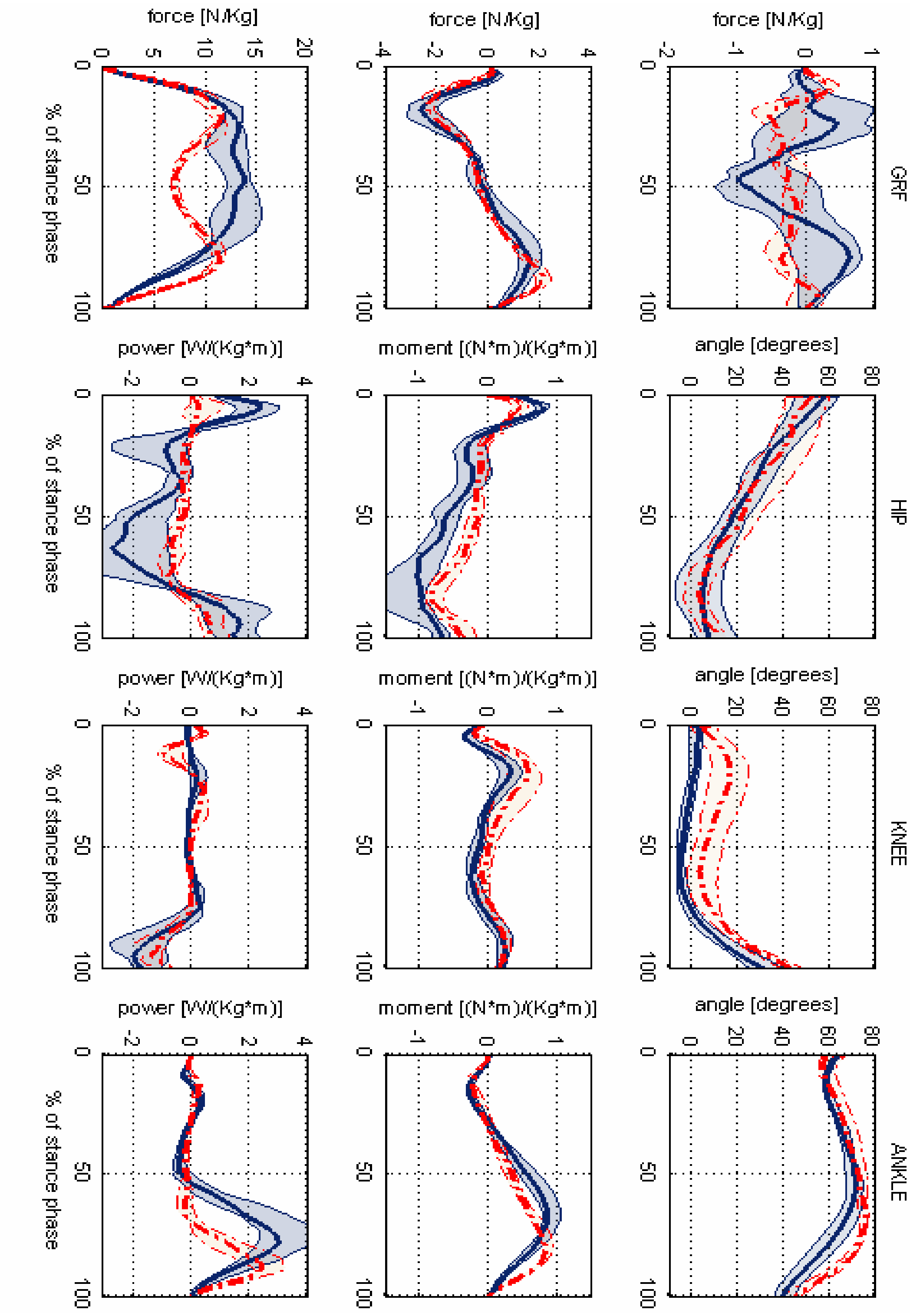

Figure 1. Average patterns (whole population) of GRF and of lower limb joints angles, moments and powers. Solid lines represent median curves of racewalking and the corresponding variability range. Dash-dot lines depict median curve of normal walking and the corresponding variability range. GRF is normalised by body weight, moments and powers are normalised by body weight and height.

During normal gait the breaking phase was wider, thus requesting a more intense forward push to maintain the horizontal velocity. Therefore, in NW, peak anterior GRF was higher and time to peak shorter. Medio-lateral forces resulted higher in magnitude during racewalking. In particular, racewalkers achieved an increased medial reaction in the mid-stance to contrast the lateral shift of the CoM, due to the pelvis lateral drop and hip adduction. Although RW involved a slight oscillation in the medio-lateral direction, the sum of positive and negative areas resulted nearly close to zero; this indicates that the subject had a correct technique, with straight progression. Cairns (Cairns et al., 1986) reported a greater peak dorsiflexion and plantarflexion moments at the ankle. These findings were not confirmed by the present study, in which the magnitude of maximum M_{ankle} resulted comparable, with a higher peak to peak rate in RW mode. This might depend on the need to contrast a greater angular acceleration of the tibia (Perry, 1992) by exploiting the contribution of the gastrocnemius as soon as possible. In fact, the early intervention of the gastrocnemius during racewalking is facilitated by the straight position of the knee. M_{knee} was clearly different in the two gait modes for most of the stance time. The extension action exerted in NW between 5% and 50% of the SP could be interpreted as the opposition to gravity force during load acceptance. This hypothesis is supported by the knee power plot: during the first 20% of contact in normal gait, an eccentric work (negative area) could be recognised. In contrast, the positive M_{knee} during RW might be seen as the effort exerted by knee extensor muscles to keep that joint straight, just like rules impose, and the P_{knee} close to zero or slightly positive for three quarters of SP confirm this extended or even hyper-extended position. The knee extension moment is followed by a flexion, greater in RW than in NW; some authors (Cairns et al., 1986; Murray et al., 1983) interpreted it as the outcome of passive structures (posterior capsule and ligaments) rather than active muscular forces. P_{hip} showed higher excursions in RW. This, coupled with the greater magnitude of M_{hip}, denotes a higher involvement of proximal joints and pelvis in achieving a better performance.

CONCLUSION: This study aimed at understanding the main features of racewalking biomechanics by analysing a population of young competitive athletes. The kinetics and kinematics of racewalking and normal walking stance have been compared in terms of ground reaction forces, angles, moments and powers of the lower limb joints. Analogies and discrepancies with literature have been outlined, and some new observations have been proposed, giving trainers and practitioners some help in understanding the peculiarities of this motor task. Some more work should be done, besides expanding the analysed sample, in order to gain more insight about racewalking technique. Swing phase has still to be analysed and more variables, such as cadence, swing/stance ratio, center of ground pression and pelvis kinetics/kinematics should be taken into account. Furthermore, the RW variables often showed a higher variability, compared to the normal gait ones. This consideration points out the need for a more refined method of technical assessment: the horizontal experimental design is just a first step and should be followed by an individual approach, so that each athlete's motor peculiarities can be identified and training methodologies can benefit from it.

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