INFLUENCE OF FATIGUE ON RACE WALKING STABILITY

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In competition race walkers have to demonstrate ground contact and knee straightening stable although the coordination of the body segments varies. The aim of this study was to investigate the stability of the movement structure adhering to the rules under the influence of increasing fatigue. Four female race walkers of the National Junior Team performed two training sessions on a treadmill. With the help of video analysis and dynamometric platforms underneath the treadmill relevant gait variables of all steps could be analyzed. Although velocity and performance level of the four athletes were comparable, the results showed individual characteristics of stability - variability of the movement structure and individual compensating effects under increasing fatigue.

KEY WORDS: race walking, fatigue, movement coordination.

INTRODUCTION:

Rule 230 of the International Association of Athletics Federations demands contact with the ground and knee straightening of the leg from touch down to vertical upright position (IAAF, 2008). Such constraints lead to a certain stability of the movement structure in race walking, especially of the first half of the support phase (Preatoni, La Torre & Rodano, 2006). However, even though the kinematics seems to be stable, the coordination of the body segments varies in a certain range, and changes occur under the influence of fatigue. All previous studies in race walking discussed this problem on the basis of single (Douglass & Garrett, 1984; Knicker & Loch, 1990; Kampmiller, Vavák, Laczo, Šelinger & Slamka, 1998) or a few steps only (Brisswalter, Fougeron & Legros, 1996; 1998; Neumann, Gohlitz & Ernst, 2005; Hanley & Drake, 2007). Thus, it was the aim of the present study to investigate the stability of race walking coordination adhering to the rules under the influence of increasing fatigue for *all steps* in typical training programs. These considerations were included because in competition one irregular step is enough to get a caution by the judges, and note, three cautions lead to disqualification.

METHOD:

Data Collection: Four female race walkers of the National Junior Team performed two training sessions on a treadmill in the Institute of Applied Training Science in Leipzig (IAT). The athletes' age was 16 years, mass 55.5 kg (±4.2) and stature 1.69 m (±0.04). The investigating period was in the competition season, athletes' season best over the 5 km race ranged from 24'40'' to 25'28''. The investigation included an aerobic training program (distance: 10 km, velocity: constant 80% of 5-km-competition) and an aero-anaerobic training program (distance: 6 km, velocity: constant 92% of 5-km-competition) five days later. All athletes were given the order to walk compliant to the competition rules. Further, to control the metabolic cost, the blood lactate concentration was determined.
Data Analysis: Two dynamometric platforms underneath each treadmill were used to register vertical ground reaction forces at a frequency of 1000 Hz and imported into the software *dwanalyse* (IAT, Gohlitz & Neumann, 2007) to calculate support time, double support/flight time, step frequency and step length. To objectify knee straightening three markers on each body side (trochanter major, epicondylus lateralis, malleolus lateralis) were painted on skin, and the whole test was filmed at a frequency of 25 Hz. Having digitalized all video sequences in half-pictures (50 Hz) the software *apvgehen* (IAT, Gohlitz & Neumann, 2007) was used to track the prepared markers with a special optic-video based algorithm automatically. The gait variables were analyzed of mean, coefficient of variation, and trend. For the measurement of possible effects of fatigue on these variables an ANOVA with repeated measures with post hoc test including the Bonferroni adjustment was made for every 0.5-km-interval.

RESULTS:
Practically all steps were compliant to the competition rules concerning the knee straightening in both training programs. Only in single steps of two athletes the knee angle didn't reach 180° at the moment of first contact with the ground. These offences appeared during the whole tests, but not systematic. An important notice is that these offences referred to one leg predominantly. In result, differences between knee angle of touch down and of vertical position for left and right leg were found in all athletes: The coordination of one leg (left *or* right) was less stable than the other. The coefficient of variation of knee angle and the other analyzed gait variables are illustrated in figure 1 for the aero-anaerobic training program and in figure 2 for the aerobic training program.

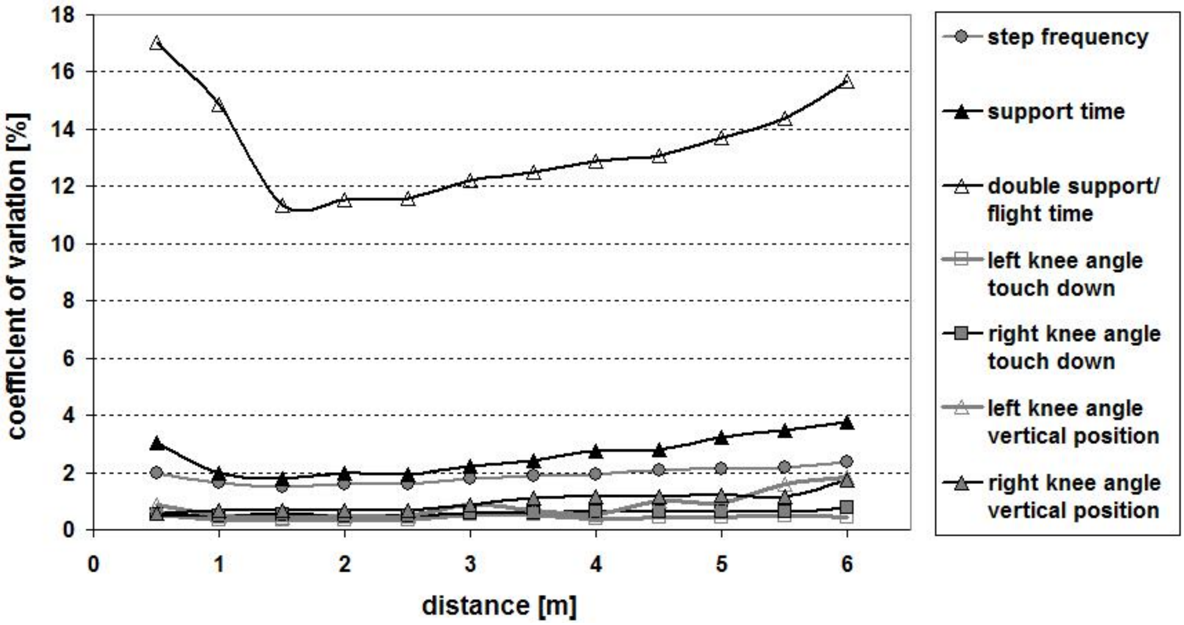

Figure 1: Coefficient of variation of gait variables of the aero-anaerobic training program over 6 km

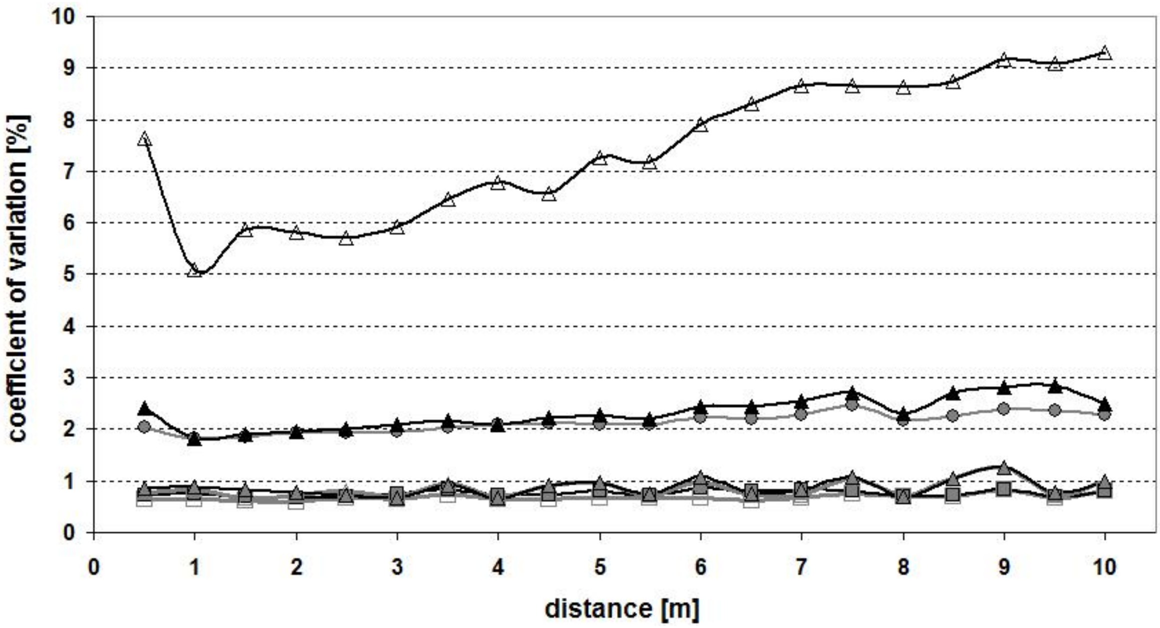

Figure 2: Coefficient of variation of gait variables of the aerobic training program over 10 km

In both training programs knee angle of the vertical position was the gait variable with the smallest, and double support/flight time with the highest coefficient of variation. It is remarkable that a high coefficient of variation of all analyzed gait variables occurred in the first 500-m-interval. In the aero-anaerobic training program flight times could be registered that increased until the end of the program continually. In comparison of both training programs the coefficient of variation of step frequency was smaller in the aero-anaerobic program, but of the inner structure of support time and double support/flight time higher. Under the conditions of increasing duration and induced fatigue the variability of all analyzed gait variables raised general, but rise in the aero-anaerobic training program was higher.

DISCUSSION:

The investigation of race walking coordination showed only a small variability of the movement structure; the values of the analyzed gait variables amounted less than studied in normal walking on a treadmill (Jordan, Challis & Newell, 2007; Hausdorff, 2008). In this context it has to be taken into account that race walking is not a natural, but a learned movement. Furthermore, the results have to be discussed in reference to the spatial constraints on the treadmill: The velocity on the treadmill was set constant, and although race walkers regulate in a small range under free conditions, stability is supported. Previous investigations of race walking events over 20 km have exposed, that competitors which finished close to the world record regulated their velocity *nearly* constant, but within a range of 3% of the mean pace (Neumann, Gohlitz & Ernst, 2005). There was no possibility of any difference to the fixed velocity in our investigations – that might effect higher requirements.

In reference to the competition rules of race walking, coordination should result in ground contact and knee straightening for each step, and in fatigue, too. Therefore compensation in the coordination of the body segments are detectable, e. g. compensating decrease of step length by increase of step frequency and vice versa, to maintain velocity and adhere the competition rules (Douglass & Garrett, 1984; Knicker & Loch, 1990; Brisswalter, Fougeron & Legros, 1996; 1998; Kampmiller, Vavák, Laczo, Šelinger & Slamka, 1998; Neumann, Gohlitz & Ernst, 2005; Hanley & Drake, 2007). Even though, the performance level and metabolic cost were comparable among the four athletes, the compensating effects turned out individual. In this context it is to stress that compensation of step length/frequency produced different successful adaptations of the inner structure of support and flight (Knicker & Loch, 1990; Kampmiller, Vavák, Laczo, Šelinger & Slamka, 1998; Hanley & Drake, 2007).

Under the conditions of constant velocity and increasing duration an increased variability of the movement structure was measurable. In this study only two velocities were investigated, but it seems that a constant realisation of higher velocities (near the individual competition pace) leads to more fluctuations and variability in support/flight. Variability that results in leaving continuous contact to the ground in several steps could be mentioned as an extra indicator of fatigue in movement coordination. Besides, it is to pay attention that comparable characteristics appear in the beginning of the training programs (first 500-m-interval). This is interpreted as effects of warming up which also could be found in training and competition (Neumann, Gohlitz & Ernst, 2005).

The investigations showed a larger increase of variability in movement structure, measured by the coefficient of variation of support time, double support/flight time, step frequency and step length, for the aero-anaerobic training program. A reason could be the higher load (velocity), and further the barring of reducing the velocity as typical reaction, which induced fatigue at an earlier time and strengthened the accumulation of fatigue in all. This explanation is supported by the earlier appearance of the compensating effects in the aero-anaerobic training program, too.

CONCLUSION:

Constant load and increased duration in race walking induce fatigue which is recognizable on changes in the movement structure. Typical compensating effects of adaptation velocity, step length and step frequency are known, and their individual character, too. The present study gained information about the changes of support/flight and knee straightening under the

influence of fatigue. With the help of dynamometric platforms underneath the treadmill and video analysis all steps could be proved of conformance to the competition rules. Next to the amount of decrease/increase of these gait variables the *reduction of their stability* could be outlined as further indicator of fatigue in movement coordination: The results showed alterations within the steps. This fact stresses the importance of investigating all steps of a training program and not only at intervals.
Although, in this study only two velocities were investigated, there was the tendency of increased variability on higher velocities (near the individual competition pace). One important reason lies in the higher requirements, due to the restriction of a constant velocity, and it is assumed that under the conditions of a high, sub maximal velocity and increasing duration fatigue is strengthened.
In next studies we want to investigate race walking stability on treadmill in condition of self-steered velocity. This will be realised with the help of a special strap construction which is fixed on the athlete's hip. Besides, outdoor analysis is necessary to obtain information about the amount of race walking stability under natural conditions. The importance of movement stability - variability does not lie in the peculiarity of race walking (competition rules), but further in the comprehension of the strategies of human coordination (Bernstein, 1967; Hausdorff, 2007).

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