COORDINATIVE THRESHOLD IN RACE WALKING

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According to the international competition rules race walkers have to keep contact to the ground and their knee straightened. In order to investigate the influence of adhering to the rules 20 race walkers performed a step test on a treadmill. Depending on velocity, movement coordination changed from a correct walking technique to an incorrect one and afterwards to running. Incorrect walking begins with occurrence of flight time and bending knee dependent on performance level between velocities of 2.75 to 4.0 m/s. The investigation shows a linear function between velocity and flight time, and a nonlinear one between velocity and knee straightening. To mark the maximum increase of offence against knee rule in course of velocity the term of coordinative threshold is introduced.

KEY WORDS: critical speed, movement coordination.

INTRODUCTION: The competition rules of the international athletic confederation demand keeping ground contact and knee straightening from touch down to the vertical upright position (IAAF, 2006). Loss of contact (as observed) and leg bent at knee are punished by the judges at once. Two cautions by different judges are tolerated, getting a third caution results in disqualification and exclusion from competition. Current studies of the world championships in athletics Helsinki 2005 show evidence of the important role of technique in race walking (Table 1).

Table 1 Summary of cautions and disqualifications in different race walking contests during the world championships in athletics Helsinki 2005

contest	athletes	Cautions	disqualifications
20 km women	47	25	6
20 km men	43	23	8
50 km men	44	32	14

At all times there has been the discussion about a critical *speed limit* in race walking (i.e. Zacharov & Fruktov, 1972; Golovina, Kučin, Farfel & Fruktov, 1977; Trowbridge, 1981; Phillips & Jensen, 1984; Sušanka, 1986; Koroljov, 1989; Knicker & Loch, 1990; Huajing & Lizhong, 1991; Yang, 1993; Gohlitz, Reiß, Ernst & Hildebrand, 1994; Kampmiller, Vavák, Laczo, Šelinger & Slamka, 1998; Johnston, Penner, Armbrust & Welborn, 2006). All previous studies discussed this problem on the basis of contact rule. However, results of relations between support time/flight time, knee straightening and velocity do not exist. Thus, it was the aim of the present study to investigate the influence of velocity on adhering to the knee rule. We obtain information whether there is also an individual critical speed level where knee straightening is not accurately following the competition rules. Furthermore, we want to investigate the relationship between occurrence of flight time and knee straightening.

METHOD:
Data Collection: To objectify the influence of velocity on ground contact and knee straightening 20 experienced race walkers of the national junior and elite team performed a step test on a treadmill in the Institute of Applied Training Science in Leipzig (IAT). At the beginning, the velocity was set to 2.0 m/s and increased by 0.25 m/s every 30 seconds. All athletes were given the order to walk regularly as long as possible. Dynamometric platforms underneath the treadmills were used to register vertical forces at the frequency of 200 Hz and imported into the software *dwanalyse* (IAT) to calculate support times/flight times. To

determine the angle of the knee we fixed 3 markers on each body side (trochanter major, epicondylus lateralis, malleolus lateralis) and filmed the whole test with a video camera at a frequency of 25 Hz. Having digitalized all video sequences we applied the software *mess2ddv* (IAT) to track the prepared markers. The following formula was taken to calculate the angle of knee α from vectors hip-knee (HK) and knee-ankle (KF):

$$a = ar\cos\left(\frac{(HKx * KFx + HKy * KFy)}{\sqrt{(HKx^2 + HKy^2)} * \sqrt{(KFx^2 + KFy^2)}}\right)$$

Data Analysis: We introduced the constant error (CE) to estimate the conformance of knee straightening at the moment of first contact (Own investigations of walking technique in elite race walkers offered that >99 % of any offences against knee straightening already appear in the moment of touch down. That's why we reduced knee rule to the moment of touch down) (Schmidt & Lee, 1999):

$$CE = \sum \frac{T - x_i}{n}$$

CE indicates degrees of precision to reach a goal respectively to keep a limit (T = 180° angle of knee, x_i = trial, n = number of all trials).

RESULTS: The analysis of influence of velocity on support time/flight time and knee angle shows three characteristic phases in race walking technique (figure 1).

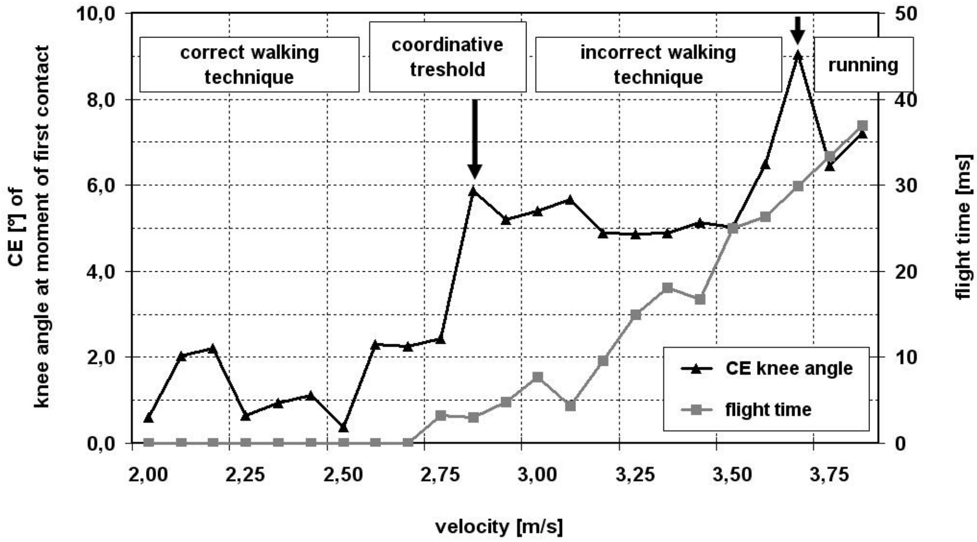

Figure 1: Coordinative threshold in race walking as an example of a weak junior race walker in a step test on the treadmill. Illustrated are values over 10 seconds of flight time and constant error (CE) of the right knee angle at the moment of first contact with the ground

The example of a weak junior race walker shows changes from correct walking technique to incorrect walking technique and finally to running. The correct double support phase and knee straightening is demonstrated by the junior race walker in the first phase at a velocity of 2.0 to 2.75 m/s. Flight times occur for the first time at a velocity of 2.75 m/s (begin of second phase) and the CE of knee angle doubles. The local maximum in course of CE of knee angle is marked with a long arrow in figure 1.

To denote this individual critical point in walking technique we introduced the term of *coordinative threshold*. A further increase of the velocity above 3.5 m/s causes an additional increase of flight time and CE of knee angle. We have outlined this transition with another arrow. Now, movement coordination changes from walking to running (phase 3).

Depending on performance level there are differences in adapting movement coordination to the velocity. Strong walkers are able to show knee straightening close to their transition to running (velocities of 5.5 m/s), whereas offences against knee rule appear at low velocities in weak walkers (velocities of 2.75 m/s).

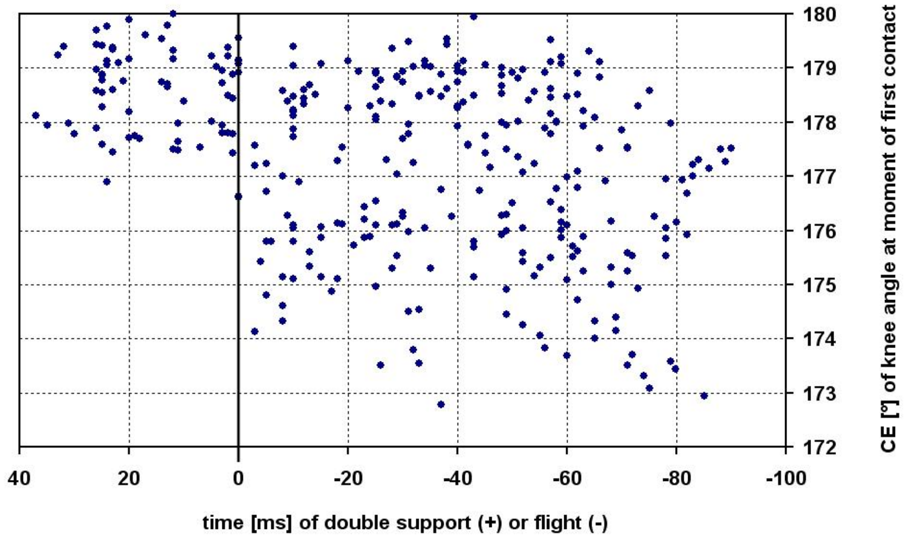

Figure 2: Relationship of knee angle at moment of first contact and support time/flight time

The examples in figure 2 show that all race walkers are compliant to knee rule when flight time occurs for the first time. However, there is only a weak relationship between angle at moment of first contact and flight time. If the walker has contact to the ground, knee rule is kept. Loosing ground contact, knee straightening diminishes depending on performance level. Strong walkers are able to straighten their knee even though flight times reach 80 ms.

DISCUSSION: The international competition rules in race walking describe correct walking technique with two criteria: athletes have to keep contact to the ground and the leg must be straightened at the knee from touch down to the vertical upright position. Different studies showed that conformance depends on velocity exclusively for support time/flight time. In our study we found evidence that knee straightening also depends on the velocity. To mark the maximum increase of offence against knee rule in course of velocity we introduced the term of *coordinative threshold* to characterize the change from a correct walking technique to an incorrect one. Race walkers have to pay attention to this individual critical speed, because rules are broken frequently and the probability of disqualification increases.
Furthermore, our analyses show that there is a relationship between flight time and knee straightening. However, the relationship is weak concerning the occurrence of flight time. In individual analyses we point out that conformance to the knee rule could still be realized as we have flight times of approximately 80 ms. In literature periods of 50-70 ms are discussed when the flight time is visible to the human eye (i.e. Sušanka, 1986; Knicker & Loch, 1990; Huajing & Lizhong, 1991; Yang, 1993). But note that technique of touch down also plays an important role in controlling the competition rules by the judges (i.e. Zhang & Chai, 2000).

CONCLUSION: The present investigations raise many questions about the dependence of movement coordination on velocity. In conclusion we emphasize that an increase in the velocity leads to changes in the movement coordination which can't be described by linear functions (i.e. Thorstensson & Roberthson, 1987; Wollny, 1993; Diedrich & Warren, 1995; Witte, Nischang & Blaser, 1998). In our study we made an approach to characterize the relationship between velocity and knee straightening. In further analyses the relationship between support time/flight time, knee straightening and stride length/stride frequency will be our main interest. In addition to investigations of the influence of speed we have to obtain information about the influence of fatigue on conformance in race walking.

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