CHANGES IN THE COORDINATION OF WALKING MOVEMENTS UNDER CONDITIONS OF CONSTANT AND VARIABLE SPEED

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INTRODUCTION: A great number of scientific studies on the biomechanics of walking are available. In addition to the analysis of the time course of kinematic and dynamic quantities, increased efforts were made for the estimation of the muscle activities. It is common to use an average of the muscle activity patterns of several steps (Zwick (1993); Konrad/Tyry (1996)). This procedure presupposes constant external constraints, similar biomechanical curves and equal muscle activity patterns. Here arises the problem: How stable or variable is the movement coordination of single steps if a) the walking speed is constant and b) the walking speed is changed?

METHODS: The investigations were carried out with three male sports students on a treadmill. As an example, the results of one subject (SR) will be represented in this presentation. Three walking speeds were selected which the subjects could realize as comfortable and below the point where running begins. The speeds for SR were 1.0 m/s (SR1), 2.0 m/s (SR2) and 2.2 m/s (SR3). The subjects walked for four minutes at each speed level. The breaks between the speed levels were used for relaxation. Muscle fatigue was thus minimized. By means of the SIMI-Motion movement analysis system and EMG-Telemetry system of Noraxon-Neurodata, two dimensional video analysis (50 s^{-1} and 200 s^{-1}) of the left side was carried out and the EMG signals of five muscles (m. biceps femoris, m. vastus medialis, m. rectus femoris, m. gastrocnemius, m. tibialis) were recorded synchronously. The cycles were divided in two phases (support and swing) on the basis of characteristics of the time courses of relative ankle velocity in relation to the hip. Due to high-speed video limitations, five cycles for SR1 and eight cycles for SR2 and SR3 could be analyzed. We applied the adaptive estimation of the momentary power of the EMG-signals for time-dependent analysis of muscle activities (Grießbach, Schack et al., 1994).

RESULTS AND DISCUSSION:

a) <u>movement coordination under condition of constant velocity</u>

For the investigation of kinematic differences between the single cycles at a constant velocity, the duration of the support phase and swing phase were estimated. Table 1 shows calculated mean values and standard deviations.

Tab. 1: Mean values and standard deviation of the duration of stance phase and swing phase

	support phase duration [s]	swing phase duration [s]
SR1	0.914 ± 0.023	0.372 ± 0.023
SR2	0.611 ± 0.012	0.338 ± 0.005
SR3	0.551 ± 0.011	0.310 ± 0.004

The slower walking velocity is characterized by a considerably higher temporal variability of single phases than the higher walking velocities. Considering that the time fragmentation of the 200-Hz-video is 5 ms, the phase durations are almost constant. To guarantee the comparability of the following investigations the times were standardized at 1. At first the average curves per velocity level were separately calculated for the swing phase and the support phase to quantify the variability of the kinematic characteristic curves. As a measure of the variability of the single curves the mean square deviation was determined from the time-dependent standard deviation (see Tab. 2).

Tab. 2: Mean value of the standard deviation of the angle - time - curves

Velocity level	joint	angle (support)	angle (swing)
SR1	ankle	1.57	1.21
	knee	0.72	1.92
	hip	0.93	1.31
SR2	ankle	1.00	1.21
	knee	1.27	0.87
	hip	0.74	0.90
SR3	ankle	1.41	1.39
	knee	1.89	1.27
	hip	0.57	0.60

In summary of table 2 it can be see that the variability of the angle-time-curves for both phases and in all three velocities is rather small. The still existing differences between the angle-curves at constant velocity lead to higher deviations of the angular acceleration-time-curves.
To exclude the possibility that these deviations result from recording mistakes of the kinematic data only the average angular acceleration-curves were considered. It is further to be expected that these deviations are caused by variations of the muscle activities. Fig. 2 shows an example of the time characteristics of muscle power.

<u>b) movement coordination under condition of different velocities</u>

For the investigation of movement coordination at different gait velocities only the mean curves were considered. In Fig. 2 the kinematic characteristic curves of the knee joint and the power estimations of the biceps femoris (flexor) and rectus femoris (extensor) are shown. The angle-time-curves of the two higher velocities (SR2, SR3) are almost identical. The angular acceleration time curves also display similar characteristics. The corresponding curves to the small gait velocity have smaller amplitudes. This can be explained by smaller and slower joint movements.
The represented power estimation of EMG-signals was obtained by averaging the standardized single curves. For this reason a quantitative comparison of the power values is not possible. The main activity of the biceps femoris for all three velocities occurs at the beginning of the support phase, when the highest angular

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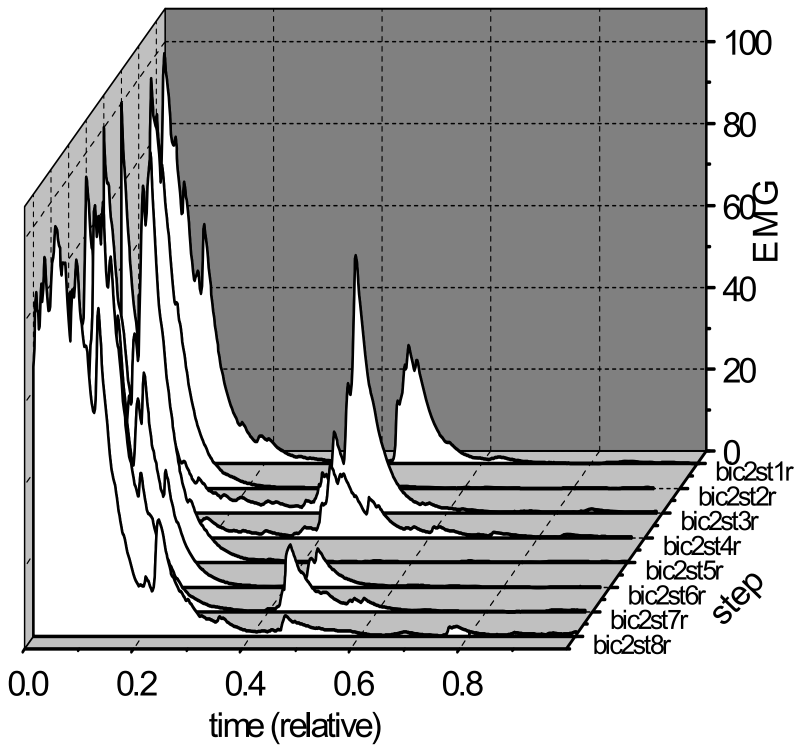

Fig. 1: Adaptive estimation of the momentary power of the EMG signals (standardized) for the m. biceps femoris during the support phase (SR2)

acceleration occurs. The main activity of the rectus femoris appears during the extension of the knee joint for SR2 and SR3. In the case of SR1, the main activity of the rectus femoris was found at the beginning of the support phase. In this period the rectus femoris works as an antagonist to the biceps femoris. Because of the low angular acceleration the second activity of the rectus femoris (at the end of the support phase) is also low.

CONCLUSIONS: The subject matter of this paper was the kinematic and electromyographic study of the coordination of walking movements on a treadmill. It was found that the time courses of the joint angles are almost constant. Higher deviations were noticed in the time courses of angular acceleration. Calculated mean curves showed variant characteristics for different velocities. The muscle activities exhibited a greater variability than the joint angle time curves.
The results of our investigations demonstrate that for gait coordination at different velocities intermuscular coordination is also different.

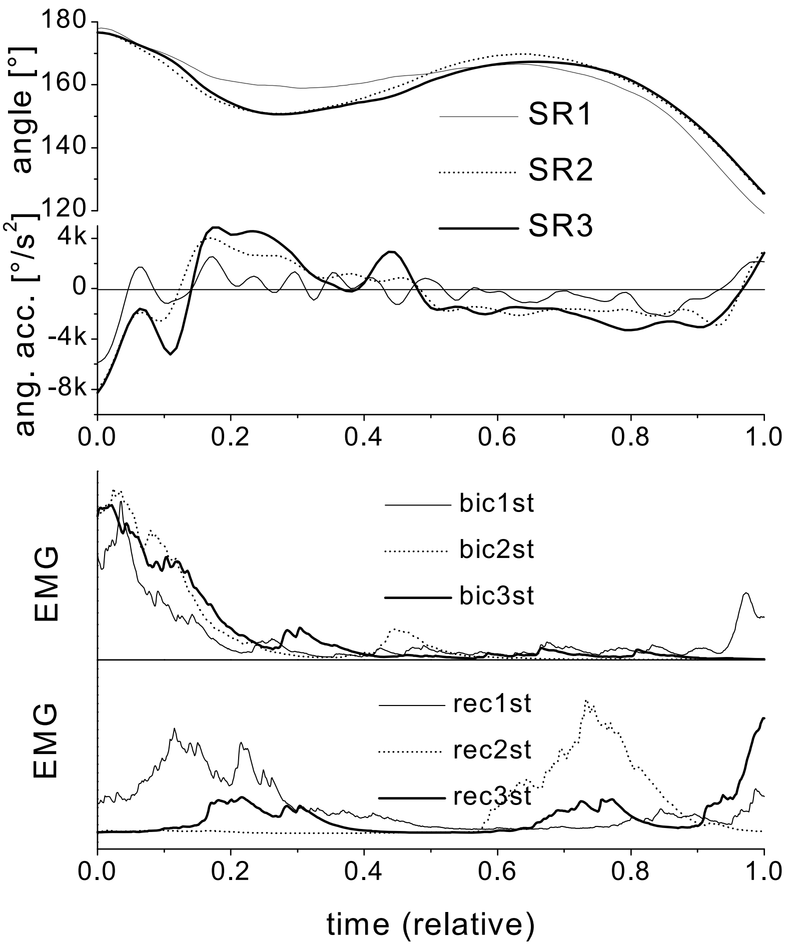

Fig. 2: Mean curves of angle-time- and angular acceleration time curves of the knee joint and the power estimations of the biceps femoris (flexor) and rectus femoris (extensor) during the stance phase

REFERENCES:

Grießbach, G., Schack, B., Putsche, P., Bareshova, E., Bolten, J. (1994). Dynamic Description of Stochastic Signals by Adaptive Momentary Power and Momentary Frequency Estimation and its Application in Analysis of Biological Signals. *Medical and Biological Eng. and Computing* **32**, 632-637.

Konrad, P., Tyry, T. (1996). EMG-Based Gait Analysis. Wien: Noraxon EMG Application Protocols.

Zwick, B. B.(1993). EMG gestützte Ganganalyse unter Einbeziehung kinematischer Daten. Mannheim: Noraxon EMG Meeting.

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